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DRINKING WATER QUALITY AND THE LONG HANDLED MUKOMBE CUP: ACCEPTABILITY AND EFFECTIVENESS IN A PERI-URBAN SETTLEMENT IN ZIMBABWE

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DECLARATION

I, JOHN MWENDA, do hereby declare that:

- this dissertation, "**Drinking water quality and the long handled mukombe cup: Acceptability and effectiveness in a peri-urban settlement in Zimbabwe"** is the product of my own work
- all sources I have used or quoted have been indicated and acknowledged by complete references
- this work has not been submitted for any degree or examination in any other university

Signed by: Mwenda, Date: 07th November 2016

JOHN MWENDA

KEY WORDS

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Unsafe water

Household contamination of stored water

Wide-mouthed storage container

Diarrhoea

Dipping cup

Water handling practices

Long handled mukombe cup

Drinking water quality

Zimbabwe

ABBREVIATIONS

ACF	Action Contre La Faim
AIDS	Acquired immunodeficiency syndrome
AMCOW	African Ministers' Council on Water
AT	Appropriate Technology
CAWST	Centre for Affordable Water and Sanitation Technology
CDC	Centre for Disease Control
CFU	colony-forming unit
E. coli	Escherichia coli
HIV	Human immunodeficiency virus
IWSD	Institute of Water and Sanitation Development
JMP	Joint Monitoring Programme
LHM	Long Handled Mukombe
LMIC	Low and medium income countries
MDG	Millennium Development Goal
MoHCC	Ministry of Health and Child Care
NFI	None Food Item
NGO	Non-governmental organisation
NIHR	National Institute of Health Research
NTU	Nephelometric turbidity units
P-O-U	Point of use
RCT	Randomised controlled trial
SDG	Sustainable Development Goal
TDS	Total Dissolved Substances
TTC	Thermotolerant Coliform

UNICEF	United Nations Children's Fund
VIP	Ventilated Improved Pit
WASH	Water Sanitation and Hygiene
WHO	World Health Organisation

ABSTRACT

Introduction: In-house contamination of drinking water stored in wide-mouthed buckets (even with lids) has been widely reported in epidemiologic investigations as vehicles for diarrhoea disease transmission. The long handled mukombe cup (LHM cup), recently developed by the National Institute of Health Research (NIHR), a department of the Ministry of Health and Child Care (MoHCC) in Zimbabwe, is a promising low cost dipping devise for extraction of water from wide-mouthed containers.

Aim: The study aim was to assess the effectiveness and household acceptability of the long handled mukombe cup in reducing bacteriological contamination of drinking water stored in wide-mouthed vessels in the home in a peri urban settlement in Harare, Zimbabwe.

Methodology: A randomised controlled trial of a long handled mukombe cup was conducted in Hatcliffe, Harare. After collecting baseline data on demographics, household water quality, and other sanitation and water handling practices, households were given basic health education before the two selected communities were randomly assigned to one of the two groups of 119 households each. The intervention group received the LHM cup while the control group received no intervention. Households were followed up after two months and assessed effectiveness and user acceptability of the intervention.

Data Analysis: Data analysis was conducted using STATA 11. Descriptive statistics were calculated and reported as percentages, proportions, frequencies and measures of central tendency. Bivariate statistics were carried out to test independent associations between use of the LHM cup and *E. coli.* All analyses were conducted in an intention-to-intervene analysis.

Results: A total of 230 households were analysed during follow-up. Samples of stored drinking water from intervention households were significantly lower in *E. coli* levels than those of control households (geometric mean *E. coli* of 0.8/100 ml vs 13.0/100 ml, $p < 0.0001$). Overall, 78.4% (987/111) of samples from the intervention households met World Health Organization (WHO) guideline value of 0 cfu/100ml sample, while 52.1% of the 119 samples from control households met such a benchmark ($p < 0.0001$). In addition, 94.6% of intervention household samples were in compliance with this intervention or presented low risk, 27.7% of samples from control group households presented intermediate or high risk. There was a statistically

significant association between LHM cup use and reduced *E. coli* bacterial contamination in stored drinking water ($p < 0.05$). There was no statistically significant difference in turbidity in both intervention and control groups, both for turbidity <5 and >5 ($p = 0.071$). Acceptability of the LHM cup was very high (100%).

Conclusion: To our knowledge, this is the first study on the evaluation and acceptability of the LHM cup in the Sub-Saharan Africa. Positive results were recorded that showed that the LHM cup was effective in minimising *E. coli* contamination in the intervention group as compared to the control group. It is postulated that this is because the LHM cup reduces hand contact with stored water during scooping, thus maintaining improved water quality in communities in Zimbabwe that collect and store drinking water in wide-mouthed containers with lids where extraction is by scooping. However, more research is required to document the LHM cup's continued and effective use, durability and overall sustainability in the absence of any serious sampling or monitoring.

DEDICATION

I dedicate this work to my amazing family: wife Miyedzo and our beloved daughters Melinda, Olinda and Lashinda.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 CHAPTER ONE: INTRODUCTION

1.1 Background

Contaminated drinking water has been implicated as the principal cause of diarrhoeal diseases (Tambekar et al., 2008). Despite substantial global progress made in reducing child deaths since 1990 and the subsequent decline in the number of under-five deaths from 5.1 million in 1990 to 2.7 million in 2015 (WHO, 2016), diarrhoea related deaths still account for high morbidity and mortality rates (Guchi, 2015). Provision of basic interventions to improve drinking water, sanitation and hygiene (WASH) for diarrhoea prevention, has potential to save many more millions of children (WHO, 2016). Furthermore, unsafe water is a threat to immunocompromised people as it increases the risk of them suffering from infectious diseases, diarrhoea, and diarrhoea-associated mal-absorption of essential nutrients (Peletz et al., 2012). An estimated 90% of HIV and AIDS patients have their plight worsened by diarrhoea (WHO, 2004). It is also estimated that 440 million school days are lost annually as a result of water-related infections (WHO, 2014).

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). Quick et al., (1999), noted an association between diarrhoeal disease transmission and an introduction of pathogens into drinking water stored in open, wide–mouthed containers. Rufener et al., (2010) assert that even home based interventions such as point of use water treatment may not guarantee health benefits because of the risk of post treatment contamination. Factors linked with recontamination of drinking water in the home include the size of the mouth of the drinking water storage container (Mintz et al., 1995) and unsanitary methods of extracting water from wide-mouthed household storage containers (Lindskog and Lindskog 1988). In addition, contaminated hands, bowls and small handled cups may also contribute to the recontamination of these water sources (Tambekar et al, 2008).

In most rural and peri-urban communities in Zimbabwe, the majority of households do not have running water, 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 transport and storage (WHO, 2016). Cholera-focused participatory health education of the 2008 - 2009 Zimbabwean cholera era, advocated for use of buckets with tight fitting lids for household drinking water collection, transportation and storage. Plastic buckets with tight fitting lids (figure 1) were therefore distributed to communities free of charge as part of the cholera intervention None Food Items (NFIs) Kit (ACF/UNICEF, 2009). Since the cholera era of 2008-9, most grocery and hardware shops now stock and sell plastic buckets with tight fitting lids at relatively affordable prices of between US$2 – 5 depending on size, quality and shop.

Figure 1 Buckets with lids as part of NFI Kit distributed during 2009 cholera intervention

Source: (ACF/UNICEF, 2009).

The most preferred size of household drinking water storage containers most preferred is of standard size (20 liters) to facilitate household level water treatment interventions. Although it was recognised and acknowledged that 20 liter containers may not be easy for vulnerable members of the communities such as children, the disabled, some women and the old to carry, the importance of a standard size for household water treatment was cited as the main drive for the need for each household to have at least one 20 liter container (CDC, 2009)

It is now common practice for communities to go for days without supplies, due to intermittent supplies (Muti et al., 2012) and other challenges. As a result residents hoard water whenever supplies are available for future domestic uses (Hove and Tirimboi, 2011). Other sources such as boreholes and wells are also becoming important drinking water sources in some urban communities.

The Long Handled Mukombe Cup

The use of mukombe (Figure 2) is a traditionally acceptable technique used for extracting stored water, beer or *maheu*[1] from wide-mouthed clay containers in the home. These mukombes are fashioned from gourds, have long handles, an oval shaped bowl and a narrow mouth. However, these ‘cups’, which are still available in some communities, are no longer as readily available, since the parent plant is only grown in selected communities in the country and their full development is not guaranteed in the changing climate. However, the mukombe has a disadvantage in which the cleaning of the interior part of the ‘cup’ is not easy due to the size of the mouth and the oval shape. Furthermore, in many communities narrow-mouthed plastic containers have overtaken the more traditional clay containers used for water storage, and these new plastic containers are too narrow for a mukombe to be used.

[1] Maheu is a traditional drink made from maize meal, sorghum and water

Figure2: Traditional mukombe (left) and Long handled Mukombe Cup (right)

Recently, with the constraints of the old mukombe cup in mind, researchers at the National Institute of Health Research, the Public Health Research Department in the Ministry of Health and Child Care in Zimbabwe, led by John Mwenda, adapted and developed a ladle, referred to as the long handled mukombe cup (also just called LHM cup or Inkhezo cup). Unlike other ladles, this LHM cup has a 25cm long handle and can extract approximately 500ml of water per scoop. This adaptation of the cup design makes it more practical to use in extracting and transferring drinking water from one wide-mouthed container to another in the home, analogous to the soup ladle used in households globally. The evaluation of the LHM cup, particularly in the field, is a critical step in determining if it is an appropriate, effective and acceptable technology for household use to extract drinking water from wide-mouthed storage containers.

1.2 Research problem

Piped water supplies are generally lacking in most communities in Zimbabwe (ZIMSTAT, 2015), including some urban communities. Harare City water supplies are erratic and unreliable (Hove and Tirimboi, 2011) and residents have indicated that even when available, borehole water for water is preferred for drinking (Manzungu et al., 2012). Households therefore collect drinking water outside homes and then transport and store it in containers in the homes. Literature suggests that water stored in such wide-mouthed containers is susceptible to contamination when water is extracted, and may not be safe at point of consumption. In Hatcliffe, Harare, the site where this study was conducted, the main storage containers are buckets with lids and the method of extracting the water is by dipping a vessel into the bucket. Though dipping a vessel into drinking water is in itself a risk factor, short handled cups are riskier due to more probable chances of hand-water contact. An appropriate dipping cup intervention in addition to household water treatment and safe storage in lidded wide-mouthed containers, could minimise contamination of safe water at point of consumption. Its effectiveness and acceptability needed to be examined.

1.3 The Research Question

Is the long handled mukombe cup an effective and acceptable dipping vessel to prevent bacteriological contamination of drinking water stored in wide-mouthed storage containers in homes?

1.4 Aim

- To assess the effectiveness and household acceptability of the long handled ‘Mukombe cup in reducing bacteriological contamination of drinking water stored in wide-mouthed vessels in the home.

1.5 Specific Objectives

- To describe the demographics and socio-economic status of households using lidded, wide-mouthed containers to store water in Hatcliffe
- To determine the effectiveness of the long handled Mukombe Cup on reduction of contamination of closed bucket water
- To determine the acceptability of the long handled mukombe cup among the intervention households in Hatcliffe settlement

2 CHAPTER TWO: LITERATURE REVIEW

2.1 Sustainable Development Goal's Safe Water Indicator

Problems associated with poor drinking water quality are significant barriers to human and economic development (Brown, 2007). Safe drinking water was an area highlighted for development in the Millennium Develop Goals (MDG) (Satterthwaite, 2016), because it is basic to human development. This focus is now being taken forward in the Sustainable Development Goals (SDGs) (Target 6.1): To achieve universal and equitable access to safe and affordable drinking water for all by 2030, (United Nations General Assembly, 2015). A recent review on MDGs by Satterthwaite (2016) noted that although the WHO/UNICEF Joint Monitoring Programme (JMP) (2015) report insists that the MDG drinking water target, which was "to halve the proportion of the population without sustainable access to safe drinking water by 2015" was surpassed, the proportion of the world's population with safe water and sustainable access was not measured and remains unknown. This is because the MDG indicator focused on access to an improved water source and did not specify the quality of the actual water provided. To achieve the SDG 6 target 6.1 requires the SDGs call for progressive elimination of inequalities through accelerated progress in the delivery of services that are both sustainable and affordable to all people including the poor and marginalised. 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.

