INFLUENCE OF HOUSEHOLD WATER HANDLING PRACTICES ON THE QUALITY OF DOMESTIC WATER IN MBARARA CITY, SOUTHWESTERN UGANDA

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ABSTRACT

Safe drinking water remains a public health challenge in low- and middle-income countries despite improvements in supply infrastructure. This study assessed the influence of household water handling practices on domestic water quality in Mbarara City, Southwestern Uganda. A cross-sectional survey was conducted between October 2024 and January 2025 among 72 randomly selected households across 12 wards. Data were collected through structured questionnaires, observations, and water sampling at three points within the household water chain: source (such as tap), storage, and drinking water. Microbiological analyses included total plate count, coliforms, and Escherichia coli, while physicochemical parameters assessed were pH, electrical conductivity (EC), and total dissolved solids (TDS).

Results showed that physicochemical parameters remained within Uganda National Bureau of Standards (UNBS) limits. However, microbiological contamination was detected in several wards, particularly at the storage stages. Post-source contamination was linked to unsafe handling practices such as the use of uncovered containers, infrequent cleaning, and prolonged storage. Regression analysis indicated significant associations between container type and EC ($\beta = 219.47$, $p < 0.01$), and between annual cleaning and elevated TDS ($\beta = 67.25$, $p = 0.045$). Socio-demographic factors, including education and income, also influenced safe water handling practices.

The study concludes that while the supply water largely met national standards, poor handling practices compromised household water safety. Interventions promoting regular cleaning of storage containers, safer storage methods, and community education on water hygiene are recommended to safeguard water quality and reduce waterborne disease risks in Mbarara City.

DECLARATION

I, **Tusimiire Benjamin**, hereby declare that this is my original work, is not plagiarized, and has not been submitted to any other institution for any award.

Signature:______________________________ Date:____________________________

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APPROVAL

This study titled "Influence of household water handling practices on the quality of domestic water in Mbarara city, southwestern Uganda" has been carried out by Tusiimire Benjamin under my supervision. All the necessary steps were duly followed and observed. It is ready for submission to the Faculty of Engineering, Design and Technology in partial fulfillment of the requirements for the award of the degree of Master of Science in Water and Sanitation of Uganda Christian University, Mukono, Uganda.

Signature: ______________________________ Date: ____________________________

Prof. S. Kizza-Nkambwe

ABBREVIATIONS

CFU	Colony-Forming Units
DO	Dissolved Oxygen
E. coli	Escherichia coli
EC	Electrical Conductivity
MUST	Mbarara University of Science and Technology
pH	Power of Hydrogen (measure of acidity or alkalinity)
PO4	Phosphates
SDG	Sustainable Development Goals
SO42-	Sulfate Ion (SO_4^{2-})
TSS	Total Suspended Solids
UBOS	Uganda Bureau of Statistics
UCU	Uganda Christian University
UN DESA	United Nations Department of Economic and Social Affairs
UNECA	United Nations Economic Commission for Africa
WASH	Water, Sanitation, and Hygiene
WHO	World Health Organization

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1. GENERAL INTRODUCTION

1.1. Background of the study

Globally, efforts to expand access to improved water sources have yielded measurable progress. Between 2015 and 2022, the proportion of people with access to safely managed drinking water services rose from 69% to 73% (United Nations Department of Economic and Social Affairs (UN DESA), 2023). However, unsafe domestic and drinking water still poses a great public health risk in developing countries (Larson et al., 2023; Khan et al., 2022). Chen et al. (2023) found that regions in Africa with a low socio-demographic index had a high burden of diarrheal diseases resulting from unsafe water (Chen et al., 2023), and approximately 80% of all illnesses in developing countries are caused by waterborne diseases, with diarrhea being the leading cause of childhood deaths (Shayo et al., 2023).

Evidence shows that a significant amount of microbiological and physicochemical household water contamination occurs after water leaves the household supply source (Luvhimbi et al., 2022). Microbiological water quality refers to the presence or absence of pathogenic microorganisms that can cause diarrheal and gastrointestinal diseases (Cahoon, 2021). Physicochemical water quality, on the other hand, pertains to non-biological parameters such as turbidity, pH, conductivity, and temperature, which affect the safety of water for consumption and its potential to support microbial growth (World Health Organization (WHO), 2024). Studies have shown that the quality of drinking water often declines significantly between the source and the point of use due to poor storage, use of unclean containers, and unhygienic serving practices (Moropeng et al., 2021; Makokove et al., 2022; Gizachew et al., 2020). Poor water handling practices greatly contribute to contamination of water during subsequent stages of the household safe water chain (Ali et al., 2024).

The safe water chain refers to the continuous set of steps that ensure drinking water remains safe from the household source/point of collection to the point of consumption (Ssemugabo et al., 2019). At each of these stages, there are opportunities for microbial and physicochemical contamination, such as the use of dirty containers or unhygienic collection methods, storage in uncovered, wide-mouthed, or infrequently cleaned containers, and hand contact when transferring water into other vessels (Ali et al., 2024; Cassivi et al., 2021). Even when piped water meets safety standards at the tap, failures in maintaining the safe water chain can cause deterioration in quality before it is consumed (Ssemugabo et al., 2019; Luvhimbi et al., 2022; Ali et al., 2024; Cassivi et al., 2021).

In Uganda, while piped water systems are increasingly available in urban centers, a large proportion of households still consume unsafe water. A recent study in Mbarara reported that over 32% household water samples were unsafe for drinking, despite being drawn from improved sources (Abaasa et al., 2024). This indicates the effect of post-supply handling practices in reversing the benefits of improved water access (Moropeng et al., 2021; Makokove et al., 2022)

By assessing both the water quality and the handling practices among households in Mbarara City, this study assessed the influence of these practices on the quality of water along the household safe water chain in Mbarara City. Additionally, the study assessed sociodemographic and household factors that influenced water handling practices. The findings of this study could serve as a basis for targeted interventions to promote safer water handling and storage within households to the point of consumption.

1.2. Statement of the Problem

Access to safe drinking water remains a critical issue in Mbarara City, Uganda, regardless of improvements in water infrastructure. Despite a reported 77.7% safe water coverage in Mbarara (Mbarara District Local Government, 2017), Abaasa et al., 2024 revealed that 70.2% of the water sources in Mbarara city had sub-standard water quality (below Grade B on the Water Quality Index), with 32.4% of the sources supplying water unfit for human consumption (Abaasa et al., 2024). Additionally, diarrheal disease from contaminated water accounted for approximately 12,000 morbidities in Mbarara as of 2017 (Mbarara District Local Government, 2017).

Access to improved water sources alone does not guarantee the safety of drinking water at the point of consumption (Luvhimbi et al., 2022). In many urban settings of low- and middle-income countries, water is supplied to households through piped networks, often meeting national quality standards at the source or point of supply (Bain et al., 2021; Weston et al., 2024).

Similarly, although efforts have been made to provide access to clean water in Mbarara City, the persistence of waterborne diseases indicates a need to focus not only on water supply but also on how water is handled at the household level. However, there is limited knowledge on the water handling practices of households within Mbarara City, and how these practices influence the quality of domestic water along the safe water chain from the point of supply to the point of consumption. This study, therefore, sought to assess both the quality of the household water supply and the influence of water handling practices on the quality of domestic and drinking water in Mbarara City. By examining the relationship between these factors, the research aims to provide evidence for the development of interventions and policies that address both access to clean water and safe water handling behaviour within households.

1.3. General objective

To assess the influence of household water handling practices on the quality of domestic water in Mbarara City, Uganda

1.3.1. Specific objectives

1. To evaluate the physicochemical and microbiological quality of domestic water in Mbarara City
2. To investigate the water handling practices among households in Mbarara City
3. To assess the influence of handling practices on the quality of domestic water in Mbarara City
4. To determine the factors influencing water handling practices in Mbarara City

1.3.2. Research questions

1. What is the physicochemical and microbiological quality of water in Mbarara City?
2. What are the water handling practices among households in Mbarara City?
3. What is the influence of handling practices on the quality of water used by households in Mbarara City?
4. What are the factors influencing water handling practices in Mbarara City?

1.4. Justification of the study

Although piped water is at a 77% coverage in Mbarara City, diarrhoeal diseases linked to contaminated water remain a major public health concern. These figures indicate that improving water access alone is insufficient to ensure safe drinking water at the point of consumption. The safe water chain within households, from the tap, through collection, storage, and serving, offers multiple points where contamination can occur (Ali et al., 2024; Cassivi et al., 2021).

While interventions in Uganda have largely focused on water source improvement, little is known about how water handling practices within households in Mbarara City contribute to post-supply contamination. This gap in knowledge limits the ability of policymakers and health practitioners to design effective interventions that address both source quality and household-level contamination risks. This study generated locally relevant evidence on changes in water quality from the point of supply to the point of consumption, the handling practices that influence these changes, and the socio-demographic factors associated with such practices.

1.5. Significance of the Study

This study investigated the influence of water handling practices on the quality of household water, as well as the household and sociodemographic factors that influence these water handling practices. These findings are particularly important for addressing household sources of water contamination that compromise the quality of water at the point of consumption despite access to safe water supply sources. By evaluating the quality of the water supply, this research provides evidence that can inform interventions aimed at improving household water quality management to reduce the incidence of water-borne diarrhoeal diseases in the rapidly urbanizing regions of Uganda, such as Mbarara city.

By determining the factors that influence water handling practices, such as socio-economic conditions and demographic characteristics, the study offers insights into the household-level barriers to the adoption of safe water practices. This knowledge is instrumental in shaping and improving community outreach programs and prioritizing resources to ensure safer water handling across diverse household settings in Mbarara City.

Additionally, this study's findings could serve as a basis for future research and contribute to the ongoing efforts to improve water quality and health outcomes in Uganda. The results could be applied to policy and implementation of targeted water, sanitation, and hygiene (WASH) initiatives by relevant authorities, including government authorities, non-governmental organizations, health practitioners, and civil society organizations.

1.6. Scope of the Study

Geographical scope

This study focused on assessing the quality of domestic water supply and examining water handling practices in Mbarara City, located in Southwestern Uganda. The study was cross-sectional and conducted within the two divisions of Mbarara City: Mbarara City North and Mbarara City South. From Mbarara City North, the selected wards included: Kamukuzi, Kakiika, Ruharo, Biharwe East, Biharwe West, and Nyakinengo. From Mbarara City South, the wards randomly selected were Ruti, Katojo, Nyamitanga, Katete, Kakoba, and Nyamityobora.

