Determining the association between household drinking water handling practices and bacteriological quality of drinking water at the point-of-use in the rural communities of Murewa district, Zimbabwe.

Makokove Rameck

A mini-thesis submitted in partial fulfilment of the requirements for the degree of Master in Public Health at the School of Public Health, University of the Western Cape

Supervisor: Dr Verona Mathews

November 2018

KEYWORDS

Bacteriological quality of water

Faecal indicator organism

Coliforms

Water quality at point-of-use

Socio-demographic factors

Water handling practices

Escherichia coli

Communal water sources

Rural communities

Zimbabwe

ABBREVIATIONS

CDC	Centre for Disease Control and Prevention
CFU	Colon forming units
CHC	Community health club
CSO	Central statistics office
DALYs	Disability adjusted life years
DDF	District Development Fund
EHP	Environmental health practitioner
FBO	Faith based organisation
MDG	Millennium development goals
MOHCC	Ministry of Health and Child Care
MRCZ	Medical Research Council of Zimbabwe
NGO	Nongovernmental organisation
PAHO	Pan American Health Organisation
SDG	Sustainable development goals
TTC	Thermotolerant coliforms
UNICEF	United Nations International Children's Emergency Fund
UWC	University of the Western Cape
VHW	Village health worker
WASH	Water sanitation and hygiene
WHO	World Health Organisation

ACKNOWLEDGEMENTS

This work will not have been possible without the will of God and my gratitude goes to the almighty. My deepest admiration and thanks goes to my supervisor, Verona Mathews for the first class supervision and guidance on this project as well as the high quality inputs into the completion of this thesis.

My sincere appreciation also goes to the school of public health administrators, Janine Kader and Corinne Carollisen for the provision of support during this challenging period of study at the University of Western Cape. Appreciation also goes to colleagues and teachers who have contributed in one way or the other to the completion of this degree.

Last but not least is my lovely family (Shumirai, Comfort, Courage and Bright), I appreciate your love and support during my studies. Be blessed.

DECLARATION

I declare that "Determining the association between household drinking water handling practices and bacteriological quality of drinking water at the point-of-use in the rural communities of Murewa district, Zimbabwe" is my own work, that it has not been submitted before for any degree or examination in any other University or College, and that all sources I have used or quoted have been indicated and acknowledged as complete references.

Makokove Rameck November 2018

Signed

ABSTRACT

There is growing awareness that drinking water can become contaminated following its collection from safe communal sources such as boreholes, as well as during transportation and storage in the house. Drinking water is the most important source of gastroentric diseases worldwide, mainly due to post collection contamination of drinking water. Globally, waterborne diseases are a major public health problem, causing millions of deaths annually.

Aim: To determine the association between household drinking water handling practices and bacteriological quality of drinking water at the point-of-use in the rural communities of Murewa district in Zimbabwe.

Methods: The study used an analytic cross sectional study design. The study populations comprised of all the rural households in Murewa district and the drinking water sources used within the district. The study sample of 381 was calculated using Epi Info 7.0's Stat calculator. Multi-stage sampling and simple random sampling were used to draw 381 households from 46,287 households in Murewa district. There were three data collection points in this research study: household stored water - water samples from household storage container; source water - water sample from borehole; and an administered questionnaire to the female head of the household or any household member > 18 years. The research assistants administered a questionnaire to respective participating households and the environmental health practitioners collected water samples from household storage containers and the source of water used by each household that participated in the study. Descriptive analysis, specifically proportions and percentages, were used to summarize data on household characteristics and drinking water handling practices. The chi-square test was used to determine associations between household characteristics, water handling practices and bacteriological quality of household stored water while multivariate analysis, using a logistic regression model, was performed on variables which showed a statistically significant association in bivariate analysis with a p-value of < 0.05.

Results: More household stored water samples (23.4%) tested positive for *Escherichia coli* bacteria as compared to only 0.26% of drinking water source samples. Household water handling practices assuring safe, uncontaminated water at point-of-use included pouring as a method of drawing water from storage containers (OR=0.002, p=0.004), washing of water

collection containers with soap before water collection (OR=0.003, p=0.002) and using tight fitting lids/caps when transporting and storing water (OR=0.004, p=0.001).

Conclusion: During the study, a significant decline in water quality was observed between collection source and point-of-use source. Various households' water handling practices and socio-demographic factors influenced the bacteriological quality of water at the point-of-use. Factors that were significantly associated with unsafe water quality at the point-of-use included water collection in uncleansed or dirty containers, the dipping of non-sterile utensils into the storage container when drawing water and using loosely fitted lids/caps to cover containers during transportation and water storage. Efforts should be deployed to strengthen behaviour change and hygiene education to promote safe drinking water handling practices across the district with great emphasis on the poor and rural communities that travel long distances to fetch drinking water.

Contents

LIST OF TABLES

Chapter 1- Introduction

In 2017, it was determined globally, that 2.1 billion people were without safely managed drinking water services (Kassie & Hayelom, 2017; Sharanya et al., 2017; Saleem *et al*., 2018).These included 1.3 billion people with access to, an improved water source, located within a round trip of 30 minutes, 263 million people with limited services, or an improved water source requiring more than 30 minutes to collect water, 423 million people drawing water from unprotected wells and springs and 159 million people drinking untreated surface water from lakes, ponds, rivers and streams. Access to safe drinking water is one of the key determinants of public health and is considered a basic human right, which must be met to avert waterborne diseases (Johnson *et al*., 2016; WHO/UNICEF, 2017;).

The provision of safe drinking water is a critical area, which was highlighted for development in the Millennium Development Goals (MDGs) as it is vital for both human and economic development (Satterthwaite, 2016). Most countries, Zimbabwe included, failed to meet the MDG 7 target 10 on drinking water, which aimed "to halve the proportion of the population without access to safe water by 2015" (WHO, 2015). The need to supply safe and sustainable drinking water is now being taken forward in the Sustainable Development Goals (SDGs), SDG 6 target 6.1, which aims to, achieve universal and equitable access to safe and affordable drinking water for all by 2030 (United Nations General Assembly, 2015). To achieve this goal, water handling practices plays a very important role along with availability and quality of water sources.

Protected ground water supplies (such as springs, boreholes and wells) and surface water supplies (piped water schemes, rainwater harvesting) have been implemented globally, to improve access to safe water coverages in low resourced countries. In low and middle income countries, Zimbabwe included, which lack on-premises water supply, all water supply programs have targeted source based water quality monitoring, aimed at providing millions of people with access to microbiologically safe water supplies (Hutton & Chase, 2016). However, many studies (Hodge et al., 2015; Satterthwaite, 2016) reported that, even with safe water sources, drinking water handling practices contaminate the water between the source and point-of-use. For this reason, water quality monitoring at the point-of-use has become a critical component of national water, sanitation and hygiene assessments. World Health Organisation guidelines set stringent limits on the faecal contamination in drinking water (World Health Organization, 2011; Tabor *et al*., 2011). *Escherichia coli* and thermotolerant coliforms (TTC) are the WHO approved indicators of faecal contamination (Hodge et al., 2015; Temesgen et al., 2015). All water quality interventions are therefore targeted at providing drinking water of zero *E. coli* (or TTC) counts per 100ml sample, in line with the WHO recommended values (World Health Organisation, 2011). Measuring water quality will form the basis for monitoring SDG Target 6.1. The indicator to measure progress in terms of Target 6.1 is "the percentage of the population using safely managed drinking water services, which also include drinking water for households and institutions free from pathogens".

According to WHO (2016), at least four million people in Zimbabwe, approximately one-third of the population, lack access to safe drinking water. Despite efforts to address water access coverage through a variety of water, sanitation and hygiene (WASH) programs, Zimbabwe failed to achieve access to clean and safe water for all by 2015 (WHO,2015). The resulting water challenges presented an even more daunting list of problems, including waterborne disease, interrupted schooling especially for girls and gender inequality. According to statistics from the UNICEF/Government of Zimbabwe (2014), approximately 120,000 children under the age of five died in 2015 with diarrhoea being the cause of more than one-third of those deaths. International attention was drawn to the extent of the deaths which were associated with dilapidated WASH infrastructure. The result was a large scale mobilization of humanitarian assistance by the international community to help the country address the immediate risks posed by the WASH related diseases and to support the rehabilitation of water supply and sanitation service in both urban and rural areas. In 2015, Zimbabwe launched an ambitious program to develop its water supply and sanitation infrastructure. By the later part of the 2016 the levels of drinking coverage increased substantially to 77% (WHO/UNICEF, 2017). However, there are significant disparities between urban households, where 95% of the people have access to an improved source of drinking water, and rural areas where just 48% of the community have access to safe drinking water (WHO/UNICEF, 2017).

In most rural communities in Zimbabwe, the majority of households do not have water distribution systems inside the home, hence drinking water is obtained outside the home and stored until it is consumed. Typically, water is stored in 20-liter buckets which are widely available in Zimbabwe, and many other countries, and which are often used for water collection and storage (WHO, 2016). In a recent survey conducted on drinking water quality at the point-of-use in Murewa, it was noted that more that 60% of water samples from household storage containers were contaminated with *E. coli* (Murewa District Environmental Health Report, 2016). While the decline in bacteriological quality of drinking water between source and point-of-use have been observed in a number of studies, the association between household socio-demographic factors, water handling practices and bacteriological quality of water at the point-of-use still remains unclear.

1.2 Problem Statement

Murewa district is one of the 33 districts in Zimbabwe that benefited from the rural water, sanitation and hygiene program. Its access to safe water sources currently stands at 71% and the district has more than 150 community health clubs formed to promote health and hygiene (Murewa District Development Fund Report, 2016). Although Murewa's access to improved water source coverage increased to 71%, waterborne diseases are still a huge challenge, contributing to more than 38% of the causes of hospital/ clinic attendance), with diarrhoeal diseases incidence rate of 56 cases per 1000 inhabitants (Murewa District Health Profile, 2016).

As mentioned above, more that 60% of water samples from household storage containers in Murewa district were contaminated with *E. coli* (Murewa District Environmental Health Report, 2016). While the decline in bacteriological quality of drinking water between source and point-of-use have been observed in a number of studies, the association between household socio-demographic factors, water handling practices and bacteriological quality of water at the point-of-use still remains unclear.

In order to minimise the burden of waterborne diseases associated with consumption of contaminated drinking water after collection at the source, a need to identify risk factors for drinking water contamination between source and point-of-use is evident. This would ensure the development of targeted hygiene programs which would minimise drinking water contamination during course of collection, transportation, and storage. Therefore, this study seeks to determine the association between household socio-demographic factors, water handling practices and bacteriological quality of drinking water at the–point-of-use.

1.3 Purpose of the Study

As mentioned earlier, the purpose of this study is to identify factors that affect the bacteriological quality of drinking water between collection at water point (borehole, deep well and protected spring) and consumption at home. The results generated from this study would be used to inform and educate the community about behaviourial change and hygiene education in order to promote safe drinking water handling practices.

1.4 Study outline

Chapter 1 introduces the study and includes the formulation of the problem statement and purpose of the study.

Chapter 2 focuses on the review of the relevant literature on the health effects of bacteriologically unsafe drinking water and continues with research studies on the difference in bacteriological quality of drinking water between source and point-of-use. Finally, it identifies and describes the household water handling practices and factors that influence household drinking water handling practices.

Chapter 3 explains the research methodology, the aim and objectives, the research design, the study population, sampling, data collection, data analysis, validity, reliability and ethical considerations.

Chapter 4 is a presentation of the results in the form of tables and graphs. Presented at this stage are the descriptive quantitative results analysed using the Statistical package (Epi Info 7.0).

Chapter 5 discusses the main findings of the study, integrated with relevant literature identified in Chapter 2. It further provides an inclusive understanding of the association between household water handling practices and the quality of drinking water at the point-of-use and the socio-demographic factors that influence household water handling practices. Limitations of the study are provided.

Chapter 6 provides the conclusion and recommendations.

Chapter 2- Literature review

2.1 Morbidity and Mortality Linked to Waterborne Diseases

Although waterborne diseases have largely been eliminated in industrialised nations, the burden of these diseases remains a major concern in many low and middle countries, particularly in Sub-Sahara Africa (Alqahtani *et al*., 2015; Tsega *et al*., 2015). Waterborne diseases are mainly attributed to water that has been contaminated by human, animals or chemical wastes (WHO/UNICEF, 2017). Drinking water is the most important source of gastroentric diseases worldwide, mainly due to post collection contamination of drinking water (Gebremichael *et al*., 2017).