2.2 Global Access to Safe Water

Diarrhoea remains a major disease burden in Sub-Saharan Africa, despite the reported increase in the number of people with access to improved drinking water sources from 76% in 1990 to 91% in 2015 (WHO, 2015). Unsafe water is a significant route of infection associated with the occurrence of an estimated 16% of diarrhoea-related deaths in children under five years of age

(Fabiszewski de Aceituno et al., 2012). According to the WHO (2015), an estimated 502 000 diarrhoea-related deaths are linked to contaminated drinking water. Preventive measures that span from the source to the point of consumption have been effectively used to prevent contamination of drinking water. While improvements of water supply sources have been documented to be effective in improving health and life expectancy (Checkley et al., 2004), recent research evidence suggests that drinking water from a safe source is often contaminated by the time it reaches home and during storage (Mattioli et al, 2014; Sharma et al., 2013; Sarsan, 2013).

2.3 Access to Safe Water in Zimbabwe

The WHO/UNICEF Joint Monitoring Programme (2015), announced that Zimbabwe had not met the MDG target of reducing the number of people without sustainable access to safe drinking water and basic sanitation by half by 2015 (Nyamanhindi, 2013). Instead the country experienced a decline in access to both water and sanitation between 1990 and 2015. In 2015, the WHO/UNICEF JMP suggested that 77% of the Zimbabwean population had access to safe water and 37% to improved sanitation. The estimates are however, higher than the national estimates (AMCOW, 2011). Furthermore, it has been noted that of these 77% with access to safe water, only 28% (compared to 33% in 1990) use water piped onto premises, while 49% use other improved sources. Twenty three percent continue to use unimproved drinking water sources. Of these, 33% are in the rural communities compared with only 3% in urban areas.

The most common water source for urban communities is water piped onto premises (a decrease from 98% in 1990 to 74%). Urban areas, particularly large cities such as Harare and Bulawayo have witnessed a rise in water source usage between 1990 and 2015 that were traditionally identified among rural communities. Various organisations such as UNICEF, NGOs and individuals have also assisted with drilling of hundreds of boreholes in urban communities around the country, in cholera-threatening areas (UNICEF, 2010) as a short term solution to alleviate the urban water challenges in Zimbabwe. In some affluent communities in Harare, residents that had the means drilled boreholes on the household’s residential premises which could be accessed for their own water supply (Muyambo and Klaassen, 2015). According to WHO/UNICEF JMP (2015), about 23% of urban households use other improved water sources (e.g. boreholes, bottled water) while 3% rely on unsafe water sources.

According to the Zimbabwe Multiple Indicator Cluster Survey (ZIMSTAT, 2014), only 29% of households in Harare have access to piped water, and some 68.7% rely on boreholes, protected wells and bottled water. Urban councils supply of safe water has been erratic for almost all urban centres of Zimbabwe, with supplies generally only available for less than half a day in most towns (Muyambo and Klaassen, 2015). It is feared that if this trend would continue, more and more people would be forced to access and obtain drinking water from sources outside the home, transport it to their homes and store it in-house till further use.

In rural areas, an estimated 95% of the households (WHO/UNICEF JMP, 2015) lack access to water piped onto premises and therefore obtain water outside the home and stored in-house. Boreholes, protected wells, and protected springs constitute the safe water sources used by the majority of the rural population. The Ventilated Improved Pit (VIP) latrine is the most common type of sanitation for rural Zimbabwe. Currently, rural sanitation coverage is estimated at 31% (down from 35% in 1990) with about 40% still practicing open defecation (WHO/UNICEF JMP, 2015).

2.4 Appropriate technology

Appropriate Technologies (AT) have been defined as those technologies that are easily and economically availed for use made from readily available resources by local communities in low income countries (Hulland et al., 2015), such as Zimbabwe. They further define AT as that technology that is tailor-made to build on already existing skills, knowledge and cultural norms of intended users taking into consideration their gender, while increasing the efficiency and productivity of their enterprises or domestic activities. An AT should by their definition meet the basic characteristics of:

- being able to solve real problems and needs
- being affordable to the majority of intended user population
- being simple in its design, operation and maintenance
- not impacting negatively on the environment

A WaterAid Report (2011) noted that when designing a technology that is appropriate to meet the user's needs, one should conform to a technical design that will be acceptable culturally, economically affordable, environmental friendly and in line with the local community's social conditions. This is mainly for sustainability reasons. Furthermore, when developing a public health technology, input from the health sector is considered paramount to ensure the technology in is line with the required health standards (WaterAid, 2011). Community participation and decision making in adoption of AT is fundamental for the sustained adoption and use of the technology (Hulland et al., 2015) and associated WASH behavior practices.

2.5 Water Quality Intervention Programmes: An overview

Diarrhoea and other waterborne diseases prevention programming, implemented to address drinking water quality challenges, has evolved tremendously since their inception, now being tailored to local contexts and adapting to population dynamics and disease trends (Hutton and Chase, 2016). Many diarrhoea-related disease causing pathogens are spread through water that is contaminated with faeces (Clasen et al., 2015). For this reason, WHO guidelines give stringent limits on the faecal contamination in drinking water supplies (World Health Organization, 2011). *Escherichia coli* and thermotolerant coliforms (TTC) are the WHO-approved 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, in line with the WHO recommended values (World Health Organisation, 2011).

In low income countries, water quality improvement programmes have targeted source based water supplies aiming to provide millions with access to improved water supplies (Hutton and Chase, 2016). Protected ground water supplies (e.g. springs, boreholes and wells), surface water supplies (piped water schemes, rainwater harvesting) have been implemented globally to address safe water access challenges. However, many studies (Hodge et al., 2015) report that, even with safe water sources, drinking water handling practices contaminate the water between the source and point of consumption. This has meant that water quality interventions have continued to evolve to address deteriorating water challenges at household levels.

Point-of-use (P-O-U) water quality improvement interventions, including boiling, chlorination, filtration, flocculation, to solar disinfection, are now widely practiced particularly in low income countries. These P-O-U water quality interventions have been endorsed by WHO and UNICEF and are spearheaded by various institutions including the public and private sector, NGOs, individuals and faith based organisations. Generally these are simple technical interventions, targeting household level hygiene and sanitation behavior change, which improve the quality of drinking water at point of use.

Effective water quality intervention programming requires that targeting is broadened to include not only water quality but also other parameters such as water access and quantity, domestic hygiene, appropriate human waste disposal, hand washing with soap or ash promotion, and other hygiene related practices (Clasen et al., 2015). Water quality interventions at household level should be complementary to other efforts such as hand washing with soap, construction and use of improved sanitation facilities, hygienic food preparation and serving among others. On the contrary, Fewtrell et al. (2005) suggested that multiple interventions (consisting of combined water, sanitation, and hygiene measures) were not more effective than interventions with a single focus. Any approach used should address all key factors such as social, cultural, economic, demographic, political, and ecological aspects (Fewtrell et al., 2005) for a sustained behavior change (Imanishi et al., 2014).

Although the MDG Target 7c, "to halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation", did not provide a global indicator for hygiene, the data on the presence of a hand washing facility with soap and water present are increasingly collected as part of nationally representative surveys, and will form the basis for efforts to monitor Target 6.2 of the SDGs.

2.6 Household drinking water management

2.6.1 Household drinking water handling Practices

The importance of appropriate drinking water management at point of consumption has been noted in many household water treatment and safe storage interventions. Sobsey (2003) acknowledges the significance of improved household drinking water management strategies at household level used in combination with hygiene education and sanitation. Other factors such as increased water storage times, high levels of dust particles in air, higher temperatures and insufficient hand washing are also risk factors contributing to bacteriological water contamination and decreased water quality (Dismer, 2012). All these factors therefore are important target areas of household based sanitation as well as hygiene education programmes.

Practices that target multiple barriers for preventing contamination are therefore proposed for best results. Treatment and safe storage barriers (WHO, 2004) and behavioural practices are the main factors for household based interventions, while preventive barriers are mainly targeting improvement of water sources.

2.6.2 Storage of drinking water in households

The design of the water storage vessel is vital in safe management of drinking water, particularly in the home. Containers with narrow-mouths, where the method of extraction is outpouring of water have been found to have a protective effect on recontamination and diarrhoeal disease (Mintz, 1995). 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. World Health Organisation (2014) safe water systems strategy recommends containers that store an appropriate standard 20 liter volume of water, with a tight fitting cover and small opening. However, large (>=20 liters) narrow-mouthed storage containers pose the challenge of not being user-friendly particularly to children, the sick and aged who cannot pour out the water easily. Generally, appropriate household drinking water collection and storage containers need to be socio-culturally acceptable, portability, of volume able to meet the daily needs of the family, easy to use and clean. For Zimbabwe, plastic buckets which are light weight with tight fitting lids and of 10 – 25 liters capacity (Dismer, 2012) are the more desired water collection and storage containers for many households. A biosand filter intervention study was conducted in Hatcliffe extension, Harare, where all 14 households recruited for the study, stored their drinking water in wide-mouthed vessels with some lids, recorded a 76% recontamination after extraction using short handled cups (IWSD, 2010).

2.7 Factors associated with contamination of household drinking water

Several factors have been associated with contamination of drinking water during collection, transportation and storage. These factors can be classified as physical, environmental characteristics and human behaviour linked practices.

2.7.1 Environmental Factors

The environment is a key component of disease transmission (Holt, 2009). World Health Organisation (2004) estimates that about a third of deaths in Low and Medium Countries (LMICs) globally are associated with environmental causes. This is due to the many varied exposures to many different environmental factors (WHO, 2006). Diarrhoea is among the four major diseases that are associated with weak environments (WHO, 2004). Children, particularly those under five years old are the most affected by the environmental risk factors. In LMICs including Zimbabwe, young children move by crawling around playing in areas that are contaminated with human and animal faeces (Ngure et al., 2013).

2.7.2 Physical factors

Physical factors have a significant effect on the quality of drinking water (Holt, 2009). For infectious diarrhoea, for example, the faecal-oral transmission routes are basically a result of interactions between the physical infrastructure and human practices (Wright et al., 2004). 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.

Water supply engineering designs, e.g. of taps that will increase the chances of hand contact with water at point of collection, increase the risk of contamination of drinking water during collection (Packiyam et al., 2016). Other physical challenges that can affect the quality of drinking water are blocked reticulated sewage systems (Chinyama and Toma, 2013) that may release raw faecal matter into the environment and water bodies (surface and ground), contaminating them in the process (Hutton and Chase, 2016). Intermittent water supplies (Muyambo and Klaassen, 2015), consistent breakdown of pumps used to draw water (especially ground water) (AMCOW, 2011) and decreasing and drying of safe water supplies impact negatively on the sustainable access to safe drinking water (WHO/UNICEF, 2015).

In addition, lack of proper and adequate sanitary facilities such as a flush toilet may contribute to contamination of stored household drinking water (Holt, 2009), even though some researchers have found contrary evidence. Eshcol et al., (2009) found no statistically significant differences in availability of improved sanitation facilities between those households with contaminated and uncontaminated stored drinking water.

2.7.3 Human behaviour linked drinking water handling practices

Studies have reported a positive association between domestic hygiene of households and the behavior of family members towards drinking water quality (Tambekar et al., 2008 and Trevett, 2005). The unhygienic practices of households result in contaminated hands and fingernails coming into direct contact with stored water, a situation that leads to various infections (Tambekar et al., 2009). 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. Hygiene of the water storage container was a key determinant of the quality of the water stored in that container.

3 CHAPTER THREE: METHODOLOGY

3.1 Introduction

This chapter details the methodology used in this study. It describes the study design, setting, study population, inclusion and exclusion criteria, sample size, sampling procedure, data collection process, intervention, outcome measurements, data analysis, variability and reliability. It also presents generalisability of findings, study limitations and ethics.

3.2 Study Design

A community based randomised controlled trial (RCT) was designed to assess the effectiveness and household acceptability of a LHM cup in reducing bacteriological contamination of drinking water stored in wide-mouthed vessels in the home over a two month period. This is an appropriate quantitative research design best suited for studying the effectiveness of an intervention. It allows the researcher to control the exposure and determine the intervention and non-intervention group.