Content scope

It covered both the physicochemical and microbiological quality of water sourced from 3 points within the household safe water chain ie., the household supply source (mainly taps), household water storage, and household drinking water. The physicochemical water quality was assessed based on the pH, electrical conductivity (EC), and Total Dissolved Solids (TDS). The microbiological water quality was assessed based on total plate counts, total coliform counts, and E. *coli* counts.

Time scope

The data collection and analysis took place between October 2024 and January 2025.

1.7. Theoretical Framework

This study was grounded in two interrelated theoretical perspectives: the Safe Water System (SWS) Framework and the Health Belief Model (HBM).

The **Safe Water System (SWS)** framework, developed by the U.S. Centers for Disease Control and Prevention (CDC) and the World Health Organization (WHO), focuses on protecting water from contamination during storage and use at the household level. The framework emphasizes three components: point-of-use water treatment (e.g., chlorination, boiling), safe water storage in appropriate containers, and behavior change through hygiene education (Gallo & Lantagne, 2008). In the context of this study, the SWS framework offers a lens to assess the extent to which households in Mbarara City adhere to best practices in water handling and storage. It is particularly applicable in low-resource settings where even piped water may become unsafe by the time it is consumed due to unsafe post-collection practices (Ali et al., 2024; Cassivi et al., 2021).

The **Health Belief Model (HBM)** complements the SWS framework by explaining the psychological and behavioral dimensions of water handling. According to the HBM, individuals' likelihood to engage in health-protective behavior, such as treating or safely storing drinking water, is influenced by their perceived susceptibility to health risks, perceived severity of consequences, perceived benefits of action, and perceived barriers to taking that action (Rosenstock, 1974).

The likelihood of individuals to engage in health-protective behavior (safe water handling) can be shaped by several external factors. Social, economic, and environmental conditions, such as education level, income, occupation, gender, and access to services, significantly influence health-related behavior and outcomes (Barakat & Konstantinidis, 2023). In this study, socio-demographic variables were treated as exogenous factors that influence the degree to which households adopt safe water handling practices. For example, a household's level of education or income may determine its ability to acquire water treatment products, access storage infrastructure, or practice hygienic water handling.

2. LITERATURE REVIEW

2.1. Introduction

While the total global mass of water remains constant (Boyd, 2019), safe water for human use is in short supply across the globe, with about 29% of the global population not having access to safe, uncontaminated water (UNICEF & WHO, 2023).

2.2. Theoretical Literature Review

This study is grounded in two interrelated theoretical perspectives: the Safe Water System (SWS) Framework and the Health Belief Model (HBM), which explain how the quality of domestic water can be influenced by household health preventive practices, such as safe water handling, which are in turn influenced by environmental conditions (such as household size, access to reliable piped water). The HBM and SWS framework, as applied to this study, complement each other in explaining why households might adopt, or fail to adopt, safe water behaviors.

The Health Belief Model (HBM)

The Health Belief Model, developed by Rosenstock (1974), indicates that individuals' readiness to engage in preventive health behavior is influenced by their perceived susceptibility to a health outcome, the perceived severity of that outcome, the perceived benefits of taking action, and perceived barriers to that action (Rosenstock, 1974). Studies have applied the Health Belief Model (HBM) to examine household behaviors related to water safety and sanitation. Munene et al (2020) employed the HBM to explore private well water testing behavior in Canada, finding that individuals' perceptions of susceptibility to contamination and the perceived benefits of testing significantly influenced their decision to test their water. The study also highlighted that barriers such as lack of awareness, inconvenience, and low perceived severity of potential water-related health risks contributed to poor testing behavior (Munene et al., 2020). Similarly, Ssemugabo et al (2019) applied the model in urban Uganda and demonstrated that perceived risk of waterborne disease significantly predicted safe water handling behavior (Ssemugabo et al., 2019).

The Safe Water System (SWS) Framework

The Safe Water System program, a household water treatment intervention developed by the Centers for Disease Control and Prevention (CDC) and the Pan American Health Organization (PAHO) in response to the cholera epidemics, provides a practical model for reducing waterborne disease transmission at the household level (Gallo & Lantagne, 2008). Its framework emphasizes three interconnected interventions: point-of-use water treatment (e.g., chlorination, filtration), safe storage in clean, narrow-mouthed containers, and behavior change communication to reinforce safe handling practices (Gallo & Lantagne, 2008). Studies across sub-Saharan Africa have validated the SWS framework's effectiveness. In Tanzania, Ngasala et al. (2020) found that households using point-of-use chlorination and proper storage containers had significantly lower levels of fecal coliforms in drinking water compared to households that did not follow these practices (Ngasala et al., 2020).

2.3. Empirical Literature Review

2.3.1. Physicochemical and microbiological quality of water

Water quality is a critical factor influencing public health, particularly in developing countries. The physicochemical and microbiological properties of water determine its suitability for human consumption (WHO, 2024). Physical water quality is assessed based on factors such as color, turbidity, and temperature (Omer, 2019). Turbidity measures the cloudiness or haziness of water caused by suspended particles, including clay, silt, and organic matter (Matos et al., 2024). It is quantified in Nephelometric Turbidity Units (NTU) using a turbidimeter (Matos et al., 2024). The recommended turbidity level in drinking water is less than 5 NTU, with an ideal target of below 1 NTU to ensure effective disinfection (WHO, 2017). High turbidity in water, which is caused by suspended particles, can reduce the effectiveness of disinfection processes and lead to microbial contamination (Tomperi et al., 2022). Watercolor, influenced by organic and inorganic substances, can indicate the presence of pollutants, including industrial wastes or decaying organic matter, which pose risks to consumers (Omer, 2019). High TDS levels above 500 mg/L can affect the taste and safety of water, and TDS is commonly assessed using a conductivity meter, as electrical conductivity (EC) correlates with the concentration of dissolved ions (Kushwah & Singh, 2024). Conductivity, measured in microsiemens per centimeter (µS/cm), indicates the water's ability to conduct electricity due to dissolved salts. WHO recommends a conductivity level of below 400 µS/cm for drinking water (WHO, 2011).

Chemical water quality involves parameters such as pH, dissolved oxygen (DO), nitrate, phosphate, and chlorine residual levels. Studies have indicated that the pH of water is essential for determining its corrosiveness and the release of harmful corrosion products into water supply. Zhang et al., 2021 reported that lower pH, lower alkalinity, higher temperature, and higher $SO4^{2-}$ concentration influenced corrosion and release of manganese into water supply (Zhang et al., 2021). Drinking water should have a pH between 6.5 and 8.5 to prevent corrosion of pipes and to ensure safety (Baloïtcha et al., 2022). Similarly, dissolved oxygen levels can provide insights into the health of aquatic systems, as low dissolved oxygen can lead to anaerobic conditions that promote the proliferation of harmful bacteria (García-Fernández et al., 2015).

Microbiological water quality remains the most immediate concern regarding human health, with pathogens such as E. coli, fecal coliforms, and other bacteria being primary indicators of contamination (WHO, 2024). These pathogens enter water sources through various channels, including animal waste, untreated sewage, and runoff from agricultural fields (Alegbeleye & Sant'Ana, 2020; Hou et al., 2024; Paruch & Paruch, 2018). WHO standards require that drinking water contain zero coliforms per 100 mL (WHO, 2011, 2024). Studies have shown that unsafe drinking, especially due to contamination with fecal pathogens is a leading cause of morbidity and mortality, especially among young children in low-income settings. Oseimo et al., noted significant associated between fecal water contamination with E.coli during wet seasons and the prevalence of diarrheal morbidity during these seasons (Osiemo et al., 2019). Similarly, in Uganda studies have shown that fecal contamination in drinking water is directly correlated with high rates of waterborne diseases, including cholera and other diarrheal diseases that disproportionately affect children compared to adults (Auma et al., 2024; Eurien et al., 2021; Nantege et al., 2022).

In urban areas like Mbarara City household and industrial wastewaters are a significant source of water supply contamination, affecting the water quality. A study in Kenya highlighted that proximity to industrial zones exacerbates the contamination levels in urban water sources (Kinuthia et al., 2020). Mbarara, which has experienced rapid industrialization, faces similar challenges. Inadequate regulation and waste management practices allow industrial effluents, including heavy metals such as lead and mercury, to enter local water supplies (Sanusi et al., 2024). Other studies within Mbarara city have identified high levels of turbidity and microbial contamination in water sources that directly undermine public health efforts aimed at reducing waterborne diseases (Abaasa et al., 2024; Lukubye & Andama, 2017; Okeny et al., 2023).

2.4. Water handling practices and their effect on water quality

Even when water is sourced from relatively clean points, poor handling practices during collection, storage, and use can lead to secondary contamination (Ondieki et al., 2022). These practices encompass the collection, transportation, storage, and treatment of water before consumption. Studies have shown that improper handling practices can lead to microbiological and physicochemical contamination, thereby increasing the risk of waterborne diseases (Ondieki et al., 2022). Water handling practices play a pivotal role in maintaining or compromising the quality of water within households. Safe water handling includes practices such as using clean containers for collection, covering stored water, regularly cleaning water storage tanks, and treating water before consumption are important to maintaining good water quality (Ali et al., 2024). The method of water collection plays a crucial role in maintaining water quality. In many developing countries, water is often collected from untreated sources such as rivers, boreholes, and unprotected wells, making it highly susceptible to contamination (Dos Santos et al., 2017). Studies have found that water collected from open sources contains higher levels of *Escherichia coli* (*E. coli*), indicating fecal contamination (Edokpayi et al., 2018).

Additionally, a major issue identified in water handling is the use of unclean or inappropriate storage containers. A study in South Africa revealed that while 37.81% of household tap water indicated fecal contamination with other fecal coliforms other than E.coli, this contamination was at 46.0% for water from household containers (Murei et al., 2024). Studies conducted in Uganda have shown that most households use jerrycans or other plastic containers for water storage (Agensi et al., 2019b; Kolawole et al., 2018). These containers are often not cleaned regularly, and over time, they accumulate dirt and microbes, creating a breeding ground for pathogens such as E. coli and Salmonella (Kolawole et al., 2018). In some cases, households store water in open containers, which increases the risk of contamination from dust, insects, and animal droppings (Kolawole et al., 2018; Too et al., 2016).

