THE EVALUATION OF THE QUALITY OF SANITATION AND STORED WATER FOR DOMESTIC USE IN THE UMLAZI P SECTION INFORMAL SETTLEMENT

Simangaliso Idiom Shangase

Submitted in partial fulfilment of the requirement for the degree of Master of Health Science, specialising in Medical Laboratory Science in the Department of Biomedical and Clinical Technology at the Durban University of Technology

Supervisor: Dr Pavitra Pillay

Co-supervisor: Ms T S Ndlovu

Date: January 2021

DECLARATION

This is to certify that this work is entirely my own and not of any other person unless explicitly acknowledged (including citation of published and unpublished sources). This work has not previously been submitted in any form to the Durban University of Technology or any other institution for assessment or any other purpose.

Signature of student

29July 2021
Date

Approval for submission

Supervisor: Dr Pavitra Pillay

Senior Lecturer Department of Biomedical and Clinical Technology, DUT

Co-supervisor: Ms T S Ndlovu
Lecturer Department of Biomedical and Clinical Technology, DUT

29 July 2021
Date

ACKNOWLEDGEMENTS

This dissertation was conducted at Durban University of Technology. I would like to express my heartfelt gratitude to my supervisor Dr Pillay and the Co-Supervisor Ms T Ndlovu for all the assistance they gave me to be able to complete this project. My appreciation also goes to Dr Kwitshana who is now my former HOD who authorised me to use the MUT laboratory facility. Thanks again to the rest of Mangosuthu University staff in the department of Biomedical Science who allowed me in and out of the laboratory giving me the support with every information I required in the laboratory. In particular my appreciation goes to Mr Khomo and Mrs Bhengu, who have allowed me to access the laboratory facility and use some of the instruments of the laboratory.

I also want to extend my deepest gratitude to the ward councillor who authorised that I can be able to go to the informal settlements to conduct my research project. Also acknowledging the informal settlements leader who was instrumental in getting me introduced to some of the members of the community. Last but not least, my appreciation goes to the participants who trusted me and let me in their houses, signed the informed consent form, answered questionnaire and gave me a sample of water from their storages for this project to be a success.

Final thanks goes to my family, particularly my wife Thobekile Shangase for all the support she gave me, my son who would accompany me and watch over the transport whilst I do a foot walk in and around the informal settlements. To all my brothers at home, thanks for the supports as well as my Pastor Dr Nkwanyana who plays a huge role in my life as a spiritual father. To God be the Glory for the gift of life and seeing me through this project by his grace.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Background

The quantity of water delivered and used for households is an important requirement for life as well as basic personal hygiene. Simple hygiene measures have become paramount due to corona-virus 2019 (Covid-2019). South Africa still lacks basic infrastructure to supply adequate quantities of water to all. This problem is exacerbated in the growing informal settlements where infrastructure is limited. A growing awareness shows contamination of water can occur during collection and storage. This results in the deterioration of water quality to the extent that the water becomes undrinkable. Contributing factors include the cleanliness of storage containers as well as the environment in which they are stored.

The aim of the study

This study aimed to investigate the quality of stored water and the related handling of storage vessels after collection for domestic use at the informal settlement of the Umlazi P Section, in the south-west of Durban.

The study objectives

The objectives of the study were to determine the knowledge and awareness of water contamination and how water resources can be protected. To discover the exposure of drinking water to waterborne pathogens due to poor storage and hygiene practices using a questionnaire. To test stored water samples for pathogenic organisms using acceptable laboratory methods and compare the findings for compliance with the South African Water Quality Guidelines for domestic use (SANS 241: 2015). To test the pH levels and macroscopic appearance of stored water in order to assess the extent of natural organic and corrosive substances dissolved in domestic water.

Study Design

This was a descriptive cross-sectional quantitative study aimed at analysing data of exposure of Umlazi P section residents to contaminated water resources. Data collection entailed the administration of a questionnaire to 269 participants, including the laboratory analysis of water samples collected from water storage containers used in each household.

Data collection tools

The questionnaire was used to obtain information on behavioural characteristics of the participants concerning their knowledge, awareness of practices related to water contamination, storage and waste management. The laboratory analysis of stored water samples included testing for the presence of pathogenic organisms, testing of pH and an analysis of the macroscopic appearance of the water. Laboratory findings were compared in compliance with the South African Water Quality Guidelines for domestic use.

Results

Majority of the participants (98.5%) indicated they use municipal water services for their daily needs. It was found that most residents (88.1%) did not have any prior education on water storage and (76.6%) indicated a lack of understanding of water contamination. There was a lack of proper hand hygiene and handling of stored water among 48 households (18%). Almost all respondents indicated that they stored their domestic water in buckets which were kept closed when not in use, and (83.3%) indicated that they cleaned the storage containers by washing it in cold water only. It was found that half of the participants are unemployed and 32% of them use pit latrines as toilets. Most of the respondents found the taste of the water palatable. A positive total coliform count was found among 13 (5%) households in the study, rendering their drinking water a high risk for domestic use, 9/13 of these households used pit latrines. The high-risk coliform count, despite it only accounting for 5% of the population is of great concern. Testing results also showed a zero count for *Escherichia coli (E.coli)* making drinking water acceptable in terms of faecal coliform bacteria.

Discussion and Conclusion

Results indicate a clear need to develop educational programmes that will enhance knowledge of water contamination to improve water quality. These educational programmes need to focus on hygiene practices to minimise water contamination. Infrastructure development remains a key recommendation as it plays an important role in the removal of human faecal waste in the distribution of water to communal taps. The infrastructure development must entail the provision of more taps to avoid overcrowding and provision of flushable toilets as an effective waste removal method.

While the Municipality has played a role in the removal of solid waste, more needs to be done to accommodate all residents in informal settlements to prevent illegal dumping which increases environmental pollution. Considering the variability of water storage periods (between a week to a month) due to the distance between settlements and collection points, the provision of low-cost quality storage containers and treatment chemicals by the Municipality is recommended. The Department of Housing, Water and Sanitation, Health, Education and other Non-Governmental organisations need strengthening of inter-sectoral collaboration to improve the quality of life in informal settlements. The National Water Act of 2003 outlines the role of local government concerning water resources of equitable allocation of water to all citizens and redistribution as well as removal of discriminatory laws that prevent equal access to water (Republic of South Africa – Government act 61 of 2003).

Keywords: Water contamination, Hygiene practices, Municipal services. Laboratory testing methods and Infrastructure

CHAPTER ONE: INTRODUCTION

In South Africa, informal dwellings such as shacks, shelter thousands of people who are deprived of adequate water resources and quality infrastructure (Suiter and Johnston 2014). The Department of Water and Sanitation (DWS) infrastructure and access to quality drinking water is still a problem in most parts of the country (Allaire, Wu and Lall 2018). The contamination of domestic water, unhygienic practices and the lack of basic education remain a major challenge in keeping with the large communities in need of water and sanitation services (Shrestha et al. 2017). Progress in providing water services is hindered by the financial burdens that come with the maintenance of infrastructure, especially when people do not use the facilities correctly (Roche et al. 2017). The efficiency of water and sanitation infrastructure requires education and training as well as maintenance of the facility by the end-users. Contamination becomes a threat to the quality of water due to poor water and sanitation and ultimately a threat to the health of the community (Odonkor et al. 2019). There is always a potential danger of contamination as people store water in their homes due to inadequate and irregular water supply. The lack of hygiene, knowledge of contamination and poor living conditions become a route for bacterial infection resulting in disease (Reddy et al. 2017).

This study aims to identify possible microbial contamination of water storage as a result of the handling of water and to assess the level of knowledge concerning hygiene as well protection of water resources from bacterial contamination among the people living in an informal settlement. The quality of water declines considerably and increases the chances of bacterial contamination from a point of collection to the household water storage for domestic use (Salisbury et al. 2018). In this study, stored water samples were collected and tested for waterborne pathogens as well as pH which would give us an idea of the toxicity of the water. Water samples were not collected from the source, since according to the South African water guidelines the treated tap water is safe for human consumption in terms of microbial content and dissolved chemical solids (SANS 241:2015). A questionnaire focusing on the variables around collection and storage was used to determine if any factors influence contamination. The findings on the study will assist the community and the DWS in closing the gap in terms of providing equal access to quality water and improving grey area with regards to water and sanitation infrastructure. Due to the increasing difficulty that citizens experience regarding access to safe drinking water, many people die from preventable illnesses. Such deaths occur through the ingestion of water contaminated by human or animal excreta or urine containing pathogenic bacteria (Kandel et al. 2017). The biggest health problem related to waterborne infections in developing countries is diarrhoea, which accounts for 4 million deaths annually, and about 2 million of these deaths are children below the age of five (Heibati et al. 2017). South Africa is still faced with a low income housing challenges lacking a water tap nearer to the toilet for handwashing. This has seen an escalation of diarrhoeal deaths contributing 3.1% of total deaths and being the eighth most frequent death in South Africa (Tenza 2018).

An effective way to reduce the impact of contaminated domestic water in public health is to improve the water and sanitation infrastructure, remove contamination caused by human and animal excreta, and strengthen basic education on hygiene practices. The South African quality and monitoring programme conducted by the DWS found that the level of water quality provided to citizens between 2013 and 2014 declined by 8% due to the high organic pollution resulting in high levels of faecal coliforms and solid waste contaminating water streams (Xaba et al. 2016). The water monitoring programmes ensure that adequate, quality water is supplied for all domestic needs of South African citizens. However, due to the increasing population, the water and sanitation facilities, as well as waste removal, remain under severe strain affecting water quality monitoring thus increasing the risk of diseases (Hoossein et al. 2016).

The questionnaire was used to evaluate the amount of solid waste accumulating in the yards of every household included in the study population and the efficiency of the system in removing the solid waste. South Africa requires more funds to meet the demand of maintaining and replacing infrastructure as well as the provision of other basic services for the large numbers of people moving into the cities (Melariri et al. 2019). The maintenance of healthy living conditions requires a consistent water supply, a high level of skilled personnel, and an effective system for the treatment of waste products. Waste products account for 81% of environmental contamination (Melariri et al. 2019). South Africa as a developing country has improved the distribution of public water network however infrastructure problems such as ageing, corrosion, insufficient disinfection creates favourable conditions for bacterial growth (Baidya et al. 2018). The study area, the Umlazi township is located as a peri-urban area of Ethekwini Municipality with challenges of high rates of unemployment, high levels of poverty, low levels of skills and literacy as well as limited access to basic household amenities (Hellberg 2017). This township is also characterised by high levels of HIV infection and tuberculosis due to socio-economic conditions including smoking, alcohol abuse, rapid urbanisation and poverty (Gounden, Perumal and Magula 2018). The rapid urbanisation has increased the population density and put extreme demand on the water and sanitation infrastructure (Allaire et al. 2018). The population in KwaZulu-Natal is estimated at 11.3 million (Statistics South Africa 2019) and the township of Umlazi has an estimated population of over half a million residents (Hlongwa et al 2020). Umlazi is confronted with 13.5% of residents who suffer diseases such as diarrhoea due to contaminated drinking water (Xaba et al. 2016). A crucial step towards resolving the crisis of access to clean water is the provision of adequate infrastructure, maintenance of infrastructure and establishing water treatment systems as it is a constitutional right of every citizen. (Navab-Daneshmand et al. 2018).

Water quality is determined by the assessment of physical, microbial and chemical characteristics using specific water quality standards (Odonkor et al. 2019). Even though the South African government has tried to provide minimum services like installation of communal piped water taps to improve the quality of water supplied, the few taps that are used by more than twenty households per single tap including sometimes registered homes are never enough to address water supply problems (Bain et al. 2014). Due to this, residents rely on storing water for all domestic purposes, and through unsafe water practices and handling, the quality of drinking water is compromised (Tenza 2018). The minimum requirement for water quality for human consumption is that it must be free of infectious organisms and must be acceptable in terms of colour, taste and odour (Clifford-Holmes et al. 2017).

The factors that affect the quality of water are mainly attributed to collection and storage conditions as well as poor hygiene related to water handling (Bain et al. 2014). The provision of quality water for domestic use is a right of all citizens of South Africa, research has shown that an improvement of water and sanitation as well as hygiene practices, and health education can minimise waterborne pathogens (Nicholson et al. 2017).

It is anticipated that through the present study, water borne pathogens may be identified. Testing for chemical corrosive substances and microbiological pathogens in stored water will also provide information on the quality of stored water. The information gained from the community knowledge and practices regarding water use and storage will be used to develop recommendations that emanate from this study for the implementation of proper storage and hygienic practices that deem stored domestic water fit for human consumption. The current study will help evaluate the quality of drinking water within the informal settlements at Umlazi P section in terms of its microbial content, and other unsafe handling practices that lead to water contamination.

1.1 The legislative framework and policies on water provision.

The provision of national policies established for the rights of citizens to receive basic services such as water supply and sanitation service. The constitution of the Republic of South Africa states that everyone has a right to sufficient food and water in terms of Act 108 of 1997 (Republic of South Africa – Government Gazette, 1997).

1.1.1 National Health Act 2003, (Act 61 of 2003)

The National Health Act states that every Metropolitan and district Municipalities must be able to provide health service equitably in areas where citizens live. These health services include water monitoring, waste management, environmental pollution control and food control (Republic of South Africa – Government Act 61 of 2003).

1.1.2 Water Services Act, 1997 (Act 108 of 1997) 29

The act states that citizens of South Africa have the right to access basic water supply and sanitation. The legislation should make a provision for a standard national tariff to regulate the water service institutions for water supply *(*Republic of South Africa – Government Gazette 108 1997).

1.1.3 South African National Standard (SANS) 241: 15

The SANS describes the acceptable quality of drinking water in South Africa in terms of microbial content, chemical composition, aesthetic and macroscopic appearance which may cause no harm at the point of consumption (SANS 241 :15).

1.2 The Aim of the Study

The aim of this study is to evaluate the quality of stored water and the related handling of water in storage vessels after collection for domestic use among community members from an informal settlement in accordance with the South African Water Quality Guidelines specified by the Department of Water and Sanitation.

