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ASSESSMENT OF WATER QUALITY IN COMMUNITY STORAGE TANKS IN

ACCRA

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AWARD OF MASTER OF PUBLIC HEALTH DEGREE**

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DECLARATION

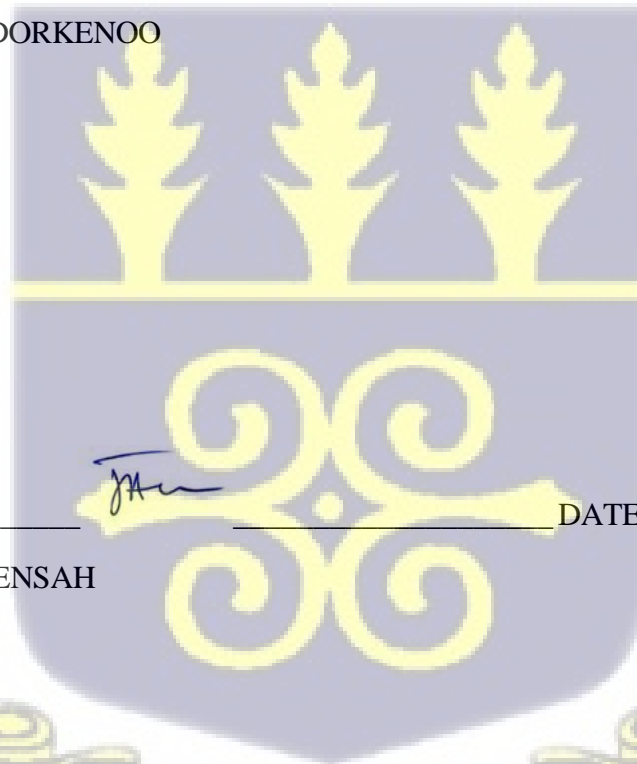
I, Samuel Antwi Dorkenoo, declare that this dissertation titled “**Assessment of Water Quality in Community Storage Tanks in Accra**” under the supervision of Dr John Arko Mensah is the result of my research work. The contribution from the works of others has been recognized and duly acknowledged. Further declare that my research work has not been previously presented or submitted in whole or in part to any university for any other previous degree



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DEDICATION

Dedicated to my lovely Mum and the Dorkenoo family



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My profound gratitude goes to the Almighty God for successfully seeing me through this program. I also want to thank my project supervisor, Dr. John Arko-Mensah of the Department of Biological, Environmental and Occupational health, School of Public health -University of Ghana, for his invaluable contribution to the success of my dissertation. I will always be grateful for your insightful advice and direction. God bless you. My sincerest appreciation goes to Mr Borbor Selorm of the Center for Scientific and Industrial Research- Water Research Institute for his immense contribution, support, and motivation. God bless you.

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LISTS OF ABBREVIATIONS

WHO- World Health Organization

GSA-Standard Authority

NTU -Nephelometric Turbidity Unit

GDWQ-Guidelines for Drinking Water Quality

GSS-Ghana Statistical Service

GWCL-Ghana Water Company Limited

GAR-Greater Accra Region

MDGs-Millennium Development Goals

STATA-Statistics and Data

TDS-Total Dissolved Solids

THB-Total Heterotrophic Bacteria

TSS-Total Suspended Solids

WASH-Water, Sanitation and Hygiene

EC-Escherichia coli

FC-Faecal Coliforms

TC-Total coliforms



OPERATIONAL DEFINITION OF TERMS

1. **Community Water Tanks:** These refer to large storage facilities, often known as poly tanks, located within neighbourhoods, used to store water for shared use by residents. In this study, community water tanks are considered a primary source of water for household use in areas of Accra where the municipal water supply is insufficient.
2. **Water Quality:** The term encompasses the physical, chemical, and biological properties of water, determining its wholesomeness for consumption and other uses. This research will assess water quality based on microbiological and physicochemical parameters against WHO standards.
3. **Microbiological Contaminants:** Pathogenic microorganisms, including bacteria, viruses, and protozoa, that can compromise the safety of drinking water. This study focuses on identifying specific microbial agents present in selected community water tanks and their potential health impacts.
4. **Physicochemical Properties:** These are measurable physical and chemical characteristics of water, such as pH, turbidity, temperature, dissolved oxygen, and electrical conductivity. This study uses these properties to evaluate the overall quality and safety of water stored in community tanks.
5. **Water Quality Index (WQI):** A numerical scale that indicates the overall state of water quality by combining multiple water quality criteria into a single value of water. This study calculates the WQI to provide an easy-to-understand measure of the safety of water in selected community tanks. This is expressed as $WQI = \sum_{i=1}^n (W_i \times Q_i)$, where Q_i indicates the quality rating of the parameter based on its observed value compared to a standard value, and W_i is the relative weight assigned to the parameter.

ABSTRACT

Background: Access to safe drinking water remains a major challenge in Accra, where community water storage tanks, often known as poly-tanks, fail to meet safety standards due to inadequate care and sanitation. Contamination of water at the source before discharge into these community water storage tanks and storage conditions could serve as a major source of water-related disease transmission, such as rotavirus, cholera, and campylobacteria among community members.

Objective: This study aimed to assess the microbiological and physicochemical quality of water stored in community storage tanks in selected communities in Accra.

Methods: This study was designed to assess the microbiological and physicochemical quality of water stored in community tanks across three urban communities in Accra. A cross-sectional analytical design was employed to capture a snapshot of water safety at the time of sampling. Water samples were systematically collected from tanks in Korle Gono, Laterbiokoshie, and Zebra Line, areas that rely heavily on stored water due to intermittent municipal supply. Microbiological indicators, including total coliforms, faecal coliforms, *Escherichia coli*, total heterotrophic bacteria, and *Pseudomonas* spp., were analysed. Physicochemical parameters such as pH, turbidity, conductivity, and total dissolved solids were measured. Together, these analyses provided an integrated assessment of stored water quality and highlighted potential health risks for the communities dependent on these tanks.

Results: Microbiological analysis revealed significant contamination levels as follows: total coliforms (mean: 3.51×10^4 CFU/100 mL), faecal coliforms (mean: 1.95×10^4 CFU/100 mL), and *E. coli* (mean: 1.68×10^4 CFU/100 mL), all exceeding WHO's acceptable limits (0 CFU/100 mL). Physicochemical findings showed a mean pH within acceptable limits (6.84), though turbidity (7.80 NTU) and total dissolved solids (830.52 mg/L) exceeded WHO

standards in some cases. Water Quality Index (WQI) evaluations classified 60% of the samples as "Good," while 32% were deemed "Poor."

Conclusion: The findings underscore critical public health risks associated with consuming stored water from community tanks in Accra. Recommendations include routine tank cleaning, improved regulatory oversight, community education, and infrastructure upgrades to safeguard water quality.

Limitation: The study was limited by its cross-sectional design, which captured only a single point in time. Seasonal variations in water quality were not accounted for, restricting generalizability. In addition, infrastructure conditions of tanks were not fully examined, which may have influenced contamination levels.



CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Water is a fundamental resource essential for sustaining life and supporting the development of human societies, livestock, and industries (Kılıç, 2020). It is vital to human wellbeing, enabling hydration, hygiene, and sanitation, which are key to preventing diseases and ensuring overall well-being. For livestock, water is vital for maintaining health, productivity, and the quality of animal products, with agriculture accounting for nearly 70% of global freshwater use (Yitbarek, 2019). In industry, water serves as a cornerstone for manufacturing, energy production, and cooling processes, driving economic activities and technological advancements. In today's world, the growing need for water is intensifying due to population expansion, urbanization, and industrialization, making its sustainable management essential for securing food supplies, supporting livelihoods, and fostering economic development (Rasul, 2016). The efficient utilization and conservation of water are therefore critical in addressing the challenges posed by climate change and ensuring the equitable distribution of this indispensable resource. It is against this backdrop that Sustainable Development Goal Six (6) has been prioritized to ensure the sustainable management of water and sanitation because access to clean water is vital for health, food security, economic growth, and environmental sustainability in an increasingly water-stressed world.

Water quality refers to the suitability of water for specific uses based on its chemical composition, biological purity, and physical characteristics (Bozorg-Haddad et al., 2021). These attributes are influenced by natural factors such as soil leaching and runoff, as well as human activities like agricultural practices, industrial discharges, and improper waste disposal

(Akhtar et al., 2021). Contaminated community storage tanks can harbour pathogens, nitrates, and heavy metals, which pose significant health risks, especially to children and immunocompromised individuals. Water quality is measured using standardized frameworks that assess physical, chemical, and biological parameters (Bhateria & Jain, 2016). The WHO and the United States Environmental Protection Agency (EPA) provide comprehensive guidelines for evaluating parameters such as turbidity, pH, heavy metal concentrations, and microbial contaminants including *Escherichia coli* (*E. coli*) (Khan & Gupta, 2020). These parameters are vital in determining water safety for human consumption. Techniques such as spectrophotometry, atomic absorption spectroscopy, and microbial culturing are commonly employed to analyse these quality indicators (Omer, 2019).

Globally, the quality of water is a crucial determinant of public health and environmental sustainability (Graham & White, 2016). The World Health Organization (WHO) estimates that approximately 2 billion people consume water from contaminated sources annually, contributing to waterborne diseases such as cholera, diarrhoea, and typhoid (Manetu et al., 2021). Given these alarming statistics, the provision of safe and clean water remains a priority under the United Nations Sustainable Development Goal 6, which emphasizes the need to ensure universal and equitable access to safe and affordable drinking water by 2030. Community water storage tanks, widely used in both urban and rural settings, have become pivotal in water supply systems, particularly in areas where centralized water distribution systems are limited. However, the lack of stringent maintenance and monitoring poses risks to the water quality they provide.

1.2 Problem Statement

Access to safe and clean water remains a critical challenge in urban areas, including Accra, Ghana's capital (Tutu & Stoler, 2016), where rapid urbanization and population growth place

significant strain on the water supply infrastructure. Community water tanks play a pivotal role in bridging the water supply gap, especially in areas where municipal water supply systems are unreliable or inaccessible (Dakyaga et al., 2018). In several communities in Accra, especially those along the Atlantic Ocean, community water tanks are major sources of water for many households. However, the quality of water stored in these tanks often fall below acceptable safety standards due to inadequate maintenance and care, poor sanitation practices, and exposure to environmental contaminants (Dakyaga et al., 2018). Community water tanks are usually filled with pipe borne water close to the tank. However, there are instances where these water tanks are filled with water from ‘water tankers’ that source water from other parts of the city away from the water tank. The processes involved in filling these tankers at water outlets through transport may end up contaminating the water before discharge into the tanks. Consequently, the consumption of such unsafe or contaminated water from these community tanks may pose a severe public health risk to consumers, including outbreaks of waterborne diseases such as diarrhoea, cholera, and typhoid (Tutu & Stoler, 2016).

Previous studies have emphasised the difficulties related to water quality in urban Ghana. For instance, Awuah et al. (2014) found high levels of microbial contamination in water samples collected from community tanks in Kumasi, attributing it to poor tank hygiene and lack of regular cleaning. Similarly, a study conducted by Amoah et al. (2017) assessed the physicochemical parameters of water in storage tanks in Greater Accra and revealed significant deviations from World Health Organization (WHO) standards. These deviations suggest potential health hazards related to the ingestion of such water. Despite these earlier findings, not many studies have systematically assessed water quality in community tanks within Accra, particularly focusing on microbiological contamination. However, communities along the coast are known for their periodic cholera outbreaks, poor water quality may be one of the

sources of these cholera outbreaks. Climatic variations such as irregular rainfall and temperature shifts can worsen water contamination risks in poorly sealed or exposed tanks.

Therefore, addressing these issues requires integrating robust water quality monitoring programs alongside community-driven maintenance efforts.

1.3 Conceptual Framework

The conceptual framework illustrates how various factors influence water quality in community water storage tanks by examining both biological and physicochemical properties. It identifies five key categories of influencing factors—physical, chemical, biological, and anthropogenic. Biological parameters, such as *Escherichia coli*, total coliforms, faecal coliforms, *Pseudomonas* spp, and total heterotrophic bacteria indicate microbial contamination, while physicochemical parameters, including electrical conductivity, total dissolved solids, dissolved oxygen, salinity, temperature, and pH, reflect the physical and chemical state of the water. Together, these parameters determine the overall quality of water stored in community storage tanks, with each factor contributing to potential contamination, degradation, or preservation of safe water standards.

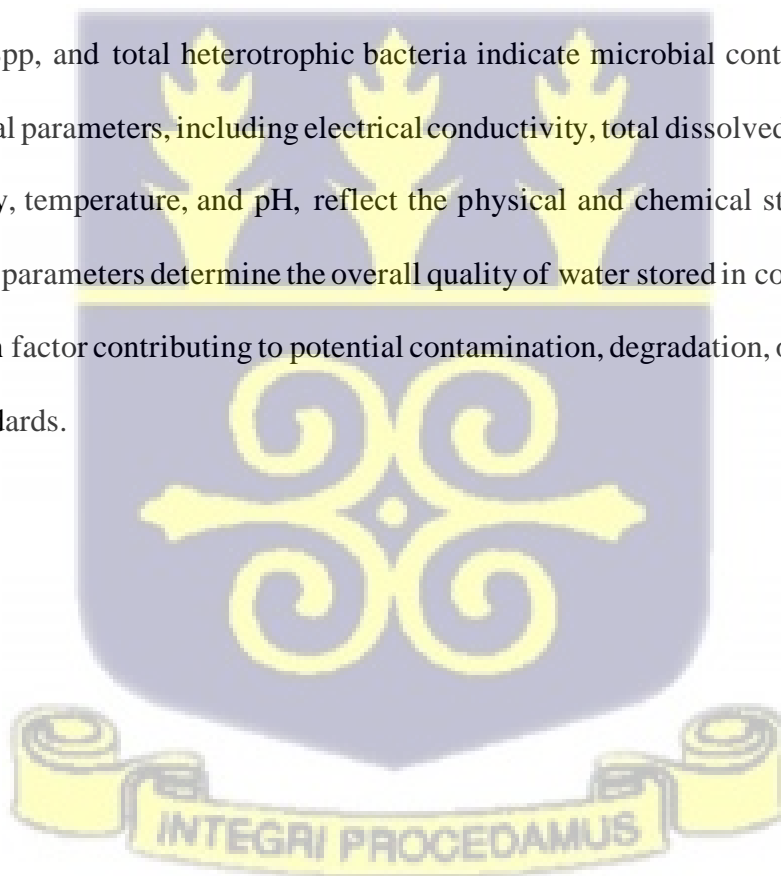
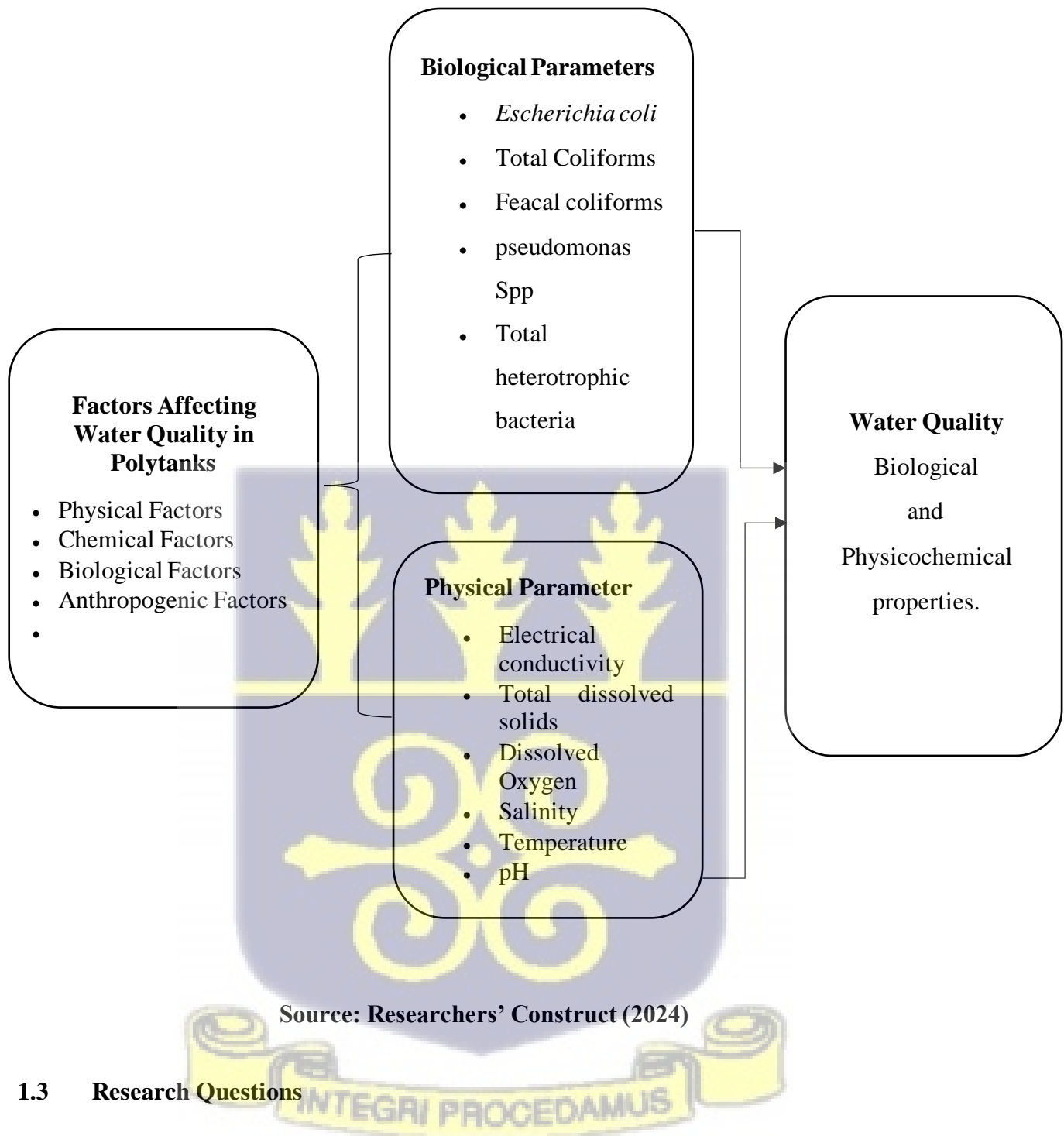


Figure 1. 1: Conceptual Framework



1.3 Research Questions

1. What are the microbiological levels of contamination in selected community water tanks in Accra?
2. What is the Water Quality Index (WQI) of water stored in selected community tanks?