Recently, it was found that 80% of the global illnesses are linked to the use of unsafe and microbiologically poor quality water (Gebremichael *et al*., 2017). In addition, Shields *et al*. (2015) found that an estimated 3.1% of deaths (1.7 million) and 3.7 % of disability adjusted life years (DALYs) (54.2 million) across the world, are attributed to unsafe water, poor sanitation and hygiene. Waterborne diseases cause around 250 million infections each year which result in 10-20 million deaths worldwide (Shrestha, *et al*., 2017).

Literature suggests that a relationship between contaminated drinking water, and waterborne diseases exists. For example, drinking water, which is contaminated by human or animal faeces, can result in contracting waterborne diseases, such as cholera, dysentery, typhoid fever, and diarrhoeal infections (Hohge *et al*., 2016). According to the UNICEF/WHO (2017), waterborne diseases, such as diarrhoea, remains the second leading cause of death among children under five, globally. Worldwide, it is estimated that 140 million people develop dysentery each year which result in 600,000 deaths (CDC, 2011). In the United States of America, waterborne disease outbreaks have been caused mainly by contaminated wells and water storage reservoirs. In 1993, an outbreak of *S. typhimurium*‖ resulted in 650 illnesses and 7 deaths in Missouri (Alqahtani *et al*. 2015). Furthermore, it is estimated that the death of nearly one in five children, that is approximately 1.5 million each year, is attributed to diarrhoea, thus, killing more young children than AIDS, malaria and measles combined (UNICEF/WHO 2009). It is also estimated and reported that diarrhoea kills 1.8 million and causes approximately 4 billion cases of illness annually, of which 88% is attributable to unsafe water (Tabor *et al*., 2011). The Centre for Disease Control (2015) reported that Typhoid fever is still common in the low income countries where it affects about 2.5 million persons each year. Tsega *et al*. (2015) reported that 2.2 million deaths in low income nations are attributed to waterborne diseases. Almost half of the population in developing countries is at high risk of exposure to waterborne diseases such as dysentery, typhoid fever, and cholera (Bhattacharya *et al*., 2011).

Diarrheal epidemics have been common in many world regions. For example, a four-year epidemic in Central America, starting in 1968, resulted in more than 500,000 cases and more than 20,000 deaths. Since 1991, dysentery epidemics have occurred in eight southern African countries of Angola, Burundi, Malawi, Mozambique, Rwanda, Tanzania, Zaire, Zambia and Zimbabwe (Abebe & Dejene, 2015). In 2011, the island nation of Haiti experienced a cholera epidemic which has reportedly killed more than 4,000 people and infected 217, 000 people (WHO, 2014).

In sub-Saharan Africa, the region in which Zimbabwe is located, diarrheal diseases are a leading cause of death in children under five years, with 480,000 under-fives dying of diarrhoea each year (WHO/UNICEF, 2017). In Zimbabwe, the country's health profile report (2014) estimated that diarrheal deaths in 2014 were 12,000. Furthermore, cholera epidemics have occurred every year between 2008 and 2014 in many parts of the country leaving hundreds dead and thousands passing through the ordeal of the infection. For instance, a total of 10,000 cholera cases and 4,000 deaths were reported across the country between 2008 and 2009 (WHO, 2015).

Consuming water free of pathogens is fundamental to halting one of the primary modes of transmission of infectious diseases. The World Health Organisation (2014) noted that provision of safe sources of water supply and water quality interventions at point-of-use, reduce diarrhoea by 5% and 19%, respectively. Partum and Khananthai (2017) found that investment on improving access to safe source of water alone does not contribute much in reducing waterborne diseases, since water regarded as safe at source can become contaminated during handling between the collection source and point-of-use.

2.2 Difference in bacteriological quality of drinking water between source and point of use

The bacteriological quality of drinking water significantly declines after collection in many settings and thus the extent of contamination after water collection varies considerably.

Gebremichael *et al*. (2017) noted that the contamination was proportionately greater where faecal and total coliform counts in source water were low. For example, studies conducted in South Africa and Zimbabwe found that more than 40% of the surveyed households using improved sources of water had household stored water samples that were unsafe at the point-of-use (WHO, 2014). A number of studies in low and middle income countries compared the quality of water between water source and point-of-use and found that household stored water samples contain more *E. coli* than water source samples (Shields *et al.*, 2015). All of the studies used one or more of the following three indicator bacteria: total coliforms which are Gram-negative bacteria that ferment lactose at 35–37 degrees Celsius within 24–48 hours; faecal thermo-tolerant coliforms which are a subset of total coliform bacteria that ferment lactose at 44–45 degrees Celsius and *E. coli* which are exclusively faecal in origin, are a sub-group of the faecal coliforms that produce the enzyme B-galactosidase and not urease. The World Health Organisation guidelines state that none of these bacteria should be detectable in a 100ml of water sample (WHO, 2006). Of these bacteria, and to date *E. coli* is regarded as the most reliable indicator of faecal contamination and total coliforms as the least reliable indicator.

Factors linked with recontamination of drinking water post collection, include the method of transport, size of the mouth of the drinking water storage container (Tsega *et al*., 2015) and unsanitary methods of extracting water from wide-mouthed household storage containers (Clasen *et al*., 2015). In addition, contaminated hands, bowls and small handled cups may also contribute to the recontamination of these water supplies in the home (Tambekar *et al*, 2008).

2.3 Water Quality Intervention Programmes

Waterborne diseases prevention programmes, implemented to address drinking water quality challenges, have evolved significantly since their inception, and are now being tailored to suit the local contexts and adapted to population dynamics and disease trends (Hutton and Chase, 2016; Classen *et al*., 2015). According to Classen *et al*. (2015), many diarrhoea-related pathogens are spread through water that is contaminated with faeces. For this reason, WHO guidelines set stringent limits on the faecal contamination in drinking water supplies (WHO, 2011). *Escherichia coli* and thermo tolerant coliforms (TTC) are used as indicators of faecal contamination (Hodge *et al*., 2015). All water quality interventions are therefore targeted at providing drinking water of zero *E. coli* (or TTC) counts per 100ml sample (WHO, 2004).

Evidence from studies across Africa (WHO, 2015, Adams *et al*., 2015; Dismer, 2012), showed that tremendous investments in the construction of communal water infrastructure (boreholes and deep wells) that are designed to provide safe drinking water is the key water quality improvement programme implemented in low income countries to address access to safe water challenges (Hutton & Chase, 2016). However, a study by Hodge *et al*., (2015) noted that, even with safe water sources, drinking water handling practices contaminate the water between the source and point-of-use. As a result, water quality interventions have continued to evolve to address deteriorating water challenges at household levels.

Point-of-use water quality improvement interventions, including boiling, chlorination, filtration, flocculation and solar disinfection, are now widely practiced, especially in low and middle income countries (Guchi, 2015). These household level water quality interventions were recommended by WHO and UNICEF and are championed by various institutions including the public and private sector, NGOs and faith based organisations. The household level water quality programmes are simple technical interventions, targeting household level hygiene and sanitation behaviour change, which improve the quality of drinking water point-of-use.

To be effective, water safety and household level hygiene programs are targeted and broadened in order to cover other parameters such as water access and quantity, domestic hygiene, appropriate human waste disposal, hand washing with soap or ash, and other hygiene related practices (Clasen *et al*., 2015). According to Imanishi *et al.* (2014), water quality interventions should address all key factors such as social, cultural, economic, demographic, political, and ecological aspects in order to achieve sustained behaviour change.

Furthermore, good personal, household and environmental hygiene are important measures in preventing stored water contamination (Beyene, 2012). For example, hands and household utensils can be contaminated with human excreta, body fluids, floor, and dust and in turn contaminate water during handling. Amenu (2013) noted that infectious disease causing agents do enter stored water mainly due to unhygienic practices. This underscores the fact that household and personnel hygiene can not only prevent diarrhea, but also several other infectious diseases such as acute respiratory infections (WHO, 2009).

2.4 Household water handling practices

According to Kassie & Hayelom (2017), safe water storage is the use of clean containers with covers and good hygienic behaviours that prevent contamination during water collection, transport, and storage in the home. Microbial contamination of collected and stored household water is caused not only by the collection and use of faecally contaminated water that, initially, was not safe but also by contamination of initially microbiologically safe water after its collection and storage. In-house contamination of drinking water is a persistent problem in many communities (Rufener *et al*., 2010), which many researchers have acknowledged (Moyo *et al*., 2001; Roberts *et al*., 2004; Oswald *et al*., 2007; Walters, 2008; Amenu, 2013; Guchi, 2015). Higher levels of microbial contamination in household storage containers are associated with the use of wide mouthed storage containers, which permits dipping of hands, cups and other water drawing utensil that can carry faecal matter into the stored water (Guchi, 2015).

Studies have reported a positive association between domestic hygiene of households and the behaviour of family members towards drinking water quality (Trevett, 2005 and Tambekar *et al*. 2008). The unhygienic practices of households result in contaminated hands and fingernails coming into direct contact with stored water, which could lead to various infections (Brown & Sobsey, 2012). Similar observations were reported by Tambekar *et al*. (2011) who witnessed that domestic hygiene of houses affected drinking water quality and that good domestic hygiene kept water at a 62% potability. The study suggested poor water storage and hygienic practices in the home as the main causes of contamination of stored water. The sterility of storage containers was a key determinant of the quality of the water stored in that container.

More specifically, Wright, *et al*. (2004), found that in most low income countries, 83.9% and 63.7% of respective households did not wash containers before water collection at source or when drawing water from storage containers.. In addition, participants in a study conducted in Lesotho used open water collection containers and approximately 68% of households surveyed, dipped utensils in the storage containers when drawing water. These practices were found to be associated with contamination of water at the point-of-use (Kirby, *et al*., 2016). This is confirmed by Onigbogi and Ogunyemi (2014), who reported high association between microbiological contamination and wide mouthed storage vessels. In addition, Johnson *et al*. (2016), cited a report by WHO (2014), which stated that storing water for longer periods of time proves to be a risk factor for the contamination of otherwise good quality water..

Evidence from previous studies conducted across the globe, suggested that using containers that were not thoroughly cleaned to store drinking water in the home, dipping as a method of drawing water from storage container and using loose lid/cap to cover drinking water containers when transporting and storing water were possible routes for post collection contamination of drinking water (Oswald, 2007; Sarsan, 2013; WHO, 2015; Pickering, 2015; Hutton & Chase, 2016). A study conducted in Ethiopia by Amenu (2013), noted an association between container cleanliness and decreased contamination risk. Similarly, a study carried out in a Malawi refugee camp has found that a person's hands are primarily responsible for the cross-contamination of stored water, due to the fact that the water collection container was rinsed by hand prior to collection in an effect to clean the mouth of the container (Holt, 2009). A study by Adams *et al*. (2015), has concluded that rural communities in South Africa spent little time on proper cleaning of the collection containers, especially if water has to be collected more than once a day.

In addition, an extended storage period increased the exposure time of collected water supplies to possible faecal contaminants. Plastic containers are generally not good for long storage time. The stored water forms a slimy layer on the inside and depending on the water source, may worsen the palatability of the water. Also, even though narrow mouthed storage containers exhibited a higher positive report for their protective ability against faecal contamination as compared to wide-mouthed containers, these containers were also regarded as inappropriate for extended water storage because it is difficult to clean the inner surface of the container. Challenges of algal growth in jerry cans have been reported in some studies (Sharma *et al*., 2013). One possible explanation is the accumulation of small sediments during storage and the formation of a biofilm as a result of suspended particles and bacteria sticking on the inner surface of the plastic casing (Boisson *et al*., 2010). Inappropriate washing and rinsing was cited as one of the major reasons for algal growth as it provides favourable conditions and an environment for growth of microorganisms (Sharma *et al*., 2013).

2.5 Drinking water storage containers

The design of the water storage vessel is vital in safe management of drinking water, particularly in the home. The United States Centres for Disease Control and Prevention (CDC) and the Pan American Health Organization (PAHO) have studied and reviewed the advantages and disadvantages of different types of water collection and storage containers from studies carried out in various regions of the world and documented the guidelines for the most desirable container to be used by households for drinking water storage (WHO, 2014). The guidelines include the following: the container must have a capacity of 15 to 25 litres, rectangular or cylindrical with one or more handles and flat bottoms for portability and ease of storage; should be made of lightweight, oxidation-resistant plastic, such as high-density polyethylene or polypropylene, for durability and shock resistance; should be fitted with a six to nine cm screw-cap opening to facilitate cleaning, but small enough to discourage or prevent the introduction of hands or dipping utensils; should have a durable, protected and preferably easily closed spigot or spout for dispensing water; should have an affixed certificate of approval or authenticity; should be affordable to the user (Mintz *et al*., 1995; CDC, 2010; Singh *et al*., 2015).