1.3 The study objectives

1.3.1 To determine the knowledge and awareness of water contamination, storage and disposal amongst community members in the informal settlement using a questionnaire.

1.3.2 To test stored water samples for pathogenic organisms using acceptable laboratory methods and compare the findings for compliance with the South African Water Quality Guidelines for domestic use (SANS 241: 2015).

1.3.3 To test the pH levels and macroscopic appearance of stored water in order to assess the extent of natural organic and corrosive substances dissolved in domestic water.

1.4 Limitations of the research study

Municipal water could not be tested as it has been tested and proven to be of acceptable quality in terms of drinking and domestic use by the Department of Water and Sanitation.

1.5 Conclusion

In this research study, the focus was on testing the following parameters: microbial content and pH of drinking water which should provide an indication of the quality of stored water in the Umlazi P households for domestic use. There is always a potential of water contamination from the point of collection to a point where water is stored for consumption (Roche *et al.* 2017).

Different factors may contribute to contamination of water such a poor water and sanitation infrastructure, unhygienic practices when storing water, lack of knowledge on maintenance and correct use of water taps and toilets facilities (Nicholson *et al.* 2017).

It was anticipated that this study would provide insight on the extent of possible bacterial infections that occur as a result of contamination of water as well as the dangers presented by the altered chemical composition of water (Reddy *et al.* 2017). A developed questionnaire was used to gain information on behavioural characteristics of the study participants with regards to waste management, and other variables that may give rise to water contamination. It was also anticipated that the study findings would provide information on how to safely apply basic maintenance of the water supply network and improve hygienic water storage to prevent microbial contamination.

CHAPTER TWO: LITERATURE REVIEW

2.1. Introduction

There are many factors that may affect the delivery of quality domestic water in the informal settlements. The contamination of water by microbial agents makes it unsuitable for drinking and cooking as it may cause disease to humans. The presence of dissolved chemical solids and other natural organic material may influence the quality of water, colour smell and taste. Water treatment and basic training may be required to maintain the quality of domestic water specified by DWS (Nicholson *et al.* 2017).

South Africa, like most developing countries, has many challenges when it comes to equitable access to water because of an increasing population (Hellberg 2017). People migrate to the cities and build themselves informal settlements with no connection to quality water sources (Salisbury *et al.* 2018). The inability of municipal authorities to keep up with the demands of the rapid growth of informal settlements results in poor living conditions. People occupy spaces in large numbers and compete for the use of limited resources. The supply of quality water to citizens is a basic necessity enshrined in our constitution (Musoke *et al.* 2018). The Bill of Rights states that all South African citizens have a right to access to clean water according to section 27(1) (b) (Cele 2018). The DWS has set up guidelines for safe and clean drinking water for South African communities with the aim to protect human health (Act 36 of 1998).

Inadequate water supply and sanitation remain a significant health concern worldwide due to inadequate infrastructure (Kurui *et al.* 2019). Many health problems arise when water and sanitation services are not sufficient to meet the demands of the community population. Where there is scarcity of water supply, people get desperate to have access to water by making illegal connections sometimes leaving the distribution network exposed to bacterial contamination (Kelava *et al.* 2018). In the present study, we investigated the source of water supply to see if it is safe and able to supply adequate water to the informal settlement in my study population. The water distribution system was also investigated for exposure to pathogens, since drinking contaminated water can cause diarrhoea amongst the community members.

As the population increases more people are faced with a housing problem thereby resulting in the building of informal structures for living (du Plessis 2019). Umlazi is one of the townships faced with an increase in the mushrooming of informal settlements, the more they increase the higher the demand for water and sanitation services (Musoke *et al.* 2018). The reality is that even though services from Municipality may be extended to the needy, not everyone may be reached, the alternative access to water becomes through storage, using household containers and vessels. The informal settlement community, which is part of this study, uses these water storage containers to avoid walking long distances to collect water from municipal taps due to safety concerns (Rayner *et al.* 2016).

Storage containers that stay uncovered remain exposed to dirt and dust, buckets kept on the floor may be contaminated by animals or children (Heibati *et al.* 2017). The high number of occupants in one household reduces the space in the house to put water storage containers away out of reach of animals and children thus exposing water storages to possible contamination (Reddy *et al.* 2017). This study investigated the methods used in cleaning the storage containers and the frequency at which the containers are cleaned. The lack of knowledge and unsafe handling of water storage containers may lead to microbial contamination and the ingestion of such water can lead to health problems (Xaba *et al.* 2016). The development of education programme is required to train residents on basic health education as well as water treatment solutions to minimise risk factors (Hemson 2016). The level of education within the study population was evaluated to provide information on the understanding from the community on what could lead to water contamination.

2.1.1 Housing, urbanisation and the effect on domestic water

Domestic water is used for different household purposes including drinking, food, bathing, and personal hygiene, washing dishes, laundry and gardening (Heibati *et al.* 2017).Therefore, a lack of quality infrastructure for water supply and sanitation becomes a major problem especially in informal settlements. The eThekwini Municipality Department of Solid Waste made a report that 40% to 50 % water pipes not being in a good state causing them to be a high risk in terms of quality water distribution (DWS 2016).

Over a third of the water supply is lost due to old infrastructure and leaking pipes before water can reach the communities (Tenza 2018). Problems of the poor infrastructure, distribution and ineffective removal of waste expose those living in informal settlements to the risk of contracting waterborne diseases such as diarrhoea, cholera, typhoid and dysentery (Musoke *et al.* 2018). Studies have shown that the key factors for the prevention of waterborne diseases are sanitation, personal hygiene and availability of water in quality and in quantity (Craun 2018, du Plessis 2019, Rubino *et al.* 2019). In 2015 Durban had a population estimated to 3.6 million with Umlazi having residents of 404 811 and 104 914 households with these numbers increasing exponentially especially in townships such as Umlazi P section having informal settlements estimated to more than 800 (Murwirapachena and Dikgang 2018). Crowding of households, poor water supply and sanitation results in people storing water inside their homes avoiding travelling a long distance and standing in queues to collect water (Salisbury *et al.* 2018). The ideal supply of water would be to have a municipal tap inside each house, however only one communal tap is used by a group of about 20 to 30 houses as the main supply of water (Kelava *et al.* 2018).

Each household needs at least 20 liters of water per day and the recommended collection point should be within 1 kilometer (Craun 2018). However, when communal water taps are provided, the quality of the water is compromised by a large number of people using them incorrectly therefore exposing taps to contamination. This study monitored the number of times that the study population had to collect water for all their domestic needs, this information would provide an idea of how long it took to use up collected water. When the pipes break because of the pressure of usage, soil bacteria are able to get into the pipe distribution network (Heibati et al. 2017). Therefore the distribution network must be secured and must be microbiologically safe as well as biochemically stable. The failure to wash hands and the unsafe handling of domestic water storage containers have an impact on the quality of water and the health of the population (Nicholson *et al.* 2017). A rise in diarrhoeal cases was reported in Umlazi during May and June 2013 related to poor hygiene (Cele 2018).

2.1.2 Storage and water handling

There is always a need to store increased volumes of water due to unforeseen lengthy water disruptions and also to avoid collecting water from outside sources during night hours (Navab-Daneshmand *et al.* 2018). However the storage containers used are often not clean enough and are exposed to organic material, dust as well as pests and insects. Some of the storage vessels are old vessels, traditional clay pitchers, old chemical and oil containers, and still carry small residue of manufactured products which may be toxic (Guerrini *et al.* 2018). The corrosion of metal containers such as copper containers can lead to gastrointestinal problems in the short term as well as kidney failure and liver damage over a period of time (Sacchetti *et al.* 2015). The faecal contamination can be caused by children putting their hands into water storage and also failure to adhere to hygienic practices when handling stored water (Salisbury *et al.* 2018). Therefore improving water storage vessels coupled with point of use water treatment can reduce transmission of waterborne diseases (Shields *et al.* (2015). Water needs to be stored in sterile containers at a cool temperature to avoid the growth of algae, however storing water directly to the sun may cause chlorine to precipitate and affect the quality of drinking water (Nicholson *et al.* 2017). The treatment of stored water and basic hygiene such as washing of hands, washing of eating utensils and disposal of waste can reduce chances of contamination (Musoke *et al.* 2018).

The informal settlements generate different types of waste such as solid waste, grey water from ablution facilities, washing clothes, runoffs, and discharge from septic tanks, sewage, human waste, animal waste, and natural soil/plant bacteria (Shrestha *et al.* 2017). Due to a lack of an effective system of treating the waste production, the generated waste is thrown around the yard creating multiple channels of grey water that runs through the community breeding bacterial infections (Nicholson *et al.* 2017).

The grey water can carry a significant concentration of pathogens introduced from washing baby nappies, laundry, and excretion of waste. The ingestion of such contaminated grey water becomes a harmful health risk (Roche *et al.* 2017). The lack of a quality infrastructure results in a high level of exposure to faecal contamination of water resources which affects about 60% population of the Umlazi informal settlements (Xaba *et al.* 2016). When the removal of human excreta is not effective, human beings remain exposed to faecal coliforms for long periods of time to a point where it enters water distribution systems. Once the faecal coliforms enter the water distribution systems there is a danger of drinking contaminated water resulting to health problems, the fatal concern being a diarrhoea (Nicholson *et al.* 2017).

The effective treatment of domestic water is necessary to control the amount of colloidal matter, organic material, and inorganic material suspended in water to ensure the quality of drinking water. An increase in colloidal suspension may influence the pH of drinking water (≥ 5 to ≤ 9.7) (SANS 241 : 15), the more water becomes acidic the more it becomes corrosive (Baidya *et al.* 2018). The pH parameter is also useful in monitoring the water treatment process as it is a very stable parameter (Heibati et al. 2017). An increase in solids can significantly affect the disinfection of water and they can affect the taste and the appearance of water (Nicholson *et al.* 2017).The overall quality of water may be assessed based on the colour, taste, odour and microbial content (Sacchetti *et al.* 2015). *Escherichia coli* is the principal microorganism that may be present in all faecal contamination and may be useful in detecting the presence of faecal coliforms in drinking water(Musoke *et al.* 2018).

2.1.3 Water related diseases

Water related diseases can be classified into different categories depending on how the infection is acquired. The infections can be acquired from different agents which includes bacteria, viruses, protozoa, parasites and fungi (Nicholson *et al.* 2017). Waterborne infections are caused by the ingestion of water contaminated by human or animal excreta containing pathogenic bacteria (Kandel *et al.* 2017).The excreta-related contamination is caused by direct or indirect contact with pathogens associated with excreta and/or vectors breeding in excreta. The Umlazi township is experiencing a lot of illegal dumping resulting in the deterioration of vegetation, contamination of water and organic material releasing heavy metals such as copper (Kelava *et al.* 2018). Some of the dumped material can produce pathogens that release toxins which infects groundwater and can be carried through to water distribution systems that supply drinking water (Hurst 2019). The presence of toxic chemicals as well and coliform bacteria indicate that water is a health risk for household use (Cele 2018).

Coliforms represent a subgroup of intestinal bacteria that may be found in human faeces and animals (Adane *et al.* 2017). Gastrointestinal diseases associated with contaminated water and food transmitted through water are cholera, salmonellosis shigellosis and diarrheagenic *E.coli* (Edokpayi *et al.* 2018). There are pathogens when isolated in water that can cause diarrhoea and produce different types of symptoms like fever, dehydration, vomiting, respiratory problems and abdominal cramps. (Reddy *et al.* 2017). This study investigated the presence of microorganisms in water storage containers as a possible cause of contamination in the homes of residents of Umlazi P section.

Shigella species can cause dysentery, characterized by copious bloody diarrhoea (Craun 2018). The *Shigella species* infection is characterised by degeneration of the epithelium and by an acute inflammatory colitis in the lamina propria (Forde, Izurieta and Ôrmeci 2019). The ulceration of the mucosa causes blood to leak into the intestinal lumen. There is failure to absorb water in the colon as a result a patient will frequently pass dysenteric stool (Allaire, Wu and Lall 2018). *Shigella species* may be spread by drinking faecal contaminated water or food. In water, *Shigella species* can survive for at least six months at a room temperature (Forde, Izurieta and Ôrmeci 2019). Humans and animals are a natural reservoir of *Shigella species* and their presence in water indicates faecal contamination of water (Hurst 2019). *Shigella* can be classified into four major species namely *Shigella dysenteriae, Shigella flexneri, Shigella boydii, Shigella sonnei*. Water treatment and disinfection has shown to be effective in removing *Shigella* from domestic water (Rayner et al. 2016) *Salmonella* *species* can cause gastroenteritis resulting in vomiting, diarrhoea, abdominal pains and be caused by eating or drinking contaminated food or drinking water (Craun 2018). *Salmonella typhi* is a member of *Enterobacteriaceae* that infects humans only and can be isolated in the environment through excreted human faeces where hand washing is less frequent (Rayner et al. 2016). It produces several endotoxins, antigen O and H and Vi *Salmonella* causes typhoid fever with symptoms of diarrhoea, vomiting fever and grave-like septicaemia (Troeger et al. 2017). Municipal sewage, agricultural pollution, and storm water runoff are the main sources of these pathogens in natural waters, however the incident of typhoid fever infection can decrease with the improvement of municipal sewage systems, improving hygienic conditions where food and water contamination is the highest cause of typhoid fever (Ashbolt 2015). *Salmonella typhi* does not multiply significantly in the natural environment, however in water with favourable conditions like pH temperature and humidity it may remain viable for several weeks.

Vibrio cholerae are commonly isolated in areas where there has been an epidemic. It is normally found where there are high levels of poverty and poor sanitation (Troeger et al. 2017). They can survive in a cultivable state in water, aquatic and marine organisms for a long period of time. *Vibrio cholerae* is an exotoxin that can be isolated in contaminated water and uncooked food which can cause severe dehydration and diarrhoea (Kandel et al. 2017).