3. What are the physicochemical properties of water in selected community water tanks in Accra?

1.4 Research Objectives

1.4.1 General Objective

The aim of this study was to assess the water quality of community water tanks in three communities in Accra, Korle Gono, Laterbiokoshie and Zebra..

1.4.2 Specific Objectives

- i. Assess the level of microbial contamination of water stored in community water tanks in Korle Gono, Laterbiokoshie and Zebra.
- ii. Measure the physicochemical properties of water stored in community tanks
- iii. Calculate the Water Quality Index (WQI) of water stored in community tanks.

1.5 Justification

Water quality in communal shared water tanks will be assessed to reveal if the water is contaminated or not, providing a foundation for determining the safety and suitability of the water for domestic use. For water service providers, the study serves as a guide to improving operational practices in managing community tanks. Insights from the research will help inform strategies for maintenance, such as regular cleaning schedules and improved structural designs to reduce contamination risks. Service providers can also use the results to enhance water treatment interventions, ensuring they meet the recommended WHO standards.

The study also holds significance for public health practitioners by shedding light on potential health risks associated with consuming water from community tanks. By understanding the

prevalence and nature of contaminants, health professionals can design and implement educational campaigns aimed at promoting safe water usage practices within communities. Additionally, the research findings can help practitioners develop targeted responses to mitigate the spread of waterborne diseases in high-risk areas.

For academia, this research advances the body of information on urban water management and quality assessment. It offers a basis for further research on water quality and related health impacts in Ghana and beyond, fostering the development of innovative approaches to sustainable water resource management.

1.6 Strengths and Limitations of the Study Strengths:

1. **Comprehensive Data Collection:** The study involved both microbiological and physicochemical analyses, ensuring a holistic evaluation of water quality. This dual focus on different parameters makes the findings robust and multifaceted.
2. **Geographical Diversity:** By selecting three distinct communities (Korle Gono, Laterbiokoshie, and Zebra Line), the study captured variability in water quality, reflecting diverse environmental, storage, and contamination conditions.
3. **Quality Control:** Rigorous measures, such as testing blanks and maintaining sterile procedures, enhanced the validity of microbial and physicochemical assessments.

Limitations:

1. **Temporal Limitations:** The cross-sectional nature of the study provides only a snapshot of water quality. Seasonal variations or long-term trends in contamination are not captured.

2. **Population Sampling:** Purposive sampling, while practical, may introduce biases and restrict generalizability across broader regions beyond the sampled communities.
3. **Infrastructure Assessment:** The study largely focused on water quality without an indepth analysis of tank infrastructure conditions, which might have illuminated structural contributors to contamination.



CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

This chapter provides a comprehensive literature review to contextualize the study on water quality in community water storage tanks in Accra. To conduct this literature review, keywords and phrases pertinent to the subject were looked up using search engines like Google Scholar, PubMed, ScienceDirect, and literature such as the fourth edition of the World Health Organization's (WHO) Guidelines for Drinking Water Quality (GDWQ), were tailored to specific articles pertinent to this study.

2.1 Overview of Water Quality

Water quality challenges affect both developed and developing countries, though the causes and severity differ. In industrialized nations, issues often stem from industrial pollution, agricultural runoff, and emerging contaminants such as microplastics and pharmaceuticals (Morin-Crini et al., 2022; Parden & Behera, 2023). Despite advanced treatment systems, problems like lead contamination in old infrastructure—as seen in Flint, Michigan—persist (Butler et al., 2016). European countries also contend with nitrate pollution and pharmaceutical residues (Piwowar et al., 2021). In contrast, developing nations face more fundamental challenges due to limited infrastructure, rapid urbanization, and lack of resources (Sarker et al., 2021). Microbial contamination from poor sanitation is widespread, especially in densely populated cities (Larsen et al., 2016; Ablo & Yekple, 2018). Community storage tanks, often used in African cities, face contamination risks due to poor maintenance (Ablo & Yekple, 2018). Climate change exacerbates these issues by causing saltwater intrusion and increasing pollutant loads during extreme weather (Khan et al., 2015; Qamar et al., 2021). Urban areas like Accra and Mumbai face combined threats from pollution, inadequate waste management,

and rapid growth (Boahen & Owusu, 2023; Balogun et al., 2017; Ghosh, 2021). Over 2 billion people consume contaminated water globally, highlighting the urgent need for sustainable management (Martínez-Santos, 2017).

2.2 Water Sources, Availability, and Quality in Accra

Water quality in urban Ghana, particularly in Accra, faces significant challenges due to rapid urbanization, population growth, and inadequate infrastructure (Cobbinah et al., 2017). Pollution from domestic, industrial, and agricultural sources affects water bodies and community storage systems, such as tanks and boreholes, which are often poorly maintained (Ketadzo, 2019). These conditions lead to waterborne diseases like cholera and diarrhoea, especially among children (Arnold, 2024). Illegal mining activities further contribute to water pollution through heavy metal contamination, which affects rivers and groundwater sources used by urban residents (Kwaah, 2023; Mantey et al., 2020). The Ghana Water Company Limited reports that treating polluted sources is becoming increasingly costly and less effective, threatening water accessibility (Cosgrove & Loucks, 2015).

Studies such as Amoah et al. (2017) reveal high turbidity and microbial contamination, including *E. coli*, in water from storage tanks, surpassing WHO standards. Although frameworks and awareness campaigns have been introduced (Amponsah et al., 2015), there is a lack of systematic evaluation of community water sources. Residents rely on diverse water sources. Pipe-borne water, supplied by the Ghana Water Company, remains primary but unreliable (Frimpong et al., 2024; Ngben & Yakubu, 2023). Alternatives include sachet water, which is convenient but environmentally problematic (Morinville, 2017), boreholes and wells (Appiah-Effah et al., 2021), rainwater harvesting (Andoh et al., 2018; Linderhof et al., 2022), and water vendors, who often charge higher prices (Illidge, 2019). A coordinated approach is essential to ensure safe, accessible, and sustainable urban water in Ghana.

2.4 Factors Influencing Water Quality

Numerous interrelated elements, encompassing physical, chemical, biological, anthropogenic, and environmental aspects, affect the quality of water (Akhtar et al., 2021), each of which is essential in establishing whether water is suitable for domestic, ecological, and public health purposes.

2.4.1 Physical Parameters

Physical factors such as turbidity, temperature, and colour significantly influence water quality.

Turbidity

Turbidity quantifies how hazy or cloudy water is owing to the existence of suspended particles such as silt, clay, organic matter, and microbes (Matos et al., 2024). Elevated levels of turbidity might hinder the penetration of light, which directly impacts photosynthesis in aquatic plants and disrupts aquatic ecosystems (Gomes & Juneau, 2017). For instance, water with turbidity levels exceeding 50 NTU (Nephelometric Turbidity Units) can hinder aquatic life and make water unsuitable for domestic use. When turbidity exceeds the WHO guideline of 5 NTU, it not only degrades the water's visual quality but also raises the possibilities of waterborne illness (Matos et al., 2024). Turbid water also decreases the efficiency of disinfection processes, as suspended particles can shield harmful microorganisms from treatment methods. Additionally, turbidity can serve as a carrier for toxic chemicals and pathogens, posing risks to human health (Weerakoon et al., 2023).

Temperature

Temperature is the degree of heat in water, influencing its chemistry and suitability for consumption, with optimal levels usually below 25°C for drinking water (Prest et al., 2016). Temperature significantly influences water quality by affecting chemical reactions, biological activity, and dissolved oxygen levels in water storage systems (Hamid et al., 2020). In community water tanks, elevated temperatures can accelerate microbial growth and chemical decomposition processes, potentially compromising water safety (Calero Preciado et al., 2021). Higher temperatures reduce water's capacity to hold dissolved oxygen, which is crucial for maintaining water quality and preventing bacterial proliferation. In urban areas like Accra, where ambient temperatures are typically high, this becomes particularly concerning for community water tanks exposed to direct sunlight or housed in poorly ventilated spaces. Temperature variations can also hinder the efficacy of water treatment procedures, including disinfection, as chemical reactions often require precise temperature ranges for maximum performance (Duan et al., 2021).

Colour

The colour of water is often an indicator of contamination and can be influenced by both natural and anthropogenic factors (Akhtar et al., 2021). Natural water systems may exhibit colour due to dissolved organic matter, while industrial pollutants can introduce unnatural hues, such as reddish or greenish tones (Kolya & Kang, 2024). For instance, water bodies near industrial zones have been observed to exceed 50 TCU (True Colour Units), signalling significant pollution and the presence of harmful substances. Coloured water can also affect public perception, as visibly polluted water is often deemed unsafe for consumption or domestic use. Furthermore, certain colours may indicate specific contaminants; for example, a yellowish tint could suggest the presence of iron, while a bluish hue might indicate copper contamination

(Kolya & Kang, 2024). Addressing colour-related issues often requires advanced treatment methods, such as activated carbon filtration or chemical coagulation, to restore water clarity and safety.

2.4.2 Chemical Parameters

Chemical factors include the presence of dissolved oxygen, pH levels, and concentrations of nutrients like nitrates and phosphates.

Dissolved Oxygen

Dissolved oxygen describes how much oxygen is dissolved in water, contributed by organic matter, temperature, and salinity (Bulbul & Mishra, 2022). When dissolved oxygen levels drop below 4 ppm (parts per million), aquatic life becomes stressed, and dead zones can form, where most organisms cannot survive (Kasper et al., 2022). These low oxygen levels are often caused by the decomposition of organic matter, which consumes oxygen during microbial activity (Bulbul & Mishra, 2022). Maintaining adequate dissolved oxygen levels is vital for sustaining healthy aquatic ecosystems and preventing biodiversity loss.

pH Levels

The measure of water's acidity or alkalinity is its pH levels and it is crucial for quality, with an ideal range of 6.5–8.5 as per WHO standards (Omer, 2019). pH levels serve as a critical parameter of water quality, reflecting the balance of acids and bases in water systems (Hamid et al., 2020). In community water tanks, pH fluctuations can trigger a cascade of chemical and biological changes that affect water safety and usability. When pH values fall outside of the 6.5-8.5 range that the WHO recommends, it can lead to corrosion of storage tank materials, potentially introducing harmful metals into the water supply (Fardowsa, 2024). Acidic

conditions can dissolve metals from pipes and tank walls, while alkaline conditions might cause scale formation and reduce the efficiency of disinfection processes (Fardowsa, 2024). In urban settings like Accra, where water sources may be exposed to various pollutants, maintaining appropriate pH levels becomes crucial for ensuring water safety. pH also influences the effectiveness of water treatment processes, particularly chlorination, as the disinfectant's efficiency varies significantly with pH levels. Regular monitoring and adjustment of pH levels are essential for maintaining water quality in community water storage systems.

Nutrients: Nitrates and Phosphates

Nitrates and phosphates are nutrients that play a significant role in water quality. While they are vital for the growth of plants, eutrophication may occur as a result of high concentrations, a process where nutrient overload causes algal blooms (Badamasi et al., 2019). These blooms cause hypoxic conditions that endanger aquatic life by lowering the water oxygen content. Sources of nitrate and phosphate pollution include agricultural runoff, wastewater discharge, and improper use of fertilizers (Badamasi et al., 2019). Controlling nutrient input through sustainable agricultural practices and effective wastewater treatment is crucial to prevent eutrophication and maintain water quality.

2.4.3 Biological Parameters

Microbiological factors include microorganisms such as Faecal coliform, *Escherichia coli*, Total coliform, *Pseudomonas* spp, and Total heterotrophic bacteria.

Faecal Coliforms

Faecal coliform is a subtype of total coliform bacteria known for its presence in the intestines of warm-blooded animals, including humans. Their existence in water stored in community

storage tanks signals contamination from faecal matter, typically introduced through poor sanitation practices, leakage from sewage systems, or unhygienic handling during water collection and storage. In Ghana and other developing countries, studies have reported that a significant proportion of household water samples stored in polytanks exceed World Health Organization (WHO) standards for faecal coliforms, especially during the dry season when water scarcity leads to the use of alternative sources without proper treatment (Awuah et al., 2016). Faecal coliforms can survive for extended periods in stored water, particularly under warm and nutrient-rich conditions, making their management crucial for public health. The detection of faecal coliforms does not identify the specific pathogens present but serves as a proxy indicator for the potential presence of disease-causing organisms such as *Salmonella*, *Shigella*, and viruses.

Escherichia coli

Escherichia coli (*E. coli*) is a specific species within the faecal coliform group and is widely regarded as a definitive sign of faecal contamination in drinking water. Its presence in polytank water suggests recent faecal pollution, which may carry pathogenic strains capable of causing diarrhea, urinary tract infections, and other gastrointestinal illnesses. *E. coli* is highly sensitive to environmental conditions, making it a reliable marker for monitoring microbial water quality. In urban Ghana, studies have reported *E. coli* contamination in as many as 40–60% of household polytank samples, especially in communities with low incomes where access to better sanitation is limited (Fosu-Mensah et al., 2019). Contamination typically results from the use of unhygienic collection containers, unclean hands during retrieval, or storage tanks placed in environments prone to contamination. While the majority of strains of *E. coli* are harmless, the detection of pathogenic strains such as *E. coli* O157:H7 poses a serious health risk, especially to children and immunocompromised individuals. Control strategies include

regular tank disinfection, avoiding direct hand contact with stored water, and covering tanks to prevent entry of animals and environmental debris.

Total Coliforms

Total coliforms are a vast category of bacteria frequently found in vegetation, soil, and animal digestive tracts. Their existence in stored water highlights general contamination and serves as a warning sign for the potential presence of pathogens. Although not all total coliforms are harmful, their detection in storage tanks suggests that the water may have come into contact with environmental contaminants or been inadequately treated. In many Ghanaian communities, total coliform counts in polytank water samples regularly exceed acceptable limits, especially when the tanks are poorly maintained or located near latrines and drainage systems (Osei-Tutu et al., 2017). Total coliforms can proliferate within tanks that are exposed to sunlight or not cleaned regularly, forming biofilms on internal surfaces that reduce the efficacy of disinfection. Unlike faecal coliforms or *E. coli*, total coliforms may not always indicate faecal contamination but point to compromised water handling and storage hygiene.

***Pseudomonas* spp.**

Pseudomonas spp. are a group of opportunistic bacteria commonly found in soil, water, and various moist environments. In water stored in polytanks, *Pseudomonas aeruginosa* is the most frequently identified species and is of particular public health concern as a result of its resistance to many antibiotics and potential to cause infections, especially in immunocompromised individuals. Unlike coliform bacteria, *Pseudomonas* manifests biofilm formation, inadequate sanitation, and prolonged water stagnation in storage systems rather than faecal contamination. Studies in West Africa have identified *Pseudomonas* spp. in household storage tanks and hospital water systems, suggesting a widespread risk of nosocomial infections and waterborne disease outbreaks (Nkansah et al., 2020). The bacteria thrive in

warm, nutrient-rich, and low-chlorine environments, making polytanks ideal reservoirs if not properly maintained. Their presence is particularly concerning in settings where water is used for wound care, eye washing, or cleaning medical equipment. Preventing *Pseudomonas* contamination requires consistent cleaning of storage tanks, the use of disinfected water sources, and limiting stagnation by rotating stored water regularly.