Narrow mouthed containers prevent introduction of bacteriological contaminants via hand contact or dipping of dispensing vessels or containers (Trevett, 2005). The same can be said of closed containers with a tap. The World Health Organisation's Safe Water Systems Strategy (2014) recommends containers that store an appropriate standard 20 litre volume of water, with a tight fitting cover and small opening. However, large (>=20 litres) narrow-mouthed storage containers pose the challenge of not being user-friendly particularly to children, the sick and aged who cannot dispense the water easily.

Generally, appropriate household drinking water collection and storage containers need to be socio-culturally acceptable, portable, of a volume able to meet the daily needs of the family, easy to use and clean. In Zimbabwe, plastic buckets which are light weight with tight fitting lids and of 10 – 20 litres capacity are the more desired water collection and storage containers for many households (Dismer, 2012).

2.6 Socio-demographic factors influencing household drinking water handling practices

Household socio demographic factors such as education and occupation play a pivotal role in a household's access to information on water quality and other resources important to preserving water quality (Partum and Khananthai, 2017). Lencha (2012) found that wealthier and smaller households have better water quality at the point-of-use compared to poor and larger households. In addition, wealthier households have access to resources which ensures the implementation or installation of improved ventilated latrines and waste disposal facilities, making their households more sanitary and thus, less of a health risk. These households also have the means to install covered metallic or ceramic containers, or special storage vessels that could be used to store household water, which may reduce contamination (Kirby *et al*., 2016).

On the other hand, formal education empowers people through shaping their knowledge, attitudes, beliefs and practices. A literate female household head is more likely to understand health-related issues including the need to consume safe water. In a study conducted in Zambia, it was found that hygienic practices and the likelihood of developing diarrhoea, was associated with the level of education (Lencha, 2012). The higher the formal education level attained, the less likely the household was exposed to unsafe practices.

In conclusion, the literature review showed that post collection contamination of drinking water is a common occurrence in low and middle income countries. The use of uncovered water collection containers, dipping of utensils when drawing water from storage container, not washing hands and water collection containers before water collection were found to be associated with poor quality of water and the point of use. However, there is limited information on the association between household socio demographic factors, water handling practices and the quality of water at the point of use.

Chapter 3- Methods

3.1 Aims and Objectives

3.1.1 Aim

To determine the association between household drinking water handling practices and bacteriological quality of drinking water at the point-of-use in the rural communities of Murewa district in Zimbabwe.

3.1.2 Objectives

The study objectives were:

- To determine the drinking water handling practices of the households;
- To describe the socio-demographic factors associated with hygienic drinking water handling practices;
- To compare the bacteriological quality of drinking water at the drinking water source and storage container at the point-of-use;
- To determine the association between household drinking water handling practices and the bacteriological quality of water at the point-of-use.

3.2 Study setting

The study was conducted in the rural communities of Murewa district in Mashonaland east province, Zimbabwe. There are 30 wards in the district, 28 rural wards and two urban wards with a total population of 191,462 (ZCSO, 2012). The district is sub divided into three constituencies that is Murewa north, south and west. Generally, the population in the district rely on boreholes and deep wells as main sources of drinking water, while the improved pit latrine is the sanitation facility of choice across the district.

Murewa district is one of the 33 districts in Zimbabwe that benefited from the rural water, sanitation and hygiene program implement between 2013 and 2017, and its access to safe water source currently stands at 71% (Murewa District Development Fund Report, 2016). The program drilled and rehabilitated 30 and 470 boreholes, respectively across the district (Murewa District Water Supply Report, 2017), providing access to borehole water to 500 communities.

In addition, the 500 communities that benefited from the water supply project were also exposed to health and hygiene promotion campaigns through community health clubs implemented by different non-governmental organisations (NGOs) and government departments. The goal of the WASH project was to reduce the burden of diarrhoea diseases within the district. Despite improvements in access to safe water coverage and exposure to health and hygiene education, the district continues to record high cases of diarrhoea, 56 cases per 1,000 population (Murewa district health profile, 2017).

Murewa district was selected for this study because the social-demographic characteristics of households in the rural communities are similar to most rural communities in Zimbabwe, hence the district is believed to be representative of a typical rural district in the country. In addition, the study area was influenced by the fact that the researcher currently works in the district and has encountered reports of increasing cases of diarrhoea-related diseases.

3.3 Study design

The study design is an analytic cross sectional study design. This study design was chosen to measure prevalence, exposure and effect at the same time and to quantify associations between certain variables although causality cannot be determined (Bruce, Pope, & Stanistreet, 2007). The research design allows measuring the association between socio-demographic factors, and water handling practices and the quality of water at the point-of-use.

3.4 Study Population

The study populations comprise all the rural households in Murewa district and the drinking water sources used within the district. "*A rural household refers to a social group/unit characterised by economic cooperation and common residence, whose dwelling is registered under the Land by-law of a rural district council*" (ZCSO, 2012:17), while drinking water sources refers to taps, boreholes and wells used for drinking purpose.

3.5 Sample size calculation

The total study population consisted of 46, 287 households in Murewa district. The desired confidence level was set at 95%, the confidence limit at 5% and the design effect at 1. Using Epi Info 7.0, the sample was calculated to be 381 households. This was based on the assumption that 50% of these households practice hygienic drinking water handling practices.

3.6 Sampling strategy

The 2012 Zimbabwean population and housing census provided the sampling frame (Murewa district rural households), from which the sample for this study was drawn. Murewa district has three administrative regions; Murewa north, Murewa south and Murewa west constituencies. Each constituent is further subdivided into wards, which are also divided into smallest administrative units, called villages. The sampling frame consisted of 46,287 households.

Multi-stage sampling is the taking of samples in stages using smaller sampling units at each stage (Weisberg, 2005). The sampling strategy is flexible in many senses. First, it allows researchers to employ random sampling after the determination of groups (Wasserstein, 1990), and can be used indefinitely to break down groups and subgroups into smaller groups until a desired size of a group is realised.

Multi-stage sampling, which involves cluster sampling and simple random sampling was used to draw a sample of 381 households from Murewa district. A computer-based random number generator (excel function, RANDBETWEEN) was used at different stages to select constituency, wards and households, respectively.

Stage one: Murewa district was divided into three constituencies; Murewa north, south and west, and each constituency was assigned a number, from one to three, respectively. After assigning numbers to the three constituencies, 30% of the three constituencies was selected using an excel function, RANDBETWEEN, which generate a random number until 30% of three constituencies was realised. One constituency, Murewa north, was randomly selected, which consisted of 10 rural wards.

Stage two: Each of the10 rural wards were assigned a number, one to 10 and the MS excel random number generator was used to select 30% of 10 the wards. A total of three wards, namely Ward four, Ward seven and Ward 16 were selected.

Stage three: The total number of households in each ward was established through the ward councillor’s records and collectively 2,713 households were identified in the three wards. Of the total number recorded, 930 households were in Ward three 763 households in Ward seven and 1020 households in Ward 16. Since the number of households were not the same in the three wards, proportions were calculated to determine the number of households to be drawn from each of the three wards to realise a sample number of 381 households, that is the sample size chosen for this study. The number of households chosen for the study were 131 households in Ward three; 107 households in Ward seven and 143 households in Ward 16. The households in each ward were allocated numbers from one to the number of the total households in each, respective ward. The numbers were linked to the village name for ease of identification during data collection. After all the households in each of the three wards were allocated a number, MS excel random numbers generator was used to generate random number without repeating until the desired number was attained.

3.7 Data collection

Three data collection points were observed during this study. Firstly, data on household demographics, sanitation practice, water supply and water handling practices was collected through a structured questionnaire (Appendix 1), which was administered by the researcher and trained research assistants (Environmental Health Practitioners [EHPs] in Murewa district). The questionnaire was administered to the female head of the household or any household member > 18 years. Training of research assistants was conducted from 21-23 February 2018 at Murewa district hospital. A total of 12 research assistants were trained focussing on research ethical issues, interviewing skills and water collection and bacteriological testing skills.

The questionnaire was developed in English, translated into Shona language (the local language of the study area). The questionnaire comprised of 31 questions that were used to collect data from household respondents on issues relating to household characteristics, household sanitation, household water supply and water handling practices. The questionnaire was pre-tested on 30 households in one of the wards in the district that was similar to the study population, but was not participating in the study. Pre- testing the questionnaire helped to check if questions were clear and unambiguous to the respondents (Bonita *et al*., 2006). Findings from the pre-testing exercise indicated that some questions on the questionnaire were interpreted differently by the respondents. Necessary corrections, mainly, wording of questions were made on the questionnaire in line with observations from the pre-testing exercise to ensure clarity of the questionnaire and suitability to participants. The findings of pre-test were not included in the final results of the study.

Secondly, data on bacteriological quality of drinking water sources and bacteriological quality of water from household storage containers, was collected using a Ministry of Health and Child Care (MOHCC) water quality monitoring form (Appendix 2). Water samples from the drinking water sources and storage containers were collected by environmental health technicians (EHT), under the supervision of environmental health officers (EHOs). Water samples from drinking water sources used by the 381 households that participated in the study, were collected on the same day the interviews were conducted, while samples from household storage containers were collected immediately after interviews with the respondent at each household was finalised.

Samples from storage containers were collected after the contents was shaken in order to resuspend any particulates present in the stored water. According to WHO (2004) bacteria settles at the bottom of storage container after 4 hours of collection, hence the need to stir the water properly before sample collection. The utensils commonly used by households in order to draw water from the storage containers was used to collect the sample. Sterilised 750 ml bottles with tight lids were used to package water samples from both sources and household storage containers. Borehole samples were collected after flame heating the spout for two to three minutes to sterilize it, after which the water was allowed to flow, undisturbed, for one minute to cool the spout (WHO, 2004). A sterile water sampling jar was used to collect samples from the deep protected wells. The membrane filtration technique was used for water quality testing, since it is cheap and most suitable for low income countries (WHO, 2004). According to World Health Organisation (2004), Membrane filter technique is a simple, effective and lower cost technique for testing drinking water samples for microbiological contamination. Membrane filter technique is the recommended test for the enumeration of faecal coliforms, using mFC agar and incubation at 44.5°C for 24 hours to produce blue coloured colonies (WHO, 2010). Faecal coliforms are generally used to indicate unacceptable microbial water quality and could be used as an indicator in place of *E. coli* (WHO, 2004). The presence of faecal coliforms in a water sample indicates the possible presence of other pathogenic bacteria such as *Salmonella* spp, *Shigella* spp, pathogenic *E. coli* and *V. cholera*, associated with waterborne diseases (WHO, 2010).

3.8 Data analysis

The information on the questionnaires and water quality monitoring form was double entered in MS Excel and imported into Epi Info version 7.0 for data analysis. Data cleaning was done by comparing duplicate entries. Where there were variations, verification was done by checking the source of data sheets. Descriptive analysis, specifically the mean, proportions and percentages were used to summarize household characteristic and drinking water handling practices. The descriptive analysis were also used to describe measures of tendencies and dispersion of bacteriological quality of source and stored water samples. Comparison of the bacteriological quality of drinking water sources samples and stored water samples was conducted using the number of colonies forming units (CFU) per 100ml of water to determine difference in contamination levels or lack of.

Statistical analyses were applied with a bivariate analysis using the chi-square test to determine associations between household characteristics, water handling practices and bacteriological quality of household stored water. A 5% confidence limit and 95% confidence level was used in determining the significance level of findings. To control variables for other associations, a multivariate regression using a logistic regression model, was performed on variables which show a statistically significant association in bivariate analysis with a p-value of < 0.05.

3.9 Validity and Reliability

Validity is the extent to which an instrument measures what it is supposed to measure and performs as it is designed to perform (Heale & Twycross, 2015), while reliability refers to the consistency of a measure to an extent that the procedure produces similar results under constant conditions at all times (Bonita *et al*., 2006). Content validity was ensured by adopting some questions from similar published work and incorporating it in the current study. The questionnaire was examined and reviewed by experts in the field of water supply and water quality and the principal investigator to ensure that questions were consistent with the content of the study. The questionnaire was pre-tested in population similar to study population and adjustments were made on the construction of questions to make them simple and precise.