Another crucial factor is the duration of water storage. In areas where water supply is intermittent, households tend to store large quantities of water for extended periods, sometimes up to a week (Kolawole et al., 2018). Prolonged storage without adequate treatment, such as boiling or chlorination, can lead to microbial growth, even if the water was initially clean (Chinye-Ikejiunor et al., 2021). Kolawole et al., 2018 reported that households who took 2 days or more to replace water in the storage container were more likely to have family members with a history of diarrheal diseases (Kolawole et al., 2018). This finding is particularly relevant for Mbarara City, where water supply is not always reliable, forcing households to rely on stored water for several days.

Several studies have also highlighted the importance of household water treatment practices. The most common methods include boiling, filtering, and the use of chlorine tablets (Admasie et al., 2022; Malan & Sharma, 2023). However, the effectiveness of these practices depends on household awareness and consistency in applying them (Ali et al., 2024; Ssemugabo et al., 2019). Research indicates that boiling is the most effective method in eliminating microbial contaminants, reducing *E. coli* presence by 99% (Dos Santos et al., 2017). However, boiling alone does not address chemical pollutants such as heavy metals and nitrates, which require filtration or chemical treatment (Edokpayi et al., 2018). Chlorination, when applied correctly, can effectively kill bacteria and viruses, yet its effectiveness depends on the proper dosing and contact time. Inconsistent chlorination practices can result in either inadequate disinfection or excessive chlorine levels, which may lead to the formation of harmful disinfection byproducts such as trihalomethanes (THMs) (Tak et al., 2020).

2.5. Factors influencing water handling practices

Various factors influence how households handle and manage water. Socioeconomic factors, such as income, education, and household size, play a critical role in determining water handling behaviors. Studies have found that households with higher education levels are more likely to adopt proper water storage and treatment practices compared to those with limited formal education. In a systematic review of water treatment practices and associated factors in Sub-Sharan Africa, Atalay et al., 2024 indicated that having formal education, a higher income, and having received training in water treatment were significantly associated with uptake of water treatment practices (Atalay et al., 2024). Studies in Ethiopia have indicated that the level of education, monthly income, knowledge about safe water handling, frequency of water collection and knowledge water treatment are significantly associated with proper water handling practices (Admasie et al., 2022; Belihu et al., 2023; Tafesse et al., 2021; Tsegaye et al., 2021).

Households with higher education levels are more likely to be aware of the health risks associated with contaminated water and, as a result, are more likely to engage in safe water handling behaviors, such as boiling or treating water with chlorine (Admasie et al., 2022; Anthonj et al., 2019; Kuberan et al., 2015). Household size also influences water handling practices. Larger households tend to use more water, which increases the likelihood of storing water for extended periods. As mentioned earlier, prolonged storage without proper treatment can lead to microbial contamination (Kolawole et al., 2018). In addition, larger households may lack the time and resources to consistently clean water storage containers or treat water before consumption, further increasing the risk of contamination (Too et al., 2016). Income level is another crucial determinant. Households with higher incomes can afford improved water storage containers and treatment methods such as filtration and chlorination, whereas lower-income households often rely on basic storage techniques, which may increase the risk of contamination (Lawrencia et al., 2023).

Water access and availability also play a significant role in shaping water handling practices. Households that rely on piped water are less likely to engage in unsafe storage practices compared to those using surface water sources such as rivers and lakes (Dos Santos et al., 2017). In regions where water supply is intermittent, households are forced to rely on stored water for extended periods, which increases the likelihood of contamination (Salehi, 2022; Niven et al., 2025). The reliability of the water supply also affects how households manage water. In areas with a continuous supply, households are less likely to store water for long durations, reducing the risk of contamination (Niven et al., 2025). A study in Sub-Saharan Africa reported that households relying on unimproved water sources engaged in multiple handling steps, such as transferring water between different containers, which increases microbial contamination risks (Lapworth et al., 2017).

Research Gap

Despite research on water quality and handling practices, most studies in Sub-Saharan Africa focus on microbiological contamination of source or supply water, neglecting the impact of handling practices on the physicochemical and microbiological water quality. This study fills these gaps by providing updated, localized data on water handling in Mbarara city, assessing both microbiological and physicochemical risks, and proposing practical interventions to improve household water safety and management.

2.6. Conceptual Framework

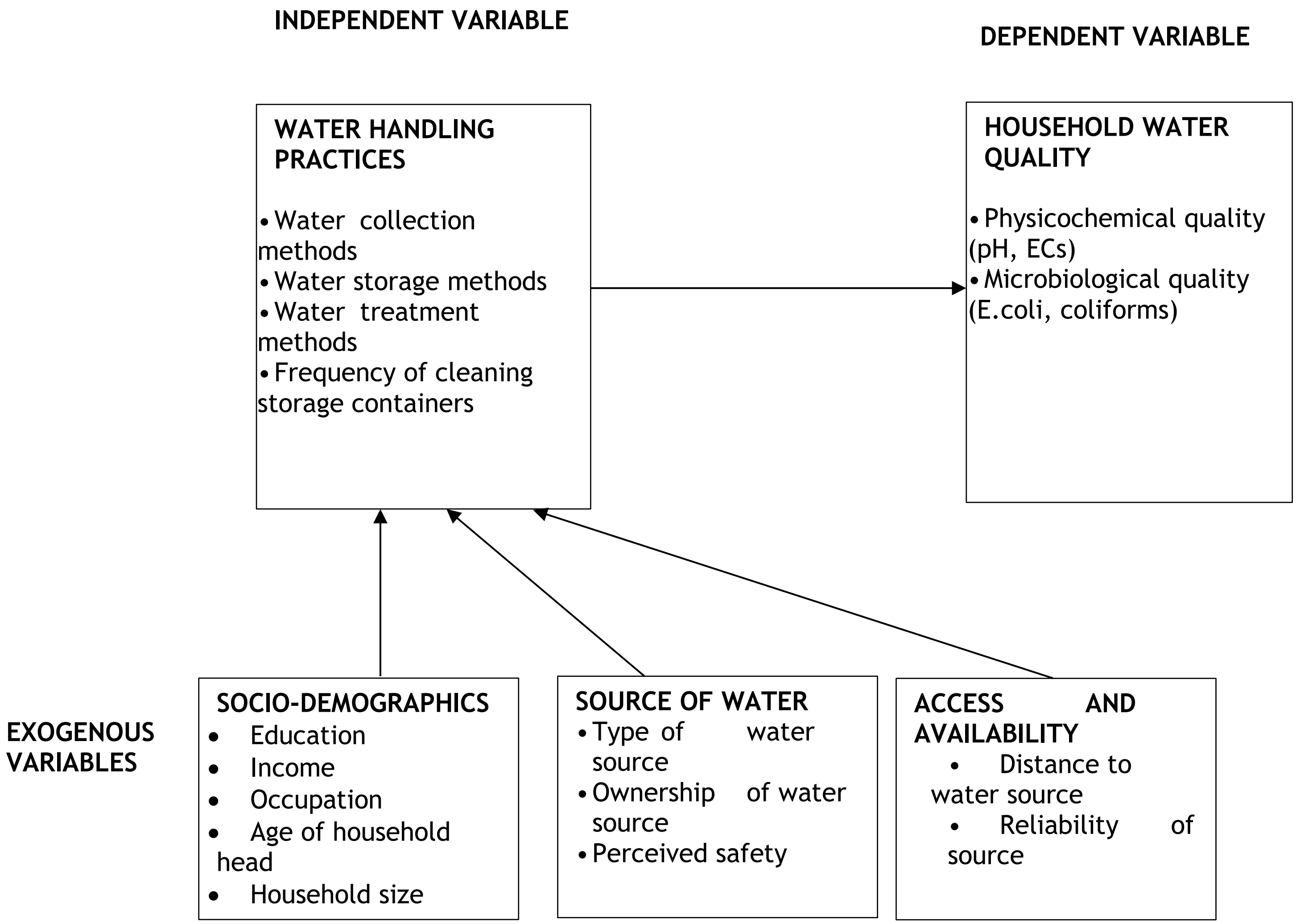

Figure 1: Conceptual framework illustrating the relationship between water quality and water handling practices, exogenously influenced by socio-demographic factors, water source, and water access

2.6.1. Conceptual Framework Narrative

The conceptual framework for this study is designed to illustrate the relationship between water handling practices and water quality, while also highlighting the factors that influence these practices. Water handling practices serve as the independent variable, encompassing how water is collected, transported, stored, and treated before consumption. Water quality, assessed based on its microbiological and physicochemical properties, is the dependent variable, as it is directly affected by handling practices. Additionally, socio-demographic factors, source of water, and water access & availability are exogenous variables that influence household water handling practices. These factors are considered exogenous because they are not themselves the direct causes, nor are they influenced by the water handling practices or water quality outcomes. Instead, they function as background determinants that shape the context in which the independent variables (water handling practices) occur (Deistler & Scherrer, 2022).

Exogenous variables (factors influencing water handling practices)

Socio-demographic factors, water source, and water access have been shown to play a significant role in shaping household water handling practices. Households with higher education levels are more likely to apply effective water treatment techniques, reducing both microbial and contamination risks (Abubakar, 2021; Suyitno et al., 2025). Additionally, in low-income households, limited access to safe storage containers and filtration systems increases vulnerability to physicochemical water degradation (Salam et al., 2024).

The source of water and accessibility further shape water handling practices. Households that rely on intermittent or distant water sources often store large quantities of water, sometimes for extended periods, without proper treatment, leading to microbial growth (Luvhimbi et al., 2022; Loubser et al., 2021). Additionally, perceived safety of the water source influences treatment behaviors, as some households may forego treatment if they believe their water is safe (Tamene, 2021).

Independent Variable (Water Handling Practices)

Water handling practices are a key determinant of water safety, as improper collection, storage, and treatment can lead to secondary contamination even when water is sourced from relatively clean supply points (Ondieki et al., 2022). Studies indicate that common water collection and storage practices, such as using unclean containers, infrequent cleaning of storage vessels, and prolonged storage without treatment, significantly increase microbial contamination (Luvhimbi et al., 2022). Additionally, studies have demonstrated that poor water storage practices can alter physicochemical properties such as pH, turbidity, and total dissolved solids (TDS). Inadequate cleaning of storage tanks allows sediment buildup, affecting turbidity and conductivity levels (Manga et al., 2021). Boiling and chlorination, while effective in eliminating pathogens, can sometimes lead to an increase in trihalomethanes (THMs) and residual chlorine, which may have long-term health implications (Ma et al., 2024).