Total Heterotrophic Bacteria (THB)

Total heterotrophic bacteria (THB) are a broad group of microorganisms that indicate the overall microbial load in water, reflecting organic matter content and potential biofilm formation. While not all THB are pathogenic, elevated levels (e.g., 3.74×10^3 CFU/100 mL in this study, exceeding Ghana's 5.00×10^2 CFU/100 mL limit) can compromise water safety by harboring harmful bacteria and reducing disinfectant efficacy (Lindmark et al., 2022). High THB counts often result from stagnant water, inadequate cleaning, or nutrient accumulation in storage tanks (Slavik et al., 2020). Monitoring THB is critical, as they serve as a general hygiene indicator and can shield pathogens from treatment processes, necessitating improved tank maintenance and water management practices.

2.4.4 Anthropogenic Factors

Human activities represent the most significant source of water pollution globally, with industrial discharge, agricultural runoff, and urbanization being the primary contributors. These anthropogenic factors introduce complex mixtures of contaminants into aquatic systems, compromising water quality and ecosystem health.

Industrial Discharge

Every year, industrial operations discharge between 300 and 400 million tonnes of hazardous sludge, solvents, heavy metals, and other contaminants into water bodies (World Bank, 2019).

Manufacturing plants frequently discharge wastewater containing lead, mercury, cadmium, and arsenic, often exceeding permissible limits by 2-10 times in developing nations (UNEP, 2021). The textile industry alone releases 72 toxic chemicals from dyeing processes, with about 30% remaining untreated in effluent (Greenpeace, 2021). Mining operations contribute to 40% of global heavy metal pollution, with acid mine drainage affecting over 19,000 km of rivers worldwide (International Mining Association, 2020). These contaminants bioaccumulate in aquatic organisms, with studies showing mercury levels in fish exceeding safe consumption limits by up to 5 times near industrial zones (EPA, 2022).

Agricultural Runoff

Modern agricultural practices introduce approximately 115 million metric tons of nitrogen fertilizers into global water systems annually (FAO, 2021). This nutrient loading has resulted in nitrate concentrations exceeding the WHO's 50 mg/L safety limit in groundwater across 36% of monitored agricultural regions (UN Water, 2022). This effect is evident in the Mississippi River Basin, which annually contributes 1.5 million metric tonnes of nitrogen to the Gulf of Mexico, resulting in a hypoxic dead zone that is on average 15,000 km² in area (NOAA, 2023). Pesticide contamination affects 38% of global freshwater resources, with atrazine and glyphosate detected in 75% of tested European water bodies (European Environment Agency, 2022). These agrochemicals persist in the environment, with glyphosate residues remaining detectable in water for up to 315 days post-application (USGS, 2021).

Urbanization Impacts

Rapid urban expansion has left 2.4 billion individuals right to use proper sanitary facilities, resulting in 80% of municipal wastewater being discharged untreated in developing countries (WHO/UNICEF, 2023). In megacities like Jakarta and Mumbai, water quality monitoring

shows faecal coliform levels reaching 50,000 CFU/100mL, 100 times above safe limits (World Resources Institute, 2022). Urban stormwater runoff carries an estimated 13 million tons of plastic waste into oceans annually, along with 50-90% of heavy metals from urban surfaces (Ocean Conservancy, 2023). The economic impact is substantial, with water treatment costs increasing by 30-50% in cities with inadequate stormwater management (OECD, 2022).

2.5 Theoretical Review

The study adopted the WHO Water Safety Plan Framework as the main theoretical underpinning of the study.

2.5.1 WHO Water Safety Plan (WSP) Framework

The WHO Water Safety Plan Framework represents a systematic approach to ensuring drinking water safety through comprehensive risk assessment and management strategies (World Health Organization, 2015). This framework is especially pertinent to community water storage systems since it prioritises prevention over end-product testing (Chorus & Welker, 2021). The WSP approach involves identifying potential hazards at each step of the water supply chain, assessing associated risks, and implementing control measures to mitigate these risks. It also includes operational monitoring procedures to ensure control measures remain effective and management plans for normal and incident conditions (Chorus & Welker, 2021).

The framework encompasses three key components: system assessment, operational monitoring, and management plans (World Health Organization, 2015). System assessment involves evaluating the entire water supply system to identify potential hazards and risks. Operational monitoring focuses on regularly checking that control measures are working effectively, while management plans provide procedures for normal operations and incident response. In the context of community water tanks, this framework guides the development of

comprehensive water safety protocols, including regular monitoring schedules, maintenance procedures, and corrective actions when problems are detected (World Health Organization, 2015).

While the WHO Water Safety Plan framework comprises system assessment, operational monitoring, and management plans, this study focused primarily on the system assessment component. Microbiological and physicochemical testing were combined with an analysis of contamination pathways and usage patterns to provide risk-related insights. The other elements of the framework, including operational monitoring and long-term management strategies, were beyond the scope of this research. This framework was selected for the study because it provides a systematic methodology for evaluating water safety in community tanks and developing effective management strategies. Its emphasis on risk assessment and preventive measures aligns with the study's objectives of identifying and addressing water quality challenges in urban Accra.

2.5.2 Environmental Health Risk Assessment Frameworks

Environmental health risk assessment frameworks provide structured approaches for evaluating threats to human populations from environmental exposures (Fayshal et al., 2023). The theory rests on four main tenets. The first tenet is *hazard identification*, which determines the nature of agents that may cause adverse outcomes (Parish et al., 2020). The second is *dose-response assessment*, which examines the relationship between exposure magnitude and health effects. The third is *exposure assessment*, which quantifies the extent, duration, and frequency of human contact with contaminants. The fourth is *risk characterisation*, which integrates hazard, dose-response, and exposure information to provide an overall measure of potential harm (Parish et al., 2020). Together these tenets establish a systematic pathway for decision-making in environmental health research and policy.

The framework emphasizes prevention through early identification of hazards and prioritization of interventions (Zhang, et al., 2021). It underscores the importance of standardized methods for measuring contaminants, evaluating exposure routes, and estimating associated risks (Rai & Singh, 2020). It also stresses the need for transparency, reproducibility, and scientific rigor in all stages of assessment. By adopting a preventive stance, the framework moves beyond reactive responses to acute events and instead supports long-term strategies for health protection. The model is widely applied in environmental science, water safety, air quality management, and food protection.

This framework provides strong relevance to the present study on community water tanks in Accra. By employing hazard identification through microbiological and physicochemical analysis, exposure assessment of households dependent on tanks, and risk characterization via water quality indices, the study mirrors the theoretical stages of environmental health risk assessment. Thus, the theory justifies the methodological design and strengthens the interpretation of findings.

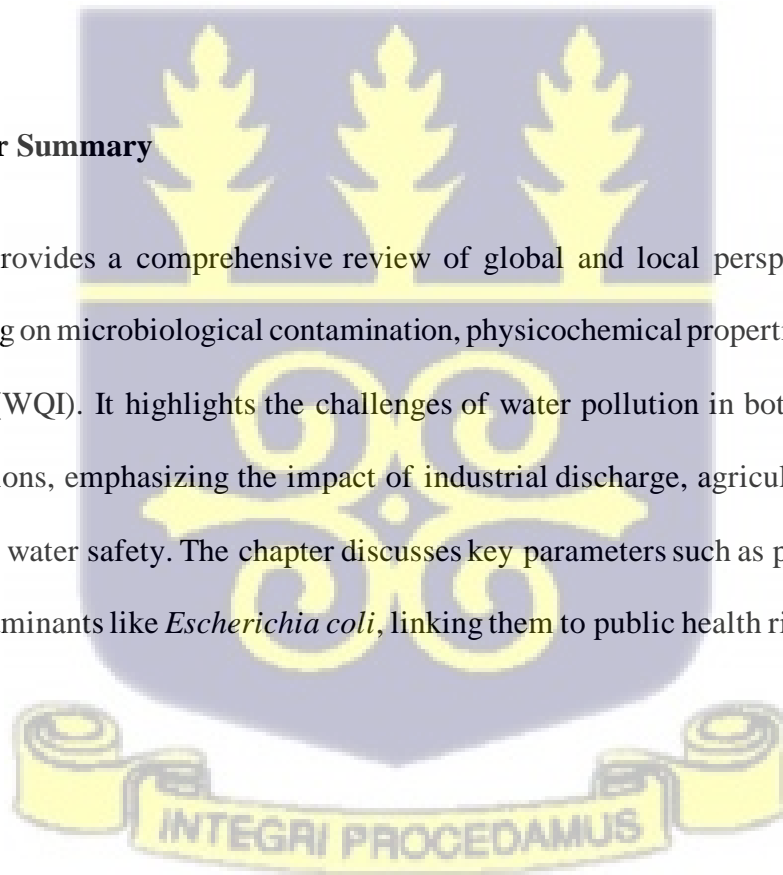
2.6 Gap in Literature

Recent studies have examined water quality in urban Ghana, with emphasis on both microbial and physicochemical indicators. Fosu-Mensah et al. (2019) reported *Escherichia coli* contamination in polytanks across low-income households but provided little insight into system-level factors. Ketadzo (2019) highlighted poor tank maintenance as a key driver of contamination, yet this study did not extend to cross-community comparisons. Amoah et al. (2017) earlier assessed physicochemical parameters in Accra tanks, but more recent evidence points to increasing risks from urbanization and sanitation deficits (Cobbinah et al., 2017; Boahen & Owusu, 2023). Despite these contributions, most studies have remained narrow in scope, often analyzing either microbial or chemical parameters without integrating both.

Gaps also remain in pathway analysis and community-level assessments. Appiah-Effah et al. (2021) emphasized alternative water sources such as boreholes and wells but did not evaluate their interface with storage tanks. Kwaah (2023) demonstrated the impact of mining-related pollution on water bodies but did not extend the findings to urban tank systems. Frimpong et al. (2024) reported supply inconsistencies in Accra but did not capture contamination pathways within storage practices. Moreover, there is scant evidence on usage patterns that determine exposure levels in dense settlements. These gaps limit the design of effective interventions. The present study addresses them by integrating microbial and physicochemical analyses with contamination pathways under the Water Safety Plan system assessment, thereby advancing evidence for community-based risk management.

2.7 Chapter Summary

Chapter Two provides a comprehensive review of global and local perspectives on water quality, focusing on microbiological contamination, physicochemical properties, and the Water Quality Index (WQI). It highlights the challenges of water pollution in both developed and developing nations, emphasizing the impact of industrial discharge, agricultural runoff, and urbanization on water safety. The chapter discusses key parameters such as pH, turbidity, and microbial contaminants like *Escherichia coli*, linking them to public health risks.



CHAPTER THREE

METHODOLOGY

3.0 Introduction

Chapter Three outlines the methodological framework employed to assess the water quality in community storage tanks in Accra. The chapter details the research design, study area, sampling techniques, data collection methods, and analytical procedures used to achieve the study's objectives.

3.1 Study Design

A cross-sectional analytical study was used to conduct a water quality assessment regarding microbial contamination and measurement of physicochemical properties of water stored in community polystyrene tanks at three communities in Accra; Korle Gono, Laterbiokoshie, and Zebra Line.

3.2 Study Area

The Greater Accra Region serves as the hub of government in Ghana. Although it is the capital region, it has the smallest land area in Ghana, occupying a total land surface of 3,245 square kilometres. The region is the most densely inhabited, with 5,455,692 residents in 2021, making up 17% of Ghana's overall population. The Eastern region forms the northern boundary of the Greater Accra Region, followed by the Volta region to the east, the Gulf of Guinea to the south, and the Central Region to the west. With 2,557,00 residents, there are 15,200,440 men and 15,631,579 women (GSS, 2021). Nonetheless, with 4,010,054 residents in 2010, it is the second most populous region in terms of population, after the Ashanti region, making up 15.4% of Ghana's overall population.

Accra is a rapidly growing urban centre with a dense population and significant reliance on water storage systems. As the economic and administrative hub of the country, it experiences high water demand that often exceeds the capacity of its direct water supply systems. Consequently, community water tanks serve as a critical resource for urban residents, necessitating a thorough assessment of their water quality.

Water supply in Accra is predominantly sourced from two major treatment plants—Weija and Kpong—operated by the Ghana Water Company Limited (GWCL). These plants supply treated water through a piped network, but this supply is frequently interrupted due to aging infrastructure, illegal connections, and increasing demand. As a result, residents often rely on alternative sources such as boreholes, mechanized wells, sachet water, and community storage tanks. In underserved areas, water tankers also supplement household supply, although the source and handling of such water are sometimes questionable.

This study focused on three urban communities in Accra: Korle Gono, Laterbiokoshie, and Zebra Line. These areas were purposively selected due to their dependence on community tanks and the documented challenges with sanitation and intermittent water supply.

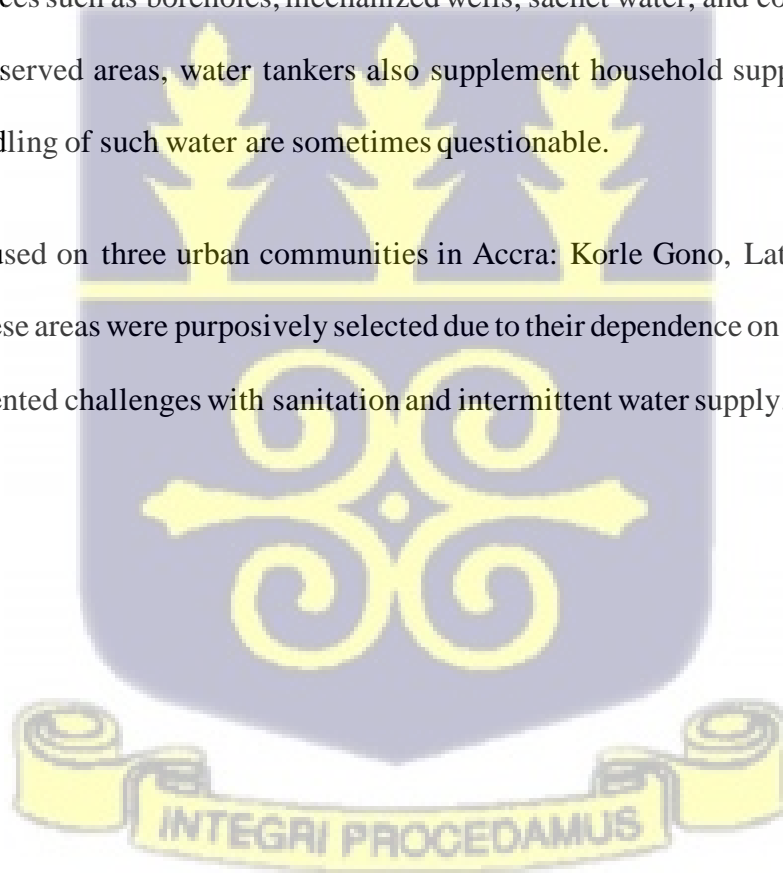




Figure 3. 1: Study Area

GPS Coordinates And Map Of The Three Communities

Korle Gono

Korle Gono is a coastal community located in the Ablekuma South Sub-Metropolitan District. It has a population of approximately 27,826 and is mainly inhabited by fishermen, small-scale traders, and artisans (GSS, 2021). Water availability is inconsistent, with irregular flow from the municipal piped network. As a result, residents rely heavily on boreholes, hand-dug wells, and community tanks to meet their water demands. The area is densely populated, and this pressure intensifies challenges in hygiene and sanitation. Open drains, poor waste management, and inadequate toilet facilities contribute to unsanitary conditions. Community tanks serve as

a major supplementary water source and are shared among multiple households, especially during periods of water rationing or supply breakdowns.

Laterbiokoshie

Laterbiokoshie is located in the Ablekuma Central Municipal Assembly and has an estimated population of 34,105 (GSS, 2021). The area is a busy urban residential community, home to middle- and lower-income households. It also features small businesses, schools, clinics, and markets. Although the community is connected to the city's piped water network, the supply is unreliable, leading to widespread dependence on water storage systems, including poly tanks and boreholes. Sanitation infrastructure is under pressure due to the high population density. Frequent blockages in drainage systems and improper solid waste disposal contribute to public health concerns. Community water tanks are a key water source, especially during disruptions in piped water supply, and play an essential role in household and small business water access.

Zebra Line

Zebra Line, also known locally as Zabramaline, is situated in the Ablekuma West Municipal District and has a population of about 25,940 (GSS, 2021). The area is an informal and densely populated settlement with poor housing and limited infrastructure. Access to piped water is nearly absent, making community tanks and water vendors the primary sources of water. Due to its high population density and limited space, the settlement faces significant sanitation challenges, including inadequate toilet facilities, open defecation, and frequent waste accumulation. Community water tanks are central to water access, and due to the lack of regulation and maintenance, residents face heightened risks of consuming unsafe water. Hygiene practices are generally compromised by overcrowding and insufficient public health infrastructure.