E.coli are generally beneficial as a normal flora in the intestines of warm blooded animals but few strains like *E.coli O157: H7* can produce powerful toxins that cause diarrhoea. *Escherichia coli* infections can give rise to haemolytic uraemic syndrome, a disease similar to dysentery and is potentially life threatening (Craun 2018). When *E.coli* has been isolated in a drinking water system that immediately poses a health risk (Moe 2007). *Enterotoxigenic E. coli (ETEC)* can cause gastroenteritis in children, In developing countries it is associated with inadequate clean water and poor sanitation (Umar *et al.* 2019). The clinical feature of this bacteria is that of a profuse diarrhoea, which leads to extreme dehydration especially in children (Ghaderpoori *et al.* 2009) Another strain is called *Enterohemorrhagic E.coli (EHEC)* Strains, associated with the consumption of contaminated food, raw milk and undercooked meat products (Hashmi et al. 2013). The largest outbreak documented is attributed to the consumption of fruits and vegetables contaminated with faeces from humans or wild animals during cultivation or handling. Though *E.coli (EHEC)* is not a concern for treated water, it is known to cause mild urinary tract infections. The *Enteroinvasive E.coli (EIEC)* strains may cause diarrhoea, vomiting, fever, chills, abdominal pains, by invading epithelial cells of the large intestine (Forde, Izurieta and Ôrmeci 2019). Water contaminated by faeces from an individual sick from the *Enteroinvasive E.coli* will produce diarrhoea, gastroenteritis, enterocolitis and dysentery, which are *Shigella* like symptoms (WHO 2017). Some bacteria can emerge as water pathogens even though they have no association with *E.coli (Seleh et al. 2008*).

Some microorganisms such as *Mycobacterium avium* are known to be resistant to chlorine and other chemical disinfectants that may be used to treat water (Edokpayi *et al.* 2018). This organism is considered opportunistic that can cause respiratory tract infections and gastroenteritis (Rubino *et al.* 2019). It is able to enter the distribution systems from rivers, lakes, plants and dust and can remain in water over a wide range of pH and temperature but it survives better in biofilms than in water (du Plessis 2019).

A discharge of human faecal matter and sewage can constitute an increase of enteric viruses in water resources (Edokpayi *et al.* 2018). These viruses cause a wide range of diseases and can be transported in the environment through groundwater, rivers, aerosols emitted from sewages (Shrestha *et al.* 2017). The pathogenicity of enteric virus groups is based on their cellular and molecular structures that make them resistant to current water treatment processes including circoviruses, torque teno virus-like viruses. Microorganisms like protozoa and parasites can survive long periods of time in the environment, they can even be found in treated water but in low quantities (Forde, Izurieta and Ôrmeci 2019).

In this study, *E.coli* was tested as it is the best bacterial indicator for the presence of faecal coliforms bacteria which are a subgroup of total coliform bacteria that exist in the intestines of human and animal faeces that can cause contamination of drinking water. The total coliform count may also provide an indication of the presence of other organisms which might have entered water streams through vegetation and soil but may be harmless. The testing of *E. coli* and total coliform count was done to investigate the degree of contamination in water used for domestic purposes in the informal settlements. The South Africa's minimum water quality specification in drinking water according to South African water guidelines indicates that *E. coli* < 1 count per 1ml of water, or faecal coliform ≤ 300 counts per 1ml of water (SANS 214: 2015).

2.1.4 Water quality

Some dissolved substances in water become a major health concern, if not managed properly they may alter the taste and odour of water. Proper guidelines are required to manage water treatments because uncontrollable chlorination of water may cause trichloramines which affect the taste of drinking water (UNICEF & WHO 2017). The unacceptable taste and odour of water is caused by the inorganic and inorganic contaminants present in the distribution system, sometimes this may develop because of long term storage of water (Rubino *et al.* 2019). Abnormal taste and odour of drinking water may be indicative of pollution of water, ineffective water treatment and due to an ageing water distribution system, this may in the long term cause health problems (Allaire, Wu and Lall 2018). Colour and turbidity may indicate the presence of potentially pathogenic bacteria (Shrestha *et al.* 2017). The questionnaire developed as a research tool in this study was used to investigate how residents perceived the smell and taste of domestic water.

Acceptable drinking water should not produce any smell or salty taste. Turbidity may also indicate the presence of suspended colloids that interfere with the transmission of light through water (Nicholson *et al.* 2017). The macroscopic examination of water samples can be used to give an indication of the presence of soil, algae and other dirty organic substances from ground which may influence the turbidity of water and make it unacceptable for drinking and cooking (Cumming & Cairncross 2016). Water may be clear and colourless but when there is a presence of organic and inorganic material from humans or vegetation it may produce colour (Roche *et al.* 2017).

The high concentration of iron and other metals have a strong influence on how water tastes. Iron precipitate present in water may cause the growth of iron bacteria which develops from oxidation of iron from ferrous iron to ferric iron (Asghari *et al.* 2018). This changes the coating of distribution pipes producing an acceptable reddish brown colour of water (Selah *et al*. 2008). The high levels of chlorine concentration that result from water treatment greater than 250mg/l in water may give rise to a salty taste of water (Hurst 2019). Copper has a corrosive action especially in water that has been stagnant in the pipe causing water to have a bitter taste (Odonkor *et al.* 2019). Copper enters the water systems through disintegration of plumbing material especially in long standing water. Consumption of high levels of copper in water may cause diarrhoea, gastric complaints, vomiting, nausea and in the long term cause liver and kidney damage (Nicholson *et al.* 2017).

The hardness of water may be caused by calcium and magnesium coming from some of the excess soaps used to achieve cleanliness, the degree of the hardness of water may vary from community to community (Khalil *et al.* 2017). The use of synthetic detergents in treatment of water must be monitored, their detectable presence in water give rise to an unacceptable taste, also it may conclude that water has been contaminated by inflow of sewage back into the distribution pipe (Edokpayi *et al.* 2018). The long term effect of high levels of calcium and magnesium concentrations is cardiovascular problems (Ashbolt 2015).

Temperature and pH are also necessary in the assessment of water acceptability in terms of taster, colour, taste and odour (Suiter and Johnston 2014). Cool water is safer than warm water, high temperature of water that exceeds 25 degrees Celsius may be conducive for the growth of bacteria as water for rehydration requires a cool temperature of 16 degrees Celsius (Bain et al 2014). Although pH has no direct impact on water consumers, it plays a role as a guiding parameter in terms of the safety of drinking water (Onda 2014). The pH may indicate the corrosiveness of water in the distribution system, in an effective chlorination of water the pH must be just less than 8, anything lower than 7 may lead to water being corrosive (Kostyla et al. 2015). Water treatment plays an important role in terms of acceptability of water (Government Gazette & Notice 2015).The best way to control the concentration of inorganic and organic material relies heavily on the process of treatment of water (Kelava *et al.* 2018). The present study investigated the concentration of chemical solids indirectly by testing the pH using a pH indicator to check the level of toxicity of water. Additionally, the study assessed the pH and macroscopic appearance of stored water in order to assess the extent of natural organic and corrosive substances dissolved in domestic water.

2.1.5 Public Health aspects including legislation and education

The Department of Health together with other stakeholders in the health sector have a role to play in ensuring that basic health education is provided to protect water resources from contamination (Cele 2018). Because of few communal taps people tend to store water for long hours or even days which can lead to diarrhoeal diseases, infectious hepatitis, typhoid, skin and eye infections (Sacchetti *et al.* 2015). Previous studies have confirmed that chlorinated water quality can remain acceptable for long periods however poor storage and handling can result in contamination of that water too. Some of the parasites may survive for a very long time in water even after treatment without being detected, other pathogens may survive when the temperature of water is low, even sunlight intensity may influence their survival (Salisbury *et al.* 2018). Heavy rainfalls may influence contamination of water resources causing an overflow of water and sewages thereby serving as a transport of pathogens (Sacchetti *et al.* 2015).

The DWS has the responsibility as a government department to ensure proper management of domestic water resources. This may include periodic inspection and surveillance of the formal drinking water systems (Suiter and Johnston 2014). Environmental experts can also assist in developing programmes that educate consumers concerning water contamination and basic hygiene (Kandel *et al.* 2017). These programmes can be administered at community level by local councillors together with health authorities to reduce water contamination (Heibati *et al.* 2017). The biggest task is to engage the community and inspire participation from all people regardless of their statuses. Ongoing support and encouragement must be maintained to ensure that safe drinking water practices continue to operate, since water is an essential necessity (Musoke *et al.* 2018).

The South African National Water Act states that water should be managed properly, monitored and protected by the users (National water act 36/1998). It further states that the community has a role to play as well ensuring that they report faulty systems, abuse and misuse which include illegal connection (National water act 36/1998). In the present study, the knowledge of contamination as well as basic health education of residents in relation to waterborne pathogens was investigated.

In South Africa there are high levels of unemployment and socioeconomic inequalities resulting in poor health conditions accompanied by *E. coli* diarrhoeal infection due to poor water and sanitation infrastructure (Nicholson *et al.* 2017). Therefore education, occupation and income play a very important role in uplifting the socioeconomic state of the community (Rubino *et al.* 2019). This study investigated the employment status, level of education and other socio economic problems can be directly linked to poor sanitation and overcrowding. The EThekwini Municipality has made significant progress in addressing developmental challenges though there is still some ground to cover with regards to infrastructure degradation, unemployment and low economic growth (EThekwini Municipality 2018/19 IDP).

The World Health Organisation (WHO) has set up targets that every country should have policies and strategies to reduce deaths associated with inadequate water and sanitation by 50% in 2015 (Musoke *et al.* 2018). On June 5, 2017, in South Africa, the DWS hosted an Integrated Water Quality Management symposium to address pressing issues of water scarcity and its overall effect (Allaire, Wu and Lall 2018). They identified the most predominant negative impact to be the nutrient content of water, salts as well as microbial contamination. The following interventions may be necessary to improve the quality of water in developing countries (Craun 2018): Improvement of the quality of drinking water supply can reduce diarrhoea morbidity by 6% to 25% (Musoke *et al.* 2018). An improvement in the access of water and sanitation for excreta removal can reduce diarrhoea morbidity by 32% and a number of infections including respiratory infections and urinary tract infections. The development of health education programmes including hygiene as well as washing of hands can reduce diarrhoea up to 45% (Musoke *et al.* 2018). Water supply interventions may include the improvement of water distribution system such as the installation of a hand pump or household connection (Craun 2018). Water quality interventions may include the provision of water treatment for the removal of microbial contaminants, either at the source or at the point of use. South Africa is plagued with different health diseases, improving water and sanitation is imperative as role player in minimising the spread of waterborne diseases (Roche *et al.* 2017). The infrastructure development is fundamental in the provision of water and sanitation services, however handling and hygiene is also key in solving issues of water contamination. High levels of diarrhoea amongst children below the age of 5 years are prevalent where there is parent neglect of hygiene

(Cumming & Cairncross 2016). This study investigated if there was diarrhoea amongst the study population of unknown origin that can be investigated further to see if it has no direct link to water contamination. The anticipated findings of the study would be the basis for recommendation on health education with a focus on water handling, storage and disease, amongst community members through workshops held at clinics and schools to assist in breaking the cycle of health diseases through drinking contaminated water (Nicholson *et al.* 2017).

This study will present its findings to DWS with the aim to contribute in the already done work to improve the quality of water and sanitation services to the informal settlements in Umlazi. The recommendations will look at how the community in this study can improve the water storage with maximum protection from waterborne pathogens. Other preventative measures may include the provision of storage containers that are only designed for storing water to protect water from contamination. The future of safe water provision is a long term vision of every household having its own running water for both domestic water and sanitation. Improvement on hygienic practices such as washing of hands is important in protecting drinking water from contamination. The house environment where storages are kept should be clean of all times to avoid settling of dust and keeping it away from animals and pests.

CHAPTER THREE: METHODOLOGY

A questionnaire and informed consent forms were distributed to each household to cover behavioural characteristics that may cause the contamination of water. The water samples were tested for the pH level using pH dipstick to see if there were any dissolved chemical substances affecting the quality of water. The water samples were also tested for the presence of *E.coli* and total coliform count to establish whether the water used for domestic purposes was safe for human consumption. Laboratory tests were performed using a 3M *E.coli* Coliform petrifilm. Data collected will be stored safely in a locked steel cupboard for a minimum period of 5 years.

3.1 Study Design

This was a descriptive cross sectional quantitative study, designed to investigate the quality of stored water, handling and use in the informal settlement located at Umlazi P Section. Data collection tools included administering of questionnaires and collection of water samples from storage containers in homes of participants. The data collected included the participant's demographics, access to municipal services employment status, educational status, collection of water, storage water handling practices, hygiene practices, and removal of solid waste.

3.2 Study Population and sampling

The study area had approximately 800 informal dwellings obtained through a physical count of houses provided with an ablution facility consisting of a few taps, portable toilets and communal shower facilities which are communally used by many of the community members. Upon visiting the study area, it was noted that water pipes were leaking forming damp areas around the main supply as well as houses. Some ground water pipes are broken on the surface, causing running water to mix with sand. The single facility for water supply, bathing and sanitation, was used by a considerable number of people. For an estimated population of 800 shacks/ informal houses in the study area, the required number of households to be included for sampling was 269 with a 5% margin of error and a 95% confidence interval. The sample size calculation was obtained using the Raosoft sample calculator (Raosoft.Inc), through consultation with Professor Glenda Matthews, a qualified statistician from Durban University of Technology.

3.2.1 Geographical location of the study area

The research project was based at Umlazi P section – Mphathi Luthuli Circle as shown in Figure 3.2.1 The area is highly populated and is surrounded by two rivers.

Figure 3.2.1 Geographical map of Umlazi P section indicating the surrounding informal settlements (https://satellite-map.gosur.com)

3.2.2 Inclusion criteria

- Both male and female consenting participants over the age of 18 based on the South African consenting age were included.

3.2.3 Exclusion criteria

- Participants below the age of 18 were excluded from the study.
- Non-consenting participants were excluded.