3.3 Setting

This study was conducted among households of Hatcliffe, one of the fastest growing urban settlements in Zimbabwe. Hatcliffe is the only high density suburb in the Northern district in Harare, situated approximately 22km from Harare city centre and about fifteen kilometres from Domboshava, a rural growth point that has been rapidly developing into a satellite of Harare (Chirisa and Muchini, 2011). It borders Hodgety Hill and Philadelphia, both of which are low density suburbs. Hatcliffe was first established to accommodate only a small population. However, as pressure for accommodation mounted, the City of Harare was forced to parcel out more housing land to home seekers to expand the suburb. The suburb has since been expanding at a rate that outpaced service delivery such that there are many housing units in Hatcliffe that now exist in communities that have no serviced roads, no social amenities including piped water supplies and no electricity. The housing units are standard urban structures constructed with brick and cement mortar and asbestos roofed. According to Dirwai (2000), most of the people who were allocated housing land in Hatcliffe came in groups mainly as displaced urban poor people who came from different places in Harare.

Hatcliffe's population has been growing fast, almost doubling from an estimated 26,083 in 2010 to 48,403 people in 2015 (Harare City Health, 2015). The last National Census (2012) had put the population at 26,660 (ZIMSTAT, 2013). Municipal water supplies are very erratic and major sources of potable water are not reticulated municipal supplies, but boreholes and shallow wells that are scattered around the suburb. Harare City council with assistance from some development partners (NGOs and individuals) has developed projects to improve extraction of ground water to augment existing safe sources. One such initiative is improvement of pumping capacities of some boreholes. The water is pumped from these boreholes to large overhead tanks near the borehole from where it is pumped to a series of public standpipes that supply water for approximately 8-12 hours each day. Each selected water point has a seven member water point committee for community based management of the facility and its environs. Most of the people in Hatcliffe collect, transport and store their potable water in predominantly wide-mouthed plastic containers with lids (IWSD, 2010). In some parts of Hatcliffe some households have also dug wells at household level for drinking and other domestic uses. For sanitation, most households have in-house flush toilets which are, due to lack of piped water supplies are now being flushed by manually pouring water. Some households staying in houses that are still under construction have built temporary pit toilets within their allocated housing land. The suburb's health system is supported by a Harare City Health polyclinic and other private health centres.

3.4 Study population

The study population was all the households in Hatcliffe without access to in-house piped drinking water who were collecting water around a particular water source.

3.5 Eligibility criteria

3.5.1 Inclusion

Requirements for the inclusion of households in this study involved criteria where a household collected and stored drinking water in wide-mouthed containers with lids. The method of water extraction from the containers in these households was by dipping a vessel to scoop out the water. Another requirement for inclusion in the study was the household and individual's willingness to participate. Households with an adult aged 18 years or older had to be present at home in order to complete the questionnaire and receive the health promotion package included, provided consent was granted

3.5.2 Exclusion

Households were excluded if they did not want to participate and if their method of serving water from the wide–mouthed drinking water storage containers was by pouring it out or from opening a tap, instead of using a vessel to scoop it out.

3.6 Sample size

The number of households recruited was based on an initial sample size calculation of 85 households per group (190 total), estimated for the study using Epi_Info version 7, Statcalc, assuming confidence level of 95%, statistical power of 80%, as well as a 30% and 50% outcome in exposed and unexposed groups, respectively. Additionally, 48 households (25% per group) were included in each group to give a total of 238 households. This figure was meant to account for households that were likely to refuse to participate or drop out during follow-up, assuming a 75% response rate. The total number of households recruited was 119 per household group (238 for the study).

3.7 Sampling procedure

Both non-probability and probability sampling methods were utilised to select the study units. Hatcliffe community was purposively divided into two separate sections to reduce cross contamination between groups. The study was conducted in two adjoining communities in Hatcliffe. Four drinking water sources were selected, two from each study section based on the representativeness of the safe drinking water sources in the study area.

No standard numbers of households per water source were identified. Furthermore, communities were approached until 119 households per group had agreed to participate, granted informed consent, and were therefore enrolled in the study. This number included the additional 25% number of households to balance for those that would have refused to participate and others lost during follow-up.

Step 1 – Identification of residential sections (groups) and drinking water sources

- A prepared list of all sections/communities available for selection in Hatcliffe was presented
- Study communities (n=2) were selected based on where the Hatcliffe Health Promoters team had previous experience and knew communities' safe drinking water points and practices of collecting water from the community water sources, transporting it home and storing it in wide-mouthed buckets with lids
- Purposively selected two communities (residential sections) during a meeting with local leadership and the Hatcliffe Community Health Promoters
- Those living close to and collecting drinking water from the selected sources within a selected residential section became the target households for selection into that particular area's group.

Step 2 *– Selection into the study of households that use the selected drinking water sources*

- Two community meetings, one per residential section were conducted to introduce the research study and explain its objectives.
- Households were randomly allocated to either (1) the intervention group receiving the LHM cup or (2) the control group. A lottery system was used. Two identical coins were each labelled with the first letter of each residential section and placed in an empty box. The randomisation was conducted by a Hatcliffe Community Officer who was not involved in the study. Research team, local leadership and Hatcliffe Community health staff witnessed the exercise, but were not involved in the randomisation. The box was thoroughly shaken before the Hatcliffe Community Officer drew out one of the coins. The first community selected was allocated to the intervention group and the other to the control group.

- A list of households for each of the selected four drinking water sources were used to construct a sampling frame from which the study units (sample households) were selected. The lists of the households were obtained from the local leadership
- The local health promotion team facilitated this process.
- All candidates who met the inclusion criterion and exclusion criteria were approached until 119 households in each of the two residential sections had agreed to participate
- Households were randomly selected from a list of households collecting water from selected water points in such a way that each household had an equal chance of being selected.
- Enrolment was only confirmed after household head responsible for drinking water management or any other representative (18 years or older) had provided a written consent
- The sample size of households recruited was based on an initial sample size calculation
- Women heads of the household were the main target respondents but in their absence any other adult representatives (18 years old or above) were interviewed

3.8 Data collection methods

3.8.1 Methods for Objective 1: Recruitment, Baseline survey and randomisation

People resident in the selected two communities in Hatcliffe, collecting their drinking water at selected safe water points were informed of the study through their local leadership and Hatcliffe Health Promotion staff. At enrolment, a trained research team comprising two men and four women interviewed all 238 households in the two selected residential sections of Hatcliffe. A baseline questionnaire, developed in English and then translated to Shona (which was later translated back to English to maintain consistency) was administered to each of the recruited households by Shona speaking data collectors (participants' home language). The baseline variables of information collected included: (1) the identification of the household, (2) demographic data of the respondent, (3) drinking water sources, (4) sanitation facilities, (5) water handling and general hygiene practices. Also for each household, baseline water samples were collected from their drinking water sources as well as from wide-mouthed drinking water storage containers with lids in the home. Following the baseline survey, the two communities were randomly assigned into two groups.

3.8.2 The Intervention

All 238 household representatives received general education on sanitation and hygiene from the research team in two separate community meetings (one in each community) before issuing of the LHM cup. Those household representatives that failed to attend were given a brief on the first visit to their home. After baseline data was collected and after the health education sessions, the community that was randomised into the intervention group, the one with families to receive the LHM cup technology was announced. The LHM cups were distributed to intervention group households. Families in the intervention group also received instructions on proper use, cleaning and storage of the special vessel. Participants that received the LHM cup were reminded that they were still free to leave the study at any time and for any reason. However, it was also made clear that the LHM cup would be taken away from the participants if they chose to abandon the study. Control group households were advised to consistently use their normal water handling practices throughout the study period. After two months and at the conclusion of the study each participating household was visited and reinterviewed.

3.8.3 Methods for Objective 2: Effectiveness of LHM cup

3.8.3.1 Water sampling

Thermotolerant coliforms, particularly *Escherichia coli (E. coli)* are accepted indicators of faecal contamination of drinking water samples (Odonkor and Ampofo, 2013) and were used as indicator organism in this study. After the initial baseline survey to determine source water quality and levels of contamination in study communities, each household was visited (two months after distribution of the LHM cup) during the follow-up phase for purposes of collecting a water sample. For the stored drinking water in the lidded bucket, trained technicians who made unannounced visits asked the household representative if there was any drinking water stored in the house and samples were collected from the identified bucket. A water sample of the stored water the household was drinking on the day of the visit[2] (from the wide-mouthed container) was collected using the cup the household had been using since the start of the project (Figure 3).

In the intervention group households, the LHM cup was used to collect the water and fill the sterile 200ml Boston round sampling bottle with a lid. For the control group households, water samples were collected the same way but using the household's usual[3] water collection cup used to scoop water stored in the bucket. These samples were stored on ice and transported to the National Institute of Health Research in cooler boxes and processed within 4 hours to assess the levels of faecal contamination. Where processing could not be achieved within 4 hours after collection, samples were stored overnight at fridge temperature of between +4°C and +10°C (Standard Association of Zimbabwe, 1997). On all but one occasion the samples were processed on the same day of collection and within the recommended 4 hours after collection. Aseptic techniques were practiced at all times in order to minimise possible contamination during sampling. Sampling procedures were in line with the WHO water sampling and analysis guidelines.

Figure 3: Water sampling from a household container: intervention (left) and control (centre and right)

[2] Only from water from wide-mouthed containers where method of collection was by scooping

[3] The pre-intervention cup

3.8.3.2 Water quality testing and analysis

Water quality analysis of the samples for *E. coli* was done for each sample using the Membrane Filtration Method on Membrane Lauryl sulphate medium (Oxoid Limited, Basingstoke, Hampshire, UK) using a Paqualab 50 field kit in accordance with the kit manufacturer's instructions. The *E. coli* counts were reported as the total number of colony-forming units present per 100 ml sample (cfu/100mL). The method of analysis as given in the Paqualab 50 Membrane Filtration method was followed. This method conforms to the WHO Guidelines for Drinking Water Quality, Volume III (WHO, 1997). Samples were cultured using Membrane Lauryl Sulphate medium. The membrane filtration petri dishes were for *E. coli.*

3.8.3.3 The Paqualab 50 Membrane Filtration method

All of the microbiological testing was performed with the Paqualab 50 Membrane Filtration kit in the NIHR Microbiology laboratory under strict aseptic conditions (Figure 4). All testing equipment was sterilized with a Bunsen burner and methylated spirit prior to any analysis. Some 100lm of the water sample to be tested was filtered through a sterile filter paper (pore size diameter 0.45µm) such that any bacteria present in the water sample is trapped on the surface of the filter paper. The filter paper was then placed in a sterile Petri dish containing a sterile membrane lauryl sulphate growth medium, and incubated in the Paqualab 50 portable incubator at 44°C for 16 - 24hours. *Escherichia coli* bacteria colonies were then physically counted and reported as the number of coliform–forming units per 100 ml sample. The filtration apparatus was sterilised (in accordance with the membrane filtration standard operating procedure) between samples to prevent any cross-contamination of samples.

3.8.3.4 Turbidity

Turbidity, a measure of physical quality, is an important measure of water quality since it impacts upon the acceptance of water by the user (Earwaker, 2006). Turbidity measurements in nephelometric turbidity units (NTU) were performed using a Paqualab 50 digital turbidimeter. The turbidimeter was calibrated with standard solution and in accordance with the manufacturer's instructions. Initial calibration was carried out in the laboratory and the turbidimeter accuracy was checked every time before a sample was measured by reading a standard (0 NTU) solution. If the turbidimeter reading of the standard solution was more than 0 NTU off the actual value, the turbidimeter was recalibrated. A transparent plastic tube was filled with sample water under investigation up to the point of the calibration mark, closed and inserted into the Paqualab 50 digital Turbidimeter. A digital figure on the turbidimeter screen denotes turbidity level.

Figure 4: Microbial water quality testing in the laboratory (photos by Researcher).

Escherichia coli was identified as the yellowish colonies or dots observed after incubation

3.8.3.5 pH

The pH was measured using a battery powered pH meter. A water sample was poured into a 50ml beaker and a pH meter probe was immersed into the water. A digital figure on the pH meter screen denotes digital reading of the pH level.

3.8.3.6 Standards for drinking water quality

The WHO Guidelines for Drinking Water Quality recommend that all water intended for Human consumption should not have any faecal contamination in any 100 ml sample. The WHO guideline for the presence of *E. coli* (or thermotolerant coliforms) in drinking water is 0 colonies per 100 ml sample (WHO, 2008).

The results of the membrane filtration are presented as the number of *E. coli* colony forming units in a 100 ml water sample. The *E. coli* counts, according to the WHO, classify the quality of an analysed water sample in terms of the risk of faecal pollution of the water and level of acceptability for human consumption. Using *E. coli* as an indicator, the level of faecal pollution and associated risk is given in Table 1.