3.3 Study Variables

The variables of interest are microbial parameters (Total coliform, Faecal coliform *E. coli*, *Pseudomonas* spp, and total heterotrophic bacteria) and physiochemical parameters (Conductivity, pH Salinity, Total Dissolved Solids, and Dissolved Oxygen) in community water tanks.

3.4 Sample Collection

Three communities within Greater Accra were selected, informed by their overdependence on community water storage tanks and poor sanitation practices. Analytical cross-sectional research was employed. Data collection was to assess the microbiological and physicochemical quality of water stored in community tanks across three communities, Korle Gono, Laterbiokoshie, and Zebra Line.

Within each community, a purposive sampling approach guided the identification of tanks that were functional, accessible, and widely used by households. After the selection of tanks, random sampling was applied at the tank level to draw water for laboratory analysis. This combined approach ensured representativeness while maintaining methodological rigor. A total of 25 samples were collected, comprising 9 from Korle Gono, 11 from Laterbiokoshie, and 5 from Zebra Line. The distribution reflected differences in the number of operational tanks across the communities.

Water samples were collected using sterile containers labelled with unique identity codes corresponding to each tank. Before sample collection, hands were washed thoroughly with water and soap, and protective hand gloves were worn. Taps were opened for the water to run for a few seconds, then, 1.5 litres of water was collected into sterile containers sealed, appropriately labelled with the location, date, and time of collection. The samples were stored

in an ice chest on ice and transported to the CSIR-Water Research Institute laboratory in Accra for microbiological analysis on the same day

On-site measurements of physicochemical parameters such as temperature, pH, turbidity, and electrical conductivity were conducted using a multiparameter water quality meter (HORIBA U-52G-10, Japan) Microbiological analysis focused on detection of total coliforms, faecal coliforms, *Escherichia coli*, and *Pseudomonas* species. The collection protocol adhered strictly to WHO guidelines for water sampling, ensuring that results were reliable and reflective of the actual conditions of water in community tanks. The GPS coordinates of each of the sites were recorded. Upon reaching the laboratory, the samples were refrigerated until analysis to prevent external contamination.

Table 3. 1: Samples Collected from Korle Gono with their Corresponding GPS

Sample	Location	North (° N)	West (° W)
Sample 1	Korle Gono	5.532773	0.223162
Sample 2	Korle Gono	5.532859	0.223779
Sample 3	Korle Gono	5.532542	0.225013
Sample 4	Korle Gono	5.532309	0.226617
Sample 5	Korle Gono	5.532449	0.228860
Sample 6	Korle Gono	5.532945	0.229789
Sample 7	Korle Gono	5.533704	0.229231
Sample 8	Korle Gono	5.530210	0.226801
Sample 9	Korle Gono	5.530726	0.226032

Table 3. 2 Samples Collected from Laterbiokorshie with their Corresponding GPS

Sample	Location	North (° N)	West (° W)
Sample 1	Laterbiokorshie	5.545243	0.251809
Sample 2	Laterbiokorshie	5.543881	0.252204
Sample 3	Laterbiokorshie	5.544893	0.253175

Sample 4	Laterbiokorshie	5.544945	0.254545
Sample 5	Laterbiokorshie	5.546699	0.256024
Sample 6	Laterbiokorshie	5.54.5112	0.256112
Sample 7	Laterbiokorshie	5.546877	0.256660
Sample 8	Laterbiokorshie	5.546300	0.257358
Sample 9	Laterbiokorshie	5.548257	0.257333
Sample 10	Laterbiokorshie	5.550050	0.253573
Sample 11	Laterbiokorshie	5.44931	0253011

Table 3. 3: Samples Collected from Zebra Line

Sample	Location	North (° N)	West (° W)
Sample 1	Zebra Line	5.531009	0.232517
Sample 2	Zebra Line	5.530096	0.230953
Sample 3	Zebra Line	5.552370	0.236951
Sample 4	Zebra Line	5.545295	0.248175
Sample 5	Zebra Line	5.547372	0.241814

3.6 Enumeration of Faecal Coliforms by Membrane Filtration

3.6.1 Scope and Field Application

This method was employed to detect and quantify faecal coliform bacteria in water samples collected exclusively from community storage tanks in Korle Gono, Laterbiokoshie, and Zebra Line. The intestines of warm-blooded animals, including humans, are frequently home to bacteria called faecal coliform. Given the possibility of enteric infections, their presence in stored water suggests faecal contamination and possible health risk. In the context of this study, the identification of faecal coliforms served as a key indicator of microbiological water quality in urban storage systems used for domestic purposes.

3.6.2 Principle

The amount of faecal coliform colonies in the water samples taken from the tanks was ascertained using the membrane filtration technique. This technique filters a predetermined amount of water through a sterile membrane, which traps the bacteria. The membrane is then placed on m-FC agar, a selective medium that supports the growth of faecal coliforms. The medium contains rosolic acid and bile salts, which inhibit the growth of non-target organisms. The plates are incubated at 37°C for 18 to 24 hours. Colonies that ferment lactose produce acid, which reacts with aniline blue in the medium, turning the colonies blue. Faecal coliforms are the result of counting and reporting these blue colonies.

3.6.3 Procedure

All samples were collected directly from selected community storage tanks and handled under aseptic conditions. Hands were washed and sanitized with 70% alcohol before beginning the procedure. The workspace and all filtration equipment were disinfected. Sterile m-FC agar was poured into Petri dishes and allowed to set. A sterile membrane filter was placed in the filtration unit using sterile forceps, and a sterile funnel was securely attached. The vacuum valve was initially closed, and 100 ml of tank water was poured aseptically into the funnel. The valve was then opened to allow filtration under partial vacuum. After filtration, the membrane was removed with sterile forceps, avoiding any contact with the central portion of the filter, and transferred onto the prepared agar plate using a rolling motion to prevent air entrapment. The plates were covered, inverted, and incubated at 37°C for 18–24 hours. Blue colonies that developed on the agar surface were identified and counted as faecal coliforms. Filters with air patches or incorrect placement were adjusted or excluded to ensure accurate results.

3.7 Enumeration of *E. coli* and Total Coliforms by Membrane Filtration

3.7.1 Scope and Field of Application

This technique was used to detect and enumerate *Escherichia coli* and total coliforms in water samples collected from community storage tanks in the three study areas: Korle Gono, Laterbiokoshie, and Zebra Line. Membrane filtration was selected for its suitability in assessing water quality in stored domestic water supplies. Total coliforms are a broad group of bacteria found in the environment, including soil, vegetation, and the gastrointestinal tracts of warmblooded animals. Their presence in stored water suggests possible contamination and highlights lapses in the maintenance or protection of water storage systems. *E. coli*, a specific member of the coliform group, is always associated with faecal matter and is a more direct indicator of faecal contamination and the likely presence of enteric pathogens. Identifying these organisms in storage tanks helps assess the potential health risks faced by households relying on such storage systems.

3.7.2 Principle

The membrane filtration method enables the enumeration of bacterial colonies by filtering a known volume of water and allowing bacteria to grow on a selective medium. For this study, water from community storage tanks was filtered through a sterile membrane that retained microbial cells. The membrane was then placed on Hicome Coliform Agar (FLUKA 81938), which contains two chromogenic substrates—Salmon-Gal and X-glucuronide. Coliforms produce the enzyme β -D-galactosidase, which cleaves Salmon-Gal, forming red to salmoncoloured colonies. *E. coli* additionally produces β -D-glucuronidase, which cleaves Xglucuronide, resulting in dark blue to violet colonies. The medium also contains tryptophan to enhance indole reactions and improve differentiation. After incubation, colonies were

differentiated based on colour: salmon-red and violet colonies were counted as total coliforms, while only violet colonies were recorded as *E. coli*.

3.7.3 Procedure

Samples were collected directly from selected community storage tanks using sterile containers. In the laboratory, hands were washed and sanitized with 70% alcohol, gloves were worn, and all filtration equipment and surfaces were sterilized. Sterile Hicome Coliform Agar was filled into Petri dishes and left to set. Using sterile forceps, a sterile membrane filter was positioned over the filtration membrane, followed by the attachment of a sterile funnel. With the valve initially closed, 100 ml of the water sample was shaken well and aseptically poured into the funnel. The valve was then opened to allow filtration under partial vacuum. After filtration, the membrane was carefully removed using sterile forceps, avoiding contact with the central surface, and placed on the agar plate using a rolling motion to prevent air entrapment. The plates were covered, inverted, and incubated at $37 \pm 2^\circ\text{C}$ for 18–24 hours. After incubation, colonies that appeared dark blue to violet were recorded as *E. coli*, while both salmon-red and violet colonies were counted as total coliforms. This method provided a direct assessment of microbial contamination levels in stored water from community tanks.

3.7.4 Procedure: Physicochemical Analysis

Analysis of the physicochemical parameters was done on-site using the Horiba U-52G-10 multi-parameter water quality meter. This water quality meter was able to measure all parameters simultaneously, measuring up to 8 parameters including pH, ORP, dissolved oxygen, conductivity, salinity, TDS, temperature, and turbidity. The sensor probe is lowered and submersed into the sample and the ON button is pressed and the measurement data from all 8 parameters appear on the screen simultaneously and are recorded.

3.7.5 Quality Control

Analytically graded reagents were adopted throughout. Plastic and glassware were soaked in 10% HNO₃ for 24 hours before being cleaned and dried overnight in the oven. All safety procedures required in the microbiological laboratory for the preparation, usage, and disposal of cultures, reagents, and materials were employed. Following filtering and application on the medium, the membrane filter surface was free of water particles. Patches of unstained membrane were avoided, which would serve as a confirmation of entrapped air. There were no clusters of colonies: they were well dispersed over the membrane filter. Blanks (sterile distilled water) were tested and used as a negative control for each batch of 10 samples tested.

Table 3. 4: Composition of Basal Medium (M-FC Agar base, Himedia M112) for the enumeration of faecal coliforms

Ingredient	Litres
Lryptose	10
Proteose Peptone	5
Yeast extract	3
Lactose	12.5
Bile salt mixture	1.5
Sodium chloride	5
Aniline blue	0.1
<u>Agar</u>	<u>15</u>
Final Ph (at 25°C) 7.4±0.2	



Table 3. 5: Composition of Hicome coliform agar (FLUKA 81938) used for the enumeration of *E. coli* and total coliforms

Ingredients	Grams/Litre
Peptone special	3
Sodium chloride	5
Dipotassium hydrogen phosphate	<u>3</u>
Potassium dihydrogen phosphate	1.7
Sodium pyruvate	1
Tryptophan	1
Sodium lauryl sulphate	0.1
Chromogenic mixture	0.2
<u>Agar</u>	<u>12</u>
Final Ph (at 25°C)6.8±0.2	

3.8 Statistical Analysis

The study employed quantitative data analysis techniques to evaluate water quality in selected community tanks. Water quality was determined by calculating the mean and standard deviation values using the microbiological and physicochemical parameters. Statistical analysis of data from the sample sites, as well as the laboratory analysis, was done using Microsoft Excel and STATA 18.0. To illustrate and explain the physicochemical and microbial characteristics of the samples, summary statistics of the mean and standard deviation were calculated.

3.9 Human Health Risk Assessment

3.9.1 Water Quality Index

The Water Quality Index (WQI) model is one of many methods that have been created to assess data on water quality. Large datasets of temporal and geographic fluctuations in water quality are evaluated in WQI models to provide a value known as the water quality index, which serves as its benchmark. Numerous factors influence water quality, but the water quality index offers a straightforward way to gauge the calibre of drinking water coming from a particular source. A water quality index provides a measurement that indicates the general quality of a water sample at a certain place and time based on a number of water quality criteria. WQI can be used to compare the quality of water from different sources and give people and the community a basic picture of the possibilities

3.9.2 Calculation of Water Quality Index

The Water quality index (WQI) are:

The quality rating scale for each parameter q_i was calculated by using this expression:

$$q_i = (C_i / S_i) \times 100$$

A quality rating scale q_i is applied to each parameter by dividing its concentration C_i in each water sample by its associated standard S_i and multiplying the result by 100.

A value inversely proportionate to the suggested standard (S_i) of the appropriate parameter was used to determine unit weight (W_i):

$$W_i = 1 / S_i$$

The overall WQI was computed by combining the quality rating (Q_i) with unit weight (W_i)

linearly: $i = n$

$$WQI = (\sum w_i q_i)$$

$$I = 1$$

The WQI result is then compared to the water quality index table and the status of the water the sample is derived from the table.

Table 3. 6: Water Quality Classification Based On WQI Value

Water Quality Index Level	Water Quality Status
<50	Poor
51-70	Good
71-90	Very good
91-100	Excellent

(Ramakrishnaiah *et al.*, 2009).

3.10 Quality Control

To maintain data integrity and ensure reliable results, analytically graded reagents and materials were used throughout the analysis. All plastic and glassware were soaked in 10% HNO₃ for 24 hours, thoroughly rinsed, and dried overnight in an oven to remove potential contaminants. All laboratory and field procedures adhered to established safety protocols for handling, preparation, usage, and disposal of cultures, reagents, and materials. Physicochemical parameters were tested using the Horiba U-52G multi-parameter water quality meter. For the microbiological analysis, particular attention was given to ensure no residual water particles remained on the membrane filter surface after filtration and placement on the selective medium. Entrapped air, indicated by patches of unstained membrane, was meticulously avoided to ensure uniform bacterial growth and accurate colony counting.

Care was taken to prevent the clustering of bacterial colonies by ensuring even dispersion on the membrane filters. Blank samples were used as negative controls, with one blank included for every batch of 5 poly tank water samples tested. This ensured that any unintended contamination or anomalies during analysis could be readily identified and mitigated.

3.11 Ethical Considerations

With ethics approval number UGMC/IRBReview/072/24, the University of Ghana Medical Centre -Institutional Research Board accepted the protocol for this research project. Before data collection, permission to access the study sites was secured from assembly members and managers of the community water storage tanks. Copies of clearance letters were provided to those who required them. The purpose and objectives of the study were clearly explained to the relevant stakeholders, and participation was entirely voluntary. Managers of the community water storage tanks maintained the freedom to leave the study at any time without facing any repercussions.

This study posed no direct risks to participants. To maintain confidentiality, personal identifiers were replaced with generated identity numbers throughout the study. While no monetary compensation was offered to the selected communities, verbal expressions of gratitude were conveyed. All water samples were securely stored in a locked laboratory, with access restricted to the researcher and the CSIR- Water Research Institute laboratory experts.



CHAPTER FOUR

RESULTS

4.0 Introduction

This Chapter presents the findings of the study on the quality of water stored in community tanks in urban Accra. This chapter provides a detailed analysis of the microbiological and physicochemical properties of the sampled water, as well as the calculated Water Quality Index (WQI). The microbial and physicochemical properties of sampled water (storage tank) from the three communities, Korle Gono, Laterbiokoshie and Zebra Line, are presented in Table 4.1 to 4.13

4.1 Microbial Quality of Stored Water

Table 4.1 presents the levels of microbial contamination detected in stored water at Korle Gono. Microbial indicators assessed total coliforms, faecal coliforms, *Escherichia coli*, total heterotrophic bacteria, and *Pseudomonas spp.* At Korle Gono, the mean total coliform concentration was $1.25 \times 10^4 \pm 3.06 \times 10^4$ cfu/100 mL. Faecal coliforms were present at a mean concentration of $9.62 \times 10^4 \pm 2.45 \times 10^4$ cfu/100 mL, while total heterotrophic bacteria levels were relatively high, averaging 4.11×10^4 cfu/100 mL. The mean levels of *Pseudomonas spp.* contamination detected was $0.31 \times 10^2 \pm 0.44 \times 10^2$ cfu/100 mL. These results suggest that, despite comparatively lower coliform levels, stored water in Korle Gono exhibited notable general microbial activity.