3.3 Permission and ethical considerations

The ethical approval was obtained from the DUT ethics committee (Ethics Number: IREC 116/18); (Annexure G) prior to the commencement of this research. Permission to conduct this research in the study area was obtained from the local councillor who is elected by the city to manage the ward (Annexure A, Annexure B). Prior to the data collection, prospective participants were provided with letters informing them about the study and at the same time, consent for participation in the study was requested

(Annexure C). The Department of Biomedical Sciences provided the laboratory facilities with a biosafety level 2 suitable for the testing of samples at Mangosuthu University of Technology (Annexure D).

Confidentiality of the participants was maintained throughout the study. Each participant was given a special code as a reference identity instead of the real name of the participant. The participants were not coerced to participate in the study, taking part in the study was voluntary and participants were allowed to withdraw from the study at any time they wished to do so. The participation on the study had no financial bearing on the side of the participants, and no remuneration was offered for participating in the study. The researcher ensured that the study complied with all legal requirements and that the rights of participants were protected.

3.4 Pilot Study

A pilot study was conducted by administering the questionnaire among five shack dwellers from an informal settlement in Umlazi area. This was done to ensure reliability and validity of the questionnaire, prior to implementation.

3.5 Data collection

The first stage of data collection was the administration of a questionnaire among consenting participants on their living conditions and practices related to water use, storage and disposal within the community (Annexure E). The questionnaires and informed consent form were administered by the researcher who is fluent in both English and IsiZulu (Annexure F). Questionnaires were administered to participants from every fifth shack/informal dwelling as part of the random sampling. Some participants however, refused to be part of the study, and in such instances, recruitment was done at the neighbouring household.

3.5.1 Questionnaire Administration

The comprehensive questionnaire was developed to investigate the handling and storage of water resources within the informal settlements. It gave insight into the type of storage containers used, the methods used to clean the containers and chemical treatments used to keep the water clean. Through the questionnaire we were able to determine the level of basic health education in relation to the use of water. It also helped provide knowledge of the type of waste generated, and the Municipality services provided regarding waste removal. The questionnaire also provided insight on the sanitation conditions and the adequacy of the available infrastructure for the community in the Umlazi P area.

3.5.2 Collection and processing of water samples

Sample collection: Water samples were collected from the water storage vessels from consenting participants for further laboratory analysis. Samples were collected in the afternoon into sterile sample containers. All samples were temporarily stored in a light proof insulated box containing melting ice or ice-packs with water to ensure rapid cooling to preserve the integrity of samples for laboratory analysis.

3.5.3 Frequency of sampling

This was a cross sectional study where one sample was collected from each household for laboratory testing. Samples were collected in the afternoon between 3pm to 6pm during the time at which residents were most likely to be actively using water storage from their storage containers for domestic purposes.

3.5.4 Selection of Laboratory testing Parameters

These following parameters were used to determine the extent of drinking water contamination.

(i) The pH for determination of corrosive substances dissolved in water.

(ii) The Coliform counts for determination of the extent of water pollution.

(iii) The *E.coli* for the determination of faecal contamination of water.

3.5.4.1 Laboratory Analysis

Water samples were tested for the presence of coliform bacteria and compared to South Africa's minimum water quality specification. The sample processing was conducted in an accredited laboratory at Mangosuthu University of Technology. The processing bench was disinfected with freshly prepared disinfectant before and after the testing conducted. This is a laboratory standard practice to eliminate potential contamination of samples being tested. A standardized 1000 µl pipettes and micro tips were sterilised for the use of dispensing water samples into the 3ml petrifilm. The inoculated 3ml petrifilms were then incubated for 24 hours in a stack of 20 to prevent cross contamination of cultures and observed the next day for bacterial growth. The tested samples were frozen between -20°C and 0°C in order to preserve the integrity of the samples during their long storage for a period of 5 years as per study ethical requirement. The accepted limit for the Total coliform count should be less than 300CFU/ml.

3.5.4.2 The macroscopic examination of samples

Samples were examined for the presence of physical substances such as mud, algae, sand, leaves and other organic material. Macroscopic examination included checking for any variation of water colour, as drinking water is supposed to be aesthetically clear. The macroscopic examination of samples was performed under a laboratory lamp magnifier.

3.5.4.3 The E.coli/ Coliform count 3ml Petrifilm test

The samples were tested for the total coliform and *E.coli* using a petrifilm 3M *E.coli* coliforms kit. The work bench was disinfected, 3ml petrifilms were labelled with the sample number and micropipette standardised to dispense 1ml on petrifilms. These tests were performed to evaluate microorganisms present in drinking water. The acceptable total coliform count in drinking water should be less than or equal to 300 per millilitre of water and *E. coli* count of less than one CFU per/ml.

3.5.4.4 3M Petrifilm principle for Rapid E. coli and Coliform

Principle: The 3M™ Petrifilm™ Rapid *E. coli*/Coliform Count Plate is a selective and differential culture medium which contains proprietary nutrients,

a Cold-water soluble gelling agent, 5-bromo-4-chloro-3-indolyl-D glucuronide (BCIG) an indicator of glucuronidase activity, and a tetrazolium indicator that facilitates colony enumeration. 3M Petrifilm Rapid *E.coli*/Coliform Count Plates are used for the enumeration of *Escherichia coli* (*E.coli*) and coliforms in the food and beverage industries. (The 3M™ Petrifilm™ Rapid *E. coli*/Coliform - interpretation guide).

The figure 3.2 shows a flow diagram on how to use the 3ml petrifilm optimally for the total coliform count and *E.coli*. The 1st step ensures that the 3m petrifilm test kit is stored at the right temperature between -2°C to 8°C. The 2nd step shows that once the pouch has been opened it must be sealed properly to avoid moisture. The 3rd step shows how to lift the top of the film and the dispensing 1ml using a pipette perpendicularly to the area of inoculation. The 4th step shows the rolling down of the top of the film gently covering the surface preventing trapping air bubbles. On the 5th step a spreader is placed on the centre of the film in order to distribute the sample on a petrifilm evenly. The spreader was lifted and a minimum of one minute given for the gel to solidify samples are incubated as indicated on the 6th step in stacks of no more than 20 at 37°C for 24 hours.

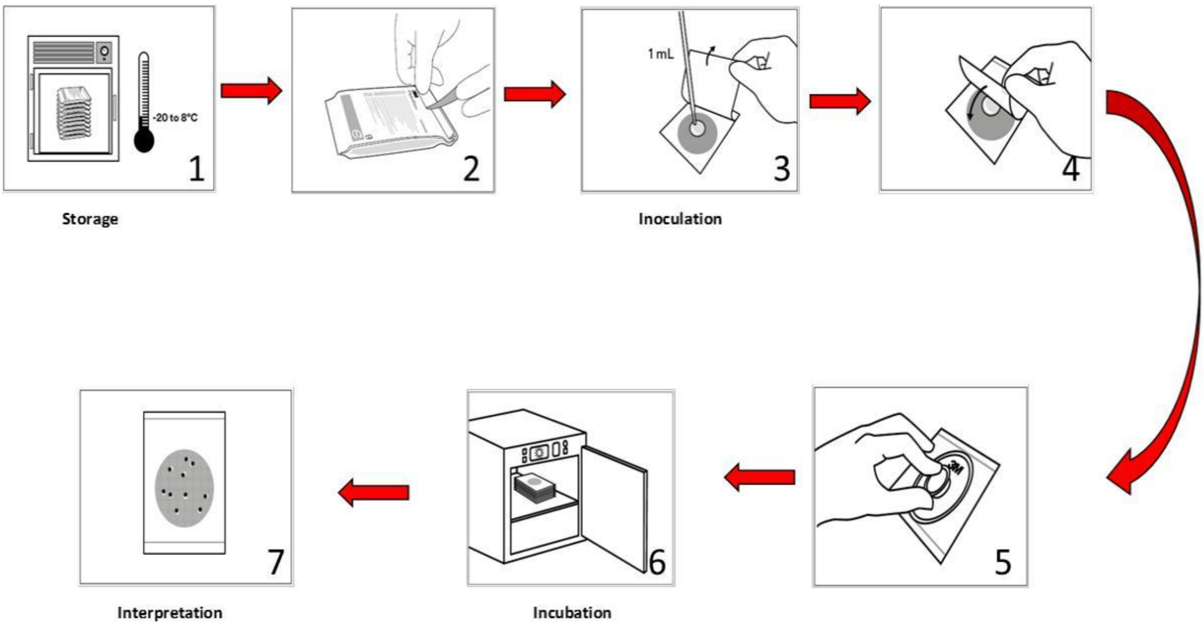

Figure 3.2 The procedure of the use of 3ml Petrifilm for the detection of coliform count and E.coli in water samples (The 3M™ Petrifilm™ Rapid E. coli/Coliform - interpretation guide).

The final 7th step plates are observed for any colonial growth, interpreted, counted and reported. A quality control *E.coli ATCC* (8739) strain was inoculated as a positive control to ensure that the 3ml petrifilm kit was working accurately.

3.5.4.5 3M Petrifilm E.coli and Coliform interpretation

The *E.coli* colonies appear as blue-green colonies with and without associated gas bubbles. The Total coliform count colonies appear red in colour with gas around it. When there is no growth on petrifilm results are recorded as *E.coli* = 0, Total coliform count = 0 as is seen in Figure 3.3. Counting of complex growth: The circular growth area on 3M Petrifilm is approximately 30cm containing greater than 100 colonies. The number of colonies are counted in one or more representative squares and the average is determined by the number per square. The average number is multiplied by 30 to determine the estimated as shown in figure 3.4

Figure 3.3 The 3ml petrifilm interpretation chart showing no bacterial growth (The 3M™ Petrifilm™ Rapid E. coli/Coliform - interpretation guide)

Figure 3.4 The 3ml petrifilm interpretation chart showing bacterial growth (The 3M™ Petrifilm™ Rapid *E.coli*/Coliform - interpretation guide)

Figure 3.5 The 3ml petrifilm interpretation chart showing an example of *E.coli* and Coliforms (The 3M™ Petrifilm™ Rapid *E.coli*/Coliform - interpretation guide)

3.5.4.6 The pH testing

The pH measures the alkalinity and acidity of a solution. Drinking water may be closely linked to biological and chemical changes. An acidic pH is a pH lower than 7.0 whilst basic pH is a pH greater than 7.0. A decrease in pH leans towards corrosive water and an increase in pH leans towards precipitation of minerals such as calcium carbonate. The pH of the water samples was measured using pH paper universal indicator checking the levels of acidity and alkalinity of drinking water. The universal indicator pH 0-14 was used to measure pH value for the water samples.

3.6.1 Data Analysis

Data was entered onto an Microsoft Excel spreadsheet and thereafter exported to IBM SPSS Statistics software 24.0 (Chicago, Illinois, USA). Descriptive statistics were used in this explorative study. Categorical variables were summarized by frequency and percentage and presented using bar charts and other figures. The odds ratios and the corresponding 95% confidence intervals were determined for 2 × 2 cross-tabulations and *p*-values less than 0.05 were considered as significant.

3.6.2 CHI SQUARE TEST

A chi-square test is any statistical hypothesis test in which the test statistic has a chi-square distribution when the null hypothesis is true, or any in which the probability distribution of the test statistic (assuming the null hypothesis is true) can be made to approximate a chi-square distribution as closely as desired by making the sample size large enough.

Specifically, a chi-square test for independence evaluates statistically significant *differences* between proportions for two or more groups in a data set.

Chi-square test statistic:

$$\chi^2 = \frac{(f_o - f_e)^2}{f_e}$$

$$df = (r-1)(c-1)$$

There are **two applications** of the chi square test:

- Chi-square goodness-of-fit-test: A univariate test, used on a categorical variable to test whether any of the response options are selected significantly more/less often that the others. Under the null hypothesis, it is assumed that all responses are equally selected.
- Chi-square test of independence: Used on cross-tabulations to see whether a significant relationship exists between the two variables represented in the cross-tabulation. In the event of the minimum expected frequency not being met, the Fisher's exact test will be used.

CHAPTER FOUR: RESULTS

The results obtained in this study are presented in this chapter. These results were obtained from the laboratory experiments performed as well as the questionnaire conducted amongst the community residents in the study. The microbiological and chemical analysis were performed in samples to determine the extent of water contamination. The parameters that were tested included the pH, the total coliform count and the *Escherichia coli*. These measured parameters were compared to South African national standards for drinking water. The analysis of results was presented in the form of tables, charts and bar graphs, standard national references were attached where required.

4.1The Research Instruments

There were two main forms of data collection, firstly the questionnaire which was administered to consenting participants. The questionnaire consisted of 40 items, with a level of measurement at a nominal or an ordinal level. The questions were divided into the following seven sub-sections: family information, shelter/housing, water, sanitation, solid wastes, hygiene practice and prevalent clinical symptoms.

The other form of data collection included the water samples collected from the storage containers in order to test for pathogenic organisms as well as to evaluate the macroscopic appearance, pH and presence of corrosive substances.

4.2 Characteristics of the study population

The study population consisted of 800 households, and 269 water samples were collected for laboratory testing. Each household signed a consent form and provided a questionnaire as a research tool. The response rate for this research project was 100%.

4.3 Questionnaire Analysis

4.3.1 Section A: Family and Housing information

This section summarises the biographical characteristics of the respondents. This information was collected to assess the living conditions, type of housing, employment status and educational levels. Table 1 assisted the research study on the number of occupants/per house who may have access to water storage containers, as they use water at different intervals. The young children become vectors of water pollutants as they may not adhere to correct hand wash practices. Research has shown that the most susceptible group to drinking contaminated water is children younger than 5 years who suffer diarrhoea (Nicholson *et al.* 2017).

Table 1. Descriptive statistics by gender

Description	N	Minimum	Maximum	Mean	Std. Deviation
Total number of family members	269	1.00	13.00	4.73	2.58
Total male members	269	0.00	7.00	1.83	1.25
Total Female members	269	0.00	12.00	2.54	1.85
Total children (less than 5 years old)	269	0.00	5.00	0.80	1.00

The mean and standard deviation values indicate on average about 5.00 ± 2.58 people per dwelling, with there being approximately 1.50 times more females than males in each household as seen in Table 1. There is on average approximately 1 child younger than 5 years old in the family unit.