By ensuring that the questionnaire was interviewer administered, any error or bias in the responses due to any misunderstanding of the questions by participants were minimised. Heale & Twycross (2015) suggested that to ensure administration of a questionnaire in a standardised way, the training of interviewers should be done by one trainer, at the same time and involve role plays and practice sessions with potential study participants. In this study, the interviewer were trained by the researcher and role plays were conducted during training to improve interviewing skills of the interviewers.

The sample calculation was based on 95% confidence level and 5% margin of error in order to obtain a sample large enough to limit the probability of chance influencing the results. In addition, all the interviewers were trained to ensure an equal understanding of all the items in the questionnaire in order to prevent inter-observer variation (Bonita *et al*., 2006). Measurement bias was minimised by using questions designed to be short and simple while selection bias was addressed through random selection of participants. Using short and simple, questions minimises ambiguity of questions, while random selection offers equal chance of being selected into the study to all potential participants (Bonita *et al*. 2006)

Potential confounding was assessed via multivariate logistic regression models.

3.10 Generalisability

The results of this study are generalisable to all rural communities in Murewa district. The results may also be generalised to all rural communities in the country with similar characteristics to those of the study population.

3.11 Limitations

This study did not focus on physical and chemical parameters of drinking water, which might influence bacteriological quality of water. This study is also limited to household socio-demographic factors and water handling practices at household level.

3. 12 Ethics Considerations

The study proposal was approved by the Ethics Committee of the University of the Western Cape (reference number-HS17/10/26) and permission was granted by Medical Research Council of Zimbabwe (reference number-MRCZ/B1418) and Mashonaland East Provincial Medical Director. Copies of the letters of ethical approval has been attached as appendices (Appendix 3-5).

All respondents participated voluntarily after a detailed explanation with the aid of the participants' information sheet (a copy of which was also made available to all respondents). The benefits, risks and voluntary nature of the study were clearly communicated to the participants and the assurance of the confidentiality of their data was given. A written and signed informed consent was obtained. As the study did not involve any invasive procedure, the adverse physical, psychological or emotional harm to the respondents was low. However, the indirect harm that may have arisen during the course of the study was addressed accordingly. There were no consequences whatsoever for households who refused to participate in the study. Participant's anonymity were honoured and the results of the study will only be made available to the public as averaged figures.

Surplus water from water sample after processing was discarded in the drainage system. Waste from processed samples (filter membrane and media pads) was incinerated at Murewa district hospital within 30 minutes after reading water quality results.

Chapter 4- Results

4.1 Socio -demographic characteristics

Table 4.1 shows that 77.84% of the respondents constituted the age group 26 to 35 years of which 94% were married. Three quarters of the respondents were staying with two or more children under five years of age within the household, while 37.8% were staying with at least two children between 5 and 18 years of age within household. The religion with the highest number of respondents was Pentecostal (34%), followed by Catholics (31%). The least common religions were Protestant and Muslim which accounts for about 2% of the respondents.

Table 4. 1 Household demographic characteristic

Variable	N	Percent
Age		
18-21 years	6	1.58
22-25 years	27	7.12
26-29 years	137	36.15
30-35 years	158	41.69
Above 35 years	51	13.46
Marital status		
Married	359	94.23
widow/widower	9	2.36
Divorced	7	1.84
Separated	1	0.26
Never married	5	1.31
Religion of head of household		
Evangelical/ Pentecostal	130	34.12
Catholic	118	30.97
Adventist	40	10.50
Protestant	6	1.57
Traditional	22	5.77
Muslim	8	2.10
Apostolic	57	14.96
Number of under 5 children within the household		
0	12	3.17
1	82	21.64
2	204	53.83
3	58	15.30
4 or more	23	6.07
Number of children between 5 and 18 years within the household		
0	78	20.47
1	159	41.73
2	80	21.00
3 or more	64	16.80

Table 4.2 shows that more than 94% of household heads attained secondary education or higher, with 73.23% (secondary education) and 19.95% (vocational training), while 68.60 % of the spouses had secondary education.

Only 12.40 % of the spouses attained tertiary education. Seventy percent (70%) of breadwinners were either self-employed or formally employed. However, more than 50% of the breadwinners had a monthly income below $50.

Table 4. 2 Level of education and monthly income

Variable	**N**	**Percent**
Household head's education level		
Primary	21	5.51
Secondary	279	73.23
Vocational	76	19.95
Tertiary /post tertiary	5	1.31
Spouse's Level of education		
not completed primary	12	3.17
Primary	52	13.72
Secondary	260	68.60
Tertiary Other	47	12.40
	8	2.11
Employment status of breadwinner		
Self employed	167	43.83
working full time	98	25.72
retired	6	1.57
Unemployed	110	28.87
Monthly income of breadwinner		
Above $100	83	22.07
Between $50-100	88	23.40
Below $50	205	54.52

4.2: Household water and sanitation characteristics

Table 4.3 shows that borehole was the most common source of drinking water, used by 91% of the surveyed households and in majority of the households (88.65%) the location of the water source was located outside of the yard/plot. Water source was located within 500 metres in half of the household surveyed.

Table 4. 3 Sources of water and distance from the household

Variable	N	Percent
Source of drinking water		
Protected Well	36	9.45
Borehole	345	90.55
Location of water source		
Elsewhere	336	88.65
In own dwelling	2	0.53
In own yard/plot	41	10.82
Distance of water source from household		
less than 500metres	196	51.44
500metres - <1km	82	21.52
1km - < 2km	72	18.90
2km - < 5km	31	8.14

Table 4.4 indicated the presents of ventilated pit latrine (73.23%) which was observed at the majority of homesteads, while 17% had a pit latrine and 10% practiced open defecation. Only 43% of respondents had a hand washing facility on or near the toilet, while 36% were using ashes/soap to wash hands after using the toilet. Most of respondents' households had a refuse pit (86%) on premises.

Table 4. 4 Household sanitary facilities

Variable	N	Percent
Kind of toilet facility in use		
Open defecation	39	10.24
Pit latrine	63	16.54
Ventilated latrine	279	73.23
Present of hand washing facility		
No	218	57.37
Yes	162	42.63
Uses ashes/soap		
No	245	64.30
Yes	136	35.70
Present of refuse pit		
No	53	13.98
Yes	326	86.02

4.3 Water handling practices

According to the results obtained, the common method of transporting water from the collection source to homestead, was by carrying the collection container on the head (66%), followed by using a wheelbarrow/scotch cart (17%) (Table 4.5).

Most of the respondents (90.55%) indicated that the water container was covered when transporting water and a tight fitting lid was used to cover the water container (86%).

Table 4. 5 Drinking water collection and transportation from source to household

Variable	n	Percent
Person who usually fetches water from source		
Family member above 18 years	364	95.54
Family member 10 to 18 years	14	3.67
Family member below 10 years	3	0.79
Type of collection containers used when transporting water		
Metal bucket	19	5.08
Plastic bucket	355	94.92
Methods used to transport water		
Use wheelbarrow/ scotch cart	65	17.20
Carry by hands	62	16.40
Carry on head	249	65.87
Other	2	0.53
Container covered when transporting water		
No	36	9.45
Yes	345	90.55
Type of cover used when transporting water		
Tight fitting lid	296	86.30
loose fitting lid	39	11.37
Tree leaves	8	2.33

The pouring method proved to be the most commonly used method of drawing water from the collection containers (75%) (Table 4.6). It was determined that the water drawing utensils were commonly stored on the drinking water container's cover (43.9%) and the table or shelf (38.21%). Only one percent of the participants indicated that they wash their hands before drawing water from the water storage containers and 83% washed their containers before collecting water from the source, with 66.79 using soap to wash the container.

Table 4. 6 Water handling practices in the home

Variable	n	Percent
Container covered when storing water at home		
No	56	14.70
Yes	325	85.30
How long do you store drinking water?		
Less than a day	162	42.74
One day	187	49.34
At least two days	30	7.92
What methods do you use to draw water from the containers		
Dipping	90	23.68
Pouring	285	75.00
Other	5	1.32
Where do you store your water drawing utensils?		
Floor	4	1.08
Hang on a wall	45	12.20
Other	17	14.61
Storage cover	162	43.90
Table or shelves	141	38.21
Person who usually draws water from the storage container		
Family member above 18 years	362	95.26
Family member 10 to 18 years	16	4.21
Family member below 10 years	2	0.53
Wash hands before drawing water		
No	377	99.21
Yes	3	0.79
Uses soap when washing hands		
No	3	100
Yes	0	0
Wash container before water collection		
No	66	17.37
Yes	314	82.63
Uses soap when washing container before water collection		
No	95	30.25
Yes	216	68.79
Other	3	0.96

4.4 Multivariable analysis

As indicated in Table 4.7 drinking water at the collection source as well as at point-of-use was contaminated. Even though the level of contamination at the collection source was observed to be 0.26%, the contamination level was significantly higher in stored water samples compared to drinking water source samples (p<0.001).

Table 4. 7 Comparison of bacteriological quality of water at source and point-of-use

	Feacal Coliforms Measured at source	**Feacal Coliforms Measured at point of use**	**Difference**	**P value for the difference**
Proportion contaminated	0.26%	23.42%	23.16%	P<0.001
N	380	380		

Tables 4.8 and 4.9 indicate the relationship between individual household demographic characteristics and bacteriological quality of water at the point-of-use. Variables that were significantly associated with bacteriological quality of water (p<0.005), were marital status, educational level (both for household head and spouse), monthly income of breadwinner, and employment status of breadwinner.

Having a household head with secondary and post-secondary level of education when compared to primary level were significantly associated with 98.5% (OR=0.015, p<0.001) and 99.7% (OR=0.003, p<0.001) reduced risk of having contaminated drinking water at point of use. Secondary and post-secondary level of education for the spouse were significantly associated with 83.1% (OR=0.169, p<0.001) and 94.1% (OR=0.059, p<0.001) reduced risk of having contaminated drinking water at point-of-use, compared to those with primary level. The odds of having contaminated water at point-of-use were 15 times higher for respondents with breadwinners earning below $50 compared to breadwinners earning above $100 (OR=14.55, p<0.001). Earning between $50 and $100 was significantly associated with 5 times higher risk of having contaminated water (OR=4.62, p=0.02) as compared to earnings above $100. All other variables were not significantly limited to the outcome at 5% level of significance.

Table 4. 8 Association between demographic characteristics & quality of water at the point of use

Variable	Clean water	Contaminated water	OR (CI)	P value
Age				
18-21 years	5(1.72)	1(1.14)	1	
22-25 years	22(7.59)	5(5.68)	1.14(0.11 11.99)	0.915
26-29 years	110(37.93)	26(29.55)	1.18 (0.13 10.55)	0.881
30-35 years	128 (44.14)	30(34.09)	1.17(0.13 10.4)	0.887
Above 35 years	25(8.62)	26(29.55)	5.2(0.57 47.69)	0.145
Marital status				
Married	280(96.22)	78(87.64)	1	
Not in union	11(3.78)	11(12.36)	3.59(1.50 8.59)	0.004
Religion				
Evangelical/ Pentecostal				
Catholic	108(37.11)	22(24.72)	1	
Protestant	86 (29)	36 (35.96)	1.82(0.99 3.36)	0.054
Traditional	37(12.71)	8(8.99)	1.06 (0.44 2.58)	0.896
Muslim	13(4.47)	9(10.11)	3.39(1.29 8.92)	0.013
Apostolic	6 (2.06)	2(2.25)	1.64(0.31 8.64)	0.562
	41(14.09)	16(17.98)	1.92(0.92 4.01)	0.084
Number of under 5 children within the household				
0	8 (2.77)	4(4.49)	1	
1	73(25.26)	9 (10.11)	0.25(.06 .985)	0.048
2	171(59.17)	33(37.08)	0.39(.11 1.35)	0.138
3 or more	37 (12.81)	65(48.32)	2.32(0.64 8.34)	0.196
Number of children between 5 and 18 years within the household				
0	63(21.65)	15 (16.85)	1	
1	141(48.45)	17 (19.10)	0.51(0.24 1.07)	0.077
2	58 (19.93)	22(24.72)	1.59(0.75 3.36)	0.222
3 or more	29(9.97)	35(39.33)	5.07(2.39 10.70)	<0.001

Table 4. 9 Association between level of education, monthly income & the quality of water at the point-of-use

Variable	Clean water	Contaminated water	OR (CI)	P value
Household head's education level				
Primary	1 (0.34)	20 (22.47)	1	
Secondary	213 (73.20)	65 (73.03)	0.015(0.002 0.115)	<0.001
Post-secondary	77 (26.46)	4(4.49)	0.003(0.0003 0.0245)	<0.001
Spouse's Level of education				
Primary	27(9.31)	36(40.91)	1	
Secondary	212 (73.10)	48(54.55)	0.169(0.09 0.31)	<0.001
Post-secondary	51(17.59)	4(4.55)	0.059(0.019 0 .182)	<0.001
Monthly income of breadwinner				
Above $100	80 (27.87)	3(3.41)	1	
Between $50-100	75(26.13)	13(14.77)	4.62(1.27 16.86)	<0.020
Below $50	132(45.99)	72(81.82)	14.55(4.43 47.70)	<0.001
Kind of toilet facility in use				
Open defecation	2 (0.69)	37(41.57)	1	
Pit latrine	29(9.97)	34(38.20)	0.063 (0.014 0.285)	<0.001
Ventilated latrine	260 (89.35)	18 (20.22)	0.037(0.001 0.017)	<0.001
Present of hand washing facility				
No	130 (44.83)	87(97.75)	1	
Yes	160(55.17)	2(2.25)	0.019(0.005 0 .077)	<0.001
Uses ashes/soap				
N	156(53.61)	88(98.88)	1	
Yes	135(46.39)	1(1.12)	0.013(0.002 0.095)	<0.001

Table 4.10 explains association between household sanitary facilities and bacteriological quality of drinking water at point-of-use. All the household sanitation facilities were significantly associated with the outcome. The odds of having contaminated water is reduced by 96.3% (OR=0.037, p<0.001) and 93.7% (OR=0.063, p<0.001) when using ventilated pit latrine and pit latrine, respectively, when compared to open defecation facilities.