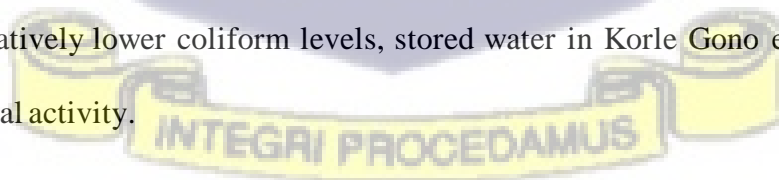


Table 4. 1: Microbiological quality of water samples Korle Gono

	Mean [\pm SD]	WHO Guideline	GSA Guideline
Total Coliform [cfu/100 mL]	1.25×10^4 [$\pm 3.06 \times 10^4$]	0	0
Faecal Coliform (FC) [cfu/100 mL]	9.62×10^3 [$\pm 2.45 \times 10^4$]	0	0
<i>Escherichia coli</i> [cfu/100 mL]	1.56×10^4 [$\pm 3.08 \times 10^4$]	0	0
<i>Pseudomonas spp.</i> [cfu/100 mL]	0.31×10^2 [$\pm 0.44 \times 10^2$]	0	0
THB [cfu/100 mL]	4.11×10^3 [$\pm 2.59 \times 10^3$]	–	5.00×10^2

THB = Total Heterotrophic Bacteria; cfu = colony forming units, WHO = World Health Organisation; GSA = Ghana Standards Authority; “–” = Not Available

In Laterbiokoshie, stored water samples were contaminated with total coliforms at a mean concentration of $6.63 \times 10^4 \pm 7.95 \times 10^4$ cfu/100 mL. Faecal coliform and *Escherichia coli* counts also followed a similar pattern, with a mean contamination level of $3.93 \times 10^4 \pm 4.98 \times 10^4$ cfu/100 mL and $2.89 \times 10^4 \pm 4.20 \times 10^4$ cfu/100 mL, respectively. Total heterotrophic bacteria contamination was detected at $4.11 \times 10^3 \pm 2.86 \times 10^3$ cfu/100 mL (Table 4.2).

Table 4. 2: Microbiological quality of water samples Laterbiokoshie

	Mean [\pm SD]	WHO Guideline	GSA Guideline
Total Coliform [cfu/100 mL]	6.63×10^4 [$\pm 7.95 \times 10^4$]	0	0
Faecal Coliform (FC) [cfu/100 mL]	3.93×10^4 [$\pm 4.98 \times 10^4$]	0	0
<i>Escherichia coli</i> [cfu/100 mL]	2.89×10^4 [$\pm 4.20 \times 10^4$]	0	0
<i>Pseudomonas spp.</i> [cfu/100 mL]	1.26×10^2 [$\pm 3.38 \times 10^2$]	0	0
THB [cfu/100 mL]	4.11×10^3 [$\pm 2.86 \times 10^3$]	–	5.00×10^2

THB = Total Heterotrophic Bacteria; WHO = World Health Organisation; GSA = Ghana Standards Authority; “–” = Not Available

Table 4.3 presents the microbial quality of water stored in community storage tanks at Zebra Line. Faecal coliform concentrations were higher, with a mean of $6.65 \times 10^3 \pm 1.76 \times 10^4$ cfu/100 mL, than the recommended 0 cfu/100 mL by WHO and GSA. Total heterotrophic bacteria levels were at $2.78 \times 10^3 \pm 2.01 \times 10^3$ cfu/100 mL, while Total coliforms and *Escherichia coli* contamination of stored water were detected at $2.40 \times 10^4 \pm 6.32 \times 10^4$ cfu/100 mL and $2.66 \times 10^3 \pm 7.03 \times 10^3$ cfu/100 mL, respectively. *Pseudomonas spp.* was present at $0.44 \times 10^2 \pm 0.68 \times 10^2$ cfu/100 mL as shown in Table 4.3 below.

Table 4. 3: Microbiological quality of water samples from Zebra Line

	Mean [\pm SD]	WHO Guideline	GSA Guideline
Total Coliform [cfu/100 mL]	$2.40 \times 10^4 [\pm 6.32 \times 10^4]$	0	0
Faecal Coliform (FC) [cfu/100 mL]	$6.65 \times 10^3 [\pm 1.76 \times 10^4]$	0	0
<i>Escherichia coli</i> [cfu/100 mL]	$2.66 \times 10^3 [\pm 7.03 \times 10^3]$	0	0
<i>Pseudomonas spp.</i> [cfu/100 mL]	$0.44 \times 10^2 [\pm 0.68 \times 10^2]$	0	0
THB [cfu/100 mL]	$2.78 \times 10^3 [\pm 2.01 \times 10^3]$	–	5.00×10^2

THB = Total Heterotrophic Bacteria; WHO = World Health Organisation; GSA = Ghana Standards Authority; “–” = Not Available

Table 4.4 presents the levels of microbial contamination identified in water samples stored in community tanks in the three communities studied. The mean value for total coliforms was $3.51 \times 10^4 \pm 6.33 \times 10^4$ cfu/100 mL. This value exceeds both the World Health Organisation (WHO) and Ghana Standards Authority (GSA) guidelines, which stipulate zero total coliforms per 100 mL. Similarly, the mean value for faecal coliforms was $1.95 \times 10^4 \pm 3.65 \times 10^4$ cfu/100 mL, surpassing acceptable limits. The mean values for *Escherichia coli* and *Pseudomonas spp.* were $1.68 \times 10^4 \pm 3.21 \times 10^4$ cfu/100 mL and $0.69 \times 10^4 \pm 2.04 \times 10^4$ cfu/100 mL, respectively.

Total heterotrophic bacteria (THB) recorded a mean count of $3.74 \times 10^3 \pm 2.52 \times 10^3$ cfu/100 mL, far exceeding the GSA guideline of 5.00×10^2 cfu/100 mL. Significant differences [$p < 0.05$] were observed in the mean values for the different microbes, as shown in Table 4.4.

Table 4. 4: Microbiological quality of water samples from the three communities

	Mean [\pm SD]	WHO Guideline	GSA Guideline
Total Coliform [cfu/100 mL]	$3.51 \times 10^4 [\pm 6.33 \times 10^4]$	0	0
Faecal Coliform (FC) [cfu/100 mL]	$1.95 \times 10^4 [\pm 3.65 \times 10^4]$	0	0
<i>Escherichia coli</i> [cfu/100 mL]	$1.68 \times 10^4 [\pm 3.21 \times 10^4]$	0	0
<i>Pseudomonas spp.</i> [cfu/100 mL]	$0.69 \times 10^2 [\pm 2.04 \times 10^2]$	0	0
Total Heterotrophic Bacteria [cfu/100 mL]	$3.74 \times 10^3 [\pm 2.52 \times 10^3]$	–	5.00×10^2

cfu= colony forming units; GSA = Ghana Standards Authority; WHO = World Health

Organisation; “– “= Not Available

4.2 Comparison of physicochemical properties of water.

4.2.1 Physical Parameters

Table 4.5 shows the physicochemical parameters of water stored in community tanks at Korle Gono. The mean pH was 7.21 ± 0.56 , which falls within both the WHO and GSA recommended limits [6.50 – 8.50]. Conductivity levels were relatively low, with a mean of 580.56 ± 584.83 μ S/cm, within acceptable thresholds. Turbidity and colour were not detected in any of the samples collected from this site. Similarly, total suspended solids (TSS) were below detection limits. The mean total dissolved solids (TDS) concentration was 348.33 ± 350.90 mg/mL, within the WHO guideline [<1000 mg/mL] but slightly approaching the upper limit of the GSA guideline [≤ 500 mg/mL].

Table 4. 5: Physicochemical parameters of water stored in community tanks at Korle Gono

Parameters	Mean [SD]	WHO Guideline	GSA Guideline
pH	7.21 [\pm 0.56]	6.50 – 8.50	6.50 – 8.50
Conductivity [μ S/cm]	580.56 [\pm 584.83]	< 1000	\leq 1500
Turbidity [NTU]	ND [NA]	\leq 5	\leq 5
Colour [Hz]	ND [NA]	\leq 15	\leq 15
Total Suspended Solids [mg/mL]	ND [NA]	Not specified	Not specified
Total Dissolved Solids [mg/mL]	348.33 [\pm 350.90]	<1000	\leq 500

WHO = World Health Organisation; GSA = Ghana Standards Authority; “ND” = Not Detected (below detection limit); “NA” = Not applicable [all readings were undetectable except in one sample]

As presented in Table 4.6, the mean pH of stored water samples from Laterbiokoshie was 6.90 ± 0.40 , remaining within the acceptable limits set by both WHO and GSA standards. Mean conductivity was $1511.22 \pm 855.64 \mu\text{S/cm}$, which slightly exceeded the GSA guideline [$\leq 1500 \mu\text{S/cm}$] but was within the WHO’s broader range. Both turbidity and colour were undetectable in all samples. TSS was also below detection limits. The mean TDS was $906.73 \pm 513.38 \text{ mg/mL}$, which remained below the WHO threshold [$< 1000 \text{ mg/mL}$] but exceeded the GSA recommendation [$\leq 500 \text{ mg/mL}$].

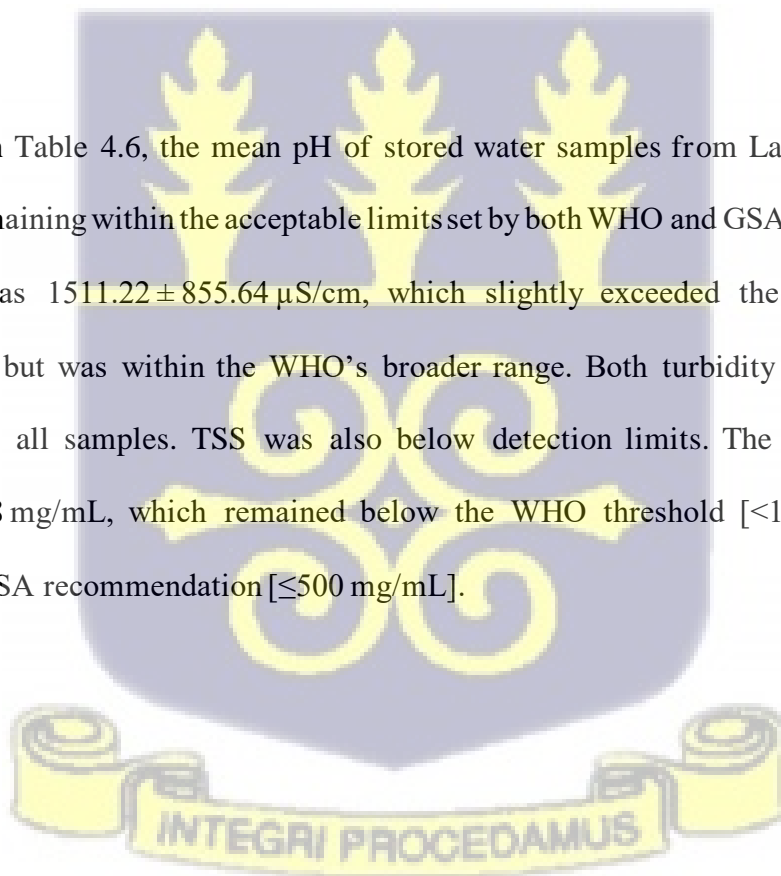


Table 4. 6: Physicochemical parameters of water stored in community tanks at Laterbiokoshie

Parameters	Mean [SD]	WHO Guideline	GSA Guideline
pH	6.90 [\pm 0.40]	6.50 – 8.50	6.50 – 8.50
Conductivity [μ S/cm]	1511.22 [\pm 855.64]	< 1000	\leq 1500
Turbidity [NTU]	ND [NA]	\leq 5	\leq 5
Colour [Hz]	ND [NA]	\leq 15	\leq 15
Total Suspended Solids [mg/mL]	ND [NA]	Not specified	Not specified
Total Dissolved Solids [mg/mL]	906.73 [\pm 513.38]	<1000	\leq 500

WHO = World Health Organisation; GSA = Ghana Standards Authority; “ND” = Not Detected (below detection limit); “NA” = Not applicable [all readings were undetectable except in one sample]

Table 4.7 summarises the physicochemical quality of stored water at Zebra Line. The mean pH was 6.29 ± 0.74 , falling below the lower limits of both WHO and GSA guidelines. Conductivity levels were the highest among all three sites, with a mean of $2254.14 \pm 953.42 \mu\text{S/cm}$, exceeding both national and international standards. Unlike the other sites, Zebra Line recorded measurable turbidity and colour, with values of 7.80 NTU and 7.50 Hz, respectively. While the turbidity exceeded the permissible limit (≤ 5 NTU), the colour remained within acceptable bounds. TSS was also detectable at this site, recorded at 8.00 mg/mL. The mean TDS level was 1352.49 ± 572.05 mg/mL, surpassing both WHO and GSA recommended thresholds.

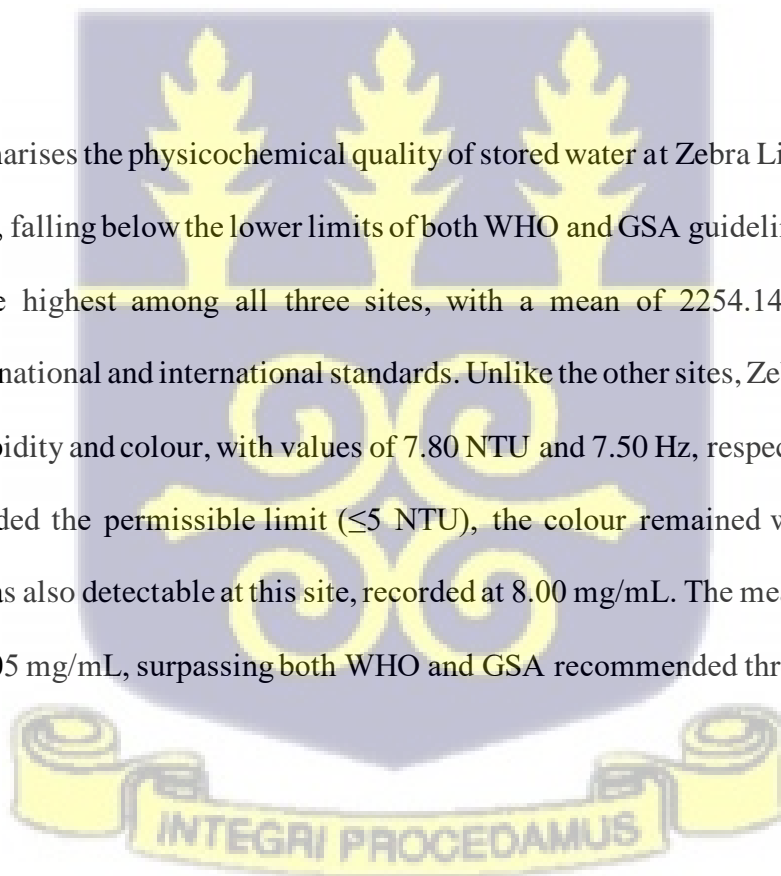


Table 4. 7: Physicochemical parameters of water stored in community tanks at Zebra Line

Parameters	Mean [SD]	WHO Guideline	GSA Guideline
pH	6.29 [\pm 0.74]	6.50 – 8.50	6.50 – 8.50
Conductivity [μ S/cm]	2254.14 [\pm 953.42]	< 1000	\leq 1500
Turbidity [NTU]	7.80 [NA]	\leq 5	\leq 5
Colour [Hz]	7.50 [NA]	\leq 15	\leq 15
Total Suspended Solids [mg/mL]	8.00 [NA]	Not specified	Not specified
Total Dissolved Solids [mg/mL]	1352.49 [\pm 572.05]	<1000	\leq 500

WHO = World Health Organisation; GSA = Ghana Standards Authority; “ND” = Not Detected (below detection limit); “NA” = Not applicable [all readings were undetectable except in one sample]

Table 4.8 highlights the findings of the physical parameters of water stored in community tanks. The pH of the water had a mean value of 6.84 ± 0.66 , which falls within the acceptable range of 6.50 – 8.50 according to both WHO and GSA guidelines. The mean electrical conductivity (EC) was $1384.20 \pm 1026.78 \mu\text{S/cm}$, approaching the upper limit of the GSA guideline ($\leq 1500 \mu\text{S/cm}$) but exceeding the WHO recommendation of $<1000 \mu\text{S/cm}$. Turbidity levels exceeded the WHO and GSA guideline limit of ≤ 5 NTU, with a mean of 7.80 NTU. The mean colour of the water, recorded at 7.50 Hz, complied with both WHO and GSA standards of ≤ 15 Hz. Total Suspended Solids (TSS) were measured at a mean of 8.00 mg/mL; however, no WHO or GSA guideline exists for this parameter. Total Dissolved Solids (TDS) had a mean value of 830.52 mg/mL [± 616.07], which is within the WHO guideline of < 1000 mg/mL but exceeds the GSA threshold of ≤ 500 mg/mL.