3. METHODOLOGY

3.1. Introduction

This chapter delineates the research methods applied during this study. The chapter describes the research design, sampling technique and population size, data collection procedure, data collection methods and instruments and data processing and analysis.

3.2. Research Design

This study employed a quantitative cross-sectional design to assess the quality of domestic water supply and examine household water handling practices in Mbarara City, Southwestern Uganda. A cross-sectional design was chosen as it allows for the collection of data at a single point in time, providing a snapshot of water quality and handling behaviors among households. This design is suitable for identifying associations between variables, such as the relationship between water handling practices and microbiological water contamination.

3.3. Area of study

This study was conducted in Mbarara City, southwestern Uganda, approximately 270 kilometers southwest of the capital, Kampala. The city spans 1,778.4 square kilometers and lies between coordinates 00°36′48″S and 30°39′30″E. According to the 2024 national census, Mbarara City has 80,500 households and a population of 261,656 (UBOS, 2024). Administratively, the city is divided into two divisions: Mbarara City North, which has 12 wards, and Mbarara City South, with 11 wards. This study randomly selected six wards, each from Mbarara City South or Mbarara City North (12 wards in total). From Mbarara City North, the wards selected were Kamukuzi, Kakiika, Ruharo, Biharwe East, Biharwe West, and Nyakinengo. From Mbarara City South, the wards randomly selected were Ruti, Katojo, Nyamitanga, Katete, Kakoba, and Nyamityobora.

Mbarara city receives an average annual rainfall of 1200 mm, with two rainy seasons during the months of September–December and February–May. Temperature ranges between 17 °C and 30 °C, with a humidity of 80–90%, and the topography is a mixture of fairly rolling and sharp hills and mountains, shallow valleys, and flat land (Abaasa et al., 2024). As of 2017, Mbarara district had 77.7% piped water coverage (Mbarara District Local Government, 2017).

According to the Ministry of Finance, Planning and Economic Development, the main economic activities in Mbarara city are Agriculture –crop and livestock and manufacturing. However, of the registered businesses in the city, 65% are in trade, 11.3% recreation and personal service, 3.6% manufacturing and only 0.9% in Agriculture (Ministry of Finance, 2021).

3.4. Sources of information

This study relied on primary data collected through fieldwork in Mbarara City. Data were obtained from household surveys, observation, and water quality sampling conducted at three points in the household water chain: tap water (point of supply/household source), household storage container water (point of storage), and drinking water (point of consumption). The household survey gathered socio-demographic information and details on water handling practices, including water treatment, storage, and container cleaning routines. Observations were conducted alongside the surveys to verify self-reported practices such as coverage of storage containers and drinking water containers. Water samples from each of the three points were analyzed for microbiological and physicochemical parameters using standard procedures to determine changes in water quality along the household safe water chain.

3.5. Study population

The study targeted all households in Mbarara City, covering both Mbarara City North and Mbarara City South divisions.

3.6. Sampling Technique

This study employed stratified random sampling. The two divisions of Mbarara city were considered the strata in this study. To ensure an equal representation from both strata, six wards were randomly selected from each stratum, and an equal number of households were selected from each ward.

3.7. Sample size determination

Using the sample size formula for proportions;

$$n = \frac{Z^2 \times p(1-p)}{e^2}$$

Where;

n = sample size

Z = 1.645 (z-score for 90% confidence level)

p = 0.5 (assuming 50% prevalence for maximum variability)

e = 0.10 (10% margin of error)

$$n = \frac{1.645^2 \times 0.5(1-0.5)}{0.10^2}$$

$$n = 67.65$$

Total sample size = 72 households (to ensure equal sample distribution within wards of the strata)

3.7.1. Sampling of households per strata

Total number of households = 80,500 (UBOS, 2024)

Assuming an equal number of households per division of 40,250

$$\frac{40250}{80500} \times 72$$

n = 36 *households per strata*

Six households were randomly selected from the 12 randomly selected wards. Six wards from each of the two strata (Mbarara City North & Mbarara City South).

3.8. Procedure for data collection

Data was collected from 6 randomly selected households from 12 randomly selected wards, six wards from each of the two strata.

3.8.1. Sample collection

Water samples were collected from the domestic water supply (taps, boreholes, wells) of each household, after storage for use within the households (jerrycans, water tanks), and drinking water. Samples were aseptically collected into sterile 100 ml plastic universal containers. Tap nozzles were flamed, the water allowed to run for about two minutes, and single samples were collected for microbiological testing and two for physicochemical testing. One ml of 1% sodium thiosulphate was added to each tap water sample to neutralize the antimicrobial effects of chlorine according to the SOPs of the Mbarara Regional Referral Microbiology Laboratory SOPs.

This is in line with recommendations for sample de-chlorination with sodium thiosulfate during microbiological water quality testing to ensure that results accurately reflect the water quality at sample collection (Murray et al., 2018).

3.9. Data collection instruments

A structured questionnaire was administered to household respondents to collect socio-demographic information, details of household water access, and water handling practices. The questionnaire was an adaptation of the WHO/UNICEF Joint Monitoring Programme Multiple Indicator Cluster Survey (MICS) water quality testing questionnaire used to collect data on water quality of households with a focus on parameters such as source, treatment, and accessibility (UNICEF, 2018). The questionnaire included sections on the type and condition of storage containers, water treatment and cleaning practices, storage duration, and perceived water quality. **Appendix I**

An observation checklist was used to record visual water quality characteristics such as colour, turbidity, odor, and presence of particles, as well as laboratory measurements of physicochemical parameters (pH, EC). Separate laboratory observation forms were used for documenting results of microbiological testing, including total coliform and Escherichia coli counts. **Appendix II**

Laboratory and field equipment included sterile 100 mL polyethylene universal sampling bottles (pre-dosed with 1ml of 1% sodium thiosulfate for chlorinated water samples) and an insulated cooler box with ice packs for sample preservation and transportation to the test laboratory.

3.10. Quality/Error Control

To ensure the validity and reliability of water quality sampling and testing, the study followed standardized procedures as outlined in the American Public Health Association (APHA) Standard Methods for the Examination of Water and Wastewater (2017) and the World Health Organization (WHO) Guidelines for Drinking-water Quality (2011).

Sterile 100 mL universal polyethylene sample containers were used for all water samples. For samples collected from chlorinated sources, bottles were pre-dosed with sodium thiosulfate (1 mL of a 1% solution) to neutralize residual chlorine and prevent further microbial inactivation during transport. Sampling from taps was carried out after allowing the water to run for 30–60 seconds to flush out stagnant water from the pipes and then flamed to sterilize the tap. For storage and drinking water samples, water was collected directly from the container or vessel using the household's usual method of water retrieval, without introducing external contamination.

All samples were handled using aseptic techniques, clearly labelled, and stored in an insulated cooler box with ice packs to maintain a temperature of 4 ± 2 °C during transport. Samples were transported to the laboratory and analysed within six hours of collection to minimise changes in microbial counts. Laboratory analyses were performed following the same laboratory standard operating procedures for all samples, using calibrated equipment and reagent quality control checks before each batch of tests.

3.10.1. Validity and reliability of the data collection tools

To ensure content validity of the data collection tools, the draft tools were checked for completeness, clarity, and alignment with the study objectives. The tools were then pre-tested in 5 households within the study area to identify ambiguous or redundant questions, improve the logical flow, and ensure that all questions were culturally appropriate and understandable to respondents.

To ensure reliability, field data collectors were trained on the use of the tools, ethical considerations, and interviewing techniques. The same field team conducted both the interviews and observations to maintain consistency. A subset of questionnaires (10%) was cross-checked by the principal investigator for completeness and accuracy during the data collection period.

3.11. Data processing and analysis

3.11.1. Microbiological water quality analysis

Water samples for microbiological analysis were delivered to the Microbiology Laboratory of the Department of Microbiology of Mbarara University of Science and Technology (MUST) in an ice-cooled box (4°C) within 6 hours of collection, and analyzed according to the standard operating procedures of the laboratory. Using aseptic procedures, water samples were diluted 1 ml each in 9 ml of sterile field phosphate buffer. Approximately 1 ml of each sample was diluted into separate sterile fields of phosphate buffer (9 ml) using a sterile micropipette tip. A volume of 1 ml of each of these dilutions was dropped into the middle of a sterile petri dish, and 18 ml of molten cooked eosin methylene blue (Levine) was poured into each petri dish, rocked several times, left to solidify, and incubated at 37°C for up to 48 hours. The colonies that formed were counted. The dilutions of the colonies were made and cultured in duplicate, and the average was taken. The final counts will be reported as colony-forming units per 100 mL (CFU/100 mL).

3.11.2. Physicochemical parameter analysis

50 ml of water collected from each water sample was transported to the Biology Laboratory at Mbarara University of Science and Technology for physicochemical analysis after microbiological tests. The sampled water was tested for Temperature, Hydrogen potential (pH), Electrical conductivity (EC), and Total Dissolved Solids (TDS).

3.12. Data management and statistical analysis

Data collected was entered into Epi-Info for initial cleaning and checking for completeness, and further analysis was conducted using **STATA software version 17**.

Descriptive Analysis

Descriptive statistics (mean, standard deviation, frequency, and percentage) was reported for household characteristics, water handling practices, and the microbiological and physicochemical quality of the water

Objective-Specific Statistical Analysis

Objective 1: To evaluate the physicochemical and microbiological quality of supply water in Mbarara City

- Descriptive statistics (means, medians, standard deviations, interquartile ranges) were used to summarize pH, electrical conductivity (EC), total dissolved solids (TDS), and microbial counts (total coliforms, *E. coli*).
- Comparisons of pH, electrical conductivity (EC), total dissolved solids (TDS), and microbial counts (total coliforms, *E. coli*) across the 12 wards were performed using ANOVA or Kruskal-Wallis tests to check for significant differences in water quality parameters.

Objective 2: To investigate the water handling practices among households in Mbarara City

- Frequencies and percentages were used to summarize household water storage methods, treatment practices, and container cleaning frequencies.

Objective 3: To assess the influence of handling practices on the quality of water used by households in Mbarara City

- Linear regression was used to determine whether water handling practices (type of storage container, frequency of storage container cleaning, duration of water storage, water treatment, coverage of drinking water) significantly influenced water quality indicators (pH, EC, TDS, microbial contamination).
- ***Objective 4: To determine the factors influencing water handling practices in households in Mbarara City***
    - Chi-square tests (x^2) were used to examine associations between sociodemographic factors (sex, age, education level, occupation, household income, household size, main water source, and distance from water source) and water handling practices.