4.3.2 Employment status of participants

Table 2. Employment status within the study population

	Frequency	Percent
Yes	134	49.8
No	135	50.2
Total	269	100.0

There were nearly as many employed respondents as there were who were unemployed ($p = 0.951$) as seen in Table 2. This result gave an indication as to how many households may be able to afford water treatment products and quality water storage buckets to protect water from bacterial contamination.

4.3.3 The type of dwelling houses

The type of houses used by the residents can be seen in Figure 4.1 where the majority of 241/269 respondents (89.6%) live in shacks/informal dwellings ($p < 0.001$). This result was in agreement with the title and the aim of the study of evaluating the quality of stored water within the informal settlements at Umlazi P Section.

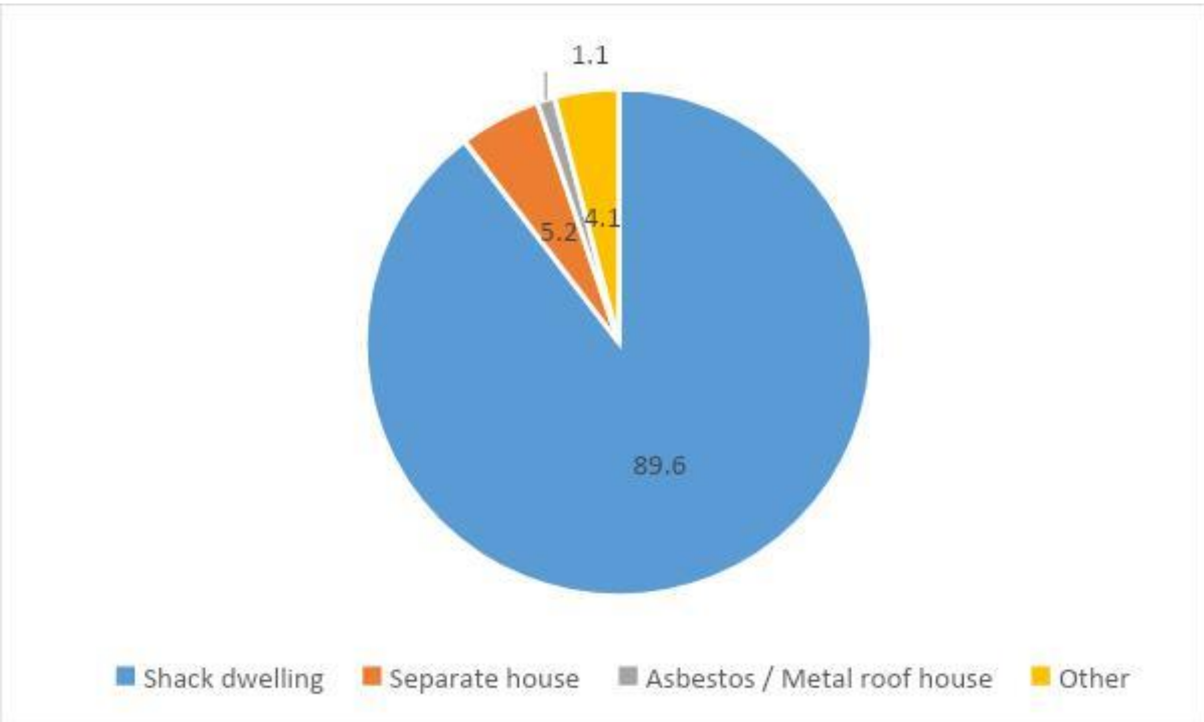

Figure 4.1. Types of houses

4.3.4 Levels of education among respondents

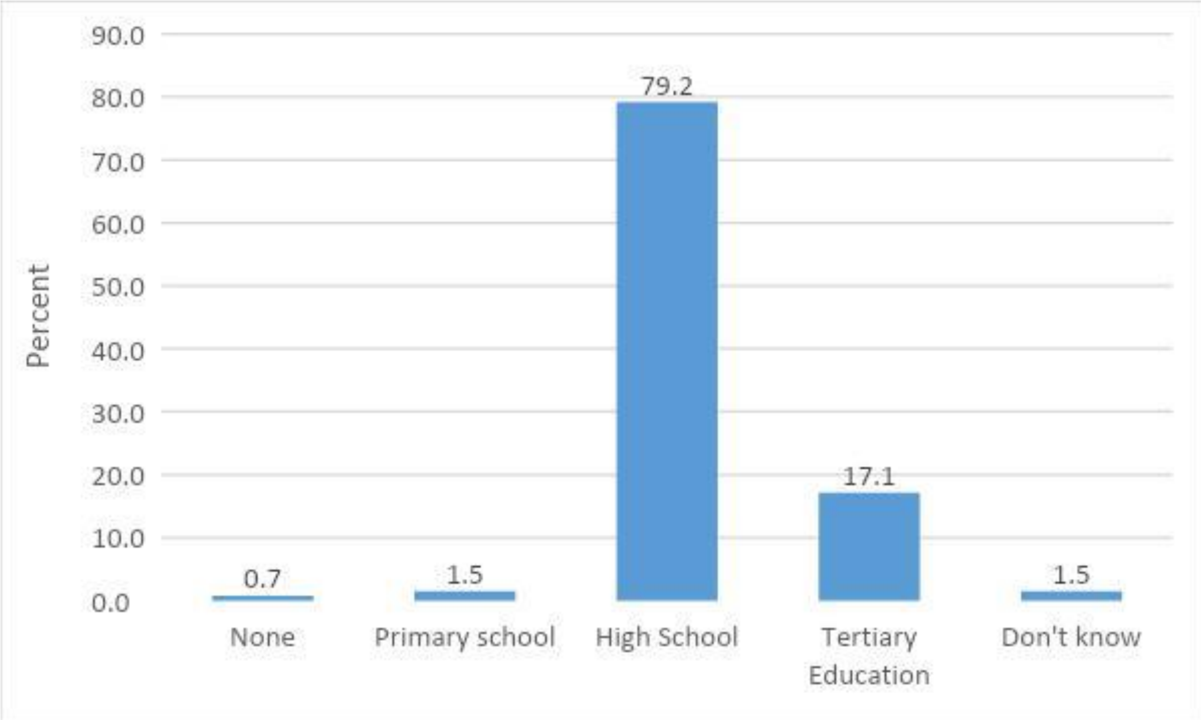

Figure 4.2. The participant's education levels

The majority of respondents, 213/269 (79%) had a high school level of education, whilst four respondents only had a primary level of education, altogether making up (81%) respondents with just basic education. Approximately 17% had a tertiary qualification ($p < 0.001$), which indicates that the majority of the respondents did not have a higher qualification as seen in Figure 4.2. These results gave the research investigation an insight as to the level of health awareness of respondents on the effects of drinking contaminated water. This was one of the objectives of this study to discover basic health knowledge on water contamination, the correct use of water and sanitation infrastructure as well as safe application of treatment chemicals to disinfect water at required intervals.

4.4 Section B: The knowledge, awareness and practices on water distribution

4.4.1 The houses water supply sources

Table 3 summarises the respondent's knowledge of different water sources and the scoring patterns between primary source of drinking water and the quality of the water according to the respondents. The different water sources included municipal piped water, tanked water and rivers. Water was collected from these sources into storage vessels and taken into a household for domestic use.

Table 3. Knowledge of water source and quality of water taste

			How does your drinking water taste?			Total
			Good	Acceptable	Unacceptable	
What is the primary source of drinking water for your household?	Municipal piped water	Count	183	78	4	265
		% within What is the primary source of drinking water for your household?	69.1%	29.4%	1.5%	100.0%
		% within How does your drinking water taste?	97.9%	100.0%	100.0%	100%
		% of Total	68.0%	29.0%	1.5%	98.5%
	Water vendor – tanker delivery	Count	1	0	0	1
		% within What is the primary source of drinking water for your household?	100.0%	0.0%	0.0%	100.0%
		% within How does your drinking water taste?	0.5%	0.0%	0.0%	0.4%
		% of Total	0.4%	0.0%	0.0%	0.4%
	River	Count	3	0	0	3
		% within What is the primary source of drinking water for your household?	100.0%	0.0%	0.0%	100.0%
		% within How does your drinking water taste?	1.6%	0.0%	0.0%	1.1%
		% of Total	1.1%	0.0%	0.0%	1.1%
Total		Count	187	78	4	269
		% within What is the primary source of drinking water for your household?	69.5%	29.0%	1.5%	100.0%
		% within How does your drinking water taste?	100.0%	100.0%	100.0%	100.0%
		% of Total	69.5%	29.0%	1.5%	100.0%

Based on the responses it is noted that there was no significant difference in the ratings by taste ($p = 0.706$). That is, a similar number of respondents rated the quality from one extreme to the other, for the different sources of drinking water. It is noted that 265 respondents (98.5%) received municipal piped water. All of the respondents indicated that the primary source of water for domestic use in their household, for example, cooking – was obtained from piped water from the Municipality. Of those that received piped water, 69.1% rated the quality of water as being good, with 1.5% indicating that the quality was unacceptable. Overall, for the piped water, 68.0% rated the quality of water as good, 29.0% as acceptable and 1.5% as unacceptable.

A small number of three respondents ($n = 3$) indicated that they collected water from a river. All 3 respondents rated the river quality water as being good. One respondent collected water from a vendor and rated the water quality as good.

4.4.2 Water collection and storage practices

4.4.2.1 The water storage purposes

The majority of 244/269 respondents (90.7%) indicated that stored water was used for domestic purposes and for drinking ($p < 0.001$) as is seen in Table 4.

Table 4. Daily use of stored water

Description	Frequency	Percent
Domestic water	15	5.6
Drinking water	10	3.7
Both	244	90.7
Total	269	100.0

4.4.2.2 The water storage vessels hygienic practices

The Figure 4.3 indicates the responses to the given statements regarding water storage and use.

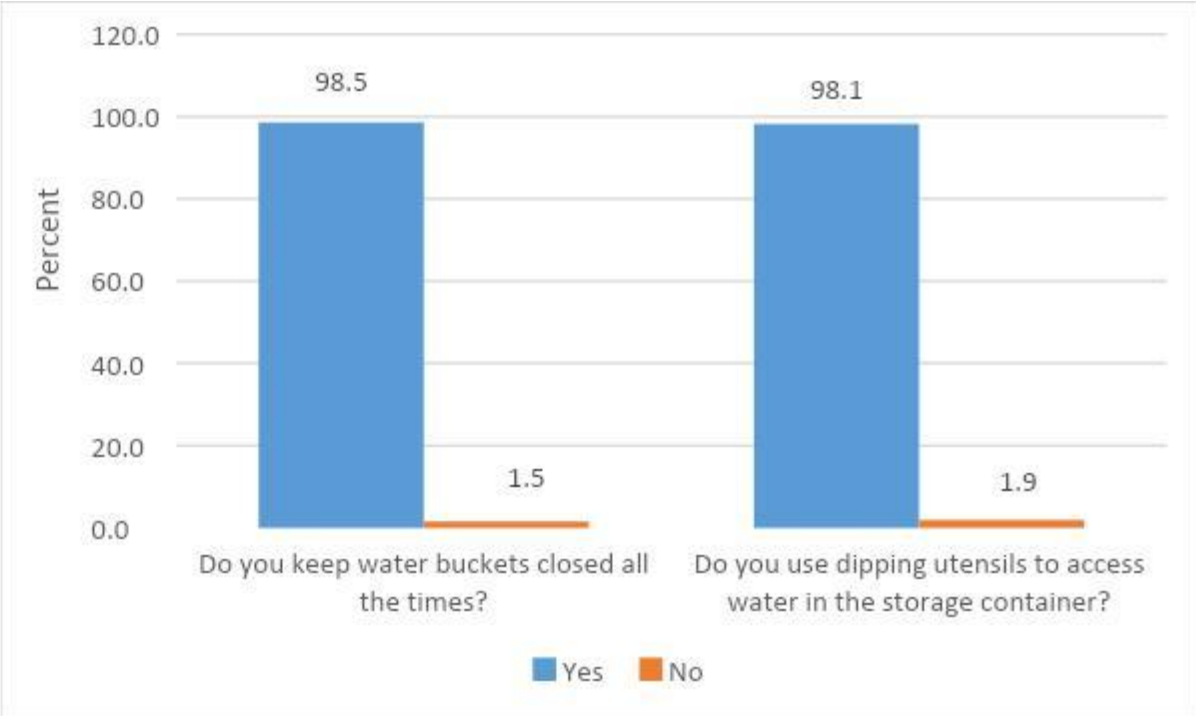

Figure 4.3. Practices regarding water storage containers

In both instances, significantly higher numbers of respondents indicated that they stored water in buckets and that they used dipping utensils to access water from the storage containers ($p < 0.001$). The result assisted in confirming the point of contamination whether it's within the household due to types of storage containers used and hygienic practices or it's at a point of collection due to overcrowded use of a communal tap.

4.4.3 Water collection practices

4.4.3.1 The frequency of water collection from external sources

The Table 5 shows how often water is collected for storage showing a significant 230 respondents collecting water every day ($p < 0.001$). Two respondents indicated that they collected water once a month. These results would assist in indicating whether long term storage affected the quality of stored water within an informal settlement household environment as 89.6% respondents live in shacks also keeping their storages within their households.

Table 5. Frequency of water collection from external sources

Description	Frequency	Percent
Everyday	230	85.5
2-3 times a day?	16	5.9
Once a week?	21	7.8
Once a month?	2	0.7
Total	269	100.0

4.4.3.2 Frequency of cleaning water storage containers

Table 6 shows how often the storage containers /buckets for water are cleaned. Most 255/269 respondents (94.8%) indicated that storage buckets are cleaned each time before water collection ($p < 0.001$).