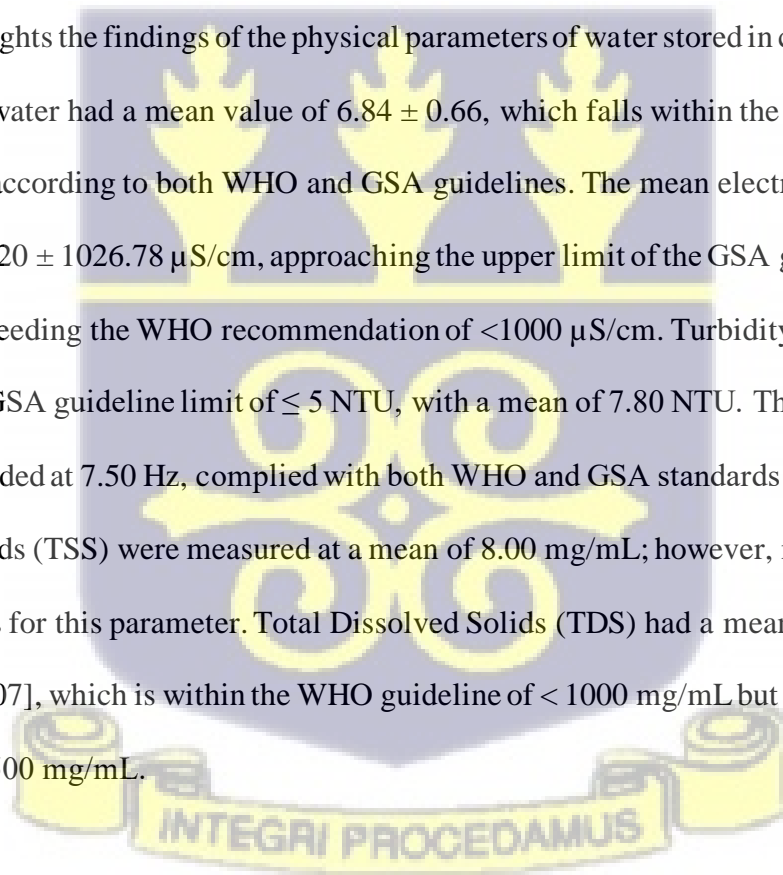


Table 4. 8: Physicochemical parameters of water samples from (Korle Gono, Zebra Line and Laterbiokoshie)

Parameters	Mean [\pm SD]	WHO Guideline	GSA Guideline
pH	6.84 [\pm 0.66]	6.50 – 8.50	6.50 – 8.50
Conductivity [μ S/cm]	1384.20 [\pm 1026.78]	< 1000	\leq 1500
Turbidity [NTU]	7.80 [\pm NA]	\leq 5	\leq 5
Colour [Hz]	7.50 [\pm NA]	\leq 15	\leq 15
Total Suspended Solids [mg/mL]	8.00 [\pm NA]	NA	Not specified
Total Dissolved Solids [mg/mL]	830.52 [\pm 616.07]	<1000	\leq 500

WHO = World Health Organisation; GSA = Ghana Standards Authority; “NA” = Not applicable [all readings were undetectable except in one sample]

4.2.2 Chemical Parameters

The water stored in community tanks at Korle Gono recorded a mean alkalinity of 70.11 ± 21.76 mg/mL. Bicarbonate levels were measured at 85.54 ± 26.55 mg/mL, while carbonate was not detected. Total hardness was 109.02 ± 31.19 mg/mL. The mean calcium hardness was 62.64 ± 15.74 mg/mL and magnesium hardness were 46.39 ± 15.85 mg/mL. Calcium and magnesium concentrations were 25.05 ± 6.30 mg/mL and 11.27 ± 3.85 mg/mL, respectively. Chloride concentration was 103.05 ± 187.49 mg/mL, and sodium was 69.73 ± 102.11 mg/mL. Potassium was found at 9.12 ± 2.59 mg/mL. Iron and manganese were recorded at 0.03 ± 0.02 mg/mL and 0.02 mg/mL, respectively. Nitrate-nitrogen was measured at 0.22 ± 0.12 mg/mL, while nitrite-nitrogen was 0.04 ± 0.03 mg/mL. Carbonate, phosphate-phosphorus, and ammonium-nitrogen were not detected. Sulphate concentration was 63.00 ± 28.61 mg/mL, and fluoride was measured at 0.12 ± 0.13 mg/mL (Table 4.9).

Table 4. 9: Chemical composition of water in community tanks in Korle gonno

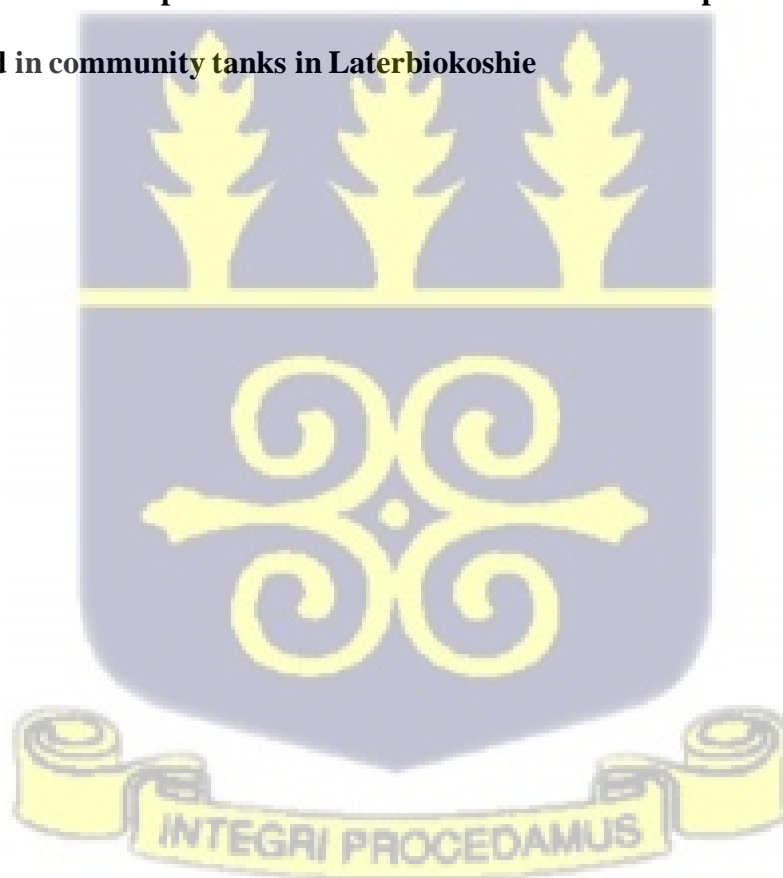
	Mean [\pm SD]	WHO Guideline	GSA Guideline
Alkalinity [mg/mL]	70.11 [\pm 21.76]	Not specified	Not specified
Bicarbonate [mg/mL]	85.54 [\pm 26.55]	Not specified	Not specified
Carbonate [mg/mL]	ND	Not specified	Not specified
Total Hardness [mg/mL]	109.02 [\pm 31.19]	\leq 500	\leq 500
Calcium Hardness [mg/mL]	62.64 [\pm 15.74]	Not specified	Not specified
Magnesium Hardness [mg/mL]	46.39 [\pm 15.85]	Not specified	Not specified
Calcium [mg/mL]	25.05 [\pm 6.30]	Not specified	Not specified
Magnesium [mg/mL]	11.27 [\pm 3.85]	Not specified	Not specified
Chloride [mg/mL]	103.05 [\pm 187.49]	\leq 250	\leq 250
Sodium [mg/mL]	69.73 [\pm 102.11]	\leq 200	\leq 200
Potassium [mg/mL]	9.12 [\pm 2.59]	Not specified	Not specified
Iron [mg/mL]	0.03 [\pm 0.02]	\leq 0.3	\leq 0.3
Manganese [mg/mL]	0.02 [NA]	\leq 0.1	\leq 0.1
Nitrate-Nitrogen [mg/mL]	0.22 [\pm 0.12]	\leq 10	\leq 10
Nitrite-Nitrogen [mg/mL]	0.04 [\pm 0.03]	\leq 0.1	\leq 0.1
Phosphate-Phosphorus [mg/mL]	ND	Not specified	Not specified
Sulphate [mg/mL]	63.00 [\pm 28.61]	\leq 250	\leq 250
Fluoride [mg/mL]	0.12 [\pm 0.13]	\leq 1.5	\leq 1.5
Ammonium-Nitrogen [mg/mL]	ND	Not specified	Not specified

“ND” = Not Detected (below detection limit); “NA” = Not applicable [all readings were below the detection limit except in one sample]; Not specified indicates that, there is no available standard limit provided for comparison

In Laterbiokoshie, the alkalinity of stored water was 147.5 ± 54.40 mg/mL, with bicarbonate recorded at 179.96 ± 66.37 mg/mL (Table 4.10). Carbonate was not detected. Total hardness

was 288.60 ± 161.82 mg/mL. Calcium hardness was 164.91 ± 125.92 mg/mL, and magnesium hardness was 123.69 ± 58.92 mg/mL. Calcium and magnesium levels were 65.96 ± 50.37 mg/mL and 30.06 ± 14.32 mg/mL, respectively. Chloride was measured at 334.96 ± 249.42 mg/mL and sodium at 198.09 ± 117.39 mg/mL. Potassium concentration was 10.06 ± 3.84 mg/mL. Iron and manganese levels were 0.04 ± 0.01 mg/mL and 0.04 ± 0.05 mg/mL, respectively. Nitrate-nitrogen was 0.62 ± 0.35 mg/mL, and nitrite-nitrogen was 0.02 ± 0.01 mg/mL. Carbonate, phosphate-phosphorus, and ammonium-nitrogen were not detected. Sulphate was measured at 85.67 ± 43.20 mg/mL. Fluoride concentration was recorded at 0.54 mg/mL.

Table 4. 10: Chemical composition of water Levels of the chemical parameters of the quality of water stored in community tanks in Laterbiokoshie



	Mean [\pm SD]	WHO Guideline	GSA Guideline
Alkalinity [mg/mL]	147.5 [\pm 54.40]	Not specified	Not specified
Bicarbonate [mg/mL]	179.96 [\pm 66.37]	Not specified	Not specified
Carbonate [mg/mL]	ND	Not specified	Not specified
Total Hardness [mg/mL]	288.60 [\pm 161.82]	\leq 500	\leq 500
Calcium Hardness [mg/mL]	164.91 [\pm 125.92]	Not specified	Not specified
Magnesium Hardness [mg/mL]	123.69 [\pm 58.92]	Not specified	Not specified
Calcium [mg/mL]	65.96 [\pm 50.37]	Not specified	Not specified
Magnesium [mg/mL]	30.06 [\pm 14.32]	Not specified	Not specified
Chloride [mg/mL]	334.96 [\pm 249.42]	\leq 250	\leq 250
Sodium [mg/mL]	198.09 [\pm 117.39]	\leq 200	\leq 200
Potassium [mg/mL]	10.06 [\pm 3.84]	Not specified	Not specified
Iron [mg/mL]	0.04 [\pm 0.01]	\leq 0.3	\leq 0.3
Manganese [mg/mL]	0.04 [\pm 0.05]	\leq 0.1	\leq 0.1
Nitrate-Nitrogen [mg/mL]	0.62 [\pm 0.35]	\leq 10	\leq 10
Nitrite-Nitrogen [mg/mL]	0.02 [\pm 0.01]	\leq 0.1	\leq 0.1
Phosphate-Phosphorus [mg/mL]	ND	Not specified	Not specified
Sulphate [mg/mL]	85.67 [\pm 43.20]	\leq 250	\leq 250
Fluoride [mg/mL]	0.54 [NA]	\leq 1.5	\leq 1.5
Ammonium-Nitrogen [mg/mL]	ND	Not specified	Not specified

“ND” = Not Detected (below detection limit); “NA” = Not applicable [all readings were below the detection limit except in one sample]; Not specified indicates that, there is no available standard limit provided for comparison

The stored water at Zebra Line had an alkalinity of 56.69 ± 42.24 mg/mL and a bicarbonate concentration of 69.16 ± 51.54 mg/mL (Table 4.11). Carbonate was not detected. Total hardness was 405.89 ± 167.80 mg/mL. Calcium hardness and magnesium hardness were recorded at 202.58 ± 95.14 mg/mL and 123.69 ± 81.20 mg/mL, respectively. The mean calcium concentration was 81.03 ± 38.06 mg/mL, while magnesium was 49.40 ± 19.73 mg/mL.

Chloride concentration was 676.00 ± 285.34 mg/mL, and sodium was 320.94 ± 140.74 mg/mL. Potassium was found at 10.19 ± 3.95 mg/mL. Iron and manganese levels were 0.04 ± 0.01 mg/mL and 0.03 ± 0.01 mg/mL, respectively. Nitrate-nitrogen was 0.54 ± 0.25 mg/mL, and nitrite-nitrogen was 0.03 ± 0.01 mg/mL. Carbonate, phosphate-phosphorus, and ammoniumnitrogen were not detected. Sulphate concentration was 83.23 ± 34.47 mg/mL, and fluoride was measured at 0.26 ± 0.17 mg/mL (Table 4.11).

Table 4. 11: Chemical composition of water Levels of the chemical parameters of the quality of water stored in community tanks Zebra Line

	Mean [\pm SD]	WHO Guideline	GSA Guideline
Alkalinity [mg/mL]	56.69 [\pm 42.24]	Not specified	Not specified
Bicarbonate [mg/mL]	69.16 [\pm 51.54]	Not specified	Not specified
Carbonate [mg/mL]	ND	Not specified	Not specified
Total Hardness [mg/mL]	405.89 [\pm 167.80]	≤ 500	≤ 500
Calcium Hardness [mg/mL]	202.58 [\pm 95.14]	Not specified	Not specified
Magnesium Hardness [mg/mL]	123.69 [\pm 81.20]	Not specified	Not specified
Calcium [mg/mL]	81.03 [\pm 38.06]	Not specified	Not specified
Magnesium [mg/mL]	49.40 [\pm 19.73]	Not specified	Not specified
Chloride [mg/mL]	676.00 [\pm 285.34]	≤ 250	≤ 250
Sodium [mg/mL]	320.94 [\pm 140.74]	≤ 200	≤ 200
Potassium [mg/mL]	9.41 [\pm 3.68]	Not specified	Not specified
Iron [mg/mL]	0.04 [\pm 0.01]	≤ 0.3	≤ 0.3
Manganese [mg/mL]	0.09 [\pm 0.02]	≤ 0.1	≤ 0.1
Nitrate-Nitrogen [mg/mL]	0.54 [\pm 0.25]	≤ 10	≤ 10
Nitrite-Nitrogen [mg/mL]	0.03 [\pm 0.04]	≤ 0.1	≤ 0.1
Phosphate-Phosphorus [mg/mL]	ND	Not specified	Not specified
Sulphate [mg/mL]	66.33 [\pm 20.42]	≤ 250	≤ 250
Fluoride [mg/mL]	0.15 [\pm 0.14]	≤ 1.5	≤ 1.5

Ammonium-Nitrogen [mg/mL]	ND	Not specified	Not specified
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“ND” = Not Detected (below detection limit); “NA” = Not applicable [all readings were below the detection limit except in one sample]; Not specified indicates that, there is no available standard limit provided for comparison

The chemical parameters of water stored in community tanks, as outlined in Table 4.12, show variability in compliance with Ghana Standards Authority (GSA) guidelines. The mean alkalinity was $[94.22 \pm 53.31 \text{ mg/mL}]$, and the bicarbonate concentration was $[114.94 \pm 69.92 \text{ mg/mL}]$; neither parameter is specified under the WHO and GSA guidelines. Carbonates were not detected in any of the samples (Table 4.12). Total hardness had a mean value of $[256.97 \pm 176.48 \text{ mg/mL}]$, well within the permissible limit of $\leq 500 \text{ mg/mL}$. Similarly, calcium hardness $[138.64 \pm 176.48 \text{ mg/mL}]$ and magnesium hardness $[118.16 \pm 83.35 \text{ mg/mL}]$ were not covered under the GSA guidelines but are critical indicators of water hardness. The mean concentrations of calcium and magnesium were $[55.45 \pm 42.42 \text{ mg/mL}]$ and $[28.71 \pm 20.25 \text{ mg/mL}]$, respectively (Table 4.12).

Chloride concentrations exceeded the recommended limit of $\leq 250 \text{ mg/mL}$, with a mean value of $[346.97 \pm 326.73 \text{ mg/mL}]$. Sodium levels, with a mean of $[186.28 \pm 153.15 \text{ mg/mL}]$, complied with the guideline of $\leq 200 \text{ mg/mL}$. Potassium levels had a mean value of $[9.54 \pm 3.27] \text{ mg/mL}$, with no guideline provided for comparison. Iron and manganese concentrations were well within acceptable limits, with mean values of $[0.04 \pm 0.01 \text{ mg/mL}]$ and $[0.06 \pm 0.04 \text{ mg/mL}]$, respectively, against their respective limits of $\leq 0.3 \text{ mg/mL}$ and $\leq 0.1 \text{ mg/mL}$ (Table 4.12).