Statistical Significance

A p-value of <0.05 was considered statistically significant for all analyses.

3.13. Ethical considerations

Ethical clearance and approval for this research was sought from the Uganda Christian University Research and Ethics committee.

Before households were enrolled into this study, informed consent was sought. The purpose of the study was explained in a language best understood to potential participants and participation was voluntary. Study participants had the right to withdraw their consent to participate with no consequence.

Unique identifiers were used for households and no names used and personal information will not be published or used outside this study. Study data is confidential and only used to fulfill the objectives of this study.

4. PRESENTATION OF FINDINGS AND DISCUSSION

4.1. STUDY PROFILE

This study enrolled 72 households in Mbarara city between November and December 2024. Six households were selected from 12 wards, Biharwe East, Biharwe West, Kakiika, Kakoba, Kamukuzi, Katete, Katojo, Nyakinengo, Nyamitanga, Nyamityobora, Ruharo and Ruti, distributed equally between the divisions of Mbarara City North and Mbarara City South.

4.1 HOUSEHOLD CHARACTERISTICS

Table 1: Household Characteristics

Mean age of respondent in years (SD)	43.6 (12.3)
Characteristic	**Frequency, n (%)**
Age categories	
18-29	9 (12.5)
30-49	42 (58.3)
50 and above	21 (29.2)
Sex	
Male	51 (70.8)
Female	21 (29.2)
Occupation	
Formal employment	3 (4.8)
Informal employment	49 (79.1)
Unemployed	10 (16.1)
Monthly income	
50,000-200,000	4 (5.5)
200,001-500,000	48 (66.7)
500,001-1,000,000	18 (25.0)
>1,000,000	2 (2.8)
Household size	
1	3 (4.2)
2-4	37 (51.3)
5-10	30 (41.7)
>10	2 (2.8)

Main water source	
Piped into dwelling	14 (19.4)
Piped into compound	26 (36.2)
Piped into neighbor	18 (25.0)
Rainwater collection	14 (19.4)
Reliability of water source	
Always available	33 (45.8)
Intermittent supply	39 (54.2)
Perceived source water properties	
Bad taste Turbidity/Particles	3 (4.2)
Bad taste and Particles	58 (80.6)
None of the above	6 (8.3)
	5 (6.9)

Study respondents had a mean age of 43.6 years (SD = 12.3), the majority aged 30–49 years (58.3%). Males comprised 70.8% of respondents. Most were engaged in informal employment (79.1%), and 66.7% earned between 200,001–500,000 UGX per month. Household sizes were predominantly 2–4 members (51.3%), and the water source was mainly piped (80.6%). Over half (54.2%) experienced intermittent water supply, and 80.6% reported turbidity or particles in their water. **Table 1**

Microbiological and physicochemical quality of household water

4.2 Microbiological water quality

The microbiological quality of water was assessed across 12 wards in Mbarara City by analyzing Total Plate Count, Total Coliforms, and Total *E. coli* counts at different points: household source, storage, and drinking water. The results are presented as median colony-forming units per 100ml (CFU/100 ml) with interquartile range (IQR). **Table 2**

Table 2: Microbiological water quality

Ward (n)	Water sample	Total Plate count (CFU/100ml), median (IQR)	Total Coliforms (CFU/100ml), median (IQR)	Total E.coli (CFU/100ml), median (IQR)

Biharwe East (6)	Source	0 (15)	0 (0)	0 (0)
	Storage	0 (2)	0 (0)	0 (0)
	Drinking	0 (0)	0 (0)	0 (0)
Biharwe West (6)	Source	9 (25)	0 (0)	0 (0)
	Storage	0 (0)	0 (0)	0 (0)
	Drinking	0 (0)	0 (0)	0 (0)
Kakiika (6)	Source	725 (2184)	0 (9)	0 (0)
	Storage	20 (400)	0 (8)	0 (0)
	Drinking	2800 (5696)	0 (0)	0 (0)
Kakoba (6)	Source	0 (0)	0 (0)	0 (0)
	Storage	0 (0)	0 (0)	0 (0)
	Drinking	0 (0)	0 (0)	0 (0)
Kamukuzi (6)	Source	25.5 (68)	5.5 (31)	0 (0)
	Storage	0 (7)	0 (0)	0 (0)
	Drinking	0 (0)	0 (0)	0 (0)
Katete (6)	Source	0 (15)	0 (0)	0 (0)
	Storage	0 (0)	0 (0)	0 (0)
	Drinking	0 (0)	0 (0)	0 (0)
Katojo (6)	Source	3.5 (8)	0 (0)	0 (0)
	Storage	0 (0)	0 (0)	0 (0)
	Drinking	0 (0)	0 (0)	0 (0)
Nyakinengo (6)	Source	2 (10)	0 (0)	0 (0)
	Storage	0 (7)	0 (0)	0 (0)
	Drinking	0 (4)	0 (0)	0 (0)
Nyamitanga (6)	Source	0 (2)	0 (0)	0 (0)
	Storage	0 (0)	0 (0)	0 (0)
	Drinking	0 (0)	0 (0)	0 (0)
Nyamityobora (6)	Source	2.5 (12)	0 (0)	0 (0)
	Storage	0 (0)	0 (0)	0 (0)
	Drinking	0 (0)	0 (0)	0 (0)

Ruharo (6)	Source Storage Drinking	5 (20) 8 (11) 0 (0)	0 (0) 3.5 (16) 0 (0)	0 (0) 1.5 (5) 0 (0)
Ruti (6)	Source Storage Drinking	0 (3) 2 (4) 0 (5)	0 (0) 0 (0) 0 (0)	0 (0) 0 (0) 0 (0)

Household source water in Kamukuzi indicated contamination with a median total coliform count of 5.5 CFU/100ml (IQR: 31). This is above the WHO and UNBS acceptable limits of 0 CFU/ml for total coliforms in drinking water (Uganda National Bureau of Standards (UNBS), 2014).

In Ruharo, contamination was noted to increase at the point of water storage with a median total plate count of 3.5 CFU/100 ml compared to 0 CFU/100ml in the source water. The total *E. coli* count was also observed to have a median of 1.5 CFU/100 ml (IQR: 5) in Ruharo's stored water compared to 0 CFU/100 ml of E. coli in the source water. These observed values are above the UNBS 0 CFU/100 ml limit for E. coli in drinking water (UNBS, 2014). This suggests post-source contamination arising from unsafe storage practices.

This trend is consistent with findings by Luvhimbi et al (2022), who reported similar microbial deterioration between source and point of use in South African households (Luyimbi et al., 2022). Gizachew et al (2020) also highlighted unsafe water storage and poor hygiene practices as major contributors to increased bacterial water contamination in Ethiopia (Gizachew et al., 2020). Fida et al (2023) also emphasize that poor domestic practices can reverse the benefits of improved water infrastructure (Fida et al., 2023). Similarly, Ali et al (2024) documented how even piped systems in low-income areas often fail to guarantee safe drinking water due to consumer-side contamination risks (Ali et al., 2024).

The Safe Water System (SWS) framework explains this result by highlighting how water can become unsafe not due to the supply infrastructure but due to human behaviors like improper storage, lack of treatment, and unhygienic serving. The deterioration from source to storage water in Ruharo observed in this study maps directly onto SWS pathways, where each stage of the water chain poses a contamination risk without adequate interventions (Gallo & Lantagne, 2008).

These findings imply that improving access to safe water sources alone is insufficient. Public health interventions should include promoting safe household storage, educating on container hygiene, and encouraging point-of-use treatment (e.g., boiling or chlorination). Local health authorities may also need to enforce guidelines on household storage practices and possibly subsidize safe containers or treatment products in high-risk areas.

4.3 Physicochemical water quality

The physicochemical quality of water was assessed across 12 wards in Mbarara City by analyzing pH, Electrical conductivity, and total dissolved solids at different points: household source, storage, and drinking water. The results are presented as median with interquartile range (IQR). These measurements were compared against UNBS standards to assess safety and to understand whether post-supply handling altered water quality.

Table 3: Physicochemical water quality

Ward (n)	Water sample	pH, Median (IQR)	Electrical Conductivity (µS/cm), Median (IQR)	Total Dissolved Solids (mg/L), Median (IQR)
Biharwe East (6)	Source Storage Drinking	6.94 (0.01) 6.94 (0.01) 6.94 (0.01)	448 (99) 68 (139) 32.5 (3)	221 (49) 34 (69) 16.5 (1)
Biharwe West (6)	Source Storage Drinking	6.94 (0.02) 6.94 (0.01) 6.94 (0.01)	478 (518) 139.5 (136) 34.5 (12)	240 (258) 70 (69) 16.5 (5)
Kakiika (5)	Source Storage Drinking	6.93 (0.01) 6.93 (0.00) 6.93 (0.00)	449 (38) 144 (99) 25 (56)	226 (21) 72 (49) 13 (27)
Kakoba (6)	Source Storage Drinking	6.93 (0.00) 6.93 (0.00) 6.93 (0.02)	477.5 (32) 154 (12) 154 (122)	238.5 (15) 76.5 (7) 77 (66)
Kamukuzi (6)	Source Storage Drinking	6.94 (0.01) 6.93 (0.01) 6.93 (0.00)	448 (34) 160 (148) 29.5 (161)	229.5 (18) 46 (72) 14.5 (80)
Katete (6)	Source Storage Drinking	6.94 (0.01) 6.93 (0.00) 6.93 (0.01)	469 (5) 147 (75) 83 (131)	236 (10) 73.5 (39) 40.5 (65)

Katojo (6)	Source Storage Drinking	6.93 (0.01) 6.92 (0.00) 6.92 (0.01)	195 (461) 76.5 (94) 149 (132)	163.5 (143) 38.5 (48) 74.5 (67)
Nyakinengo (6)	Source Storage Drinking	6.94 (0.02) 6.93 (0.01) 6.93 (0.01)	277 (256) 17 (11) 28 (25)	141.5 (126) 9 (4) 14 (14)
Nyamitanga (6)	Source Storage Drinking	6.94 (0.01) 6.94 (0.01) 6.93 (0.02)	519.5 (117) 175.5 (26) 79.5 (159)	241 (43) 83.5 (13) 38.5 (79)
Nyamityobora (6)	Source Storage Drinking	6.92 (0.02) 6.92 (0.01) 6.92 (0.01)	177.5 (15) 145 (89) 23 (4)	88 (6) 72 (44) 11 (2)
Ruharo (5)	Source Storage Drinking	6.93 (0.01) 6.93 (0.01) 6.93 (0.00)	413 (30) 157 (35) 27 (15)	207 (17) 81 (6) 14 (7)
Ruti (6)	Source Storage Drinking	6.93 (0.01) 6.93 (0.01) 6.92 (0.02)	236.5 (439.5) 68 (146.5) 104 (127)	120.5 (222) 73 (67) 53 (63)

Across all wards and sampling points, the median pH values consistently ranged between 6.92 and 6.94, with very narrow interquartile ranges (IQRs). These values fall within the UNBS permissible range of 6.5 to 8.5, suggesting that the pH of the water remained relatively stable through the household water chain. All measured EC values remained well below the UNBS upper limit of 1500 µS/cm, indicating low salinity and ion concentration.