Table 1: Faecal Pollution and its Associated Risk

E. coli Count per 100 ml sample (CFU/100 ml sample)	Risk category	Recommended Action
0	safe water quality	In conformity with WHO guidelines
0-10	Reasonable quality	Water may be consumed as it is
11-100	Polluted	Treat if possible, but may be consumed as it is
101-1000	Dangerous	Must be treated
> 1000	Very Dangerous	Rejected or must be treated thoroughly

(WHO, 1997; Centre for Affordable Water Sanitation (CAWST), 2009)

The WHO (1997) risk-based categories show that:
At <1 *E. coli* CFU per 100ml sample, the risk to an individual from drinking water contaminated to this level is negligible. The water is bacteriologically safe for drinking.
At <10 CFU per 100ml sample, the risk of waterborne disease is categorised as “low”.
The risk of disease increases with increase in *E. coli* counts per 100ml sample.

3.8.3.7 Observation

A sanitary survey to visually assess the environment, basic operating and maintenance requirements recommended by the project is critical in monitoring the project to ensure safe drinking water. Other simple observations researchers undertook in this study included identifying potential water quality risks linked to water handling practices and the environment, among others. Key areas that were observed included general hygienic conditions of persons and environments at home and around the water source, water collection, transportation and storage practices including the containers used. These and sanitation practices all affect the quality of water consumed and the risks of contamination of the water before, during and after storage. Observed situations were recorded and addressed subsequently.

3.8.4 Methodology for Objective 3: Acceptability

As with the baseline survey, a follow-up questionnaire, developed in English and then translated to Shona (which was later translated back to English to maintain consistency) was administered to each of the households in the intervention group by a different set of data collectors than the ones that administered the baseline questionnaires. The survey questions were designed in simple and straight forward logical sequence using easy to comprehend terms. The questions were revised several times and piloted before use in the study to minimise any ambiguity as well as to make them as effective as possible. It was also ensured that the completion time would not exceed 15 – 20 minutes. The follow-up (or acceptability) questions were administered to an adult representative of the household.

Households were visited during the mid to late morning hours for the interviews at which times it was assumed most household chores would have been completed or almost done. The research team interviewed any adult that was at home and as a result both men and women were interviewed. Men were interviewed by men, in situations where both men and women were in the same team. The interview data reflects more of women's points of view, an important point as they are the primary managers of household drinking water and users of the LHM cups.

3.9 Data Analysis

Data obtained from intervention interviews, household visits and water quality tests were recorded manually, entered in Excel, checked for accuracy and consistency before it is analysed in Stata 11.0 (Stata Corporation, College Station, Texas, US). The primary analysis was on intention to intervene. Descriptive statistics were calculated and reported as percentages, frequencies, proportions and measures of central tendency used to describe participating households' demographic information and to compare the geometric mean bacteriological contamination of the intervention versus the non-intervention groups. Statistical analysis of bacteriological data from water quality tests were conducted after log transformation of the *E. coli* count values to explain any skewed distribution. Bivariate statistics were done to examine independent associations between household characteristics and use of the LHM cup. Prevalence ratios were used to analyse user acceptability of the LHM cup intervention. Binary logistic regression was used to uncover statistically significant associations between the more highly contaminated stored water samples (with *E. coli* counts >100 cfu/100ml) and service utilisation and the other covariates.

3.10 Validity

Validity, one of the key measures of rigour in scientific research, is defined as the extent to which a concept is accurately measured in a quantitative study (Heale and Twycross, 2015). In this study face validity (degree an instrument measures what it is supposed to test) and content validity (items making up an instrument adequately capture key content that defines the variable being measured) were employed to develop the data capturing tools that were used. Criterion validity was not applicable as there was no gold standard tool in use.

Face validity: Face validity was ensured through a process that involved the core research team, community representatives and other experts' knowledge and experiences in such health surveys. Water testing equipment and data collection tools were pretested before wider application as part of the validation exercise. Appropriate modifications such as calibrations of all equipment to be used were done in accordance with the findings of the pretest. All members of the research team were trained in a pilot on practical application of data collection tools. A formal meeting was conducted with the research team to finalise the data collection tools and ensure they would collect the data they were designed for.

Content validity: Content validity was guaranteed through extensive review of other similar studies and research reports in addition to engaging core research team and other experienced experts who assisted with definition of some terms and their appropriate applications in this study. Content validation was a process involving planning, developing and evaluating data collection equipment's objectives as well as components. Senior technicians reviewed the standard operating procedures for water sampling and testing using the membrane filtration method. The theoretical basis for a tool is reflected through its component parts and can only be achieved following a thorough, rational evaluation of the equipment's objectives.

The fact that the surveys were conducted during the day when some people were not at home did not bring any strong sample bias as it was anticipated that there was little difference with respect to key variables such as use of the LHM cup and hygiene practices, as no differences were observed between the employed and the unemployed. Zimbabwe, according to the 2012 population census report has a high literacy rate of 96%, with Harare at 99%. Furthermore, those of the population that are employed are mostly in the informal sector – a sector that stretches from backdoor offices in the backyard of houses to better organised structures in the city.

3.11 Reliability

Heale and Twycross (2015) define reliability as the level to which a research instrument consistently produce the same results when used in a similar situation on repeated occasions. It is a measure of the accuracy or dependability of the instrument to give similar results in different but similar environments. All questionnaires were prepared in both English and Shona prior to use in the research. Questionnaires were pre-tested through back-translation from Shona to English and used in a practical data collection exercise (pilot) to establish suitability of content, structure and consistency. The necessary corrections in the questionnaire were made.

3.12 Generalisation

Findings from this study are likely to be regarded as a generalised trend to other communities living in similar socio-economic conditions with poor access to water, who have similar household drinking water handling practices and who have a similar cultural awareness of the LHM cup.

3.13 Limitations

A major limitation of this study as with many other RCT's of environmental interventions, is the difficulty of the exercise to completely blind participants and research personnel because of the nature of the intervention. However, in this study separate groups of intervention implementers and data collectors were used to reduce observer bias. The study was also limited by its short duration (two months) which did not account for seasonal effects.

3.14 Ethical considerations

Ethical approval to conduct the study was given by the local Ethical Review Committee at the Medical Research Council of Zimbabwe and the Higher Degrees Senate Research Committee at the University of the Western Cape, where the study was registered. Authorisation to conduct the study in Hatcliffe was obtained from the City of Harare Health Department and local leadership in Hatcliffe. Participation was voluntary. A participant information sheet (Appendix 1) formulated in English and then translated into Shona, the local language of the community and containing general information regarding the nature of the study, the study objectives, benefits and risks was administered and explained to the community leadership and participants. The research team also explained that two different cups were to be tested to see which one was more effective in minimising bacteriological contamination of drinking water stored in buckets. Written consent (Appendix 2) was obtained from an adult (aged 18 years or older), preferably the resident primarily responsible for drinking water collection and management in each household.

No incidences of harm or intimidation towards participants were observed or reported during the conduction of the study. However, the time required for participants to complete the questionnaire, was regarded as a risk factor. In order to minimise this possible risk, the questionnaires were very brief but in line with the research objectives. In addition, water sampling and interviews were conducted simultaneously per household visited. All participants freely expressed their willingness to participate. The identity of participants was kept confidential and codes rather than names or house numbers were assigned to each household during data processing and analysis. Completed questionnaires were safely guarded in the field by storing them in a portable lockable cabinet (for field use) under the custody of the researcher. These questionnaires were transferred into lockers where only the researcher had access.

3.15 Dissemination of results

The summarised study findings and recommendations will be shared with the Hatcliffe health office that the community and other concerned partners working on the water supply, sanitation and hygiene program. A summary of the final document will also be shared with the Harare City Health office, Ministry of Health and Child Care office and the Medical Research Council of Zimbabwe.

4 CHAPTER FOUR: RESULTS

4.1 Study Population and Socio-demographic characteristics

4.1.1 Recruitment, enrolment, withdrawals and completion

At the commencement of the study (May 2016), 238 households with a total of 1254 persons were enrolled and interviewed after obtaining informed consents (Figure 6). Household demographics are shown in tables 1 and 2. Of the 1254 persons enrolled into the study, 48.8% (612/1254) were in the intervention group while 51.2% (642/1254) were in the control group. The intervention and control groups were each allocated 119 (50%) households in a 1:1 ratio. Hatcliffe study communities were randomised on May 4 2016, and the LHM cup distributions took place for the 119 households randomised into the intervention group from May 5 – 11, 2016.

During the intervention period of the study (May – July 2016), eight households (3.4%), all from the intervention group, were lost to follow-up. Although this loss to follow-up was significant (p = 0.003), the proportion of households that completed the study did not differ significantly by study group (93.3% intervention group versus 100% control group, p = 0.456). In total, the overall complete follow-up for those initially enrolled was 96.6 percent. Females (96%) constituted the majority of the respondents recruited for the study (Figure 5).

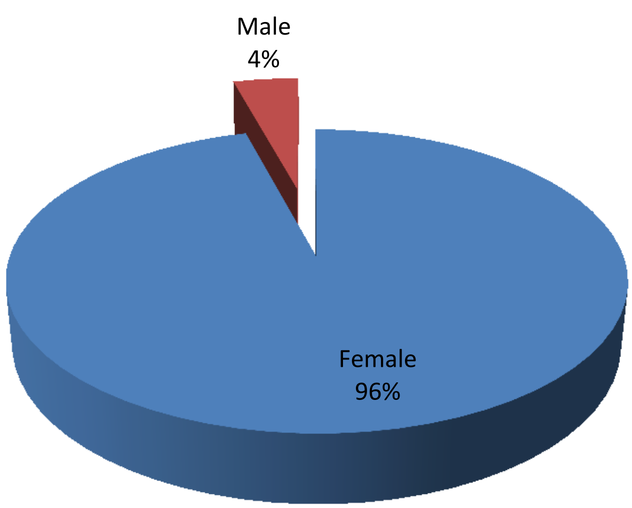

Figure 5: Sex of Respondents

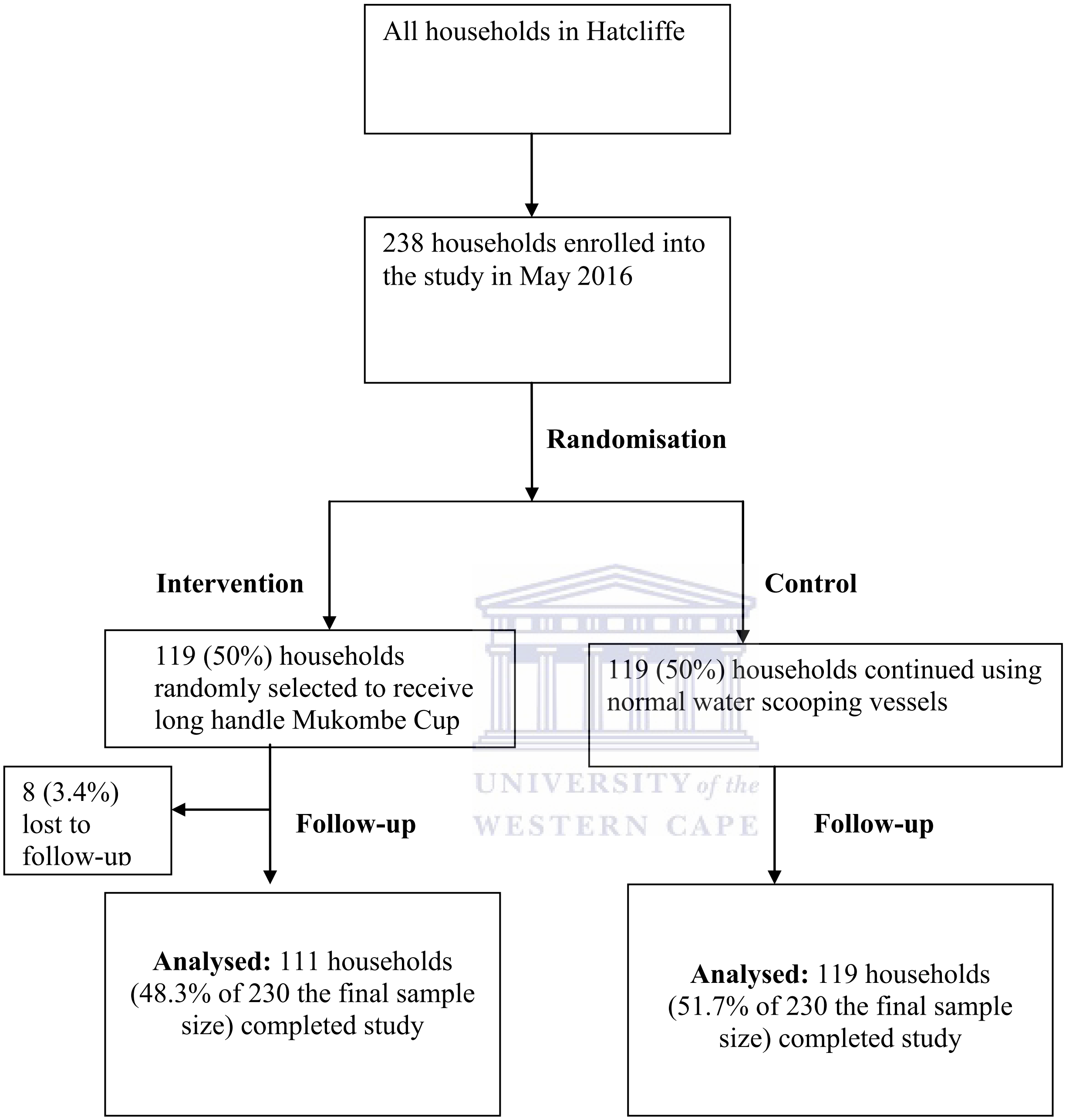

Figure 6: Recruitment process flow diagram

4.2 Socio-demographic characteristics

Socio-economic variables of the study participants interviewed (Table 2), showed that the majority of the respondents recruited for the study were females, 95% (113/119) in intervention group and 96.6% (1015/119) in control group), with the rest being males. Statistically, intervention and control groups were similar in terms of socio-demographic characteristics.