Nitrate-nitrogen $[0.46 \pm 0.31 \text{ mg/mL}]$ and nitrite-nitrogen $[0.02 \pm 0.03 \text{ mg/mL}]$ were significantly below their respective limits of $\leq 10 \text{ mg/mL}$ and $\leq 0.1 \text{ mg/mL}$ as indicated by the WHO and GSA. Phosphate-phosphorus and ammonium-nitrogen were undetectable in the samples. Sulphate concentrations were well within the guideline of $\leq 250 \text{ mg/mL}$, with a mean

value of $[72.09 \pm 33.30 \text{ mg/mL}]$. Fluoride concentrations, at a mean of $[0.17 \pm 0.18 \text{ mg/mL}]$, were substantially below the permissible limit of $\leq 1.5 \text{ mg/mL}$ (Table 4.12).

Table 4. 12: Chemical composition of water Levels of the chemical parameters of the quality of water stored in community tanks in the three sampling sites

Parameters	Mean $[\pm \text{SD}]$	WHO Guideline	GSA Guideline
Alkalinity (ALK) [mg/mL]	94.22 $[\pm 53.31]$	Not specified	Not specified
Bicarbonate (HCO_3) [mg/mL]	114.94 $[\pm 69.92]$	Not specified	Not specified
Carbonate (CO_3) [mg/mL]	ND	Not specified	Not specified
Total Hardness (T. Hard.) [mg/mL]	256.97 $[\pm 176.48]$	≤ 500	≤ 500
Calcium Hardness (Ca Hard.) [mg/mL]	138.64 $[\pm 176.48]$	Not specified	Not specified
Magnesium Hardness (Mg Hard.) [mg/mL]	118.16 $[\pm 83.35]$	Not specified	Not specified
Calcium (Ca) [mg/mL]	55.45 $[\pm 42.42]$	Not specified	Not specified
Magnesium (Mg) [mg/mL]	28.71 $[\pm 20.25]$	Not specified	Not specified
Chloride (Cl) [mg/mL]	346.97 $[\pm 326.73]$	≤ 250	≤ 250
Sodium (Na) [mg/mL]	186.28 $[\pm 153.15]$	≤ 200	≤ 200
Potassium (K) [mg/mL]	9.54 $[\pm 3.27]$	Not specified	Not specified
Iron (Fe) [mg/mL]	0.04 $[\pm 0.01]$	≤ 0.3	≤ 0.3
Manganese (Mn) [mg/mL]	0.06 $[\pm 0.04]$	≤ 0.1	≤ 0.1
Nitrate-Nitrogen ($\text{NO}_3\text{-N}$) [mg/mL]	0.46 $[\pm 0.31]$	≤ 10	≤ 10
Nitrite-Nitrogen ($\text{NO}_2\text{-N}$) [mg/mL]	0.02 $[\text{ytk} \pm 0.03]$	≤ 0.1	≤ 0.1
Phosphate-Phosphorus ($\text{PO}_4\text{-P}$) [mg/mL]	ND	Not specified	Not specified
Sulphate (SO_4) [mg/mL]	72.09 $[\pm 33.30]$	≤ 250	≤ 250
Fluoride (F) [mg/mL]	0.17 $[\pm 0.18]$	≤ 1.5	≤ 1.5
Ammonium-Nitrogen ($\text{NH}_4\text{-N}$) [mg/mL]	ND	Not specified	Not specified

WHO = World Health Organisation; GSA = Ghana Standards Authority; “ND” = Not Detected (below detection limit); “NA” = Not applicable [all readings were below the detection limit except in one sample]; Not specified indicates that, there is no available standard limit provided for comparison.

4.3 Water Quality Index of Water Stored in Community Tanks

Figure 4.1 depicts the distribution of water quality index (WQI) grades among the samples analysed. Most of the samples (60.0%, n=15) were classified as "Good" [WQI: 26 – 50], while 32.0% [n=8] were graded as "Poor" [WQI: 51 – 70]. A small proportion of the samples [8.0%, n=2] fell within the "Excellent" category [WQI: 0 – 25].

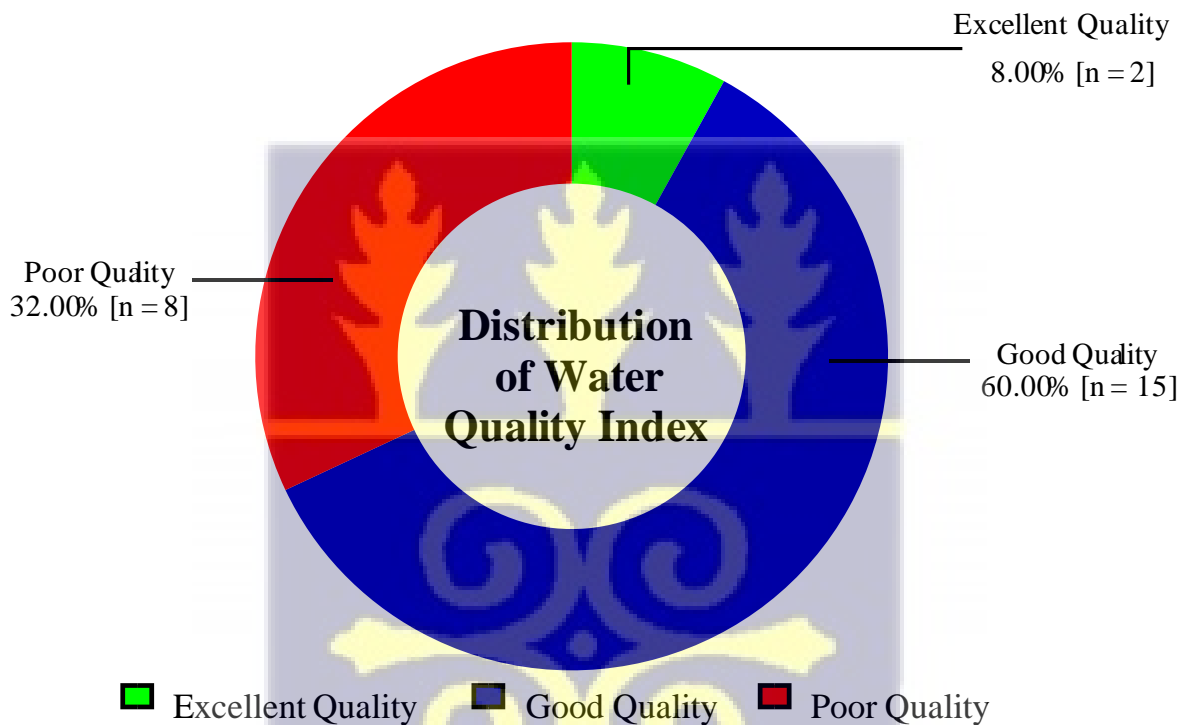


Figure 4. 1: Quality index of the water sampled from community tanks

Table 4.13 presents the distribution of water quality index (WQI) across the sampling locations. At Korle Gono, 77.78% [7/9] of the water samples were classified as Good [WQI: 26–50], while 11.11% [1/9] were rated as Excellent [WQI: 0–25] and 11.11% [1/9] as Poor [WQI: 51–70]. Similarly, in Laterbiokoshie, most samples [66.67%, 6/9] fell within the good category, with 22.22% [2/9] classified as Poor and 11.11% [1/9] as Excellent. At Zebra Line, a distinct

pattern was observed, where 71.43% [5/7] of the samples were classified as Poor, 28.57% [2/7] as Good, and none as Excellent The proportion of samples rated as Excellent or Good was significantly lower in Zebra Line compared to Korle Gono and Laterbiokoshie [$p < 0.05$].

Table 4. 13: Distribution of water quality index of sampled water tanks across the study sites.

	Water Quality Index (WQI)		
	Excellent Quality n [%]	Good Quality n [%]	Poor Quality n [%]
Korle Gono	1 [11.11]	7 [77.78]	1 [11.11]
Laterbiokoshie	1 [11.11]	6 [66.67]	2 [22.22]
Zebra Line	0 [0.00]	2 [28.57]	5 [71.43]

Sampling Site n = total number



CHAPTER FIVE

DISCUSSION

5.0 Introduction

Chapter Five of this study discusses the findings of the study on water quality in community tanks in urban Accra, interpreting the results in relation to existing literature and established water quality standards.

5.1 Microbial Quality of Water Stored in Community Tanks

Water safety and quality are fundamental to human development and well-being, and infectious diseases like cholera, dysentery, and diarrhoea are connected to contaminated water and inadequate sanitation practices. This study has revealed notable deficiencies in the microbial, physicochemical, and chemical quality of water stored in community storage tanks for domestic drinking and domestic use, a situation that could have negative public health implications on consumers, indicating the need for efficient water management practices.

The microbial analysis of water stored in community tanks revealed different levels of contamination, raising serious concerns about its suitability for human use. The mean values of total coliforms in water stored in community tanks far exceeded the zero-tolerance recommended by both the World Health Organisation (WHO) and the Ghana Standards Authority (GSA) (Table 4.4). The total coliforms in the stored water samples indicate a severe compromise in water quality and potential breaches in safety protocols during collection, transport or storage (Rani *et al.*, 2024; Seki *et al.*, 2024). Total coliforms function as primary indicators of microbial contamination in water, and their existence indicates an increased likelihood of other pathogenic microorganisms being present (Tambi *et al.*, 2023). Generally, the presence of total coliforms in water is indicative of contamination from faecal matter, poor sanitation, or compromised water storage systems, which allow for the proliferation of

these organisms. Similar studies conducted in Ghana have reported findings that provide empirical support for the findings of this study. A study in the Greater Accra Region by Dongdem *et al.*, (2023) reported that total coliforms were detected in water stored in public tanks, which aligns with this study's findings. Also, in a recent study in Accra among communities along the Odaw River, the researchers revealed that drinking water in these communities was contaminated with total coliforms (Baffoe *et al.*, 2024). Although the levels of total coliforms reported in both studies vary from what was reported in the present study, it all suggests that the water from these sources has levels of microbial contamination and may pose a health risk to consumers (Nwadike *et al.*, 2024).

Faecal coliforms were also detected at significant levels, above the acceptable limit set by GSA (Table 4.4). Their presence strongly suggests faecal contamination, which could arise from improper sealing of storage tanks or contamination during water collection and transfer. This is particularly concerning because faecal coliforms are closely associated with the presence of pathogens such as *Escherichia coli* and enteric viruses, known to cause waterborne diseases. A study in Ethiopia showed contamination of water storage tanks with total and faecal coliforms that exceeded acceptable limits set by the WHO, primarily due to crosscontamination during distribution and unsafe storage practices (Chalchisa *et al.*, 2017). In rural settings in the North Gondar Zone of Ethiopia, a study found that 56.5% of water sources tested positive for faecal coliforms, with factors such as educational status and sanitary conditions significantly influencing contamination levels (Getachew *et al.*, 2018). In the Bakavu region of the Republic of Congo, high levels of faecal coliforms were recorded in water tanks, suggesting that environmental conditions can exacerbate contamination risks (Bisimwa *et al.*, 2022). Furthermore, inadequate sanitation practices and poor faecal sludge management have been identified as primary pathways for faecal coliform contamination in drinking water, even in areas with improved sanitation infrastructure (Roy *et al.*, 2023).

The detection of *Escherichia coli* in the water samples above the acceptable limits provides further evidence of faecal pollution (Table 4.4). The presence of this organism in water sources meant for human consumption is a serious public health risk, as it serves as a more specific indicator of recent faecal contamination compared to total coliforms (Gomes *et al.*, 2024). *Escherichia coli* is the only member of total coliform found exclusively in the faeces of humans and other animals, and its presence in water suggests the potential presence of bacteria, viruses, and protozoa that cause digestive diseases in addition to recent faecal contamination of the water (Lima *et al.*, 2022; Nowicki *et al.*, 2021). The presence of *E. coli* points to the possible infiltration of untreated wastewater or poor hygienic practices during water handling. Consistent with this study's findings, a cross-sectional study conducted in Peru found water stored in tanks laden with *E. coli* (Hernández-Vásquez *et al.*, 2023). In a recent study, Mochware *et al.*, (2024) revealed the presence of *E. coli* in water stored in tanks which is consistent with the findings of this study. In Ghana, a study carried out in the Talensi District in the northern part revealed that drinking water stored in tanks in the district was contaminated with *Escherichia coli* (Kichana *et al.*, 2022), which is an indication of the unwholesomeness of the water and provides empirical support to the findings of this study.

The presence of *Pseudomonas spp.* and Total Heterotrophic Bacteria (THB) further corroborates poor water quality, as these organisms are often associated with biofilm formation and nutrient-rich water environments (Table 4.4). The levels of *Pseudomonas spp.* add another dimension to the contamination observed. While not directly indicative of faecal pollution, *Pseudomonas spp.* are opportunistic pathogens that thrive in nutrient-rich water and biofilms, particularly in storage systems that are not properly maintained (Kaestli *et al.*, 2019; Waqas *et al.*, 2023). Their presence could result from organic matter accumulation, stagnant water, or ineffective cleaning of storage facilities. The presence of *Pseudomonas spp.* raises concerns about potential infections in individuals with weakened immune systems, particularly if the

water is used for bathing or wound care (Stec *et al.*, 2022). In support of the findings of this study, Borjac *et al.*, (2023) found water stored in tanks in Sidon, Lebanon were contaminated with *Pseudomonas spp.* Similarly, another study conducted in Dubai showed that water stored in tanks were contaminated with *Pseudomonas spp.* (Khan & AlMadani, 2017), which is consistent with the findings of this study. In consonance with the findings of this study, Stec *et al.*, (2022) also reported *Pseudomonas spp.* as one of the bacterial pathogens isolated from stored water aside *Escherichia coli*.

The findings of this study showed a high Total Heterotrophic Bacterial (THB) level (Table 4.4), and this suggests that the water provides an environment conducive to bacterial growth, potentially leading to the establishment of microbial communities that could include harmful pathogens. These elevated counts may result from the organic material in the water, insufficient chlorination, or poor storage conditions that promote bacterial proliferation (Tudararo-Aherobo & Egieya, 2023). The presence of high THB levels also has implications for the effectiveness of disinfection processes (Dias *et al.*, 2022). Elevated bacterial loads can decrease the efficacy of chlorine or other disinfectants, rendering the water unsafe even after treatment (Lindmark *et al.*, 2022).

The significantly higher contamination levels at Korle Gono compared to Zebra Line and Laterbiokoshie (Table 4.1) may reflect differences in local environmental conditions, storage practices, or tank maintenance routines. The statistical significance observed in the differences between the mean values of these contaminants [$p < 0.05$] points to variability in contamination levels across the samples, which may reflect differences in the handling, storage practices, or source water quality in the communities studied. Inadequate cleaning of storage tanks or poor sanitary conditions in surrounding areas can contribute to elevated microbial loads (Chalchisa *et al.*, 2017; Waqas *et al.*, 2023). Additionally, the urban density and associated infrastructure challenges at Korle Gono might lead to increased exposure to faecal contamination from

leaking sewer systems or unprotected water sources. Consuming water contaminated with total coliforms, faecal coliforms, and *Escherichia coli* exposes individuals to the risk of gastrointestinal infections, including diarrhoeal diseases, cholera, and typhoid fever (Banseka & Tume, 2024; Pal *et al.*, 2018). Children, the elderly, and people with impaired immune systems are among the vulnerable groups most at risk of developing severe illness.

5.2 Physicochemical Profile of Water Stored in Community Tanks

Water quality is influenced by several physical attributes that determine its safety, usability, and aesthetic appeal. The physical properties of stored water can impact both its chemical composition and microbiological stability, making their assessment essential for public health protection. Variations in parameters such as pH, conductivity, turbidity, colour, and suspended solids can provide important information regarding potential contamination sources and the effectiveness of water storage and treatment practices.

The pH of the water stored in community storage tanks is a crucial element that determines its suitability for consumption and its interaction with plumbing materials. The mean pH value of 6.84 ± 0.66 (Table 4.8) falls within the acceptable range of 6.50 – 8.50 set by the Ghana Standards Authority (GSA). However, variations across different sampling locations suggest potential influences from environmental and anthropogenic factors (Table 4.5, Table 4.6, and Table 7). Water with a pH approaching the lower limit of acceptability [6.50 – 8.50], as observed in some samples, may contribute to the corrosion of metal storage tanks and pipelines, leading to the leaching of metals such as lead and copper (Pieper *et al.*, 2016). This process could introduce additional chemical contaminants into the water, which may have adverse health effects when consumed over extended periods. Consistent with this study's findings, Makoko *et al.*, (2021) found the pH of domestic water stored in tanks to be within the acceptable limit in a rapidly growing urban community in Uganda. However, the study Makoko *et al.*, (2021) reported a pH value of 7.3, which is slightly higher than the 6.84 reported in this

study. Similarly, in South-Western Ethiopia, Chalchisa *et al.*, (2017) also reports that domestic water stored in tanks had a pH between 7.14 and 7.46, which is within the acceptable limit for pH as described by GSA. It is worth noting that although the study Chalchisa *et al.*, (2017) provides empirical support for the findings of this study, there is a variation in the pH level reported. This can be attributed to the differences in sampling technique and analytical methods used in the two studies. In Brazil, the average pH of water stored in household tanks was found to be 6.5, which is within the acceptable range for potable water according to Brazilian standards (Julião *et al.*, 2021).