Presence of a hand washing facility near the toilet (OR=0.019, p<0.001), using soap/ashes when washing hands after using the toilet (OR=0.013, p<0.001) and households having a refuse pit (OR=0.057, p<0.001), were protective factors against having contaminated drinking water at the point-of-use.

Table 4. 10 Association between household sanitary facilities and bacteriological quality of water at point-of-use

Variable	**Clean water**	**Contaminated water**	**OR (CI)**	**P value**
Kind of toilet facility in use				
Open defecation	2 (0.69)	37(41.57)	1	
Pit latrine	29(9.97)	34(38.20)	0.063 (0.014 0.285)	<0.001
Ventilated latrine	260 (89.35)	18 (20.22)	0.037(0.001 0.017)	<0.001
Present of hand washing facility				
No	130 (44.83)	87(97.75)	1	
Yes	160(55.17)	2(2.25)	0.019(0.005 0 .077)	<0.001
Uses ashes/soap				
No	156(53.61)	88(98.88)	1	
Yes	135(46.39)	1(1.12)	0.013(0.002 0.095)	<0.001

Table 4.11 shows that borehole water, when compared to water from a protected well, yielded significantly higher (6 times higher) contaminated water levels at the point-of-use location (OR=5.75, p=0.018)). Having a water source located in the dwelling or within the yard/plot was associated with significantly lower chances of water becoming contaminated (86% less) its final destination when comparing it to a water source situated elsewhere (OR=0.14, p=0.008). It was evident that a water source situated at least one kilometre away from the household, resulted in higher contamination levels of the water at the point-of-use location. When compared to water source less than 500 metres away, contamination levels at point-of-use location were significantly higher (6 times higher) at point-of-use (OR=6.38, p<0.001).

Table 4. 11 Association between sources of water, distance travelled to fetch water and quality of water at the point-of-use

Variable	Clean water	Contaminated water	OR (CI)	P value
Source of drinking water				
Protected Well	34(11.68)	2(2.25)	1	
Borehole	257(88.32)	87(97.75)	5.75(1.35 24.45)	0.018
Location of water source				
Elsewhere	249(85.86)	86(97.73)		
In own dwelling/ yard/plot	41(14.14)	2 (2.27)	0.14(0.033 0 .59)	0.008
Distance of water source from household				
less than 500metres	169 (58.08)	26(29.21)		
500metres - <1km	70(24.05)	12(13.48)	1.11 (0.53 2.33)	0.774
1km - < 5km	52(17.87)	51(57.30)	6.38(3.62 11.22)	<0.001

As shown below, Table 4.12, only one type of water handling strategy employed during transportation from the source did not have significant association with contaminated drinking water at point-of-use. Plastic water collection containers as opposed to metal containers (OR=0.013, <0.001) as well as having containers covered during transportation (OR=0.011, p<0.001) contributed to decreased contamination levels of water at the point-of-use. Using loose fitting lid as cover when transporting water was associated with higher water safety risk at the point-of-use, when compared to using tight fitting lid (OR=110.8, p<0.001).

Table 4. 12 Association between water handling practices during transportation from the source and the quality of water at the point-of-use

Variable	Clean water	Contaminated water	OR (CI)	P value
Methods used to transport water				
Use wheelbarrow/scotch cart	55(19.10)	10(11.24)		
Carry by hands	47(16.32)	15(16.85)	1.76 (0.72 4.27	0.215
Carry on head	186(64.58)	62(69.66)	1.83(0.88 3.81)	0.105
Type of collection containers used				
Metal bucket	1(0.35)	18(20.69)		
Plastic bucket	285(99.65)	69(79.31)	0.013(.002 .102)	<0.001
Container covered when transporting water				
No	2 (0.69)	34(38.20)		
Yes	289(99.31)	55(61.80)	0.011(0.003 0.047)	<0.001
Type of cover used when transporting water				
Tight fitting lid	282(97.92)	14(25.45)		
loose fitting lid	6(2.08)	33(60.00)	110.8(39.86 307.87)	<0.001
Tree leaves	0	8(14.55)	1	

Table 4.13 shows that most of the water handling practices in the home contributed significantly to water becoming contaminated at the point-of-use location. Storing water for at least one day provided increased contamination opportunities at home (OR=35, p<0.001) compared to using water within the same day of collection. Family members, 18 years and younger, drawing water from collection containers compared to older family members also increased the risk of contaminating drinking water sources at point-of-use (OR=5.14, p=0.001) and (0R=5.14, p0.001).

Table 4. 13 Association between water handling practices in the home and quality of water at the point-of-use

Variable	Clean water	Contaminated water	OR (CI)	P value
How long do you store drinking water				
Less than a day	159(54.83)	3(3.37)	34.79(10.75 112.57)	
At least one day	131(45.17)	86(96.63)		<0.001
Container covered when storing water at home				
No				
Yes	2(0.69)	54(60.67)		
	289(99.31)	35(39.33)	0.004(.001 .019)	<0.001
What methods do you use to draw water from the containers?				
Dipping				
Pouring	9(3.09)	81(91.01)		
Other	281(96.56)	4(4.49)	0.002(.0005 .0052)	<0.001
	1(0.34)	4(4.49)	0.44(.045 4.419)	0.489
Where do you store your water drawing utensils?				
Storage cover				
Table or shelves	128(45.39)	34(39.08)		
Other(floor, hang on wall)	110(39.01)	31(35.63)	1.06(0.612 1.837)	0.833
	44(15.60)	22(25.29)	1.88(0.99 3.55)	0.051
Person who usually draws water from the storage container				
Family member above 18 years				
Family member 18 years & below	284(97.59)	78(87.64)		
	7(2.41)	11(12.36)	5.72(2.14 15.24)	<0.001
Wash hands before drawing water				
No	289(99.31)	87(98.86)		
Yes	2(0.69)	1(1.14)	1.66(0.15 18.53)	0.680
Wash container before water collection				
No	6(2.06)	60(67.42)		
Yes	285(32.58)	29(32.58)	0.01 (.004 .025)	<0.001
Uses soap when washing container before water collection				
No				
Yes	68(23.86)	27(93.10)		
	214(75.09	2(6.90)	0.02(0.005 0 .101)	<0.001

Having containers covered when storing water (OR=0.004, p<0.001), washing of water containers before drawing water (OR=0.01, <0.001) and use of soap when washing containers before water collection (OR=0.02, p<0.001) significantly decreased chances of having contaminated water at point-of-use.

4.5 Logistic multivariable analysis

All variable indicating significant correlation with the expected outcome were selected for multivariate analysis. In the final analysis model represented in (table 4.14) only four variables significantly contributed to increased water contamination levels at the point-of-use location. These variables included the employment status of the breadwinner, type of toilet facility in use, the method used to draw water from the water storage containers, and using soup when washing containers before water collection. When comparing a household with self-employed breadwinners to unemployed breadwinners, the self-employed breadwinner households exhibited a 99% lower chance of having contaminated water at point-of-use (OR=0.01, p=0.0029). However, relationships between breadwinners working full time and those self-employed didn't show significant differences. Using a ventilated pit latrine was associated with a 98% less chance of having contaminated water at point-of-use, when compared with those practicing open defection (OR=0.02, p=0.046). It was evident that using a pit latrine rather than practicing open defecation would pose reduced health risk by having safe water at home. However, the water difference was not statistically significant (OR=8.03, p=0.351). Pouring water as a method of drawing from containers as compared to dipping yielded a low risk of contaminated water (OR=0.0002, p=0.004). The use of soap when washing containers before water collection, was also found to be more advantageous than collecting water in dirty or improperly rinsed containers (OR=0.003, p=0.02).

Table 4. 14 Logistic multivariable analysis

Variable	OR (CI)	P value
Marital status		
Married	1	
Not in union	0.084(.002 2.882)	0.169
Household head's education level		
Primary	1	
Secondary	0.048(0.0003 7.512)	0.238
Post-secondary	2.71 (0.003 224)	0.829
Employment status of breadwinner		
Self employed	1	
working full time	0.99(0.048 20.55)	1
Not employed	0.01 (0.0001 0.588)	0.029
Kind of toilet facility in use		
Open defecation	1	
Pit latrine	8.03(0.101 640.7)	0.351
Ventilated latrine	0.02(0.0003 .932)	0.046
Present of hand washing facility		
No	1	
Yes	0.10(0.002 5.13)	0.248
Uses ashes/soap		
No	1	
Yes	2.78(0.002 3410)	0.778
Methods used to transport water		
Use wheelbarrow/ scotch cart		
Carry by hands	0.42 (0.01 22.52)	0.672
Carry on head	1.02 (0.029 35.97)	0.990
Type of collection containers used		
Metal bucket		
Plastic bucket	0.010(0.0003 1.75)	0.078
Container covered when transporting water		
No		
Yes	2.49(.048 127)	0.649
Type of cover used when transporting water		
Tight fitting lid	1	
loose fitting lid	2.47(0.064 93.9)	0.626
How long do you store drinking water		
Less than a day	1	
At least one day	0.26(0.011 6.34)	0.410
What methods do you use to draw water from the containers?		
Dipping	1	
Pouring	0.0002(0.000015 0.033)	0.004
Other	3.48(0.0003 42603)	0.834
Where do you store your water drawing utensils?		
Storage cover		
Table or shelves	1	
Other(floor, hang on wall)	0.06(0.003 1.08)	0.057
	0.28 (0.020 4.04)	0.355
Uses soap when washing container before water collection		
No		
Yes	1	
	0.0003(3.77 0.192)	0.020

Chapter 5- Discussion

Introduction

This chapter discusses the findings of the current study in relation to relevant literature. The main objective of this study was to determine the association between household drinking water handling practices and bacteriological quality of drinking water at the point-of-use location. The discussion will be presented broadly under household socio-demographic characteristics, comparison of bacteriological quality of drinking water at source and in storage container at the household, and association between household drinking water handling practices and bacteriological quality of water at point-of–use location.

5.1 Socio-demographic characteristics

The current study observed the relationships between various household socio-demographic factors and bacteriological quality of water at point–of-use. The factors that were found to be significantly linked to bacteriological quality of water at point-of-use were the level of education, monthly income, household sanitary facility, as well as source of water and distance of the water collection point from the house.

5.1.1 Level of education

When compared to their counterparts with primary level education, the household heads with secondary and post-secondary level of education were associated with a respective 98.5% (OR=0.015, p=<0.001) and 99.7% (OR=0.003, p<0.001) reduced risk of contaminating water at the point-of-use location. In addition, spouses with secondary and post-secondary education levels were more likely to have bacteriologically safer drinking water at home compared to spouses with primary level education, which was consistent with study findings obtained in south-western Ethiopia (UNICEF & WHO, 2016). Formal education empowers both men and women through shaping their knowledge, attitudes, beliefs and practices. A literate person is more likely to understand health-related issues, including the need to consume safe water. In Zambia, a study to assess the effects of formal education on the practice of hygiene in order to prevent diarrhoeal diseases indicated that, the higher the level of formal education attained, the less likely the household was exposed to unsafe hygiene practices (Lencha, 2012). Hodge *et al.* (2015) suggested the use of audio visual aids during hygiene promotion sessions to address and consider the needs of the illiterate.