Table 2: Demographic and socio-economic characteristics of intervention and control households in Hatcliffe

Variables	Category	Intervention N (%)	Control N (%)	P-value
Age	< 20 years	2(1.7)	3(2.5)	0.651
	20 - 29 years	33(27.7)	27(22.7)	0.417
	30 - 39 years	43(36.1)	32(26.9)	0.171
	40 - 49 years	28(23.5)	29(24.4)	1.000
	50 - 59 years	5(4.2)	21(17.6)	0.002
	60 - 69 years	7(5.9)	5(4.2)	0.516
	> 69 years	1(0.8)	2(1.7)	0.561
Recruited Households population	Total population	612(48.8)	642 (51.2)	0.777
	Children ≤ 5 years	130(50.1)	126(49.9)	1.000
	Children 6 - 10 years	101(52.6)	91(47.4)	0.396
	Children 11- 18 years	96(47.3)	107(52.7)	0.396
	Adults ≥ 18	285(47.3)	318(52.7)	0.396
Level of education	Never went to school	3(2.5)	12(10.1)	0.045
	Primary	24(20.2)	27(22.7)	0.606
	Secondary (up to A' levels)	90(75.6)	78(65.5)	0.119
	Tertiary level	2(1.7)	2(1.7)	1.000

The mean age of household respondents was 33.7 years (range 18 – 73). The two groups did not significantly differ in age of participants for the below 20 years ($p = 0.651$), 20-29 years ($p = 0.417$), 30-39 years ($p = 0.171$), 60-69 years ($p = 0.516$) and older than 69 years ($p = 5.61$). Both groups had similar number of participants in the 40-49 years age group ($p = 1.000$). However, there was a significant statistical difference between the two groups in age of participants for the 50-59 years age group ($p = 0.002$).

The family size ranged between 2−13 people per household with a mean of 5.3 people, including one median child below the age of five years (range 1- 4) living in each household. The two groups did not differ significantly in their highest level of education attained. The majority of participants interviewed in both groups reported that they had some formal education and were literate, (eighty seven percent of the respondents (97.5% (116/119) in intervention group versus 89.9% (107/119) in control group). Among these, 77.3% (92/119) in intervention group and 67.2% (80/119) in control group had studied beyond primary school education level. Of the 6.3% (15/238) that had indicated not having had any formal education, 53.3% (8/15) however, indicated they were literate (defined as ability to read and write).

4.3 Water, sanitation and hygiene practices

Intervention and control group characteristics regarding water, sanitation and hygiene practices are presented in Table 3. The two groups were not significantly different in their type of main drinking water sources. The water sources in the study area were public taps and public boreholes (Appendices 4 and 5). The frequency of use of public taps at the time of the interview was 89.1% in the intervention group versus 98.9% in the control group ($p = 0.818$), while that of the borehole was 10.9% in the intervention group versus 10.1% in the control group ($p = 0.470$), differences that were not statistically significant ($p > 0.05$). Distances travelled to water source were not significantly different between the two groups in both the "less than 100 metres" ($p = 0.06$) and the "100 – 500 metres" ($p = 0.253$) categories. However, the two groups differed significantly in the "> 500metres" category ($p = 0.001$).

The two groups were statistically different in the type of sanitation used and in distance from household of the toilet facility they use. Pour flush toilets were the most common type of sanitation type used in both groups, 69.7% and 100% in the intervention and control groups, respectively (p = 0.001). Other type of toilet used by the remaining 30.3% households in the intervention group was the pit latrine (p = 0.001).

Table 3: Water, sanitation and hygiene practices comparison of intervention and control households in Hatcliffe

Variables	**Category**	**Intervention N (%)**	**Control N (%)**	**p-values**
Water Source				
Drinking water source	Borehole	14(10.9)	12(10.1)	0.470
	Public tap	105(89.1)	107(89.9)	0.818
Distance of water source from house	< 100 metres	45(37.8)	61(51.3)	0.064
	100 - 500 metres	46(38.7)	56 (47.1)	0.253
	> 500 metres	28(23.5)	2(1.7)	**<0.001**
Sanitation				
Sanitation type	Pit Toilet	36(30.3)	0(0.00)	**<0.001**
	Pour /Flush toilet	83(69.7)	119(100)	**<0.001**
Where toilet is located	Inside the house	55(46.2)	118(99.2)	**<0.001**
	< 50m outside house	64 (53.8)	1(0.8)	**<0.001**
Sharing Toilet	Yes	61(51.3)	52(43.7)	0.322
	No	58(48.7)	67(56.3)	0.322
Hygiene practices				
Always wash hands:	after using the toilet	69(58.3)	50(41.7)	**0.016**
	after waking up in the morning	62(52.1)	57(47.9)	0.572
	after changing baby's nap	119(100)	119(100)	1.000
	before feeding the baby	101(51)	97(49)	0.777
	before eating your meal	119(100)	119(100)	1.000
	before preparing food	93(46.3)	107(56.7)	0.120

All of the households in both groups reported having their own sanitation facilities, located either in the house (46.2% in the intervention group versus 99.2% in the control group) or outside the house, but within their property (53.8% in the intervention group versus 0.8% in the control group), differences that were statistically significant ($p < 0.05$). There were no significant differences between the two groups for those that reported sharing their toilet as well as for those that did not.

In the study area all residents interviewed confirmed use of plastic buckets with lids for drinking water collection and storage in the home. All the interviewed participants reported on washing their hands with soap after using the toilet, soon after waking up in the morning, after changing a baby's nappies and before eating a meal. Hand washing after using the toilet, and before eating a meal (100% in both groups ($p = 1.000$)) were the most common hygiene practices. Most of the respondents also informed that they always wash their hands before feeding the baby (84.8% in the intervention group versus 82.4% in the control group ($p = 0.777$)). About 52% in the intervention group versus 57% in the control group ($p = 0.572$) reported always washing their hands soon after waking up every morning, while 46.3% (55/119) in the intervention group versus 56.7% (68/119) in the control group ($p = 0.120$) claimed to always wash their hands before any food preparations.

4.4 Water Quality Results

4.4.1 Water sources and water quality

The physico-chemical and microbiological results of the drinking water sources presented in Table 4 involved measurement of the following physico-chemical parameters: temperature, pH, electrical conductivity and turbidity. Temperature and electrical conductivity both do not have WHO recommended health based values (WHO, 2008). Water from the public water distribution taps and public boreholes in both groups met the recommended WHO drinking water value (and ranges) for turbidity (of < 5 nephelometric turbidity units (NTUs)) and of no detectable bacterial colonies (zero *E. coli*). Water samples from public water distribution taps and public boreholes showed no significant differences in total coliforms, *E. coli*, Temperature and pH between the two groups. The temperatures of public boreholes and public water distribution taps water samples ranged from 21.7°C to 23°C (mean 22.4°C). The pH for all water sources ranged from 7.03 to 7.11 (mean 7.07) and was within the recommended range of between 6.5-8.5 for drinking water. Conductivity for all the samples was below 20. There is no health effect linked to drinking water with high conductivity levels but, at 335µS/cm (500 mg/L of TDS)[4].

Table 4: The mean baseline water quality characteristics in intervention and control group s for different water sources

Parameter	Intervention		Control	
	Public Borehole	Public Tap	Public Borehole	Public Tap
pH	7.09	7.11	7.03	7.05
Temperature in °C	22.6	23	22.3	21.7
Electrical Conductivity in µS/cm	19	4	4	6
Turbidity in NTU	0.2	0	0	0
Total coliforms cfu/100ml	0	0	0	0
***E. coli* cfu/100ml**	0	0	0	0

WHO guidelines: - pH – 6.5-8.5 Conductivity – No normal range/value
Turbidity – 1-5NTU Temperature – No WHO normal range/value

4.5 Intervention Follow-up Household Drinking Water quality comparisons

4.5.1 LHM cup Microbiological Effectiveness

The bacteriological performance of the intervention was assessed based on their capacity to reduce recontamination of stored drinking water in wide-mouthed containers with lids. Stored water quality showed some marked differences between the intervention and control groups. The prevalence of *E. coli* in water samples from the control household storage containers was

[4] Total Dissolved Substances (TDS or ppm) = Electrical Conductivity (µS/cm).

higher (47.1% (56/119) than in intervention household containers (21.6% (24/111). The quality of stored drinking water was significantly better in the intervention group households than in the control group households ($p < 0.001$). Table 5 presents the percentage of stored drinking water samples examined that fall into the various WHO risk categories for faecal contamination.

Overall, 78.4% (87/111) of intervention group water samples and 52.1% (62/119) of control group water samples yielded plates that had zero colony forming units (cfu)/100ml. All these plates met the WHO guidelines for zero cfu/100ml. Conversely, 26.9% (32/119) of samples from control households had 101-1000 cfu/100 ml compared to 5.4% (6/111) of samples from intervention households ($p < 0.001$).

Table 5: Classification of water samples based on levels of *E. coli* at follow-up testing

Risk Classification	Range (cfu per 100ml)	Intervention N (%)	Control N (%)	p-value
Good (In compliance)	0	87(78.4)	62(52.1)	**<0.001**
Low Risk	1 – 10	18(16.2)	24(20.2)	0.462
Intermediate Risk	10 – 100	6(5.4)	32(26.9)	**<0.001**
High Risk	100 – 1000	0 (0.0)	1(0.8)	0.316
Very High Risk	>1000	0 (0.0)	0 (0.0)	……….
Total		111	119	

The *E. coli* counts in water samples from the two groups were categorised into those containing <100 *E. coli* colonies per 100 ml and those ≥100 *E. coli* colonies per 100 ml sample (Table 5). The intervention group had a greater proportion of samples that contained <100 *E. coli* per 100 ml sample than the control ($p = 0.001$). Water quality in the intervention group was significantly better than in the control group, even when stratifying by level of faecal contamination (<100 or ≥100 *E. coli* per 100 ml) at point of use.

It is clear from the information given (Table 6) that a large proportion of those households that were using the LHM cup to scoop water from wide-mouthed containers, 94.6%(105/111), were in compliance with WHO recommended values of safe water or presented low risk of ingesting water contaminated with pathogenic microorganisms of faecal origin. Statistically there was a significantly higher risk of faecal contamination of drinking water stored in wide-mouthed containers by households in the control group(27.7% (33/119)) than those in the intervention group ($p = 0.001$).

No intervention group or control group samples were higher than 1000cfu/100ml. The differences between the intervention group and the control group were statistically significant, and there was also a statistically significant association between LHM cup use and reduced *E. coli* bacterial contamination in stored drinking water ($p < 0.05$).