All physicochemical parameters measured across wards and at all points of the household water chain remained within acceptable national safety thresholds. Like with other studies, these findings indicate that physicochemical contamination is not a significant contributor to household water quality degradation in sub-Saharan Africa. In a study in a comparable urban city in Kenya (Kisii), Ondieki et al. (2021) found that TDS and electrical conductivity of the analyzed water samples were within the recommended standards of less than 1000 ppm and 1500 µSCM^{-1} respectively (Ondieki et al., 2021). Similarly, in South Africa, Edokpayi et al. (2018) found that he pH, electrical conductivity, chloride, fluoride, nitrate and sulphate levels were below their permissible limits for drinking water (Edokpayi et al., 2018). Additionally, this is consistent with the findings of previous studies in Mbarara city, which found microbiological contamination to be a greater risk to household drinking water safety compared to chemical contamination (Abaasa et al., 2024).

Water handling practices among households

4.4 Water handling practices

The water handling practices of practices were assessed for each of the 72 households across the 12 selected wards in Mbarara city as shown in **Table 4**

Table 4: Water handling practices

Characteristic	Frequency, n (%)
Type of water storage container	
Plastic water tank	13(18.0)
Plastic jerrycan	58(80.6)
Concrete water tank	1(1.4)
Covered Storage container	
No	47(65.3)
Yes	25(34.7)
Storage container cleaning frequency	
Daily	2(2.8)
Weekly	34(47.2)
Monthly	23 (31.9)
Annually	13 (18.1)
Drinking water storage duration	
2 days	13(19.1)
2-7 days	50(73.5)
>7 days	5 (7.4)
Observed drinking water source	
Covered container Uncovered container	63 (87.5) 3 (4.2)
Unable to observe	6 (8.3)
Water treatment for drinking	
Boiling	68 (94.4)

Chlorine	1 (1.4)
Bottled water	3 (4.2)
Treatment frequency before drinking	
Always	70(97.2)
Sometimes	2(2.8)

The study found that plastic jerrycans were the most commonly used storage containers, with 80.6% of households relying on them. However, 65.3% of households used uncovered storage containers, increasing the risk of airborne contamination and vector exposure. Weekly cleaning was the most common practice, reported by 47.2% of households, but 18.1% cleaned their storage containers only once a year. Drinking water was stored for 2 to 7 days in 73.5% of households, and while 94.4% relied on boiling as a treatment method, the risk of secondary contamination due to poor storage remained high.

These results highlight a partial adherence to safe water handling practices. Although most households use covered containers, lapses in hygiene and treatment compromise water safety. The low rate of container cleaning suggests knowledge or resource gaps. These findings are consistent with Abaasa et al. (2023), who examined community perceptions and practices regarding the quality and safety of drinking water in Mbarara City. The study highlighted that poor waste disposal, inadequate treatment, and insufficient maintenance of water systems contributed to the deterioration of drinking water quality. They also reported that residents perceived their drinking water as poor due to issues such as poor waste disposal, inadequate water treatment, and lack of proper system maintenance. It emphasized the need for community education on proper water treatment, storage, and surveillance. Additionally, studies by Tsegaye et al. (2021) in Ethiopia and Mohamed et al. (2016) in Tanzania similarly found that even when water is initially safe, inadequate storage practices often result in microbial regrowth, further endangering household health.

Influence of handling practices on the quality of water used by households

Table 5: Influence of water handling practices on physicochemical water quality

Dependent Variable	Independent Variable	Coefficient	P-value	Confidence Interval
	Plastic water tank	-0.13	0.35	[-0.39, 0.14]
	Concrete water tank	-0.22	0.61	[-1.08, 0.64]
	Plastic jerrycan	4.20	0.00	[4.09, 4.32]

Storage pH	Uncovered storage	0.11	0.33	[-0.11, 0.33]
	Weekly storage cleaning	0.25	0.57	[-0.62, 1.12]
	Monthly storage cleaning	0.33	0.46	[-0.55, 1.21]
	Annual storage cleaning	0.22	0.62	[-0.67, 1.12]
	Daily storage cleaning	3.91	0.00	[3.05, 4.77]
Storage EC	Plastic water tank	35.89	0.09	[-5.27, 77.05]
	Concrete water tank	219.47	0.00	[89.12, 349.83]
	Plastic jerrycan	101.53	0.00	[84.11, 118.95]
	Uncovered storage	-41.73	0.02	[-76.82, -6.64]
	Weekly storage cleaning	76.53	0.27	[-59.94, 213.00]
	Monthly storage cleaning	101.05	0.15	[-36.62, 238.72]
	Annual storage cleaning	133.83	0.06	[-6.17, 273.83]
	Daily storage cleaning	18.00	0.79	[-116.51, 152.51]
Storage TDS	Plastic water tank	20.22	0.05	[-0.33, 40.77]
	Concrete water tank	-35.53	0.28	[-100.61, 29.56]
	Plastic jerrycan	50.53	0.00	[41.83, 59.22]
	Uncovered storage	-15.48	0.07	[-32.31, 1.35]
	Weekly storage cleaning	38.12	0.24	[-25.86, 102.09]
	Monthly storage cleaning	44.19	0.18	[-20.35, 108.73]
	Annual storage cleaning	67.25	0.05	[1.62, 132.88]
	Daily storage cleaning	9.00	0.78	[-54.06, 72.06]
Drinking pH	2-7 days drinking water storage	-0.10	0.53	[-0.40, 0.21]

	>7 days drinking water storage	0.34	0.27	[-0.27, 0.96]
	2 days drinking water storage	4.30	0.00	[4.04, 4.57]
	Uncovered drinking water container	-0.28	0.43	[-1.00, 0.43]
	Unableto observe drinking water containing	0.24	0.28	[-0.19, 0.66]
	Covered drinking water container	4.25	0.00	[4.12, 4.38]
	Chlorine drinking water treatment	0.49	0.34	[-0.53, 1.50]
	Use bottled drinking water	0.21	0.57	[-0.51, 0.93]
	Boiling drinking water	4.25	0.00	[4.13, 4.38]
Drinking EC	2-7 days drinking water storage	-4.79	0.82	[-45.73, 36.14]
	>7 days drinking water storage	-52.49	0.21	[-136.16, 31.19]
	2 days drinking water storage	76.15	0.00	[39.92, 112.39]
	Uncovered drinking water container	-43.48	0.36	[-137.01, 50.05]
	Unableto observe drinking water containing	-17.65	0.53	[-73.39, 38.10]
	Covered drinking water container	71.98	0.00	[55.05, 88.92]
	Chlorine drinking water treatment	63.30	0.34	[-66.77, 193.37]

	Use bottled drinking water	-51.70	0.27	[-144.38, 40.97]
	Boiling drinking water	69.70	0.00	[53.57, 85.84]
Drinking TDS	2-7 days drinking water storage	-2.35	0.82	[-22.77, 18.07]
	>7 days drinking water storage	-26.26	0.21	[-67.98, 15.47]
	2 days drinking water storage	37.92	0.00	[19.86, 55.99]
	Uncovered drinking water container	-21.40	0.36	[-68.08, 25.29]
	Unableto observe drinking water containing	-9.06	0.52	[-36.89, 18.76]
	Covered drinking water container	35.90	0.00	[27.45, 44.35]
	Chlorine drinking water treatment	30.23	0.36	[-34.73, 95.20]
	Use bottled drinking water	-25.77	0.27	[-72.06, 20.52]
	Boiling drinking water	34.77	0.00	[26.71, 42.82]

Regression analysis revealed significant associations between water storage container type and storage electrical conductivity (ECs). Water stored in concrete tanks exhibited significantly higher ECs compared to plastic tanks (β = 219.47, p = 0.001), likely due to increased ion dissolution from concrete materials. Annual cleaning was significantly linked to increased TDS (β = 67.25, p = 0.045), indicating that infrequent cleaning contributes to higher scale/biofilm build-up and sediment accumulation that later re-enters the stored water, increasing dissolved solids. However, storage pH, TDS, and drinking water quality parameters (pH, ECs, TDS) were not significantly affected by handling practices (p-values > 0.05). These findings align with studies in Kenya (Ondieki et al., 2022) and Tanzania (Mohamed et al., 2016) also suggest that improper cleaning leads to mineral buildup and microbial regrowth in stored water, reinforcing the importance of routine maintenance and safe storage practices.