Conductivity serves as an indicator of the total dissolved ion concentration in water, which reflects its mineral content and potential sources of contamination (Wang *et al.*, 2019). The mean conductivity value of $1384.20 \pm 1026.78 \mu\text{S}/\text{cm}$ (Table 4.8), though within the GSA guideline of $\leq 1500 \mu\text{S}/\text{cm}$, suggests a substantial presence of dissolved solids. Water with elevated conductivity levels may originate from natural mineral deposits or anthropogenic activities such as agricultural runoff, industrial waste, or wastewater discharge (Makoko *et al.*, 2021). While moderate conductivity is not inherently harmful, persistently high values may affect water taste and indicate the presence of undesirable ionic compounds, including heavy metals (Bozorg-Haddad *et al.*, 2021). Furthermore, variations in conductivity between different sampling sites (Table 4.5, Table 4.6, Table 4.7) suggest that local geological formations and human activities influence the water quality. Although at Samaru community in Northwest Nigeria, researchers found that the conductivity levels were within acceptable limits, similar to this study (Adesakin *et al.*, 2020), the values reported are lower ($256 \mu\text{S}/\text{cm}$) than what was reported in the present study. Also in Kenya, Sila, (2019) a conductivity level between 43.90 and $816 \mu\text{S}/\text{cm}$, was reported within the acceptable limit, similar to the findings of this study. However, the levels of conductivity reported were lower than the $1378.00 \mu\text{S}/\text{cm}$ reported in this study.

Turbidity, which measures the extent to which suspended particles obstruct light's ability to pass through water, was recorded at a mean value of 7.80 NTU. This exceeds the recommended limit of ≤ 5 NTU, indicating the presence of significant particulate matter. Elevated turbidity levels may arise from inadequate filtration or organic matter accumulation in storage tanks (Slavik *et al.*, 2020). High turbidity is particularly concerning as it can reduce the effectiveness of disinfection processes, such as chlorination, by shielding microorganisms from exposure to disinfectants (Khedikar *et al.*, 2021). Additionally, the presence of suspended solids may foster microbial growth, further compromising the microbiological quality of the water (Gomez & Aggarwal, 2019). Several other studies have also reported high levels of turbidity in water stored in tanks. In Kenya, the turbidity of water samples analysed in the study of Sila, (2019) was between 9.10 and 1235.60 NTU. However, in Kampala, Uganda, Makoko *et al.*, (2021) reported turbidity levels below 1 NTU which contradicts the findings of this study. Also, Chalchisa *et al.*, (2017) reported safe levels of turbidity between 2.1 and 2.9 NTU which varies with the findings of this study.

The mean colour measurement of 7.50 Hz (Table 4.8) complies with the GSA standard of ≤ 15 Hz. Colour in water is typically influenced by the existence of dissolved organic compounds, metallic ions, and suspended particles (WHO, 2022). The water's aesthetic quality is acceptable based on the recorded values, although there is a colour fluctuation across locations (Table 4.5, Table 4.6, Table 4.7) may indicate differing sources of contamination. Water with noticeable colouration may contain organic matter from decaying vegetation or trace amounts of iron and manganese, which could alter its chemical profile (Albrektienė & Rimeika, 2010). Although colour alone does not always indicate health risks, persistently high values could suggest the presence of contaminants that warrant further analysis and treatment. In a similar study in rural Kenya, the colour measurement recorded was extremely high (Sila, 2019) as compared to the findings of this study.

Total Suspended Solids (TSS) reflect the concentration of insoluble particles in water, which may originate from soil erosion, decaying organic material, or industrial discharge (Adjovu *et al.*, 2023). The mean TSS level of 8.00 mg/mL does not have a specified GSA guideline for comparison, but its presence in stored water is notable. Excessive suspended solids can lead to aesthetic and operational issues, such as sediment accumulation in tanks and distribution pipes (Zezulka *et al.*, 2024). Moreover, these particles provide a medium for microbial attachment and growth, further exacerbating the risk of contamination. Effective sedimentation and filtration measures should be implemented to maintain lower TSS levels and improve overall water clarity and quality. Comparatively, the findings of Adesakin *et al.*, (2020) in Northwest Nigeria in water stored in tanks was higher than what was reported in this study.

Total Dissolved Solids (TDS) encompasses a range of dissolved minerals, including calcium, magnesium, sodium, and potassium, which influence the taste and palatability of the water.

The mean TDS concentration of 830.52 mg/mL falls within the GSA permissible limit of ≤ 1000 mg/mL, indicating that the water contains a considerable amount of dissolved inorganic and organic substances. While the recorded levels do not pose immediate health risks, elevated TDS may affect the acceptability of the water for drinking and cooking. In addition, plumbing systems and appliances may scale as a result of elevated TDS levels, raising maintenance costs. The variability in TDS concentrations among different sampling sites suggests that local geological characteristics and human activities, such as agricultural or industrial practices, may be contributing factors. Long-term monitoring of TDS levels is essential to ensure that they remain within acceptable limits and do not indicate increasing contamination over time. In a similar study conducted in Palestine, the researchers found the levels of TDS [426 mg/mL] to be within the acceptable limit (Al-Khatib *et al.*, 2023) , and this is consistent with the findings of this study. The variations in the levels of TDS reported between this study could be attributed to the differences in water source and the analytical methods, and the equipment used. Also,

the TDS levels reported in the Ankober District in Ethiopia were within the acceptable limits (Kassegne & Leta, 2020) , similar to the findings of this study.

The chemical composition of stored water varied across the sampling locations, with some parameters exceeding established regulatory limits (Table 4.9 – 4.11). The alkalinity and bicarbonate concentrations, though not covered under Ghana Standards Authority (GSA) guidelines, suggest the presence of dissolved carbonates that contribute to water buffering capacity (Middelburg *et al.*, 2020). The absence of detectable carbonate levels (Table 4.12) may indicate that the primary source of alkalinity is bicarbonate rather than carbonate salts. This composition plays a role in stabilising pH, which is essential for minimising fluctuations that could affect microbial growth and corrosion of storage tanks. In a study conducted at Dodowa in the Greater Accra Region of Ghana, the reported level of bicarbonate (Arko *et al.*, 2019) is well below what was reported in this study. The variations in the reported levels of bicarbonate could be attributed to the difference in source water and the geographical location, as well as the analytical method and equipment used in the measurement. In another study in Kenya, Sila, (2019) also reported alkalinity levels of 94.57 – 130.03 mg/mL, which is comparable to 94.22 mg/mL reported in this study. Also, the study Adesakin *et al.*, (2020) reported lower levels of alkalinity as compared to the 94.22 mg/mL reported in this study.

Total hardness levels remained within the permissible limits, with variations observed across the sampling sites (Table 4.9 – 4.11). The contributions of calcium and magnesium to hardness were not explicitly regulated, but their presence in significant amounts suggests geological influences from aquifers supplying the stored water. Elevated hardness levels, particularly at Zebra Line (Table 4.11), may result from prolonged contact with limestone or dolomitic formations (Ingin *et al.*, 2024). Although not directly harmful, excessive hardness can reduce soap efficiency and contribute to scaling in plumbing systems, necessitating periodic maintenance (Cabiguen *et al.*, 2018).

Chloride concentrations exceeded the recommended threshold at certain locations, particularly in Zebra Line (Table 4.11), where levels were substantially elevated. Elevated chloride levels could stem from anthropogenic activities such as wastewater discharge, agricultural runoff, or saline intrusion from groundwater sources. Excessive chloride presence can affect the palatability of water and pose risks to individuals with conditions such as hypertension (Strifling, 2018). Mitigating chloride contamination requires targeted interventions, including periodic assessments of the sources contributing to elevated concentrations. Comparatively, the findings of Akani *et al.*, (2021) suggest that the chloride content of water in the tank in a tertiary institute in Nigeria is lower than what was reported in this study. Another study in Zaria, Northwest Nigeria, indicated that the levels of chloride detected were within the acceptable limit (Adesakin *et al.*, 2020) and lower than what was reported in the study.

Sodium concentrations remained within acceptable limits (Table 4.12), though some sites recorded levels approaching the upper threshold. Sodium presence in drinking water is typically influenced by natural mineral dissolution, but anthropogenic sources such as road salt application or industrial discharge could contribute to variations (Akhtar *et al.*, 2021). While sodium intake from water is generally not a primary health concern, its accumulation, when combined with dietary intake, could have implications for individuals with sodium-sensitive health conditions (Grillo *et al.*, 2019; Thompson *et al.*, 2022). Comparatively the level of sodium reported in the study of Arko *et al.*, (2019) in the Greater Accra Region of Ghana was lower than what was reported in this study.

5.3 Water Quality Index (WQI) Water Stored in Community Tanks

Site-specific variations in WQI scores reveal distinct trends (Table 4.13). Water samples from Korle Gono demonstrated the highest proportion of good quality [77.78%], with a small percentage labelled as either Poor or Excellent. Consequently, it implies that while water quality concerns persist, contamination levels at this location were comparatively moderate.

Laterbiokoshie exhibited similar patterns, with 66.67% of samples classified as Good and a lower proportion [22.22%] falling into the Poor category. In contrast, Zebra Line displayed a concerning distribution, with 71.43% of water samples classified as Poor and none falling within the Excellent range. This pattern indicates more severe water quality issues in Zebra Line, potentially linked to elevated microbial and chemical contamination observed in earlier analyses (Devane *et al.*, 2020; Vadde *et al.*, 2018).

The significant differences in WQI scores across locations ($p < 0.05$) suggest that local environmental conditions, infrastructure, and water management practices contribute to variations in stored water quality (Akhtar *et al.*, 2021). Factors such as tank hygiene, frequency of cleaning, and exposure to contaminants likely influenced these results. The relatively poor WQI ratings at Zebra Line may reflect increased exposure to contamination sources, suboptimal storage conditions, or inadequate treatment measures (Ahmed *et al.*, 2021). The presence of high turbidity, microbial contaminants, and elevated chloride levels in this location supports the observed deterioration in water quality. In contrast to this study's findings, none of the water samples analysed in the study of Adu-Gyamfi *et al.*, (2020) conducted in the Adentan Municipality of the Greater Accra Region of Ghana were of poor quality.

From the above, it is evident that marked differences emerged between the three communities in both microbial and physicochemical outcomes. Korle Gono exhibited comparatively lower levels of total coliforms yet showed higher counts of faecal coliforms, suggesting contamination linked to specific sanitation practices near storage tanks. Laterbiokoshie recorded consistently high counts across microbial indicators, which may reflect the dense settlement pattern and frequent reliance on tank water during supply interruptions. Zebra Line presented fewer tanks and smaller volumes, yet contamination levels were still significant. The differences suggest that tank location, maintenance frequency, and local sanitation practices

influenced water quality. These variations highlight the importance of tailoring interventions to community contexts rather than applying uniform strategies across Accra.

The findings from this study have critical public health consequences, particularly in communities relying on stored water for drinking and domestic purposes. The consistent detection of *E. coli* and faecal coliforms in the water samples signals the potential existence of disease-causing organisms, including viruses, protozoa, and other bacteria. This raises the likelihood of outbreaks of waterborne illnesses such as diarrhoea, cholera, and typhoid fever. Vulnerable groups, such as young children, pregnant women, and immunocompromised individuals, are at heightened risk of severe outcomes from these infections. The role of poor water quality in exacerbating malnutrition and other systemic conditions cannot be overlooked, as repeated gastrointestinal infections can impair nutrient absorption.

5.4 Differences in Water Quality Between Communities

The data highlight distinct microbial profiles across the three study communities. Korle Gono presented elevated faecal coliform levels, yet total coliform counts were lower. This pattern reflects contamination events influenced by sanitation near water storage structures. The high faecal coliform levels indicate possible infiltration from nearby sewer lines. Such contamination often reflects urban infrastructure deficiencies, including cracked sewer channels and poorly sealed tanks. Although the total coliform levels remained significant, they were comparatively lower than in other sites. This discrepancy suggests episodic faecal intrusion rather than constant microbial loading. Environmental density at Korle Gono, coupled with complex sanitation networks, may shape these variations. This community thus demonstrates risks that are both intermittent and severe. The findings underscore the need for targeted infrastructural audits and improved monitoring. Addressing infrastructural weaknesses would reduce the vulnerability of consumers relying on these storage systems.

Laterbiokoshie revealed a distinctly different microbial profile when compared to Korle Gono. The community showed consistently high counts of total and faecal coliforms. Such outcomes suggest a persistent contamination cycle driven by household and community practices. The dense settlement pattern within Laterbiokoshie compounds the challenges of maintaining safe water. Storage tanks are frequently filled from multiple sources during periods of scarcity. The multiplicity of inputs increases the probability of contamination within stored water. In addition, the tanks are rarely cleaned at regular intervals. Biofilm formation may therefore persist within tank surfaces, elevating microbial survival. The high microbial counts across all parameters reveal systemic failures in water management. Unlike Korle Gono, where infiltration dominates, Laterbiokoshie suffers sustained contamination pressures. These findings call for urgent community-focused interventions. Promoting structured cleaning protocols and enforcing sanitary practices would reduce microbial persistence. Without such interventions, exposure to pathogenic organisms remains an inevitable outcome.

Zebra Line demonstrated contamination dynamics that differ significantly from the other communities. Despite the smaller number of tanks, microbial and chemical loads were disproportionately high. The WQI scores indicated severe deterioration of water quality in this location. Elevated chloride concentrations and turbidity levels compounded the microbial risks observed. The findings suggest direct exposure of tanks to saline or wastewater sources. Zebra Line is located within a low-lying area prone to environmental inflows. Runoff from surrounding activities and possible leaching from waste deposits may influence water stored. Unlike Korle Gono and Laterbiokoshie, Zebra Line contamination is both multi-faceted and entrenched. The absence of excellent WQI scores underscores the gravity of the problem. Local storage infrastructure appears insufficient to protect against both microbial and chemical hazards. Interventions must therefore focus on engineering solutions alongside sanitation reforms. Without such changes, consumers in Zebra Line remain exposed to complex waterborne risks.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.0 Introduction

Chapter Six provides a summary of the key findings from the study on water quality in community tanks in urban Accra, highlighting the major trends in microbiological contamination, physicochemical properties, and Water Quality Index (WQI) assessments. The chapter presents the conclusions drawn from the results, linking them to the study objectives and existing literature on water quality standards. Additionally, it outlines practical recommendations for improving water storage, treatment, and monitoring to ensure safer water for community use. These recommendations are directed at policymakers, water service providers, and community members, emphasizing the need for regular water quality assessments, enhanced maintenance practices, and public awareness initiatives to mitigate health risks associated with contaminated water.

6.1 Conclusions

The findings indicate that stored water in community tanks does not consistently meet microbial and chemical quality standards. The detection of total coliforms, faecal coliforms, and *Escherichia coli* above permissible limits suggests a potential risk to public health due to faecal contamination. The presence of *Pseudomonas spp.* and elevated heterotrophic bacteria counts further emphasise the need for improved sanitation measures in water storage and handling.

The physicochemical parameters varied across locations, with some values exceeding regulatory thresholds. Elevated turbidity and conductivity levels in certain areas suggest possible contamination sources that require further investigation. The high chloride and sodium

concentrations in Zebra Line exceed acceptable limits, pointing to the potential influence of saline intrusion or pollution from anthropogenic activities.

The water quality index classifications indicate that while most samples fall within acceptable limits, a significant proportion do not meet recommended standards. This calls for targeted interventions, including routine monitoring, improved water treatment measures, and community education on safe storage practices. Addressing these issues will be essential in ensuring the safety of stored water and minimising health risks associated with microbial and chemical contaminants.

6.2 Recommendations

1. Addressing the water quality challenges identified in this study requires a multifaceted approach involving community engagement, infrastructure development, and regulatory oversight. Routine monitoring of microbial and physicochemical parameters is essential to identify contamination sources and implement timely remedial actions. Community education campaigns should focus on proper water handling and storage practices, including regular cleaning of tanks and the use of safe collection methods.
2. Infrastructure improvements, such as the installation of water treatment facilities or point-of-use disinfection systems, could enhance water quality at the source. For example, the use of chlorination or ultraviolet (UV) treatment could mitigate microbial contamination effectively. In areas like Zebra Line, where chloride and TDS levels were significantly elevated, additional measures such as reverse osmosis or distillation may be required to ensure water suitability for consumption.
3. Policymakers and water management authorities should prioritise investment in sustainable water supply systems, including the provision of piped water to reduce reliance on stored water. Additionally, stricter enforcement of water quality regulations

and periodic audits of storage facilities can help maintain compliance with safety standards. Long-term improvements in water quality and public health outcomes will require cooperation between government agencies, non-governmental organisations, and community leaders.



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