Table 6: Comparison of risk levels between intervention and control groups at follow-up

Risk differences	Intervention	Control	p -value
Less Risk (0 – 100)	105(94.6)	86(72.3)	0.001
More Risk (≥ 101)	6(5.4)	33(27.7)	
Total	111	119	

Turbidity

During the follow-up phase, which was conducted two months from the time the participants received the LHM cups, stored drinking water samples from both the LHM cup intervention and control had similar mean water turbidities: 0.02 and 0.00 nephelometric turbidity units (NTU), respectively, ($p = 0.071$) and range (0 – 1.00).

Observations

The main observation was the practice of households hiring water vendors to collect water on their behalf. For 'easier and more comfortable' transportation, vendors used wheel burrows and carts. Empty containers were transported stacked together (Figure 7).

Figure 7: Water vendors' water transportation system

Acceptability

The acceptability of the technology was evaluated through a follow-up household survey (Table 7). Interviews were carried out with representatives of 111 households who remained in the project at follow-up. The LHM cup intervention achieved high uptake during the two months study period. Among 110 households using the LHM cups, nearly all households (99%(110/111)) reported exclusively using the cup provided to scoop water from their wide-mouthed drinking water storage containers with lids into drinking cups and other point of use vessels such as cooking pots. One household (1%) indicated it seldom used the cup; as the mother had it locked up for safe keeping.

When questioned why the LHM cup was used in this manner, nearly all participants agreed that the LHM cup usage prevented hands from getting into direct contact with stored drinking water. It also ensured that stored drinking water had much less risk of any physical and bacteriological contamination.

Table 7: Acceptability data summary for households in the intervention group at follow-up

	Question	Answers by % of respondents
1	**How often is the LHM cup currently being used?**	Always 100% Sometimes 1%
2	**Would you recommend the cup to a friend?**	Yes 100%
3	**If you lost the LHM cup would you want to buy another one?**	Yes 100%
4	**What is it that you liked about the LHM cup?**	Long handle 100% Prevents hand contact with stored water 100%
5	**How could the cup be changed to make it more user friendly?**	Ok as it is 71.2% Suggested some changes for improvements 28.9%
6	**Where is the LHM cup stored?**	Hung on the wall On top of the drinking water storage container In some other place including inside drawer

Results therefore indicate that residents have accepted the LHM cup and believe that it provides them with better and safer method of extracting water for drinking from wide-mouthed storage vessels. Children were cited as the main culprits in recontamination by hand contact of drinking water stored in containers where the method of extraction is by dipping a vessel. In addition, when asked if they would recommend the cup to a friend, 100% of the 111 households responded positively. All participants (100%) also indicated buying an additional cup upon completion of the study, in order to have an extra cup in stock for further use, despite the fact that the price of the cup had not been established at that point.

Regarding improvements to the cup, 71.2% (79/111) were satisfied with the cup as is. Approximately 29% (32/111) were for change. According to participants, the material the cup is made of should be changed to plastic as the cup in its current state is fragile and susceptible to easy damage particularly when the cup hits against a harder surface.

In general, 111 interviewees in all 111 households (100%) involved in the project were satisfied with the LHM cup and indicated they would carry on using this technology (100%). The product was even introduced to relatives and other people participants came into contact with.

5 CHAPTER FIVE: DISCUSSION

5.1 Introduction

This study constitute the first randomised controlled trial of a locally designed and produced ladle, the LHM cup, for scooping water from wide-mouthed storage containers in the home. This study is also the first to determine the effectiveness and user acceptability of the LHM cup in minimising microbial contamination of water stored in wide-mouthed containers within the home. This chapter attempts to explain and interpret the study findings with reference to other similar studies.

The discussion will therefore revolve around the two main findings of this study (given in Table 4) that: (i) *E. coli* counts in water samples from control group drinking water household containers were higher (almost twice as much at 47.1%) than that observed in the water samples from the intervention household containers (21.6%), (ii). the LHM cup intervention was very highly accepted by 100% of those who reported using the devise throughout the study period.

The discussion chapter has therefore been structured into the following sub titles: socio-demographic characteristics of respondents, effect of the LHM cup on stored household drinking water quality, water storage containers, sanitation and household drinking water handling practices and acceptability of the LHM cup intervention. Lastly, this chapter will present the limitations of this study.

5.2 Socio-demographic characteristics of respondents

As presented in the results (Figure 1), a total of 238 households participated in the study. The majority of the respondents were females (96%). 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 were women. The main explanation to this is that in most communities it is females who are mainly responsible for collection, transportation (Dismer, 2012) and management of drinking water in the home (Sharma et al., 2013).

The majority of the respondents in the study (93.2% in the intervention group and 94.1% in the control group) were less than 60 years old. The mean age of the respondents was 33.7 years. This was consistent with Lencha (2012) who in their study in Ethiopia had 91.9% of their respondents being younger than 60 years with mean age of 37.8%. The age group, 50-59 years old, was significantly different between the two groups (17.6% in the control group compared to 4.2% in the intervention group). The older people are generally less likely to adhere to safe drinking water handling and hygiene practices in the home.

Almost all respondents had gone through formal education (97.5% in intervention group versus 89.9% in the control group). There was a significant difference in the group with no formal education (10% in control group versus 3% in intervention group). Hatcliffe is a fast growing peri-urban high density suburb that has been offering new residential land to landless Zimbabweans including some who had been living in former white owned commercial farms. Access to formal education in farms has traditionally been low. The literacy rate of the community in this study was lower than the national figure of 96% and Harare's 99% (ZIMSTAT, 2013). Formal education empowers people through shaping their knowledge, attitudes, beliefs and practices. A literate female household head is more likely to understand health-related related issues including the need to consume safe water. It was found that hygiene 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. A community that has the majority of its households (80%) practicing improved sanitation and hygiene, is likely to have reduced diarrhoeal disease incidences (Strategy, 2006).

The family size ranged from 1-13 people per household with a mean of 5.3 people. The family sizes in Hatcliffe are generally bigger than the national average of 4.2 (ZIMSTAT, 2014). Larger households are more often prone to contaminated stored drinking water in the home. Many studies have established that the greater the number of people in a household, the greater the levels of *E. coli* contamination found in the water samples (Teixeira and Heller, 2006).

Eight households, all from the intervention group, withdrew from the study after intervention delivery. In all cases the decision to withdraw came from the head of the household, a demonstration of the authority of the household head in decision making.

5.3 Effect of the LHM cup on stored household drinking water quality

The study demonstrated that a novel LHM cup intervention was effective in preventing chances of contamination of drinking water stored in wide-mouthed containers in the home and was therefore protected against faecal contamination. The LHM cups were also associated with reducing bacteriological contamination of stored drinking water that was safe at point of supply. The LHM cup completely protected stored water from any *E. coli* contamination in approximately 78% of the water samples in the intervention group and 52% in the control group. These findings were consistent with those of other researchers (Tambekar et al., 2011; Thomson et al., 2003) which found that using dippers with long handles for withdrawal of stored water prevents transmission of contaminants into stored water. In their study to determine drinking water quality deterioration in households of students with high illness absenteeism in India, Tambekar et al. (2011) established that using a long handled dipper had a 100% protective effect against contamination during storage. All (100%) water samples from wide-mouthed containers where long handled cups were used, remained potable.

Drinking water quality based on *E. coli* counts was better for LHM cup households than for control households. The implication of the LHM cup intervention as observed in the study, is that covering the wide-mouthed container and LHM cup plus health education intervention has generally the same protective effect of the drinking water quality in homes as that of narrow-mouthed containers with lids (Zin et al., 2013). Elsewhere, narrow-mouthed water storage containers and some modified large mouthed containers with a spigot (CDC, 2011) have been shown to protect stored drinking water from contamination through contact with dirty hands (Psutka et al., 2011). CDC Safe Water Systems recommends use of water storage containers with a small opening or any other plastic or ceramic container where dispensing of the water prevents dipping of a container to minimize contact with hands (CDC, 2011). These CDC recommended containers which are all modified products of either jerry cans or wide-mouthed buckets are not widely available in many countries including Zimbabwe. Instead, buckets with lid and no tap are the more widely used in many countries for water transportation and storage (CDC, 2011).

It is worth noting that, although the LHM cups were effective in protecting household drinking water stored in wide-mouthed containers from microbial contamination in both study groups, ongoing contamination continued, even though, even though the intervention group had a means to prevent hand water contact and the control had better sanitation. This suggests that some other factors other than the LHM intervention were likely introducing faecal contamination into the stored drinking water. Several factors could explain this observation. Firstly, the presence of *E. coli* in intervention water samples (although low (<100cfu/100ml sample) posing moderate to low risk) may be an indicator that there is on-going contamination, which might be attributable to the LHM cup itself becoming contaminated during storage. One possible risk factor is that of the cup being accessible to young children who, in attempting to use it, may touch the bowl part with contaminated hands. Secondly, the contamination may be due to hygiene related factors.

Lastly, lack of education of users may expose the cup to other environmental linked risk factors. Cleaning the cup by wiping with a cloth is a risk factor that may result in transfer of pathogenic bacteria from the cloth to the cup. It was also speculated that the older, less educated population in the control group may be less likely to implement recommended water handling practices in their homes.

5.4 Water Storage containers

Clean safe water is contaminated when poured into dirty containers. The implication of the presence of *E. coli* counts in both groups of the study, though in reduced amounts, as observed in this study, is therefore that drinking water from the safe sources was most likely contaminated when it was poured into dirty already contaminated containers. Other likely sources of contamination could be when removing the lid or closing the container. Keeping the wide-mouthed buckets covered all the time when not in use, is to some extent capable of protecting or minimizing any new contamination into the household stored drinking water. That is if these containers are appropriately cleaned with soap or ash and thoroughly rinsed using clean water before it is filled with safe drinking water and appropriate hygiene practices are adhered to. This is in line with Trevett et al., (2004) who observed that the type of water storage container was not a major determinant of the contamination levels of stored water. From the study it was concluded that contamination was a result of behavioural patterns.

The distance travelled to fetch water, the intermittent water supplies, the troubles associated with traveling and queuing long hours at water sources, are factors which force households to collect and store drinking water in large quantities. Long storage times are a risk factor for bacteriological contamination. The types of storage vessel and storage period are key determinants of the level of microbiological contamination of the water (Subbaraman et al., 2013). This is confirmed by Onigbogi and Ogunyemi, (2014), who reported high association between microbiological contamination and wide-mouthed storage vessels, and Shwe, (2010), cited in Packiyam et al., (2016) who reported that storing water for long hours is a risk factor for contamination of even otherwise good quality water.

Longer storage time allow stored water more exposure time for faecal contamination. 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. Even the narrow-mouthed storage containers, despite the high positive reports in many studies of their protective ability to faecal contamination as compared to wide-mouthed containers, are rendered inappropriate for storing water for long time. 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). Algal growth in small mouthed plastic containers was observed in some homes during door to door household visits. 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).

While most documented studies have referred to 'wide-mouthed storage containers' without specifying whether they had a cover (lid) or not, the current study displayed different results in that the study community involved all used bucket with lids. Covering stored water has a protective effect on the quality of the water. An association between buckets with lids and the LHM cup studied over a longer time than the two months of follow-up has great potential to be as protective in minimizing microbial contamination as probably narrow-mouthed containers. Hygiene practices are fundamental particularly with the wide-mouthed containers.

5.5 Sanitation and Household Drinking water handling practices

Our review of the literature suggested that using containers that were not thoroughly clean to store drinking water in the home (Pickering, 2015), other factors such as sanitation (Oswald, 2007; WHO, 2015; Hutton and Chase, 2016), drinking water handling and safe storage practices (Sarsan, 2013; WHO, 2015), and unsafe storage of water dispensing vessels (Rufener et al., 2010) are other possible routes of contamination. It was possible that these factors could have contributed to the contamination observed within the current study.

With a good quality water source free of any *E. coli* cfu/100ml sample, as was found in most cases in this study, it is expected that there would be a higher protective effect of faecal contamination of stored drinking water in wide-mouthed containers with lids. If the *E. coli* levels found in stored water are not from the public borehole or tap, then it could be related to the hygiene of the water storage container. The explanation could be that buckets were not cleaned adequately with soap before water collection. The study protocol did not however include observations on how community members cleaned the buckets. The practice of households hiring water vendors to collect water for them could introduce a risk, together with the practices of carrying the buckets as noted in Figure 7 of the results. Water vendors could be more likely not to clean the buckets before refilling as the exercise may be time consuming a factor, which impacts negatively on their business of supplying water for money as requested by the customer. In this instance, water quality issues are likely to be secondary.