Table 6: Influence of water handling practices on microbiological water quality

Dependent Variable	Independent Variable	Coefficient	Std. Err.	P-value	95% Confidence Interval
Storage Total Plate count	Plastic Water tank	-23.25	35.76	0.52	[-94.58, 48.08]
	Concrete Water tank	-25.48	117.52	0.83	[-259.93, 208.97]
	Jerrycan	25.48	15.30	0.10	[-5.04, 56.01]
	Uncovered storage	4.73	28.73	0.87	[-52.56, 62.03]
	Covered storage	17.84	23.21	0.45	[-28.45, 64.13]
	Weekly storage cleaning	14.76	83.73	0.86	[-152.32, 181.85]
	Monthly storage cleaning	3.30	84.84	0.97	[-165.98, 172.59]
	Annual storage cleaning	71.46	87.41	0.42	[-102.96, 245.88]
	Daily storage cleaning	-1.95E-13	81.37	1.00	[-162.37, 162.37]
Storage Total coliforms	Plastic Water tank	-0.60	21.37	0.98	[-43.23, 42.02]
	Concrete Water tank	-10.76	70.23	0.88	[-150.86, 129.34]
	Jerrycan	10.76	9.14	0.24	[-7.48, 28.99]
	Uncovered storage	7.69	17.09	0.65	[-26.40, 41.78]
	Covered storage	5.48	13.81	0.70	[-22.06, 33.02]
	Weekly storage cleaning	17.38	50.75	0.73	[-83.88, 118.64]
	Monthly storage cleaning	1.09	51.42	0.98	[-101.51, 103.69]
	Annual storage cleaning	10.77	52.97	0.84	[-94.94, 116.48]
	Daily storage	3.55E-15	49.32	1.00	[-98.41, 98.41]

	cleaning				
Storage Total E. coli	Plastic Water tank	0.16	2.66	0.95	[-5.15, 5.47]
	Concrete Water tank	-1.38	8.75	0.88	[-18.84, 16.08]
	Jerrycan	1.38	1.14	0.23	[-0.89, 3.65]
	Uncovered storage	0.72	2.13	0.74	[-3.53, 4.97]
	Covered storage	0.92	1.72	0.60	[-2.51, 4.35]
	Weekly storage cleaning	2.29	6.31	0.72	[-10.31, 14.89]
	Monthly storage cleaning	3.77E-14	6.40	1.00	[-12.77, 12.77]
	Annual storage cleaning	1.69	6.59	0.80	[-11.46, 14.85]
	Daily storage cleaning	-3.80E-14	6.14	1.00	[-12.25, 12.25]
Drinking total plate count	2-7 days drinking water storage	451.47	465.27	0.34	[-477.73, 1380.67]
	>7 days drinking water storage	-1.69	786.44	1.00	[-1572.33, 1568.94]
	2 days drinking water storage	1.69	414.49	1.00	[-826.10, 829.49]
	Uncovered drinking water container	-195.11	827.58	0.81	[-1846.09, 1455.87]
	Unable to observe drinking water containing	1520.22	598.34	0.01	[326.57, 2713.88]
	Covered drinking water container	196.44	176.44	0.27	[-155.55, 548.43]
	Chlorine drinking water treatment	-333.53	1474.67	0.82	[-3275.42, 2608.36]
	Use bottled drinking water	-333.53	863.65	0.70	[-2056.47, 1389.41]

	Boiling drinking water	333.53	177.53	0.07	[-20.63, 687.69]
Drinking Total coliforms	2-7 days drinking water storage	18.20	29.50	0.54	[-40.71, 77.11]
	>7 days drinking water storage	2.75E-14	49.86	1.00	[-99.58, 99.58]
	2 days drinking water storage	-2.84E-14	26.23	1.00	[-52.48, 52.48]
	Uncovered drinking water container	-14.44	54.50	0.79	[-123.17, 94.29]
	Unable to observe drinking water containing	-14.44	39.41	0.72	[-93.06, 64.17]
	Covered drinking water container	14.44	11.62	0.22	[-8.74, 37.63]
	Chlorine drinking water treatment	-13.38	92.98	0.89	[-198.88, 172.11]
	Use bottled drinking water	-13.38	54.46	0.81	[-122.02, 95.26]
	Boiling drinking water	13.38	11.19	0.24	[-8.95, 35.71]
Drinking Total E. coli	2-7 days drinking water storage	7.00	13.38	0.60	[-19.72, 33.72]
	>7 days drinking water storage	1.48E-14	22.62	1.00	[-45.17, 45.17]
	2 days drinking water storage	-1.42E-14	11.92	1.00	[-23.80, 23.80]
	Uncovered drinking water container	-5.56	24.70	0.82	[-54.83, 43.72]
	Unable to observe drinking water containing	-5.56	17.86	0.76	[-41.18, 30.07]

	Covered drinking water container	5.56	5.27	0.30	[-4.95, 16.06]
	Chlorine drinking water treatment	-5.15	42.13	0.90	[-89.20, 78.90]
	Use bottled drinking water	-5.15	24.67	0.84	[-54.37, 44.08]
	Boiling drinking water	5.15	5.07	0.31	[-4.97, 15.27]

While most factors showed no statistically significant associations, the results indicated that drinking water samples from sources that could not be observed by the data collectors had significantly higher total plate count compared to water collected directly from the source (β = 1520.22, 95% CI: 326.57–2713.88, p = 0.013).

The fact that drinking water from unobserved sources showed significantly higher contamination raises concerns about social desirability bias in self-reported water source data in which study participants are inclined to present themselves in a positive light to researchers (Paulhus, 2017). Households may have provided drinking water samples from safer or pre-treated sources when under observation, while their actual drinking water sources may have been of lower quality.

Factors influencing water handling practices in households

Table 7: Factors influencing water handling practices in households

Dependent Variable	**Independent Variable**	**Chi-Square Value**	**p-value**
Storage Covered	Sex	0.15	0.70
	Age Group	0.74	0.67
	Education Level	1.33	0.51
	Occupation	1.10	0.58
	Household Size	5.97	0.11
	Monthly Household Income	5.33	0.15
Cleaning Frequency	Sex	5.20	0.16
	Age Group	9.09	0.17

	Education Level	13.05	0.04
	Occupation	12.92	0.04
	Household Size	6.61	0.68
	Monthly Household Income	11.74	0.23
Drinking Water Storage Duration	Sex	2.55	0.28
	Age Group	10.48	0.03
	Education Level	2.69	0.61
	Occupation	3.74	0.44
	Household Size	11.23	0.08
	Monthly Household Income	7.53	0.28
Drinking Water Source	Sex	4.24	0.12
	Age Group	2.41	0.66
	Education Level	5.19	0.27
	Occupation	2.79	0.59
	Household Size	5.88	0.44
	Monthly Household Income	6.68	0.35

This study found that cleaning frequency was significantly associated with education level (p = 0.042) and occupation (p = 0.044), suggesting that individuals with higher education levels and those in specific occupations may clean their water storage containers more frequently. Additionally, drinking water storage duration was significantly associated with age group (p = 0.033), indicating that older individuals may store drinking water for longer durations. These findings highlight specific sociodemographic influences on water handling practices while suggesting that other factors beyond demographics may shape overall behaviors.

Similar findings have been reported by Rosa & Clasen (2017), who found that education plays a critical role in influencing water treatment and storage practices. Their study indicated that individuals with formal education are more likely to adopt safe water handling behaviors due to increased awareness of health risks. Similarly, Atalay et al. (2024) found that employment status affects water handling, with individuals in formal occupations being more likely to engage in frequent cleaning due to exposure to health and safety guidelines at workplaces. However, their study also emphasized that social norms and convenience often outweigh knowledge in determining actual behaviors. These insights suggest that while education and employment play a role, targeted behavioral interventions are necessary to promote improved water storage and handling practices.

5. CONCLUSION AND RECOMMENDATIONS

5.1. CONCLUSIONS

This study examined the quality of water supply and water handling practices in Mbarara City, focusing on microbiological and physicochemical water quality, household water storage, and factors influencing water handling behaviors. The findings highlight key concerns related to water safety, contamination risks, and the role of household practices in ensuring safe drinking water.

Microbiological and Physicochemical quality of household water

While the majority of water samples from sources met Uganda National Bureau of Standards (UNBS) and World Health Organization (WHO) guidelines for microbiological quality (0 CFU/100ml for E. coli and total coliforms), in one ward E.coli contamination increased from zero between source and storage, with stored-water E. coli at a median 1.5 CFU/100 mL (IQR 5), consistent with post-supply contamination.

Physicochemical parameters i.e., pH, TDS, and Electrical Conductivity, remained within acceptable UNBS/WHO limits (UNBS, 2014).

Water handling practices and their influence on household water quality

Household water handling practices emerged as critical determinants of water safety. While boiling was the predominant treatment method, secondary contamination risks were heightened due to poor storage practices, infrequent cleaning of containers, and prolonged storage durations. 80.6% of households stored water in plastic jerrycans, 65.3% stored in uncovered containers, only 2.8% cleaned containers daily, and 73.5% kept drinking water for 2–7 days.

The study found that concrete tanks for household storage had significantly higher storage EC than plastic tanks ($\beta = +219.47$, $p = 0.001$), and annual cleaning was associated with higher storage TDS ($\beta = +67.25$, $p = 0.045$).

Sociodemographic factors influencing Household water handling practices

The study found that education and occupation significantly influenced cleaning frequency, while age was associated with storage duration, emphasizing the role of sociodemographic factors in shaping water handling behaviors.

5.2. RECOMMENDATIONS

- In assessing the physicochemical and microbiological quality of water, the study noted that all physicochemical parameters met UNBS standards; however, microbial contamination was demonstrated at storage points in one ward. Interventions should prioritize post-source hygiene rather than treatment at the source alone, such as community water safety campaigns that focus on microbial risk, even when water appears physically clean.
- The observation of unsafe water handling practices, such as infrequent cleaning and use of uncovered storage containers, calls for the need for sensitization to promote water handling practices that would maintain the safe water chain.
- Addressing socioeconomic barriers to safe water practices is just as important as improving infrastructure. Since education and occupation play a role in how people manage their drinking water, interventions should consider these factors to design targeted and effective awareness programs.
- Further research should be undertaken to explore the long-term health effects of drinking water quality in Mbarara City, focusing on both microbial and physicochemical risks. Additionally, studies on the behavioral factors influencing water handling practices can help develop better strategies to encourage safe water use in households and communities

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Appendix 1: Structured Questionnaire

UGANDA CHRISTIAN UNIVERSITY
A Centre of Excellence in the Heart of Africa

FACULTY OF ENGINEERING, DESIGN AND TECHNOLOGY DEPARTMENT OF ENGINEERING AND ENVIRONMENT

QUESTIONNAIRE FOR SOCIO-DEMOGRAPHIC AND WATER HANDLING PRACTICES

STUDY TITLE: Quality of supply water and water handling practices in Mbarara city, southwestern Uganda

Section 1: Sociodemographic Information	
Household Information	**Household ID:** ______ **Division (Select):** ☐ Mbarara City North ☐ Mbarara City South Ward: ______________________
Household Head Information	**Sex:** ☐ Male ☐ Female **Age:** _________years **Education level:** ☐ None ☐ Primary ☐ Secondary ☐ Tertiary **Occupation:** ☐Formal employment ☐Informal employment ☐Unemployed

	Monthly household income* (UGX): □ < 50,000 □ 50,000–200,000 □ 200,001-500,000 □500,001-1,000,000 □>1,000,000 **Household size (No. of members):** ___