Table 6. Frequency of cleaning water storage buckets

Description	Frequency	Percent
Not at all	5	1.9
Every time during collection	255	94.8
Once a week	9	3.3
Total	269	100.0

4.4.3.3 The methods of cleaning storage containers

The Table 7 shows the method used when washing buckets for collection, a significant number of 224 respondents (83.3%) indicated that this was done by rinsing with cold water ($p < 0.001$). Using soap was indicated by 43 of the respondents (16%). This result provided insight on the quality of stored water since (83.3%) of respondents don't use any form of disinfectant or soap to clean their storage buckets. This may be attributed to affordability of cleaning products as the study shows that half of the study population is unemployed.

Table 7. Cleaning methods of storage containers

Description	Frequency	Percent
Rinsing with cold water	224	83.3
Rinsing with boiling water	2	0.7
Washing with soap	43	16.0
Total	269	100.0

4.4.3.4 The topping up of water practices

The Table 8 compares whether the respondents "top up" water vessels or they finish all the water and collect new fresh water in a cleaned storage container. Most respondents indicated that they did not "top up" water, ($p < 0.001$).

Table 8. Water topping up/replenishing practices

	Frequency	Percent
Yes	39	14.5
No	230	85.5
Total	269	100.0

4.4.4 The Sanitation infrastructure and removal of faecal waste

4.4.4.1 The types of toilets used in study population

Figure 4.4 shows the type of toilets used by the residents as an effective method for the removal of human faecal waste. A total of 87 respondents (32%) almost a third of the respondents had pit latrines where faecal waste is not removed but treated with antimicrobial chemicals. The ablution toilets are provided by the Municipality as an interim measure to prevent random defecation in the environment. These are shared among community members. From the study population it was found that 60 respondents use the ablution toilets. The 118 respondents (43.9%) show that they have sit down toilets with a flush inside their households. There are no significant differences in the number of respondents for each type of toilet used ($p < 0.001$).

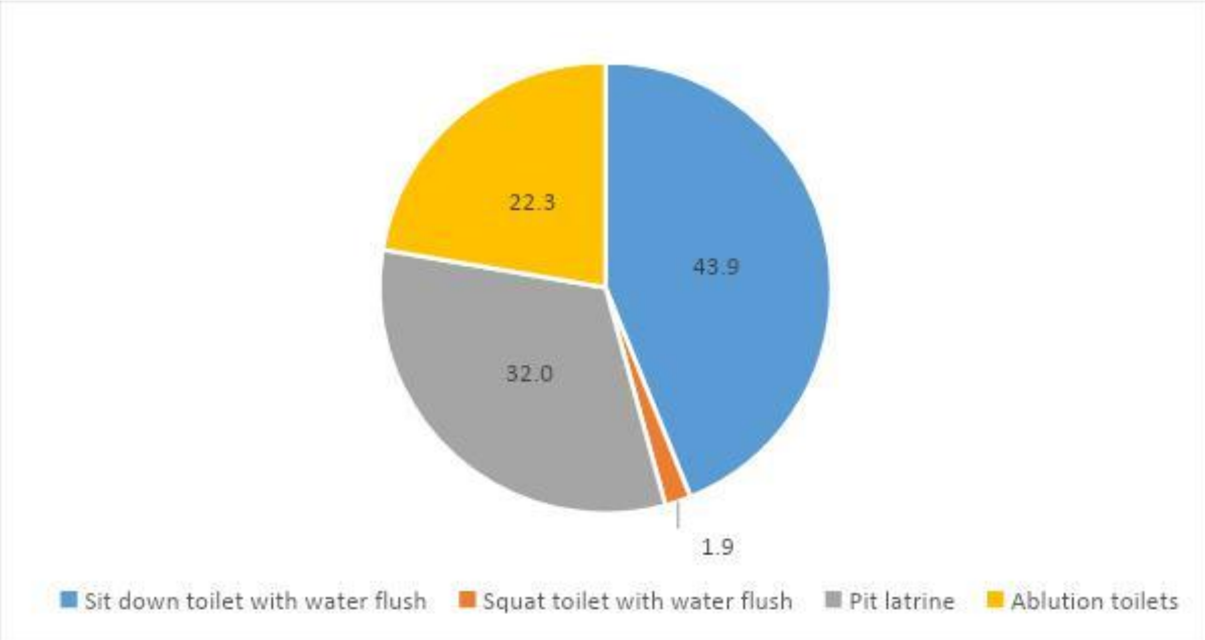

Figure 4.4. Types of sanitation Infrastructure

4.4.4.2 The waste water accumulation

Table 10 shows if there is stagnant or sewage water near the houses. Although 70.3% of respondents indicated that there was no stagnant water ($p < 0.001$), it is noted that nearly a third of the respondents (80/269) did have stagnant water or sewage leaks in the vicinity of their dwelling.

Table 9. Stagnant water or sewage water on the yard

	Frequency	Percent
Yes	80	29.7
No	189	70.3
Total	269	100.0

4.4.4.3 The solid waste piles

Table 10 shows the presence of solid waste piles near the houses. A total of 193/269 respondents show that they have solid waste piling in their yards. This result helped to determine the extent of environmental pollution within the yards of houses and this could have an impact on the influence of solid waste in water contamination.

Table 10. Frequency solid waste accumulation

	Frequency	Percent
Yes	76	28.3
No	193	71.7
Total	269	100.0

4.4.4.4 The domestic waste collection services

The Table 11 shows the frequency of solid waste collection from the respondent's households. A municipal service of waste collection is effectively removing the waste from the community as a standard practice within all communities of eThekwini residents. The results show that 253 respondents did not have waste piles close to them as the waste was collected often ($p < 0.001$).

Table 11. Frequency of waste collection

Description		Frequency	Percent
Collected once every week or more		253	94.1
Collected every two weeks		1	0.4
We deal with it ourselves		15	5.6
Total		269	100.0

4.4.5 Education on water storage practices

4.4.5.1 The water storage hygiene knowledge

The Table 12 shows whether the respondents have ever received any basic health education on water storage. Significantly more respondents 237 indicated that they had not received basic education ($p < 0.001$). This result helped determine the level of understanding in relation to contamination of stored water at a household level. It also ascertained whether respondents do apply hygienic practices based on their health knowledge such as washing of hands, disinfection of storage vessels, knowledge of transmission of waterborne pathogens and chemical treatment of stored water.

Table 12. Participant's education on water knowledge

	Frequency	Percent
Yes	31	11.5
No	237	88.1
Maybe	1	0.4
Total	269	100.0

4.4.5.2 Hand washing/hand hygiene

The Figure 4.5 shows the frequency at which hands are washed during the handling of water. A total of 122 respondents (45.3%) indicated that the respondents do comply with washing of hands, however a combined percentage of 147 showed inconsistency to hand hygiene by either not washing hands at all or washing sometimes (54.7%). The significant number of 48 respondents shows that they do not comply with hand hygiene practice ($p < 0.001$). This result provided insight on the level of exposure of residents who are noncompliant with hand hygiene.

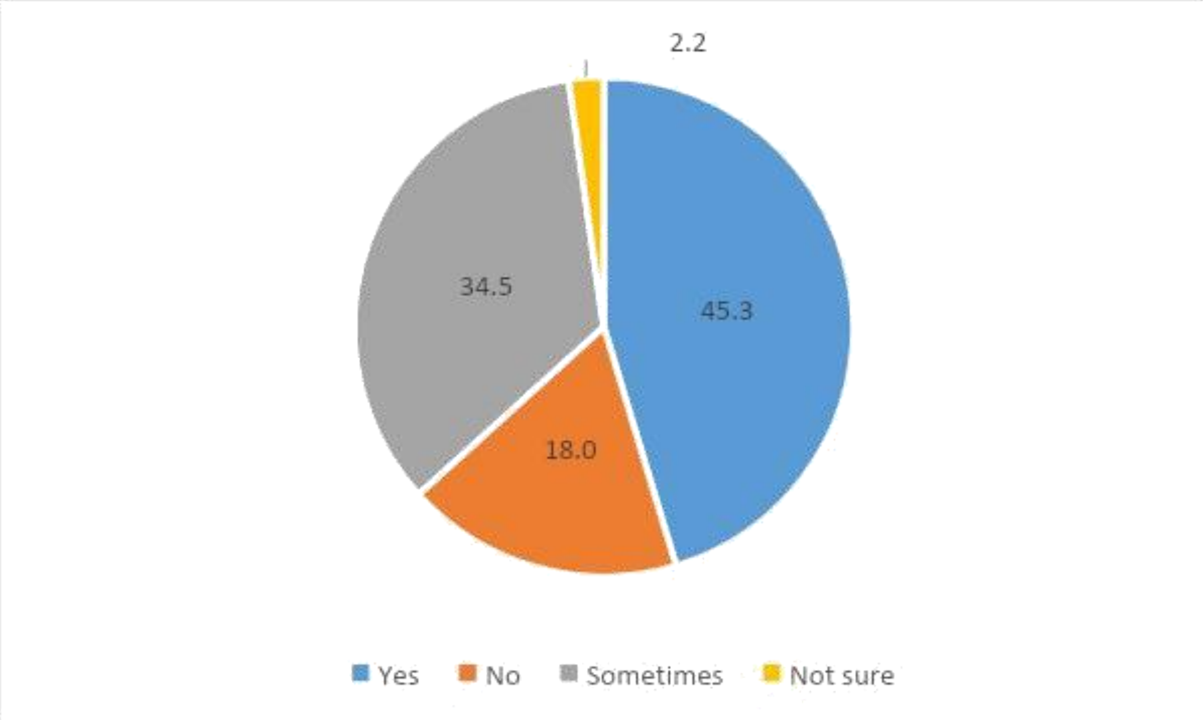

Figure 4.5 hand hygiene daily practice

4.4.5.3 Respondents understanding of water contamination

The Table 13 shows that a total of 206 respondents of participants lacked understanding of how water contamination of water occurs.

Table 13. Participant's understanding of water knowledge

	Frequency	Percent
Yes	63	23.4
No	206	76.6
Total	269	100.0

4.4.5.4 Household pets and exposure to stored water

Domestic animals can be a vector of infections as they enter in and out of the house. Table 14 looks at the frequency at which pets entered the household and for this statement there is a significant “No” response ($p < 0.001$) as 243 of the respondents (90%) indicated they had no pets and animals entering the house.

Table 14. Frequency of domestic animals entering households

	Frequency	Percent
Yes	27	10.0
No	242	90.0
Total	269	100.0

4.4.6 Prevalence of Clinical Symptoms

4.4.6.1 Prevalent diarrhoeal symptoms of unknown origin

The Table 15 shows a response of participants to a questionnaire about the prevalence of diarrhoea of unknown origin. A total of 253 participants had no clinical symptoms for diarrhoea whilst 16 respondents agreed to have had episodes of diarrhoea of unknown origin.

Table 15. Frequency of clinical symptoms

	Frequency	Percent
Yes	16	5.9
No	253	94.1
Total	269	100.0

4.5 Section C: The Laboratory analysis of collected samples

Water samples were collected and tested for *E.coli,* Total coliform count, and pH. These results would indicate if there was any contamination of water by microbiological agents in stored water that was used for domestic use. The pH would be tested on each sample for the presence of corrosive substances dissolved in water. The results were reported in terms of acidity or alkalinity levels of the water samples.

4.5.1 The Macroscopic analysis of water samples

The Table 16 shows the macroscopic appearance of domestic water samples under the laboratory lamp magnifier. The colour of water can vary due to the presence of disinfecting chemical agents dissolved in water, however 264 of samples looked clear and one sample visibly mud stained soil, 4 samples with a visible cloudiness. These results provided insight on the presence of physical substances that influenced the taste, the smell and the colour of the samples. This also assisted the study in determining whether the physical substances came through the distribution system or within household storage vessels.

Table 16. Macroscopic analysis of water samples

Macroscopic analysis	Frequency	Percent
clear & colourless	264	98.1
Cloudy	4	1.5
slightly muddy	1	0.4
Total	269	100.0

4.5.2 The pH of collected water samples

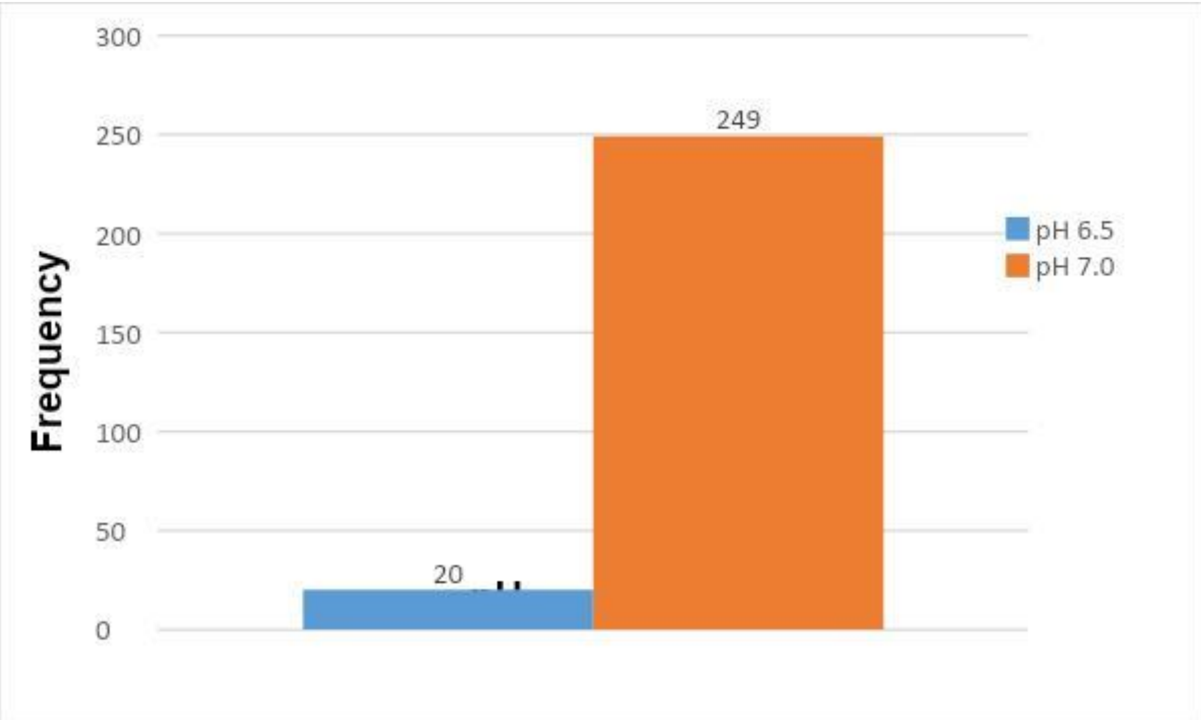

Figure 4.6. The pH of collected water samples

Table17. Ph range of collected water samples

pH results	Frequency	Percent
≥ 5 to ≤ 9.7	269	100.0

The pH measured the acidity and alkalinity of domestic water using a Universal pH indicator. This test would determine the quality of water stored in terms of its chemical content whether its concentrations do not exceed the required level for an acceptable quality of drinking water. The pH range for drinking water is ≥ 5 to ≤ 9.7. The table 17 shows that all the samples tested fell within the acceptable range with 249 samples testing 7.0 and 20 samples testing 6.5. The pH results indicate that the water quality was of an acceptable standard level according to SANS 241: 2015 (Annexure H).