The number of people per household could be another reason why some intervention households had contaminated water. Due to manpower and time constraints, this study lacked the capability to investigate this. Eschol et al. (2009) in India, showed that the larger the number of people in a household consuming water stored in a wide-mouthed container, the greater the *E. coli* concentration levels. The study reported incidents of children in the under five years age group who were linked to the contamination of drinking water stored in wide-mouthed drinking water storage containers by dipping their hands during water scooping. This was a very common problem as reported by households who indicated the inability to control the access of children to drinking water containers and the fact that they scoop water by themselves with unclean hands.

Most households, particularly in the intervention group, reported instances of children, particularly under five years, failing to judge appropriately the level of stored water in buckets and dipping cups too deep resulting in their hands (usually dirty) coming into direct contact with the water. This finding is consistent with that documented by Jensen et al. (2004) who presented higher chances of water contamination where children take water themselves after playing without washing their 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.

The type of public taps located within the intervention group could have further contributed to water contamination as its mechanism of action led to the user's hand getting wet and water dripping from the hand into the bucket. This means that a holistic intervention in this community would need to include attention to water source infrastructure.

5.6 Acceptability of the intervention

In the follow-up survey, LHM cup users valued the technology as easy to use and appropriate, as it fitted very well into the lifestyles of participants without making substantial changes to the household's water use, storage and hygiene practices. This was in line with the definition of appropriate technology. The study results show very high user compliance, which is a key factor in attaining health benefits from water sanitation and hygiene interventions (Brown and Sobey, 2012). The implication of the high compliance with the LHM cup intervention as observed in the study, was that the users had incorporated it into their lifestyles as an appropriate technology. It allowed for the desire to transform current practices of storing drinking water handling behaviour into practical action, an important feature that qualifies the LHM cup as an appropriate technology.

Also in compliance with AT acceptability and adoption criteria, indicating acceptability and adoption of the LHM cup, the cup did not depend on any intensive household level promotion (Pickering et al., 2015). It instead depended on the initial acceptance by the household head, appropriateness to meet household's needs, perceived benefits (Tharakan, 2010) and its successful performance (Pickering et al., 2015).

As mentioned, the incorporation and use of the LHM cup had an intuitive amongst participants that it prevented hands coming in contact with stored water thus protecting households from diarrhoeal diseases. Users also preferred the intervention for aesthetic reasons. The LHM cup was accepted in homes like any other household utensils as it could be easily cleaned and used for the purpose of hygienically drawing drinking water stored in wide-mouthed containers in the homes. This was supported by the high level of users' likelihood to recommend it to other people, a feat which many reported to have already done during intervention period. This also implies that the LHM cup was an acceptable choice of option available for hygienically drawing water from wide-mouthed containers in the homes.

Overall, the intervention was well accepted by the community of Hatcliffe in Harare, who incorporated it into their safe drinking water management practices and expressed an intention to continue using it after the study period this despite the missing issues on accessibility. Accessibility is a key factor considered for acceptability. The cost of the LHM cup was not disclosed as it was important to first evaluate the effectiveness and acceptability of the intervention in minimising contamination of drinking water stored in wide-mouthed containers with lids in the homes. During the course of the study the LHM cup was not yet available on the market in Zimbabwe.

It has been established that the retail cost per cup would unlikely be more than that of a plastic bucket with a lid. The current mean cost of a plastic bucket with a lid is US$3. This will be generally affordable to the majority, where despite the socio-economic challenges in the country since 2000, the number of cell phones per 100 people has exploded exponentially, particularly in urban areas, thus indicating the affordability of the cup.

5.7 Validity

Validity, one of the key measures of rigour in scientific research, is defined as the extent to which a concept is accurately measured in a quantitative study (Heale and Twycross, 2015). In this study, face validity (degree an instrument measures what it is supposed to test) and content validity (items making up an instrument adequately capture key content that defines the variable being measured) were employed to develop the data capturing tools that were used. Criterion validity was not applicable as there was no gold standard tool in use.

Face validity: Face validity was ensured through a process that involved the core research team, community representatives and other experts' knowledge and experiences in these health surveys. Water testing equipment and data collection tools were pretested before wider application as part of validation exercise. Appropriate modifications were done in accordance with the findings of the pre-test. All members of the research team were trained in a pilot study on practical application of data collection tools. Formal feedback meetings to validate the tools ensured the tools would collect exact data they were designed for.

Content validity: Content validity was guaranteed through extensive review of similar previous studies and research reports in addition to engaging core research teams and experienced experts who assisted with definitions of some terms and their appropriate applications in this study.

The fact that the surveys were conducted during the day when some people were not at home did not bring any strong sample bias as it was anticipated that there was little difference with respect to key variables. The use of the LHM cup and hygiene practices showed no differences between the employed and unemployed. Zimbabwe, according to the 2012 population census report has a high literacy rate of 96%, with Harare at 99%. Furthermore, those of the population that are employed are mostly in the informal sector – a sector that stretches from backdoor offices in the backyard of houses to better organised structures in the city. And this also seems to suggest that the socio-economic gap between the employed and unemployed including behaviour in Hatcliffe.

5.8 Reliability

Heale and Twycross (2015) define reliability as the level to which a research instrument consistently produce the same results when used in a similar situation on repeated occasions. It is a measure of the accuracy or dependability of the instrument to give similar results in different but similar environments. All questionnaires were prepared in both English and Shona prior to use in the research. These questionnaires were pre-tested through back-translation from Shona to English and used in a practical data collection exercise (pilot) to establish suitability of content, structure and consistency. Data collectors were trained prior to and during the piloting of the study and data collection tools.

5.9 Generalisation

Findings from this study are likely to be generalisable to the other communities who live in similar socio-economic conditions with poor access to water and sanitation, who have a similar cultural awareness of the LHM cup and used wide mouth storage container with a lid in the home.

5.10 Limitations

The major limitation with this study and with many other RCTs of environmental interventions is the difficulty to completely blind participants and research personnel because of the nature of the intervention. However, in this study separate groups of intervention implementers and data collectors were used to reduce observer bias. The study was also limited by its short duration (2 months), which did not account for seasonal effects.

6 CHAPTER SIX: CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The results presented in this study show that the quality of stored drinking water was significantly better in water storage buckets where the LHM cup was used as the only vessel for extracting the water (the intervention group households) than it was in the water storage buckets where the short handled cups and others without handles (the control group households) were used.

In terms of structural design, the LHM cup is made of appropriate material, has an appropriate handle length of 28cm, a cup bowl and user friendly. In other words, the LHM cup is suitable to minimise microbial contamination of water stored in wide-mouthed containers with lids at household level. The LHM cup has potential to be a valuable addition to the suite of hygiene enabling technologies for household drinking water interventions and is a worthy investment. It is also relevant for implementation in Zimbabwe, and any other communities that store drinking water at household level in wide-mouthed containers where extraction is by scooping (using short handled cup).

The results achieved from microbiological water tests in the laboratory proved that the LHM cup, even as it was used alone without any point of use water treatment system, markedly protected the drinking water in wide-mouthed storage containers from being microbiologically contaminated. The use of the LHM cup in households in Hatcliffe displayed significantly lower *E. coli* concentrations in stored household drinking water in intervention households compared with control households during the 2-month intervention period.

The LHM cups were highly accepted in the intervention community in Hatcliffe, not only by the 111 households that took part in the project but also by other households when they observed the technology in use. LHM cup ensured that drinking water stored in buckets remained uncontaminated primarily by preventing hands from getting into the water during scooping. This household based drinking water transferring tool as it was embraced was also added into their suite of household safe drinking water storage and handling practices. The protective effect of the LHM cup, its use and acceptability by the target population is an indicator of the potential positive impact on people's health.

In conclusion, there is the potential to explore options to distribute the LHM cup more widely as a successful household based hygiene enabling vessel for scooping drinking water from wide-mouthed drinking water storage containers, although it still requires to undergo some structural improvements.

6.2 Recommendations

6.2.1 Health Benefits studies

This study's findings suggest that the LHM cups are a promising cost effective hygiene enabling water transfer tool for use at household level where drinking water is stored in the home in wide-mouthed containers with lids and extracted by dipping a vessel that merits further research. Efforts should be undertaken to build on this evidence and evaluate long-term impact on drinking water quality and human health to inform users, hygiene project implementers and policy makers in Zimbabwe.

Epidemiologic research is also required to determine perceived health benefits at household and community level and the role the LHM cup technology can play to improve the association with diarrhoea reduction. The study can be designed to include a disease outcome such as diarrhoea to measure the actual health benefits of the LHM cup intervention. An example of such a study would be a randomised controlled trial to assess the efficacy of this hygiene enabling LHM cup technology in preventing diarrhoeal diseases particularly among young children.

Other technologies or strategies could be designed to also measure as part of a study, other significant associations observed with water, sanitation, and hygiene related factors such as hand washing, education, and general household health after adjusting for the presence of the intervention.

6.2.2 Actions to improve the technical design based on the pilot

The technology designers and manufacturers are advised to consider the various recommendations from the users to implement technical recommendations on further improvements of the LHM cup including further laboratory based Research and Development.

6.2.3 Assessing performance and sustainability

Since this study is the first field study of the NIHR designed LHM cup, more research is recommended to describe its performance and sustainability. The time for this study was too short to allow for education and periodic follow-up and a longer period of study focusing on seasonal trends would also be required to assess the longevity of the LHM cup and ensure their durability beyond the two months follow-up period in this research.

6.2.4 The use of the wide-mouthed storage containers with lids

A further research study using a safe storage container in form of a bucket with a lid, household water purification and the LHM cup is recommended as a simple, affordable and easily disseminated method to help improve the quality of drinking water consumed in homes. One of the most promoted materials during the 2008-2009 cholera epidemic in Zimbabwe that affected 55 of the 62 districts of the country, causing an estimated 100,000 reported cases and 4,300 deaths is the bucket with a lid. The LHM cup technology dovetails with the widely existing wide-mouthed storage containers with lid that are now used throughout the Zimbabwe in communities that collect and store drinking water in the home. Should this future study show that the intervention prevented or greatly reduced recontamination of drinking water stored in buckets with lids where extraction of the water is by dipping a vessel, then the LHM cup would be shown to be a reliable and appropriate technology.

6.2.5 Point of Use Water Treatment for study population

The high levels of contamination of water stored in wide-mouthed containers where extraction is by dipping a short handled vessel, even when source water is free of any contamination, is a cause for concern. It is recommended that the Harare City Health Department assist in the mobilisation of resources for a household water treatment and safe storage project in Hatcliffe. Whilst safe drinking water storage training remains the main focus for improved drinking water handling practices and associated health, hygiene enabling technologies and sanitation issues have an important role to play not only in sustaining the benefits of a water sanitation and hygiene programme, but also to protect the uninfected.

6.2.6 Affordability and Marketing of the LHM cup

In the follow-up interviews, most households indicated the willingness to purchase replacement LHM cups. This can only be possible if the cups are commercially produced and marketed which could make it accessible to everyone.

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APPENDICES

Appendix 1: Information Sheet

UNIVERSITY OF THE WESTERN CAPE

Private Bag X 17, Bellville 7535, South Africa

Tel: +27 21-959 2809 Fax: 27 21-959 2872

E-mail:soph-comm@uwc.ac.za

INFORMATION SHEET

<u>Project Title</u>: **Drinking Water Quality and The Long handled mukombe cup: Acceptability and effectiveness in a peri-urban settlement in Zimbabwe**

What is this study about?

This is a research project being conducted by **JOHN MWENDA**, a student studying Masters in Public Health at the University of the Western Cape. You are being invited to participate in this study because your household is one of the many households in Hatcliffe who have no access to in-house piped drinking water, collect and store their drinking water in wide-mouthed containers with lids. The purpose of this research project is to assess the effectiveness and acceptability of a cup in reducing bacteriological contamination of drinking water stored in wide-mouthed vessels in the home.

What will I be asked to do if I agree to participate?

You will be asked to participate in a survey as one of the selected households and you will be asked to complete some questionnaire on your knowledge, attitudes and practices on water, sanitation and hygiene including on safe drinking water handling practices. Your household will be provided with one of the two cups free of charge that you will be asked to use to extract water from the drinking water storage bucket with a lid. Your household will be requested to dedicate the cup only for extracting drinking water from storage buckets with lid. You will be encouraged to use the cup daily from the date the project starts in as hygienic a manner as will be given by hygiene trainers. Research technicians will be visiting your household to collect water samples from your drinking water storage bucket for water quality analysis. You will also be asked on your household's experiences with the cup and any suggestions on how the cups can be improved to become more user friendly. Each interview will take about 20 minutes of your time.