5.1.2 Monthly income

Poverty and unemployment have long been associated with poor access to social services including access to safe drinking water. Recent studies in low income countries show that wealthier households have better water quality at the point-of-use compared to poor households (Partum and Khananthai, 2017; Sarsan, 2013). In this study it was found that the odds of having contaminated water at the point-of-use were 15 times higher for respondents with breadwinners earning below USD$50.00 per month, compared to breadwinners earning above USD$100.00 per month (OR=14.55, p<0.001). Similarly, Kirbey *et al.* (2016) found that households who earn more, have resources that would make the household more sanitary and could afford covered containers or special storage vessels that could be used to safeguard water, thereby reducing contamination. Since monthly income is significantly associated with quality of water at point-of-use, it is necessary and important to integrate livelihood programs into water supply and hygiene projects to enable communities to increase their income, so that they can afford to buy resources required to preserve water quality (Boisson *et al*., 2010).

5.1.3 Household sanitary facilities

Lack of physical infrastructure and appropriate technologies such as improved toilets and safe water supply sources, coupled with the practice of open defecation may increase the risk of contamination of drinking water (Hutton and Chase, 2016). The current study observed that the odds of having contaminated water is reduced by 96.3% (OR=0.037; p<0.001) and 93.7% (OR=0.063, p=0.001) respectively, when using ventilated pit latrines and pit latrines compared to open defecation. These findings correspond to the findings obtained in a study by Hutton & Chase (2016), where dust from faecally polluted fields was indicated as the major contaminant of household stored water.

This study found that the presence of handwashing facilities near a toilet (OR=0.019, p<0.001), using soap/ashes when washing hands after using toilet (OR=0.013, p<0.001) and having a refuse pit (OR=0.0057, p<0.001) were protective factors against having contaminated drinking water at point-of-use. These findings concur with the results of a study by Satterthwaite (2016), where hand washing after using the toilet and practices safe disposal of refuse were found to prevent stored water contamination. In 2013, Sarkar asserted that hands and household utensils can become contaminated with human excreta, body fluids, floor and dust and in turn contaminate drinking water during handling.

5.1.4 Distance of water point from the house

In sub-Saharan Africa, many households especially in rural areas lack piped water or access to nearby community water source (Saleem *et al*., 2018). Households with a travel time of more than 30 minutes to the nearest water collection source have been shown to collect progressively less water and store water for longer periods (WHO, 2015). Having access to reduced quantities of water and storing water for longer periods was found to be associated with compromised hygiene practices, which raise the risk of cross contamination of stored water (Sarkar, 2013). During this study it was observed that having a water source located in the dwelling or within the plot/yard was associated with 86% less chances of having contaminated water at the point-of-use when compared to having water source one kilometre or more away from the home (OR=0.14, p=0.008). A study done in Kenya, found that when households travel long distances to fetch water, limited quantities of water is allocated for personal and household hygiene (Miner *et al*., 2016).

5.2 Comparison of bacteriological quality of water at source and in the storage container at household

Studies conducted in Nigeria by Shrestha *et al*. (2017) compared bacteriological quality of drinking water at a water collection source and point-of-use and found that 44.1% of household stored water samples tested positive for *E.coli* compared to only 6.8% detected in source water samples. Similar findings were observed in Malawi by Holm *et al*. (2016), who noted that 60% of household stored water samples contained Faecal coliforms compared to only 0.16% in source water samples. In this study, only 0.26% of the water source sample were contaminated compared to 23.42% of stored water samples (p<0.001). A study in Ethiopia found that more than 75% of surveyed households using improved sources of water had household stored water samples that were contaminated with *E.coli* at the point-of-use (Usman, 2016). In India, Abebe & Dejene (2015) found that 73% of stored household water samples were contaminated with Feacal coliforms compared to only 11% borehole water samples. The main explanation to this is that in low income countries the main sources of drinking water are communal boreholes, protected springs and deep wells which are located away from dwellings (WHO, 2014). These communal sources of water are safe but water become contaminated due to the amount of handling involved between drinking water sources and point-of-use (Hodge *et al.,* 2015).

Household stored water is more contaminated than the source water, indicating that interventions are needed to decrease the contamination of water at the point of use.

Chlorination, use of Aquatabs and boiling are some the small scale water treatment methods that can be used in poor resource settings, together with safe water handling practices (Mengistie *et al.*, 2013).

5.3 Water handling practices from source to home

As presented in the results (Table 5.3.), the common method of transporting water from source to the house was carrying on head (66%) followed by using wheelbarrow/scotch cart (17%). This was in line with a study to determine water handling practices in Ethiopia by Sharma *et al*., (2013) who observed that 91% of their respondents transported water from source to the house by carrying on their head. The similarity of methods used to transport water could be due to similar settings between the current study setting and Ethiopia were communities used communal water supply sources situated between 500m to one kilometre from dwellings. These distances are relatively short, therefore participants used their heads to carry water.

The majority (90%) of the current study participants reported that they cover water containers with tight fitting lids/caps when transporting water from sources to the house. This was consistent with a study conducted in Ethiopia and found that 89% of respondents used covered plastic containers when transporting water from source (Lencha, 2012) . Plastic containers are the most commonly used water collection containers particularly in sub-Saharan region (Holm *et al*. 2016). This study found that 94.92% of the respondents used plastic containers to transport water from source. These findings are similar to the results of a study done in India by Raju *et al*. (2014), where three quarters of respondents used plastic containers to transport water.

As shown in the results (Table 4.4), using plastic containers to collect water and having containers covered when transporting water significantly contributed to reduced risks of having bacteriologically unsafe water at the point-of-use (OR=0.013, $p<0.001$) and (OR=0.011, $p<0.001$), respectively. On the other hand, using a loose fitted lid as a cover when transporting water was associated with higher odds of having contaminated water at point-of-use compared to using tight fitting lids (OR=110.8, $p<0.001$). These results could be attributed to the fact that covering of containers with tight lids prevented contaminants such as dust and dirt from hands from coming into contact with water.

5.4 Water handling practices in the home

The literature suggests that drinking water storage practices (Sarsan, 2013; WHO, 2015), using containers that were not properly cleaned to store water in homes and storing water longer than one day (Pickering, 2015), unsafe storage of water drawing utensils (Rufener *et al*., 2016) and other factors such as unsafe personal hygiene practices (Oswald, 2017; WHO, 2015; Hutton and Chase, 2016) are possible routes of drinking water contamination in the house.

The practice of washing water storage container, especially with soap/ashes help prevent formation of slimy layer and build-up of biofilm inside the storage containers (Boisson *et al*., 2010). A study by Sharma *et al*., (2013) found that inappropriate washing and inadequate rinsing of containers results in algal growth inside container, which provides favourable conditions and environment for growth of pathogens. In this study, washing water storage container, especially with soap/ashes was found to be significantly associated with decreased chances of having contaminated water at the point-of-use(OR=0.02, $p<0.001$).

Having a family member 18 years and below, especially five year olds and younger, who usually draw water from storage containers when compared to family member older than 18 years was associated with high risk of contaminated drinking water at the point-of-use(OR=5.14, $p=0.001$). This finding is consistent with that documented by Jensen *et al*. (2004) who noted higher chances of drinking water contamination where children draw water themselves after playing without washing hands. Tambekar *et al*. (2011) showed that children withdrawing drinking water by dipping their hands, contaminate stored water, reducing its quality and palatability. The practice of washing hands with soap is a vital step known to be effective in preventing transmission of waterborne infection.

Pouring water as a method of drawing water from the container when compared to dipping was protective against having contaminated water at the point-of-use (OR=0.0002, $p=0.004$). This finding is in line with that documented by Tambekar et al. (2011) who noted higher chances of drinking water contamination where dipping was used as a method of drawing water from storage container. A study by Hutton and Chase (2016) found that dipping of water drawing utensils in storage containers contaminates the water by introducing dirt and dust from external environment into the water.

5.5 Limitations

Information on household socio-demographic characteristics and drinking water handling practices is based on self-reports of respondents. Information received through self-reports is subject to recall and social desirability biases. Secondly, this study cannot establish causal relationships between water quality at point-of-use and any of the independent variables because of the cross-sectional nature of the survey.

Chapter 6- Conclusion and recommendation

Introduction

This chapter provides the conclusions from the study and recommendations for practice about effects of socio-demographic factors and household water handling practices on bacteriological quality of drinking water at the point-of-use in the Murewa district.

6.1 Conclusion

Overall, 23.42% of household stored water sample were contaminated with Faecal coliforms compared to only 0.26% of source water samples. This indicate that bacteriological quality of water declines after collection from a safe source. Households that have a household head or spouse with below secondary level education, breadwinner who earn below USD$50.00/month, practice open defecation, collect water from sources located more than 1km from home, do not have handwashing facilities, do not wash water collection containers before collecting water, do not use tight fitting lid and store water for more than a day, had higher odds of having contaminated water at the point of use. Despite the limitations, this study highlights that water quality declines after collection, mainly due to unhygienic handling practices during transportation and storage in the home. Efforts should be deployed to promote safe drinking water handling practices across the district with great emphasis on the poor and rural communities that travel long distances to get drinking water.

6.2 Recommendations

6.2.1 Actions to improve household water handling practices at community and household level

- The Environmental health technicians and village health workers should intensify community health and hygiene education focusing on promoting safe water handling practices. The health and hygiene sessions should aim to encourage community members to: use containers with tight fitting lid when collecting or storing drinking water; wash water collection containers with soap or ashes before water collection; use long handle scoops to draw water from containers or use pouring to dispense water from storage containers; practices safe personal hygiene like washing hands with soap or ashes before fetching water from sources or storage container and use clean utensils when drawing water from the storage containers..

6.2.2 Actions recommended to households to prevent contamination of stored drinking water

- The Environmental health practitioners (EHPs and Village health workers (VHWs) should educate households to store water in tightly closed containers and use clean, long handle scoops to draw water from the containers or use pouring to dispense water from storage container.
- Household members should always properly wash hands with soap or ashes before fetching water from the storage containers.
- Household members should practices safe disposal refuse and excreta, and always wash hands after using the toilet.

6.3.3 Actions recommended to households to prevent water contamination during collection from sources and transportation to home

- Household members responsible for fetching water from the source should properly wash their hands with soap or ashes before collecting water. In addition, they should always wash water collection containers with soaps or ashes before water collection and ensure that containers are properly and securely closed when transporting water from source to home.

6.3.4 Point-of-use water treatment for Murewa district rural households

The results of the study indicated that drinking water quality declines between collection and utilisation, and 23% of household stored water samples tested positive for *E.coli*. In light of these results households should treat drinking water at the point-of-use.

- The Environmental health technicians and village health workers should encourage households to treat drinking water at the point-of-use, using appropriate water treatment methods such as chlorination, boiling and Aquatabs.
- Households should treat drinking water at the point-of-use, using locally accepted and affordable small scale drinking water treatment methods to ensure that drinking water is always safe for human consumption.

The findings of this study will be shared with the Ministry of Health and Child Care (MOHCC) at national, provincial and district monthly meetings. The researcher will take advantage of MoHCC monthly meetings to share findings of the study. A copy of the research report will be given to MoHCC National, Mashonaland East Provincial Medical Director, and Murewa

District Medical Officer in order to determine the best way forward and hence, develop strategies to educate communities about the relationship between contaminated water and human health.

REFERENCE LIST

Abebe, B. & Dejene, H. (2015). Bacteriological and Physicochemical Quality of Drinking Water Sources and Household Water Handling Practice Among Rural Communities of Bona District, Sidama Zone-Zouthern, Ethiopia. *Science Journal of Public Health*. 3 (5): p. 782-789.

Adams, Ellis & Boateng, Godfred & Amoyaw, Jonathan. (2015). Socioeconomic and Demographic Predictors of Potable Water and Sanitation Access in Ghana. *Social Indicators Research.*

Alqahtani, J. M., Asaad, A. M., Ahmed, E. M., & Qureshi, M. A. (2015). Drinking water quality and public health in Southwestern Saudi Arabia: The need for a national monitoring program. *Journal of family & community medicine*, *22*(1), 19-24.

Amenu, D. (2013). Drinking Water Quality. World Journal of Arts, Commerce and Sciences, 1 (2):1-8.

Bain, R., R. Cronk, J. Wright, H. Yang, T. Slaymaker, & J. Bartram (2014a), Fecal contamination of drinking-water in low-and middle-income countries: A systematic review and meta-analysis, *PLoS Medicine*, 11(5), e1001644.