Section 2: Water Access and Water Source Information	
What is the main source of water for members of this household?	**Piped water** □Piped into dwelling □Piped into compound □Piped into neighbor □Public tap/standpipe □Borehole or tubewell **Dug well** □Protected well □Unprotected well **Water from spring** □Protected spring □Unprotected spring □ **Rainwater collection** **Delivered water** □Tanker-truck □Cart with small tank/drum **Packaged water** □Bottled water □Sachet water

	□ **Surface water (river, stream, lake, pond)** Others (specify):………………………………….
Distance of household from water source* (not applicable if within dwelling or yard)	□ <1km □ 1-5km □ >5km
Reliability of water source	□ Always available □ Intermittent supply
Section 3: Water handling practices	
What type of container do you use to store household water?	**Plastic** □ Water tank □ Jerrycan □ Other plastics **Metallic** □ Water tank □ Other metallic **Ceramic/Cement**

	□Water tank □Other ceramic Other (specify):……………………………….
Is the storage container covered?	□Yes □No

How often do you clean the storage containers	□Daily □Weekly □Monthly □Annually Other (specify):……………………………….
What are the main uses of the stored water	□Drinking □Cooking □Washing □Bathing Other (specify):……………………………….
Do you use the same container for drinking and non- drinking purposes?	□Yes □No
How long do you store drinking water?	□2 days □2-7 days □>7 days
Could you please provide me with a glass of the water that members of your household usually drink? *(collect and label sample)*	□Yes □No

Source of drinking water (*Observe and record whether the water was collected directly from the source or from a separate storage container)*	□Direct from Source □Covered container □Uncovered container □Unable to observe
Have you or any other member of this household done anything to this water to make it safer to drink?	□Yes □No □Don't know
What has been done to the water to make it safer to drink?	□Boiled it □Added Chlorine □Strained it through a cloth □Used a water filter (ceramic, sand, composite, etc) □Solar disinfection □Let it stand and settle Other (specify):…………………………….
How often do you treat water before drinking?	□Always □Sometimes □Never □Don't know
Section4: Perception and Satisfaction with Water Quality	
Have you ever noticed any of the following in your water?	□Bad taste □Odor □Turbidity □Particles
Have you or any member of your household experienced any of the following waterborne diseases: typhoid, diarrhea, H. pylori ulcers, schistosomiasis within the past 6 months? *(probe for other water related diseases they may have experienced)*	□Yes □No If Yes, specify illnesses……………………………….

Appendix 2: Observation Checklist for Physicochemical and Microbiological Water Quality Tests

STUDY TITLE: Quality of supply water and water handling practices in Mbarara city, southwestern Uganda

OBSERVATION CHECKLIST FOR PHYSICOCHEMICAL WATER QUALITY TESTS

General Information	
Date of Observation: ________________ Location of Sample Collection: ________________ Household ID: ________________ Sample ID: ___________________ Type of Water Source: ☐ Borehole ☐ Piped Water ☐ River/Lake ☐ Well ☐ Rainwater ☐ Other (Specify) ________________	
Physicochemical Parameters (Laboratory Observations)	
Water colour:	☐ Clear ☐ Slightly Cloudy ☐ Murky
Odor Presence:	☐ None ☐ Mild ☐ Strong (Describe: ________________)
Presence of Floating Particles:	☐ Yes ☐ No
Temperature & Conductivity	
Temperature:	
pH Level:	
Electrical Conductivity:	

OBSERVATION CHECKLIST FOR MICROBIOLOGICAL WATER QUALITY TESTS

General Information	
Date of Observation: ______________ Location of Sample Collection: _____________ ____________________________ Household ID: Sample ID: _________________ Type of Water Source: ☐ Borehole ☐ Piped Water ☐ River/Lake ☐ Well ☐ Rainwater ☐ Other (Specify) ______________	
Microbiological Parameters (Laboratory Observations)	
Total Coliforms (CFU/ml):	
E. coli Presence (CFU/ml):	
Other Bacterial Contaminants Detected:	

UNIVERSITY CHRISTIAN UNIVERSITY (UCU)

POSTGRADUATE RESEARCH CORRECTION MATRIX

PROGRAMME: MASTER OF SCIENCE IN WATER AND SANITATION

NAME OF STUDENT: TUSIIMIRE BENJAMIN

REG. NO.:
SIGNATURE: DATE:

Research Title: INFLUENCE OF HOUSEHOLD WATER HANDLING PRACTICES ON THE QUALITY OF DOMESTIC WATER IN MBARARA CITY, SOUTHWESTERN UGANDA

Title/ heading and numbering	**Areas of correction**	**Correction**	**Page**
Title and abstract	Very Interesting!!!! Your study does not have an Abstract is it intended or forgotten???? Improve your title to clearly show the "Couse and Effect" relationship.	Abstract has been added to the dissertation Title has been adjusted as follows: *"Influence of household water handling practices on the quality of domestic water in Mbarara city, Southwestern Uganda"*	2 1
	Follow the Graduate dissertation guide, How you have structured your chapters is not accepted please change. All your paragraphs should be of 4 to 5 sentences, line spacing 1.5 all throughout font 11Trebuchets or font 12 Roman New times.	Dissertation structured based on UCU research manual and formatted to line spacing 1.5 and font 11Trebuchets	

Chapter 1: Introduction	Some phrases in the background are not adequately referenced	Updated references in the background	12-13
	A safe water chain should be well explained in the problem statement to bring out the actual source of contamination from the Source, collection, transportation and storage	Problem statement updated to explain the household safe water chain and bring out the points of contamination within this chain	13
	Significance and scope of the study need to be well placed; reference can be made to the UCU Research Manual	Order of the background section re-organized according to the UCU research manual	12-16
Chapter 2: Literature Review	Some references in this section need revision so that the most recent references on the same topic can be well captured to highlight new developments	Older references replaced with newer references	17-22
	For the physicochemical and bacteriological characteristics of water, all key parameters of interest should be clearly spelt out with definitions, equipment used and units of measurement	Updated to define key parameters that were of interest and their measurements	18
Conceptual Framework	Poorly constructed. In your what are the influencing factors? How different are they with independent variables??? It is so confusing; the	The dependent variable is the microbiological and physicochemical household water quality, and the independent variables are the household handling practices. However, the study also intended to assess the household and sociodemographic factors that could influence the household water handling practices such	24

	Dependent variables seem to be more of independent variables than DVs??? This is supposed at the end of chapter 2 not here.	as income, education, reliability of the water source. While these factors may not directly influence the quality of the water, they can influence how it is managed in the household, and are now indicated as exogenous variables because they *"are not themselves the direct causes, nor are they influenced by the water handling practices or water quality outcomes. Instead, they function as background determinants that shape the context in which the independent variables (water handling practices) occur (Deistler & Scherrer, 2022)."* -The conceptual framework has been moved to the end of chapter 2	
Chapter 3: Methodology	What methodological approach did you adopt, and why?	Methodology section reorganized to bring the research design forward as per the UCU research manual. A quantitative study design was used to allow for collection of data at a single point, providing a snapshot of water quality along the household safe water chain and associated handling practices.	26-32
	What sampling protocols did you use to ensure validity and reliability of the water quality sampling and testing from source, collection container, storage?	Quality/Error control section included to address this	29-30
	How were the data collection instruments developed for the non-experimental data collection? How did you ensure their validity and reliability?	Section on validity and reliability of the data collection tools has been added under the quality control section to address this	29
	1. Use past tense consistently Since this is a completed	1. Checked for past tense 2. Sample size formular corrected and referenced 3. Ensured full reference list, updated numbers	26-32

	study, methods should be described in past tense. 2. Correct and format the sample size formula Present the formula clearly, number it, and reference it in the text. 3. Ensure APA 7 compliance Provide a complete References list matching all in-text citations. Standardize numbers and units. Define all abbreviations at first use. 4. Remove redundancy Avoid repeating sampling details in 3.5, 3.6.1, and 3.7—summarize once. 5. Clarify statistical approach Explain conditions for choosing between ANOVA and Kruskal-Wallis. 6. Improve appendix referencing Use APA 7 conventions for appendices and refer to them in-text correctly. 7. Proofread for grammar and flow Check for missing articles	and units, define abbreviations in citations at initial mention 4. Summarized sampling details 5. Added conditions in which ANOVA or Kruskal-Wallis was utilized as follows; "*ANOVA was used to compare means when the data were normally distributed, and the Kruskal-Wallis test was used otherwise*" 6. Updated appendix referencing 7. Checked for grammatical errors	

	(“the,” “a”), spacing around symbols, and avoid awkward breaks in sentences.		
Chapter 4: Results and discussion	Avoid repeating Objectives in this chapter, instead make them sub topics	Change in phrasing from objectives to sub-topics	33-48
	Start with results (Tables or graphs) and then discuss the results after each of these	Tables presented before the results’ narrative	33-48
	Table 2 is raw data, show results may be on a graph	The values presented in table 2 are the medians and interquartile ranges of the total plate counts, total coliforms, and E. coli counts. Instead of raw results, what’s presented is a result of descriptive analysis (medians & interquartile ranges). The median and interquartile ranges was computed as opposed to the mean because the data was heavily skewed, with some wards having very high plate counts while others had no or very limited microbial growths.	34-36
	Table 4 is also raw data. Please show results graphically	The values presented in table 4 (now Table 3) are the medians and interquartile ranges of the physicochemical parameters.	37-38
	Use one form of results presentation for the same objective than both. For example, once you use a graph for one set of results, you do not need to use a table for the same set of results	Used tables to present results	33-48
	It would have been useful to have well analysed data to give you results to present in chapter 4 for all objectives so	Descriptive statistics was used for objectives 1 and 2 (frequencies, medians, and IQR), and inferential statistics were used for objectives 3 and 4	33-48

	that they are well discussed. How they are presented now is basically raw data.		
Chapter 5: Conclusion and Recommendations	Provide summary findings from each specific objective	Conclusion organized according to objectives	50
	1. Reference to Standards Missing: The conclusions mention contamination and parameter variations but do not state whether these values breach WHO or Ugandan standards. This makes it harder to judge severity. 2. Lack of Quantitative Emphasis: Percentages, mean values, or comparative statistics would add strength and credibility. 4. Recommendations Not Directly Matched to Each Objective: Recommendations are sound but not clearly linked back to each objective. A more structured "Objective → Conclusion → Recommendation" format would enhance clarity.	1. In-text citations and reference list have been update 2. Comparison to UNBS standards and limits has been made 3. Statistics have been added to the conclusion to strengthen it 4. Recommendations has been structured to match the objectives	49-50