Would my participation in this study be kept confidential?

We will do our best to keep your personal information confidential. To help protect your confidentiality, data that we will collect will not contain information that may personally identify you". We will not use any names on data forms. Identification codes will be used instead. Your household will be allocated a code which will be placed on the survey and other data collected. The researcher will be the only person able to link your data form to your identity and only the researcher will have access to the identification key. All data forms will be safely kept in lockable filing cabinets and storage areas where access is restricted. All data forms in the computer will protected through use of password-protected computer files. The information that will be gathered in this investigation will be used for research purposes only. If we write a report or article about this research project your identity will be protected as much as possible.

What are the risks of this research?

You may be uncomfortable with the researchers entering your household and asking some information that you may consider embarrassing or personal. We will nevertheless minimise such risks and act promptly to assist you if you experience any discomfort, psychological or otherwise during the process of your participation in this study. Where necessary, an appropriate referral will be made to a suitable professional for further assistance or intervention.

What are the benefits of this research?

The benefits of participating in this study is that your household will be provided with a cup for extracting drinking water free of charge and in addition more knowledge on the importance of safe drinking water management practices at household level. This research is not designed to help you personally, but the results may help the investigator learn more about the effectiveness and user acceptability of the cups used to transfer drinking water from wide-mouthed buckets with lids. We hope that, in the future, other people might benefit from this study through improved understanding of safe household management of drinking water stored in wide-mouthed containers with lids including extraction by dipping a container. No monetary incentive will be provided for taking part in the study.

Do I have to be in this research and may I stop participating at any time?

Your participation in this research is completely voluntary. You may choose not to take part at all. If you decide to participate in this research, you may stop participating at any time. If you decide not to participate in this study or if you stop participating at any time, you will not be penalized or lose any benefits to which you otherwise qualify.

What if I have questions?

This research is being conducted by **JOHN MWENDA** from the University of the Western Cape. If you have any questions about the research study itself, please contact John Mwenda at: the National Institute of Health Research, Corner Mazowe Street and Josiah Tongogara Avenue, P.O. Box CY573, Causeway, Harare. Cell: 0772 907 325.

Should you have any questions regarding this study and your rights as a research participant or if you wish to report any problems you have experienced related to the study, please contact:

Head of Department
Dean of the Faculty of Community and Health Sciences:
Prof Jose Frantz
University of the Western Cape
Private Bag X17
Bellville 7535
Email: chs-deansoffice@uwc.ac.za

Appendix 2: Consent Form

UNIVERSITY OF THE WESTERN CAPE
Private Bag X 17, Bellville 7535, South Africa
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CONSENT FORM

Title of Research Project: **Drinking Water Quality and The Long handled mukombe cup: Acceptability and effectiveness in a peri-urban settlement in Zimbabwe**

The study has been described to me in language that I understand. My questions about the study have been answered. I understand what my participation will involve and I agree to participate of my own choice and free will. I understand that my identity will not be disclosed to anyone. I understand that I may withdraw from the study at any time without giving a reason and without fear of negative consequences or loss of benefits.

Participant's name…...……………..

Participant's signature …………………………...

Date………………………...

Appendix 3: Baseline Questionnaire

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RESPICE PROSPICE

BASELINE QUESTIONNAIRE

Topic: Knowledge attitudes and practices on drinking water handling practices

INSTRUCTIONS: INDICATE YOUR RESPONSE WITH EITHER AN 'X' OR '√' IN THE APPROPRIATE BOX THAT BEST FITS YOUR ANSWER. YOU SHOULD ALSO FILL IN THE DOTTED

Demographic Data

1. Serial/Code number………………………………………….
2. Age of respondent in years ………………………………….
3. Date of Birth of the respondent……………………………….
4. Respondent's highest level of education completed:

No formal schooling	**1**
Pre- School	2
Primary school (Grade 1-7)	3
Secondary school (Form 1 – 4)	4
Advanced Level (Form 5 – 6)	5

Tertiary Level	6

5. How many people live in your household? (*mumhuri menyu muri kugara muri vangani?*)

children ≤ 5 years	**1**
children 6 -10 years	2
children 11-18 years	3
Adults > 18 years	4

Water Questions

6. What is your source of drinking water? (*Mvura yekunwa munoiwanepi?)*

Unprotected well	**1**
Protected well	2
Borehole	3
Public tap	4
Other	5

7. How far is the water source from your house? (*Kure zvakadii kubva pamba penyu?)*

Less than 100metres from household	**1**
Between 100 – 500 metres from household	2
Over 500m	3

Sanitation

8. What type of sanitation does your household use? (*Munoshandisa chimbuzi cherudz irwupi?)*

Pit toilet	**1**
Flush toilet	2

Pour flush toilet	3
None	4
Other (Specify)	5

9. Do you share the toilet with other households? (*Mune vamwe here vasiri vemhuri yenyu vanoshandisao chimbuzi chenyu?)*

Yes	1	
No	2	

10. Where is the toilet located? (*chimbuzi ichi chiri kupi?*)

In house	**1**
Less than 50m from household	2
Between 50 – 100 metres from household	3
Over 100mtres from nearest house	4

11. How often would you, or household member responsible, wash your hands with the following activities (*Ndedzipi nguva dzamunogeza kana dzinogeza maoko vemhuri yenyu?*)

a. Before preparing food

Never ☐ Seldom ☐ Sometimes ☐ Often ☐ Always ☐

b. After using a toilet

Never ☐ Seldom ☐ Sometimes ☐ Often ☐ Always ☐

c. After waking up in the morning

Never ☐ Seldom ☐ Sometimes ☐ Often ☐ Always ☐

d. After cleaning the baby's buttocks

Never ☐ Seldom ☐ Sometimes ☐ Often ☐ Always ☐

e. Before feeding the baby

Never ☐ Seldom ☐ Sometimes ☐ Often ☐ Always ☐

f. Before eating your meal

Never ☐ Seldom ☐ Sometimes ☐ Often ☐ Always ☐

Thank you very much for your participation

Appendix 4: Follow-up Questionnaire

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FOLLOW-UP QUESTIONNAIRE

Topic: Long handled mukombe cup effective use

INSTRUCTIONS: INDICATE YOUR RESPONSE WITH EITHER A 'X' OR '√' IN THE APPROPRIATE BOX THAT BEST FITS YOUR ANSWER. YOU SHOULD ALSO FILL IN THE DOTTED

1. Interviewee Code	
2. Sex	
3. Date	

4. How often is the long handled Mukombe cup currently being used per day (*Munoshandisa komichi yemukombe iyi zvakanyanya zvakadii pazuva?)*

Never ☐ Seldom ☐ Often ☐ Always ☐

5. Would you recommend the cup to a friend (*Mungakurudzire shamwari yenyu kuti iwaneo komichi iyi here?)*

Yes ☐ No ☐

6. If you lost this cup would you want to buy another? *(Kuri kuti marasikirwa nekomichi iyi mungade kutenga umwe here?)*

Yes ☐ No ☐

6 What is it that you like about the cup ? (*Chii chinokufadzai pakomichi iyi?)*

....

....

8. How could the cup be changed to make it more useful to you? (*Chii chamungakurudzira kuti chigadziriswe pakomichi iyi kuti ukushandirei zvirinani?)*

....

....

....

9. Storage (how is the cup being stored) (***Observed)***

....

....

....

1 of 1

Appendix 5: UWC Senate Research Committee Approval Letter

UNIVERSITY *of the* WESTERN CAPE

DEPARTMENT OF RESEARCH DEVELOPMENT

10 December 2015

To Whom It May Concern

I hereby certify that the Senate Research Committee of the University of the Western Cape approved the methodology and ethics of the following research project by: Mr J Mwenda (School of Public Health)

Research Project:	Drinking water quality and the long handled "Mukombe' cup: Acceptability and effectiveness in a peri-urban settlement in Zimbabwe.
Registration no:	15/7/13

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

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

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T: +27 21 959 2988/2948 . F: +27 21 959 3170
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A place of quality,
a place to grow, from hope
to action through knowledge

Appendix 6: Ministry of Health and Child Care Approval letter

Telephone: +263-4-798537-60
Telegraphic Address:
"MEDICUS", Harare
Fax: +263-4-729154/79363
(702293 FHP)
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22211ZW

ZIMBABWE

Ministry of Health and Child
Care
P O Box CY1122
Causeway
HARARE

Dr S L Mutambu

RE: <u>REQUEST FOR PERMISSION TO CONDUCT RESEARCH ON "DRINKING WATER AND THE LONG HANDLED "MUKOMBE" CUP: ACCEPTABILITY AND EFFECTIVENESS IN A PERI-URBAN SETTLEMENT IN ZIMBABWE</u>."

Your letter dated 1 February 2016 on the above subject matter refers.

The MOHCC has no objection to your request to conduct the above study, in line with good, ethical research practices and clearance from MRCZ.

Sincerely

SECRETARY FOR HEALTH & CHILD CARE
PRINCIPAL DIRECTOR
PREVENTIVE SERVICES
05 FEB 2016
CAUSEWAY

Dr G Mhlanga
<u>Principal Director,Preventive Services</u>
For Permanent Secretary

Appendix 7: Harare City Health Department Approval Letter

CITY OF HARARE

Director of Health Services

DR PROSPER CHONZI
MBChB, MPH,MBA

All correspondence to be addressed to the
DIRECTOR OF HEALTH SERVICES

Ref:--

Your Ref:--

DIRECTOR OF HEALTH SERVICES
Rowan Martin Building,
Civic Centre,
Pennefather Avenue,
off Rotten Row,
Harare, Zimbabwe.

P.O. Box 596
Telephone: 753326
753330/1/2
Fax: (263-4) 752093

25 February 2016

Dr Susan L Mutambu
Ministry of Health and Child Care
National Institute of Health Research
P O Box CY573
HARARE

Dear doctor

RE: REQUEST FOR PERMISSION TO CONDUCT RESEARCH ON "DRINKING WATER QUALITY AND THE LONG HANDLED "MUKOMBE" CUP: ACCEPTIBILITY AND EFFECTIVENESS IN A PERI-URBAN SETTLEMENT ZIMBABWE

I acknowledge receipt of your letter in connection with the above.

Permission has been granted for you to conduct a research on drinking water quality and the long ***handled "mukombe" cup: acceptability and effectiveness in a peri-urban settlement Zimbabwe".*** at Hatcliffe, Harare for the purpose of evaluating the cup with the aim of rolling it out to the wider community of Zimbabwe.

Thank you.

Yours faithfully

DIRECTOR OF HEALTH SERVICES
IC/rm

c.c. Ethics committee

Appendix 8: Medical research council of Zimbabwe Approval Letter

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/991** **10 March, 2016**

John Mwenda
National Institute of Health Research
P.O.Box CY573
Causeway
Harare
Zimbabwe

RE: DRINKING WATER QUALITY AND THE LONG HANDLED 'MUKOMBE' CUP: ACCEPTABILITY AND EFFECTIVENESS IN A PERI-URBAN SETTLEMENT IN 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) English and Shona Consent Forms

- **APPROVAL NUMBER** : **MRCZ/B/991**

This number should be used on all correspondence, consent forms and documents as appropriate.

- **APPROVAL DATE** : **10 March, 2016**
- **TYPE OF MEETING** : **EXPEDITED REVIEW**
- **EXPIRATION DATE** : **09 March, 2017**
  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.co.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

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MRCZ SECRETARIAT
FOR CHAIRPERSON
MEDICAL RESEARCH COUNCIL OF ZIMBABWE

MEDICAL RESEARCH COUNCIL OF ZIMBABWE
2016 -03- 10
APPROVED
P.O. BOX CY 573 CAUSEWAY, HARARE

PROMOTING THE ETHICAL CONDUCT OF HEALTH RESEARCH

Appendix 9: Communal Drinking Water Sources - Intervention Group

Solar powered borehole water stored in large tanks (Left) from which it is piped to public standpipes (Right)

Borehole fitted with hand pump (Type B Bush pump)

Appendix 10: Communal Drinking Water Sources - Control group

Engine powered borehole water stored in large tanks (Left) from which it is piped to public standpipes (right)

Borehole fitted with a hand pump (Type B Bush Pump)

Appendix 11: Wide-mouthed Drinking water storage containers with lids