4.5.3 Microbiological Analysis of collected water samples

4.5.3.1 Microbiological testing for Total coliform

The table below showed total coliform count on water, which showed risk levels of an exposure to infection. The number of colonies grown in the 3ml petrifilm were counted in order to determine the suitability of water quality for human consumption. A numerical count of colonies of greater than 300 colonies per ml deemed the water as high risk for household use. A positive control ATCC *E.coli* was used to check the accuracy of 3ml petrifilm.

Table 18. Total coliform count results on participant samples

Total	Minimum	Maximum	Mean	Std. Deviation
269	0.00	150.00	1.75	12.22

The mean and standard deviation was 1.75 ± 12.22. The large standard deviation is due to the extreme values that are observed in the data set, with a minimum of zero and a maximum of 150. A box and whisker plot identified 13 extreme values (> 3), but all values were retained as actual readings.

Table 19. The criteria and risk category of microbial water quality in this study

Households (n=269)	Total coliform count (CFU/ml)	*E.coli* count	SANS 241: 2015 Guidelines *E.coli* < 1, Total Coliforms ≤ 100 per mil
256	<1, ≤100	0	Low risk
1	300	0	High Risk
1	500	0	High Risk
1	600	0	High Risk
2	800	0	High Risk
2	1200	0	High Risk
1	1500	0	High Risk
1	1700	0	High Risk
1	1900	0	High Risk
1	3600	0	High Risk
1	4800	0	High Risk
1	5800	0	High Risk

Tables 18 and 19 show the total coliform count on water, that while 256/269 (95%) of households had a low risk total coliform count, the remaining 5% households had exposure to contaminated water and the results indicated that they have a coliform count exceeding 300 coliform per ml (SANS 241: 2015 Drinking Water Standards). The presence of coliforms in water generally indicates the presence of other forms of microbial agents other than the *E.coli* which is a major pathogen when isolated in drinking water.

Further analysis was done on these 13 households where the total coliform count was found to be high risk. The following was deduced from these 13 households:
It was found that 8/13 (61,5%) respondents did not understand the concept of water contamination. The level of education of 9/13 (69.2%) of respondents showed that they only had basic education up to high school and all 13 (100%) respondents saying they have never had any basic health education. The hand hygiene shows that 7/13 (53.8%) respondents were inconsistent with washing of hands, with 4/13 respondents saying they don't wash hands at all, while 3/13 only wash sometimes. The study population showed that 241 respondents were living in shacks with 86 still using pit latrines as their faecal waste removal system. From 13 positive respondents 5 (38.4%) were still using pit latrines as their sanitation system, 10 (76.9%) of them having solid

waste and sewage spills on the yard. Though the study showed that 253 (94%) respondents have their waste collected by Municipal service, 12 (92%) respondents from 13 positive tested samples with high risk total coliform counts, indicated that they deal with the waste by themselves. The 10/13 (76.9%) respondents indicated they are unemployed with a significant 11 (84.6%) of them washing buckets with only cold water, whilst only 2 could afford to wash with soap.

4.5.3.2The Microbiological testing for Escherichia coli

As per the findings depicted in Table 20, it is evident that no *E.coli* was isolated in water samples. These results provided insight on the water quality since the presence of *E.coli* in water is an indication of water faecal contamination. After inoculation of 3ml petrifilm with water samples and 24 hour incubation, there was no detection of green or blue coloured colonies which indicated no presence of *E.coli*.

The kit used was specific for the *E.coli* 0157:H7 human type which is a major strain when detected in water as it can cause severe diarrhoea. The absence of *E.coli* detection in drinking water indicated that there was no faecal contamination in drinking water. In this study population these results indicated that the drinking water met the expected standards according to (SANS 241:2015).

Table 20. *Escherichia coli* test results

E.coli count	**Frequency**	**Percent**
0	269	100.0

Table 21. Drinking water for SANS 241:2015: South African National Standard

Parameter	**Units**	**Standard limits**
Total coliform count	CFU/100ml	10
Escherichia coli	CFU/100ml	0
pH	pH units	≥ 5 to ≤ 9.7

This South African standard was approved in March 2015 by National Committee SABS/TC 147, Water, in accordance with procedures of the SABS Standards Division, in compliance with Annexure 3 of the WTO/TBT agreement.

Table 22. SPSS Output Variables

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1a	Are you employed?	0.454	0.293	2.396	1	0.122	1.575
	House type	0.170	0.257	0.436	1	0.509	1.185
	Education	-0.116	0.291	0.158	1	0.691	0.891
	Constant	0.686	1.136	0.365	1	0.546	1.987

a. Variable(s) entered on step 1: Are you employed? House type, Education.

Dependent variable: Do you understand anything about water contamination?

A respondent who is employed is 1.575 times more likely to understand about water contamination than one who is not employed. Education and House type do not show extreme odds.

CHAPTER FIVE: DISCUSSION AND LIMITATIONS

5.1. Discussion

5.1.1 Introduction

The aim of this study was to evaluate the quality of stored water, the handling and use of water and water storage practices for domestic purposes in the Umlazi P informal settlement. A comprehensive questionnaire was developed and administered to participants to give insight on water hygiene practices including the level of health awareness with regards to water contamination and disposal. This questionnaire also contained areas that provided insight in the evaluation of the quality of water and sanitation infrastructure and other methods of solid waste removal. This study also focused on detecting the presence of corrosive organic material as well as identifying the possible microbial contamination of household stored water. The water samples collected from households within the informal settlement were tested for pH levels , total coliform count and *E.coli* using laboratory approved testing standards. The combined data obtained from administration of questionnaire and laboratory experiments was used to evaluate quality of stored water against the South African National Standards. The SANS 241: 2015 states that drinking water should be of acceptable standard in terms of microbial content as well as taste, colour and odour. This study unveiled challenges faced by the residents of the informal settlements at Umlazi P section with regards to quality water as well as other related practices affecting water quality

5.1.2 Knowledge of contamination, water storage and hygiene practices

The prevalence of water borne infections is commonly associated with drinking contaminated water giving rise to infections such as diarrhoea, dysentery, typhoid fever and cholera (Kurui *et al.* 2019). Even when water is from a reliable source, the quality may be jeopardised by poor handling and unhygienic storage practices. In this study, most residents (88.1%) had not had any prior education on water storage and 76.6% indicated a lack of understanding of water contamination. Most of the residents (79.2%) indicated that they only had a high school level of education with no basic health education training. Furthermore the study results indicated that half of the residents in the population were unemployed, making access to quality health education and training unaffordable. Contamination is likely to be higher in poor households as they cannot afford to purchase products to safeguard their water from contamination. Contamination of drinking water is a worldwide problem particularly at the household level where stored water may be exposed to various types of pollution such as dust, insects even from human beings and animals (Nicholson *et al.* 2017). In the present study, the quality of water was found to be of a reasonably acceptable standard at the collection point as it has already be tested by the Municipality, but maintenance of its quality requires knowledge of how to handle the storage buckets and protect them from dust, human and animal pollution (Nicholson *et al.* 2017).

5.1.3 Water storage and hand hygiene

The data obtained from this study showed that there was an imminent exposure of water to contamination showing about 5% of the residents being at a risk of getting infections. The results also indicated the lack of proper hygiene with 48 households (18%) not complying with the hand wash practice when handling stored water. The study also discovered that 34.5% were inconsistent with hand hygiene indicating to wash their hands sometimes. The inadequate hand hygiene has a direct link to the spread of infections within a community potentially exposing stored water to contamination (Wolfe *et al.* 2018). Contamination may be progressive in families of low income with this study results already showing that 50% of residents are unemployed making it difficult for them to afford water treatment chemicals and soaps for cleaning.

The biggest threat to contamination of stored water is the use of unsealed containers, uncleaned scoops and unwashed hands (Edokpayi *et al.* 2018). In the present study almost all respondents indicated that they stored their domestic water in buckets which were kept closed when not in use, and 83.3 % indicated that they cleaned the storage containers by washing in cold water only. It is critical that soap be applied when washing hands especially after defecation or before handling water storage and touching food (Heibati *et al.* 2017). This study has shown that some of the residents only use tap water to clean their storage containers, whilst research has shown that the application of soap and the use of other chemical detergents can be effective in removing pathogens (Rubino *et al.* 2019). The poor hand hygiene enables pathogens to be transmitted from fingers to water storage containers especially when residents open and close buckets during water collection and topping up (Odonkor *et al.* 2019).

5.1.4 Solid waste removal and grey water

The environment suffers a great deal of pollution as a result of generated waste from households and industries (Kelava *et al.* 2018). The generated waste influences the changes in soil, air, water and microbial content of the environment which has a direct impact on human health (Rubino *et al.* 2019). Research has shown a connection between environmental pollution and water borne infections such as diarrhoea, typhoid, cholera, hepatitis and respiratory infections (Hurst 2019). In this study population 29.7% of the participants indicated that they have sewage water accumulating in their yards generated from laundry wash off, bathing, cleaning, food material, and storm-water drainage, human and animal faecal matter. A number of microorganisms inhabit different types of waste and propagate their growth within the environmental waste. The accumulation of waste has some degree of influence in the provision of safe water by effecting change to the chemical composition and microbiological content of safe water (Boelee *et al.* 2019).

The removal of solid waste and treatment of ground water becomes critical in protecting water resources from contamination. The eThekwini Municipality has been able to effectively remove generated waste from the community in the Umlazi P section as most residents (94%) indicated to having their waste collected weekly. However this study has shown that some residents (5.6%) use other means of waste disposal such as burning or disposing waste in illegal dumping areas or vacant spaces close by or in the river which can expose them to infections. The waste material does release powerful toxins that prove to be dangerous to people especially if waste is not handled correctly (Heibati *et al.* 2017. The stringent application of correct methods for the removal of solid waste must be mandatory to avoid piling of waste and cultivation of pathogens. This can be achieved on basic training on adverse effects of illegal dumping practices (Hurst 2019).

5.1.5 Water and sanitation infrastructure

The total removal of waste also depends on the quality of water and sanitation infrastructure available for the removal of human faecal matter. There are pathogens that are found in human and animal faeces, which when in contact with sources of community water can cause health problems (Hurst 2019). The water and sanitation infrastructure such as toilets, water distribution pipes and sewage systems must be effective enough to deal with the amount of faecal waste generated from humans and animals. This study has shown that residents use different types of toilets such as flushing toilets, ablution toilets and pit latrines. The ablution toilets are a Municipal sponsored facility that provides communal toilets and showers which are used by the community. The cleanliness of the ablution facility is important because 22.3% of the study population confirmed to be using these facilities for washing, laundry, bathing as well as for their toilet needs.

However the general public also have access to these ablution facilities increasing the chances of contamination. The pit latrines are a low cost type of toilets used by communities where there is a high incidence of unemployment and poverty (Umar *et al.* 2019). This study showed that just about half of the study population is unemployed and 32% of them use pit latrines as toilets. The pit latrines often lack a solid structure to meet sanitation requirements as a result microbial contaminants may escape the pit leaching into greywater (Otsuka *et al.* 2019). The accumulation of faecal material within the groundwater can expose water systems to coliform bacteria which may adversely affect human health (Allaire, Wu and Lall 2018). The pit latrines at some instances may be used for the disposal of other waste material such as diapers, condoms, pads, tampons and over time the pit is reduced in size almost to the level of the ground. The pathogen concentration becomes higher and waste takes longer to be degraded inside the pit. The high concentration of pathogens in the faecal sludge may include bacteria, parasites, and viruses, when transmitted via the oral route may cause severe diarrhoea in humans (Boelee *et al.* 2019). At the rate at which the pit fills up, chemical treatment becomes a requirement to degrade the pit content and this becomes a financial burden as half of this study population is unemployed. The current study showed that 9/13 positive samples for total coliform count were collected from households who use pit latrines as a waste removal system.

5.2 Laboratory investigation

5.2.1 Macroscopic appearance and Physical substances

Drinking water distribution systems (DWDS) are prone to microbial and physicochemical changes due to distribution pipe material corrosion, water treatment chemicals as well as the ingress of microorganisms during water works and storage of water for domestic needs (Rubino *et al.* 2019). In this study water samples were collected from storage vessels and tested for pH, total coliform count and *E. coli*. Even though drinking water was collected from tested sources, this study sought to evaluate possible contamination of water by microorganisms from storage vessels. Due to the aging of water distribution pipes, they break at some point due to external corrosion allowing physical substances such as mud, sand and other organic material to enter the distribution system (Ngasala *et al.* 2019). The first step of the experimental work was to investigate the macroscopic appearance of water to see any presence of physical substances that could influence the colour, odour or taste. The macroscopic examination showed just about 0.4% of water samples to have visible substances in it and 1.5% showing cloudiness. However a total of 100 % of residents reported the taste of drinking water testing to be acceptable.