Beyene, H. A. (2012). Factors Affecting the Sustainability of Rural Water Supply Systems: The Case of Mecha Woreda, Amhara Region, Ethiopia. Cornell University.

Bhattacharya M, Joon V & Jaiswal V. (2011) Water handling and sanitation practices in rural community of Madhya Pradesh: A knowledge, attitude and practice study. Indian *Journal of Epidemiology and Community Health.*; 42(1):94-7.

Boisson, S., Kiyombo, M., Sthreshley, L., Tumba, S & Makambo, J. (2010). Field assessment of a novel household-based water filtration device: A randomised, placebo-controlled trial in the Democratic Republic of Congo. PLoS One 5:e12613.

Bonita, R., Beaglehole, R., & Kjellstrom, T. (2006). *Basic epidemiology*. Geneva: World Health Organisation.

Bradley, D. J., & J. K. Bartram (2013), Domestic water and sanitation as water security: Monitoring, concepts and strategy, *American Journal of Tropical Medicine and Hygiene*, 371(2002), 20120420.

Brown, J. M & Sobsey, M. D. (2012). Boiling as household water treatment in Cambodia: a longitudinal study of boiling practice and microbiological effectiveness. *American Journal of Tropical Medicine and Hygiene*. 87:394 – 398.

Bruce, N., Pope, D., & Stanistreet, D. (2007). *Quantitative research methods in public health; A practical, interactive guide.* England: John Wiley and Sons.

Centre for Disease Control (CDC). (2011). The Safe Water System: Safe Storage of drinking Water. http://www.cdc.gov/safewater/pdf/safestorage_2011-c.pdf

Clasen, T. F., Alexander, K. T., Sinclair, D., Boisson, S., Peletz, R., Chang, H. H., Majorin, F & Cairncross, S. (2015). Interventions to improve water quality for preventing diarrhoea. *The Cochrane database of systematic reviews*, 10, CD004794. doi:10.1002/14651858.CD004794.pub3

Dismer, A. (2012). Rural Kenyan Household Stored Water Quality. MPH Thesis, Emory University.

Ell-Amin, A., Sulieman, A. E., & Ell-Khalifa, E. A. (2012). Microbiological assessment of drinking water quality in Wad-Medani & Khartouman States. *In sixteenth international water technology conference, Istanbul, Turkey, IWTC,* Vol.16, 231-239.

Gebremichael, G., Haftu, D., Ajema, D., & Gedamu, G. (2017). Water handling and low cost treatment practices of practices of people living with human immunodeficiency virus (HIV) in Arba Minch Town, Southern Ethiopia, 2016. *Journal of AIDS and HIV Research, 9(8),* 171-178.

Guchi, E. (2015). Review on Slow Sand Filtration in Removing Microbial Contamination and Particles from Drinking Water. *American Journal of Food and Nutrition*, 3(2): 47-55.

Heale, R. & Twycross, A. (2015). Validity and Reliability in Quantitative Studies. *Evidence Based Nursing Online First*. World Health Organization.

Hodge, J., Chang, H. H., Boisson, S., Collin, S. M., Peletz, R. & Clasen, T. (2016). Assessing the Association between Thermotolerant Coliforms in Drinking Water and Diarrhoea: An Analysis of Individual Level Data from Multiple Studies. *Environmental Health Perspectives*. DOI: 10.1289/EHP156.

Holt, S. (2009). A survey of water storage practices and beliefs in households in Bonao, Dominican Republic in 2005. Thesis, Georgia State University. http://scholarworks.gsu.edu/iph_theses/116.

Hutton, G., Chase, C. (2016). The Knowledge Base for Achieving the Sustainable Development Goal Targets on Water Supply, Sanitation and Hygiene. *International Journal of Environmental Research and Public Health*, *13*(6), 536; doi: 10.3390/ijerph13060536.

Imanishi, M., Kweza, F. P.,Slayton, B. R., Urayai, T., Ziro, O., Mushayi, W., Francis-Chizororo, M., Kuonza, R. L., Ayers, T., Molly M. Freeman, M. M., Govore,M., Duri, C., Chonzi, P., Mtapuri-Zinyowera, S., Manangazira, P., Kilmarx, H. P., Mintz, E., Daniele Lantagne, D., and the Zimbabwe Typhoid Fever Outbreak Working Group 2011–2012. (2014). Household Water Treatment Uptake during a Public Health Response to a Large Typhoid Fever Outbreak in Harare, Zimbabwe. *The American Society of Tropical Medicine and Hygiene*. 90(5): 945-954.

Jensen, P. K., Jayasinghe, G., Van der Hoek, W., Cirncross, S., Dalsgaard, A. (2004). Is there an association between bacteriological drinking water quality and childhood diarrhea in developing countries? *Tropical Medicine and International Health*, 9: 1210-1215.

Johnson RC, Boni G, Amoukpo H, Barogui Y, Diez G, Agossadou D, Sopoh GE & Boko M. (2016). Microbiological Quality Assessment of Drinking Water in Lalo Commune, Benin (West Africa). *Journal of Water Resource and Protection.* 8:816-822.

Kassie, G. G., & Hayelom, D.H (2017). Bacteriological quality of drinking water from source to point-of-useamong rural communities of Farta Woreda in North West, Ethiopia. *African Journal of Microbiology Research*, 11 (26), 1069-1074.

Kirby, M., Nagel, C. L., Rosa, G., Iyakaremye, L., Zambrano, L. D., & Clasen, T. F. (2016). Faecal contamination of household drinking water in Rwanda: A national cross-sectional study. *Science of the Total Environment, 571*, 426-434.

Lanata, C., Ochoa, T. J., Lozada, M., Pineda, I., & Verastegui, H. (2014). Faecal contamination of food, water, hands, and kitchen utensils at the household level in rural areas of Peru. *Journal of environmental health. 76(6),* 102.

Lencha, A. T. (2012). Rural water supply management and sustainability in Ethiopia with special emphasis on water supply schemes in Adama area. Swedish University of Agricultural Sciences. http://stud.episilon.slu.se

Mengistie, B., Berhane, Y., & Worku, A. (2013). Household Water Chlorination Reduces Incidence of Diarrhea among Under-Five Children in Rural Ethiopia: A Cluster Randomized Controlled Trial. PLoS ONE, 8(10), e77887. doi: 10.1371/journal.pone.0077887

Miner CA, Dakhin AP, Zoakah Al, Zaman M, Bimba J (2016). Physical and Microbiological Quality of Drinking Water Sources in Gwafan Community, Plateau State, Nigeria. *International Journal of Research in Environmental Studies.* 3(1):001-006.

Mintz. D. E., Fred, M. R., Tauxe, V. R. (1995). Safe Water Treatment and Storage in the Home A Practical New Strategy to Prevent Waterborne Disease. JAMA, 273(12):948-953.

Moyo, S., Wright, J., Ndamba, J., Gundry, S. (2001). Realising the maximum health benefits from water quality improvements in the home: A case from Zaka district, Zimbabwe. World Health Organisation. 79(4).

Murewa District Health Report (2016). *Murewa District Health Profile.* Murewa.

Murewa District Environmental Health Report (2016). *Murewa District Health Profile.* Murewa.

Murewa District Development Fund Report (2016). *Water and Sanitation update* 2016. Murewa

Murewa District Health Report (2017). *Murewa District Health Profile.* Murewa.

Onigbogi, O and Ogunyemi. O. (2014). Effect of Storage Containers on Quality of Household Drinking Water in Urban Communities in Ibadan, Nigeria. *International Journal of Public Health Science*. 3(4):253 258.

Oswald, E. W., Lescano, G. A., Bern, C., Calderon, M., Cabrera, L., Gilman, H. R. (2007). Faecal Contamination of Drinking Water within Peri-Urban Households, Lima, Peru. *The American Journal of Tropical Medicine and Hygiene*, 77(4): 699–704.

Packiyam, R., Kananan, S., Pachaiyappan, S., Narayanan, U. (2016). Effect of Storage Containers on Coliforms in Household Drinking Water. *International Journal of Current Microbiological Applied Science*. (2016) 5(1): 461-477

Pickering, A. J., Crider, Y., Amin, N., Bauza, V., Unicomb, L., Davis, J, Luby, S. P. (2015). Differences in Field Effectiveness and Adoption between a Novel Automated Chlorination System and Household Manual Chlorination of Drinking Water in Dhaka, Bangladesh: A Randomized Controlled Trial. PLoS ONE 10(3): e0118397. doi:10.1371/journal.pone.0118397

Partum, C. & Khananthai, N. (2017). Assessment of Factors Affecting Drinking Water Quality from Free Water Dispensers in the Higher Education Institution. *International Journal of Environmental and Science Education, 12(4), 787-797.*

Roberts, L., Chartier, Y., Chartier, O., Malenga, G., Toole, M., Rodka, H. (2004). Keeping clean water clean in a Malawi refugee camp: a randomized intervention trial. Physics and Chemistry of the Earth, Parts A/B/C. 29(15): 1295–129.

Rufener, S., Mausezahl, D., Mosler, H and Weingartner. (2010). Quality of Drinking water at Source and Point- of consumption—Drinking Cup As a High Potential Recontamination Risk: A Field Study in Bolivia. *Journal of Health Population Nutrition*; 1:34-41.

Saleem S, Ali W, Afzal MS (2018) Status of Drinking Water Quality and its contamination in Pakistan. *International Journal of Environmental Research* Vol.2: No.1: 6.

Sarsan, S. (2013). Effect of storage of water in different metal vessels on coliforms. *International Journal of Current Microbiology and Applied Science*. 2(11): 24-29

Satterthwaite, D. (2016). Missing the Millennium Development Goal targets for water and sanitation in urban areas, Environment and Urbanization. 28(1): 3–18.

Sharma, R. H., Worku, W., Hassen, M., Tadesse, Y., Zewdu, M., Kibret, D., Gashe, A., Meseret, M., Gessesse, D., Kebede, A. (2013). Water Handling Practices and Level of Contamination between Source and Point-of-Use in Kolladiba Town, Ethiopia. *Environment and International Journal of Science and Technology*. 8:25-35

Shields, K., Bain, R. E., Cronk, R., Wright, J. A., & Bartram, J. (2015). Association of supply type with fecal contamination of source water and household stored drinking water in developing countries: A bivariate meta-analysis. *Environmental health perspectives, 123(12)*, 1222.

Shrestha, A., Sharma, S., Gerold, J., Erismann, S., Sagar, S., Koju, R., & Cisse, G. (2017). Water quality, Sanitation, and Hygiene Conditions in Schools and Households in Dolakha and Ramechhap Districts, Nepal: Results of A cross-sectional Survey. *International journal of environmental research and public health, 14(1)*, 89.

Singh, A. K., Gupta, V. K., Sharma, B., Singla, B., Kaur, P., & Walia, G. (2015). What are we drinking? Assessment of water quality in an urban city of Punjab, India. *Journal of family medicine and primary care*, *4*(4), 514-8.

Tabor, M., Kibret, M., & Abera, B. (2011). Bacteriological and physicochemical quality of drinking water and hygiene-sanitation practices of the consumers in bahir dar city, Ethiopia. *Ethiopian journal of health sciences*, *21*(1), 19-26.

Tabor, M., Kibret, M., Abera, B., (2011). Bacteriological and physicochemical quality of drinking water and hygiene-sanitation practices of the consumers in Bahir Dar city, Ethiopia. *Ethiopian Journal of Health Sciences* 22(1), 19−26.

Tambekar, H. D., Gulhane, R. S., Jaisingkar, S. R., Wangikar, S. M., Banginwar, S. Y., and Mogarekar, R. M. (2008). Household Water Management: A Systematic Study of Bacteriological Contamination between Source and Point of Use. *American-Eurasian Journal Agriculture and Environmental Science*. **3**: 241-246.

Trevett, A. F., Carter, R. C., Tyrrel, S. F. (2005).The importance of domestic water quality management in the context of faecal oral disease transmission. *Journal of Water and Health*.3:259-270.

Tsega, N., Sahile, S., Kibret, M., & Abera, B. (2014). Bacteriological and physico-chemical quality of drinking water sources in a rural community of Ethiopia. *African health sciences*, 13(4), 1156-1161.

UNICEF/Government of Zimbabwe. (2014). Water Supply and Sanitation in Zimbabwe. A Baseline Survey of 33 Rural Districts. Harare.

United Nations General Assembly. (2015). Draft Resolution a/69/l.85: Transforming Our World: The 2030 Agenda for Sustainable Development. United Nations; New York, NY, USA.

Walters, A. (2008). A performance evaluation of the LifeStraw: a personal point-of-use water purifier for the developing world. University of North Carolina. Chapel Hill.

Wassertheil-Smoller S. (1990). Biostatistics and epidemiology. New York: Springer-Verlag: 66 –74.

Weisberg S. (2005) Applied linear regression. Wiley.

World Health Organisation. (2004). Guidelines for Drinking-water Quality. Fourth Edition. Geneva, Switzerland.

World Health Organisation. (2006). Almost a quarter of all disease caused is by environmental exposure. World Health Organization, Geneva, Switzerland.

World Health Organisation/UNICEF. (2009). Diarrhoea: Why children are still dying and what can be done. The United Nations Children's Fund (UNICEF)/World Health Organization (WHO).

World Health Organisation. (2011). Guidelines for Drinking-water Quality. Fourth Edition. Geneva, Switzerland.

WHO and UNICEF. (2014). Progress on Drinking Water and Sanitation – 2014 update. World Health Organization and UNICEF.

World Health Organisation. (2015). Drinking Water. Fact Sheet no. 391. Geneva: World Health Organization.

World Health Organisation. (2016). Water Sanitation and Hygiene Interventions to prevent diarrhoea. http://www.who.int/elena/titles/wsh_diarrhoea/en/.

World Health Organisation; United Nations Children's Fund. (2015). Progress on Drinking Water and Sanitation: 2015 Update and MDG Assessment; Joint Monitoring

World Health Organisation/ United Nations Children's Fund. (2017). Progress on Drinking Water, Sanitation and Hygiene: 2017 Update and SDG Baselines. Geneva: World Health Organization (WHO) and the United Nations Children's Fund (UNICEF)

Programme for Water Supply and Sanitation; WHO: Geneva, Switzerland; UNICEF: New York, NY, USA,

World Health Organization. (2004). *Guidelines for drinking-water quality* (Vol. 1). World Health Organisation

Wright, J., Gundry, S., Conroy, R. (2004). Household drinking water in developing countries: a systematic review of microbiological contamination between source and point-of-use. *Tropical Medicine & International Health*; 9: 106-17 http://dx.doi.org/10.1046/j.1365-3156.2003.01160.x.

Zimbabwe Central Statistics Office. (2012). *National Population Census Report.* Harare: Central Statistics Office.

APPENDICES

Appendix 1: Questionnaire

Questionnaire

Household Survey

Interviewer's name: ________________ Date: / / / Start Time: ______Stop Time_______

District: ____

Ward number: ____

Household ID: ____

PART 1: HOUSEHOLD CHARACTERISTICS

101. What is your age range in years?

1	18-21 years	☐
2	22-25 years	☐
3	26-29 years	☐
4	30-35 years	☐
5	Above 35 years	☐

102. Gender:

1. Male ☐	2. Female ☐	3. Other Specify..........................

103. What is your marital Status?

1	Married	☐	4	Cohabitating	☐
2	single	☐	5	Seperated	☐
3	Widow/widower	☐	6	Divorced	☐
7	Other				

104. What is the highest Education Level of the household head?

1	Tertiary/Post – tertiary)	☐	4	Primary	☐
2	Vocational (Post - secondary)	☐	5	No education	☐
3	Secondary	☐	6	Other Specify…………………………………………	

106. What is the current employment status of the household bread winner?

1	Working full time	☐	4	Unemployed	☐
2	Working part-time	☐	5	Retired	☐
3	Self employed	☐	6	Other………………………	

107. What is the monthly income of bread winner?

1. Below ☐ USD $50.00	2. Between ☐ USD $50-100	3. Above ☐ USD $100

108. What is the religion of the household head?

1	Catholic	☐	4	Muslim	☐
2	Protestant	☐	5	Evangelical/ Pentecostal	☐
3	Adventist	☐	6	Traditional	☐
7	Other				

109. How many children < 5 years are currently living in this household?

1	One	☐	3	Three	☐
2	Two	☐	4	Four or more than four	☐
5	Other				

110. How many children > 5 years but < than 18 years are currently living in this household?

1.	One ☐	2	Two ☐	3.	Three or more ☐ than three	Others ☐

PART TWO: HOUSEHOLD SANITATION

201. What kind of toilet does your household use?

1	Ventilated latrine	3	Flush toilet
2	Pit latrine	4	Open defecation
5	Other		

202. Do you have a hand washing facility on or near the toilet?

1	Yes	**2**	No

203. Do you use ashes/soap when washing hands after using toilet?

1	Yes	2	No

204. Does your household have a refuse pit?

1	Yes	2	No

PART THREE: HOUSEHOLD WATER SUPPLY & WATER HANDLINING PRACTICES

301. What is your household's current source of drinking water?

1	Borehole	2	Protected Well	3	Protected Spring	Others specify

302. Where is the water source located?

1	In own Dwelling	2	In own yard/plot	3	Elsewhere

303. What is the distance of water source from your household?

1	Less than 500 metres ☐	3	2 km to 5 km ☐
2	500 metres to a 1km ☐	4	Others Specify..

304. What method does your household use to transport water from source to home?

1	Carry by hands	3	Use wheelbarrow/ scotch cart ☐
2	Carry on head	4	Others

305. Who is the person assigned to fetch water from the source in this household?

1	Family member below 10 years	3	Family member above 18 years ☐
2	Family member 11 to 18 years	4	Other Specify

306. What type of water collection container do you use?

1	Jerry can ☐	3	Traditional clay pot ☐
2	Metal Bucket ☐	4	Plastic Bucket ☐
5	Other specify		

307. Do you cover the container when transporting water from source?

1	Yes ☐	**2**	No ☐

308. Do you cover the container when storing water at home?

1	Yes ☐	**2**	No ☐

309. What type of cover to you use to cover the water collection containers when transporting water

1	Tight fitting lid	3	Tree leaves
2	Loose lid	4	Others

310. How long do you store drinking?

1	< 1 day	2	> 1 day but < 2 days	3	> 2 days

311. What method do you use to draw water from storage container?

1	Pouring	2	Dipping	3	other specify

312. Where do you store your water drawing utensils?

1	Hang on well	4	Storage cover
2	Table or shelves	5	Floor
3	Inside the container	6	Other

313. Who is assigned the responsibility of drawing water from the storage container in this household?

1	Family member below 10 years	4	Family member above 18 years
2	Family member 11 to 18 years	5	other

314. Do the person assigned to draw water from the storage container wash hands before drawing water?

1	Yes	2	No	3.	Others

315. Do the person assigned to draw water from the storage container use soap when washing hands before drawing water?

1	Yes	2	No

316. Do you wash your container before water collection?

1	Yes	2	No	3	Others

317. Do you use soap when washing your container before water collection?

1	Yes	2	No	3	Others

This is the end of the questionnaire. Thank you for taking time to answer these questions. We appreciate your help.

Appendix 2: Ministry of Health and Child Care Sample Collection Form

Ministry of Health and Child Care Sample Collection Form

Sampling & Bacteriological Analysis

Locality ____

Sample site____

Place ____

Source____

Date collected ____

Time collected____

Sender ____

Date analysed____

Time analysed ____

Results

Total coliform____

Faecal coliform____

(Other)____

Laboratory Sample number____

Water bacteriological

Safe ☐ unsafe ☐

Action taken____

Appendix 3: Ethic approval from UWC

UNIVERSITY of the WESTERN CAPE

OFFICE OF THE DIRECTOR: RESEARCH
RESEARCH AND INNOVATION DIVISION

Private Bag X17, Bellville 7535
South Africa
T: +27 21 959 2988/2948
F: +27 21 959 3170
E: research-ethics@uwc.ac.za
www.uwc.ac.za

29 November 2017

Mr R Makokove
School of Public Health
Faculty of Community and Health Sciences

Ethics Reference Number: HS17/10/26

Project Title: Determining the association between household drinking water handling practices and bacteriological quality of drinking water at the point-of-use in the rural communities of Murewa district, Zimbabwe.

Approval Period: 29 November 2017 – 29 November 2018

I hereby certify that the Humanities and Social Science Research Ethics Committee of the University of the Western Cape approved the methodology and ethics of the above mentioned research project.

Any amendments, extension or other modifications to the protocol must be submitted to the Ethics Committee for approval.

Please remember to submit a progress report in good time for annual renewal.

The Committee must be informed of any serious adverse event and/or termination of the study.

Ms Patricia Josias
Research Ethics Committee Officer
University of the Western Cape

PROVISIONAL REC NUMBER - 130416-049

Appendix 4: Letter of Approval from MRCZ

Telephone: 791792/791193
Telefax: (263) - 4 - 790715
E-mail: mrcz@mrcz.org.zw
Website: http://www.mrcz.org.zw

Medical Research Council of Zimbabwe
Josiah Tongogara / Mazoe Street
P. O. Box CY 573
Causeway
Harare

APPROVAL LETTER

REF: MRCZ/B/1418 **19 January, 2018**

Rameck Makokove
House No 4087
Zvataida Street
Chesvingo
Masvingo

RE: DETERMINING THE ASSOCIATION BETWEEN HOUSEHOLD DRINKING WATER HANDLING PRATICES AND BACTERIOLOGICAL QUALITY OF DRINKING WATER AT THE POINT-OF-USE IN THE RURAL COMMUNITIES OF MREWA DISTRICT, ZIMBABWE

Thank you for the above titled proposal that you submitted to the Medical Research Council of Zimbabwe (MRCZ) for review. Please be advised that the Medical Research Council of Zimbabwe has **reviewed** and **approved** your application to conduct the above titled study. This is based on the following documents that were submitted to the MRCZ for review:

a) Study proposal
b) Informed Consent Forms
c) Data collection tools

APPROVAL NUMBER : **MRCZ/B/1418**
This number should be used on all correspondence, consent forms and documents as appropriate.

- **APPROVAL DATE** : **19 January, 2018**
- **TYPE OF MEETING** : **Expedited**
- **EXPIRATION DATE** : **18 January, 2019**
  After this date, this project may only continue upon renewal. For purposes of renewal, a progress report on a standard form obtainable from the MRCZ Offices should be submitted one month before the expiration date for continuing review.
- **SERIOUS ADVERSE EVENT REPORTING:** All serious problems having to do with subject safety must be reported to the Institutional Ethical Review Committee (IERC) as well as the MRCZ within 3 working days using standard forms obtainable from the MRCZ Offices.
- **MODIFICATIONS**: Prior MRCZ and IERC approval using standard forms obtainable from the MRCZ Offices is required before implementing any changes in the Protocol (including changes in the consent documents).
- **TERMINATION OF STUDY**: On termination of a study, a report has to be submitted to the MRCZ using standard forms obtainable from the MRCZ Offices.
- **QUESTIONS**: Please contact the MRCZ on Telephone No. (04) 791792, 791193 or by e-mail on mrcz@mrcz.org.zw.

Other

- Please be reminded to send in copies of your research results for our records as well as for Health Research Database.
- You're also encouraged to submit electronic copies of your publications in peer-reviewed journals that may emanate from this study.

Yours Faithfully

……………………………………………………

MRCZ SECRETARIAT
FOR CHAIRPERSON
MEDICAL RESEARCH COUNCIL OF ZIMBABWE

MEDICAL RESEARCH COUNCIL OF ZIMBABWE
2018 -01- 19
APPROVED
P.O. Box CY 573 CAUSEWAY, HARARE

PROMOTING THE ETHICAL CONDUCT OF HEALTH RESEARCH

Appendix 5: Permission letter from MOHCC

Telephone: 24207/8, 24571
Telegraphic Address:
"PROVMED, MARONDERA"
Fax: 23967

ZIMBABWE

Reference:
MINISTRY OF HEALTH AND
CHILD CARE
PROVINCIAL MEDICAL DIRECTOR
(MASHONALAND EAST)
P.O BOX 10
MARONDERA
ZIMBABWE

8th March 2018

The District Medical Officer
MUREWA DISTRICT HOSPITAL

RE: PERMISSION TO CONDUCT A RESEARCH STUDY : RAMECK MAKOKOVE

The above matter refers.

Permission has been granted for the above-named to carry out a research study on determining the association between household drinking water handling practices and bacteriological quality of drinking water at the point-of-use in the rural communities of Murewa District.

May you please assist him.

Kind regards

MIN. OF HEALTH & CHILD CARE
P.M.D. MASHONALAND EAST
08 MAR 2018
P.O. BOX 10, MARONDERA

S.T. Zizhou
PROVINCIAL MEDICAL DIRECTOR – MASHONALAND EAST