5.2.2 The significance of pH measurement

As water distribution systems age, they also suffer and internal corrosion of pipes as a result corrosive products may be found dripping in communal taps (Li *et al.* 2019). When corrosive chemical substances such as iron and copper are found in drinking water that becomes a major deterioration point of the quality of drinking water. (Shrestha *et al.* 2017). As corrosive material compounds overtime in distribution systems it becomes detrimental to human health. The pH measurement gives an idea as to the extent of dissolved substances present in water either making it too acidic or basic (Li *et al.* 2019). Drinking water with a low acidic pH can lead to health conditions such as diarrhoea, dehydration, diabetes and gastritis (Rubino *et al.* 2019). The drinking water with a very high basic pH leads to conditions like renal failure, respiratory alkalosis, kidney stones and other kidney related disorders (Shrestha *et al.* 2017). In this study water samples were tested for pH to determine the extent of corrosive substances dissolved in drinking water. A total of 269 (100%) samples fell within an acceptable pH range of ≥ 5 to ≤ 9.7 according to SANS 241: 2015 drinking water standard.

5.2.3 The significance of the total Coliform count results

The water samples were tested for total coliform count to detect the presence of water pollutants. The presence of microbial agents in drinking water leads to failure of water to meet quality guidelines and this has a direct link to health diseases. Water borne infections can be caused by a contingent of microorganisms such as bacteria, protozoa, viruses and parasites. The total coliform count represents all organisms that may be present in the environment even those which are not of faecal origin (Ngasala *et al.* 2019). These bacteria may be introduced into the water system through contamination of the water source and the distribution system (Odonkor *et al.* 2019). The detection of coliforms in water exceeding 300CFU/ml when using a 3ml petrifilm indicates that water has been contaminated by microbial pathogens and is unsuitable for human consumption. (Wolfe *et al.* 2018). The results from the present study showed a positive total coliform count of the samples collected from 13 households in the study population rendering their drinking water a high risk for domestic use. This finding is of concern, despite it only accounting for 5% of the study population, since the tested water samples were collected from the municipal water supply. It is possible in these cases that there could have been contamination either from the communal tap or at the point of use. Another likelihood of water contamination occurs when water is stored for long periods of time as water becomes a harbour for pathogens (Adane *et al.* 2017). The further cause of water deteriorating in quality is the use of unsuitable storage containers and the household environment at which they are kept making it susceptible to coliform bacterial contact and chemical changes.

On further analysis of these 13 households where the total coliform count was found to be “high risk”, it was found that 8/13 (61.5%) respondents did not understand the concept of water contamination and 9/13 (69.2%) of respondents had only basic education up to high school and all 13 (100%) respondents indicated that they have never had any basic health education. With regard to hand hygiene, 7/13 (53.8%) of respondents indicated that they were inconsistent in their handwashing practices, with 4/13 (30.7%) respondents indicating that they don't wash their hands at all, and 3/13 (23%) only wash sometimes. The overall study population showed that 241 respondents were living in shacks with 86 still using pit latrines as their faecal waste removal system. From the 13 respondents with high coliform counts, 9/13 (69.2%) were still using pit latrines as their sanitation system, 10/13 (76.9%) of them having solid waste and sewage spills on their yard. Though the overall study population 253/269 (94%) indicated that respondents have their waste collected by Municipal service, but 12 (92%) of this subgroup of 13, indicated that they dispose of the waste by themselves. The 10/13 (76.9%) of the respondents indicated that they are unemployed with 11/13 (84.6%) of them washing their storage containers with only cold water. This study showed that residents 2/13 (15.4 %) of the study population store water for a period between from a week to a month which may require chemical treatment products to protect it from decline in quality

5.2.4 The significance of *E.coli* water testing results

The water samples were tested for the presence of *E.coli* as an indicator for faecal contamination. The study results revealed that that water quality met the South African standard for drinking water where the *E.coli* count must be < 1CFU/100ml. The provision of clean water is a requirement for both human life and health. The good quality water should have no odour, no smell, practically no taste and a total absence of *E.coli* (Hoossein *et al.* 2016). In this study water samples were collected from storage containers to test for *E.coli* which has a potential of causing health diseases when detected in drinking water (Melariri *et al.* 2019). *E.coli* represents the entire group of bacteria found in the faeces of human beings and animals (Adane *et al.* 2017) *E.coli* detection remains the best biological indicator for faecal contamination and has been used worldwide as a standard method in testing drinking water quality (Wolfe *et al.* 2018).

The isolation of *E.coli* in water indicates a greater health risk than just a positive total coliform count only. Even though research suggests that the coliform count may not be faecal contamination specific, however in most cases of water research its presence points to *E.coli*. The *E.coli* is the only faecal coliform bacteria which inhabits the gastrointestinal tract as a predominant bacterium compared to other *Enterobacteriaceae* (Craun 2018). Though *E. coli* is considered to be a commensal in the gut of the human beings and animals but some strains of *E. coli* such as *E.coli O157: H7* can produce harmful toxins causing diarrhoea (Edokpayi *et al.* 2018). The *E.coli* can survive in a water distribution system for 4 to 12 weeks at a temperature of 15 to 18 °C. This present study showed no *E. coli* present in water samples tested, and this indicated that the expected standards of drinking water in terms of faecal coliform bacteria were met. However the absence of *E.coli* does not eliminate the exposure of water to other forms of microbial contaminations as indicated by the presence of total coliform count in this study. The water treatment chemicals such as chloramine are known to be effective against even virulent strains such as *E.coli* O157: H7 (Adane *et al.* 2017). The *E.coli* is known to survive for long periods of time in cold water, therefore the quality of stored water requires chemical disinfectants to be available at all times in households (Rubino *et al.* 2019). This will ensure that one of the quality standards that water must be acceptable in terms of microbial content is maintained.

5.3 Limitations

The study was a cross sectional study, samples that were collected were only tested once, the study results might have been strengthened if several samples were collected from the same households to evaluate the quality of water in relation to the length of storage. Future studies are recommended with more intensive follow up sampling and testing to close the gaps and make a more comprehensive report on any other possible microbial contamination other than *E.coli.* Some houses were leased to occupants; this was a limitation to some of the information required as per the questionnaire. The consenting age for the present study was 18 years and above, households headed by those under the age of 18 were therefore excluded from the study. The houses that had no registered house numbers for the purposes of records and follow up were excluded. During the study design, the researcher wished to collect water samples from the municipal taps, however this was prohibited by the Municipality since they indicated that all tapped water is tested already. The consultation was made with the eThekwini Municipal Institute of Learning where engagements made did not result in the approval of testing piped water. This is viewed as a limitation, since it was not possible to determine if there was a difference between the water from the municipal taps and water in stored containers.

5.3.1 Recommendations

The eThekwini Municipality has provided water and sanitation infrastructure for the delivery of safe water and removal of solid waste, however some of the informal settlement residents at the Umlazi P Section still cannot access proper and effective water and sanitation services.

The challenges of safe water delivery arise when residents illegally connect water pipes to a communal standpipe to receive water at their homes. These improper connections sometimes leave distribution systems at risk of contamination particularly at the main distribution point. The improvement of infrastructure becomes vital in protecting water distribution points to curb the spread of infections.

5.3.2 Recommendation on basic health education

It is recommended that educational programmes that will address a lack of health knowledge with regards to water storage practices and hygiene are developed and implemented in communities in which access to water and sanitation is strained. This may be conducted by creating group classes for the community, developing posters and periodically doing home visits.

5.3.3 Infrastructure development and maintenance

As shown through this study South Africa still lacks basic infrastructure to supply adequate quantities of water and sanitation to all citizens. Due to the limited number of communal taps, crowding around taps becomes unavoidable leaving taps unhygienic and dirty. The provision of quality infrastructure will go a long way in improving the health conditions of informal settlement dwellers. The infrastructure should include piped water and sanitation facilities for each household. A programme of maintenance must be in place to monitor its functionality.

5.3.4 Removal of solid waste

All informal settlement residents must be integrated to Municipal services for removal of solid waste to avoid certain sections of residents having to employ unsafe methods of waste disposal. Residents should also be encouraged to avoid dumping waste in rivers and non-designated areas, to minimise the adverse effects of environmental pollution.

5.3.5 Low cost storage and treatment

It is recommended that SABS approved water storage containers and water treatment chemicals must be made available at a low cost that can be affordable to the communities to ensure improved water quality and storage.

5.3.6 Legislation and infrastructure

The Municipality needs to establish stringent laws and monitoring programmes that protect water and sanitation infrastructure from any form of vandalism that put end users at health risk.

5.4 Conclusion

The bacterial contamination of domestic water is a serious problem that accounts for many health concerns globally. Water is essential for human life, therefore it must be delivered at a quality that is fit for human consumption. The access to adequate quantities of water is critical to maintain cleanliness and household hygiene. Due to distance between households and communal tap some residents in this study employ a method of storing water for domestic use. The aim of this study was to evaluate the quality of water stored for domestic needs of residents in Umlazi P informal settlements.

The data collected from the study highlighted significant challenges with hygienic storage practices and infrastructure. These challenges are augmented by unemployment, poverty, education levels, financial resources, population growth and poor housing structure. In conclusion, a combined collaborative effort between the community and all stakeholders such as the Department of works, Department of Health, Department of Water and Sanitation and the Department of Human Settlements is critical in addressing problems of safe drinking water. At the centre of these efforts infrastructure development and health education programmes should be implemented with emergency. This will go a long way in assisting the Umlazi P section community improve their health and living conditions.

6. REFERENCES

Adane, M., Mengistie, B., Kloos, H., Medhin, G. and Mulat, W. 2017. Sanitation facilities, hygienic conditions, and prevalence of acute diarrhea among under-five children in slums of Addis Ababa, Ethiopia: baseline survey of a longitudinal study. *PloS one*, Volume 12 Pg. 1-18

Allaire, M., Wu, H. and Lall, U. 2018. national trends in drinking water quality violations. *Proceedings of the National Academy of Sciences*, 115 (9): 2078-2083.

Altmann, M., Altare, C., Van Der Spek, N., Barbiche, J.-C., Dodos, J., Bechir, M., Aissa, M. A. and Kolsteren, P. 2018. Effectiveness of a household water, sanitation and hygiene package on an outpatient program for severe acute malnutrition: a pragmatic cluster-randomized controlled trial in chad. *The American Journal of Tropical Medicine and Hygiene*, 98 (4): 1005-1012.

Asghari, F. B., Jaafari, J., Yousefi, M., Mohammadi, A. A. and Dehghanzadeh, R. 2018. Evaluation of water corrosion, scaling extent and heterotrophic plate count bacteria in asbestos and polyethylene pipes in drinking water distribution systems. *Human and Ecological Risk Assessment: An International Journal*, 24 (4): 1138-1149.

Ashbolt, N. J. 2015. Microbial contamination of drinking water and human health from community water systems. *Current environmental health reports*, 2 (1): 95-106.

Bae, S., Lyons, C. and Onstad, N. 2019. A culture-dependent and metagenomic approach of household drinking water from the source to point of use in a developing country. *Water Research x*, 2: 100026.

Bain, R., Cronk, R., Hossain, R., Bonjour, S., Onda, K., Wright, J., Yang, H., Slaymaker, T., Hunter, P. and Prüss- Ustün, A. 2014. Global assessment of exposure to faecal contamination through drinking water based on a systematic review. *Tropical Medicine & International Health*, 19 (8): 917-927.

Cabral, J. P. 2010. Water Microbiology. Bacterial pathogens and water. *International Journal of Environmental Research and Public Health*, 7 (10): 3657-3703.

Cele, A. 2018. An Assessment of the Effectiveness of Water Quality Monitoring and Drinking Water Quality Compliance by Environmental Health Practitioners at Selected Metropolitan and District Municipalities in South Africa during 2013-2014. University of Cape Town January 2020 Available: http://hdl.handle.net/11427/29893 (Accessed 18 April 2019 2020). Page 1-66

Chhipi-Shrestha, G., Hewage, K. and Sadiq, R. 2017. *Fit-for-purpose Wastewater Treatment: Conceptualization To Development of Decision Support Tool (i). Science of the Total Environment*, 607: 600-612.

Chikoto, T. 2010. Informal settlements in South Africa. University of Pretoria, Fuculty of Engineering October 2009, Page 1-55.

Clifford- Holmes, J. K., Slinger, J. H., de Wet, C. and Palmer, C. G. 2017. Modelling in the 'Muddled Middle': A Case Study of Water Service Delivery in Post- Apartheid South Africa. *Social Systems Engineering: The Design of Complexity*, 7702: 215.

Craun, G. F. 2018. *Waterborne Diseases in the US*. CRC Press. Health Effects Research Laboratory, US Environmental Protection Agency: Page 1-182.

Cumming, O. and Cairncross, S. 2016. Can water, sanitation and hygiene help eliminate stunting? Current evidence and policy implications. *Maternal & Child Nutrition*, 12: 91-105.

du Plessis, A. 2019. Establishing South Africa's Current Water Quality Risk Areas. In: *Water as an Inescapable Risk*. Springer, 173-181. https://doi.org/10.1007/978-3-030-03186-2_8 (Accessed 23 October 2019)

Edokpayi, J., Rogawski, E., Kahler, D., Hill, C., Reynolds, C., Nyathi, E., Smith, J., Odiyo, J., Samie, A. and Bessong, P. 2018. Challenges to sustainable safe drinking water: a case study of water quality and use across seasons in rural communities in Limpopo Province, South Africa. *Water*, 10 (2): 159.

Etale, A., Jobin, M. and Siegrist, M. 2018. Tap versus bottled water consumption: the influence of social norms, affect and image on consumer choice. *Appetite*, 121: 138-146.

Forde, M., Izurieta, R. and Ôrmeci, B. 2019. Water and health. *Water quality in the Americas*: 27. Page 1-626 https://www.interacademies.org/sites/default/files/publication/water_quality_in_the_americas.pdf (Accessed 24 October 2019)

Ghaderpoori, M., Dehghani, M. H., Fazelzadeh, M. and Zarei, A 2009.Survey of microbial quality of drinking water in rural areas of Saqqez, Iran. *Am Eurasian Journal Agricultural and Environmental Science*. 5 (5): 627-632.

Gounden, S., Perumal, R. and Magula, N. 2018. Extra pulmonary Tuberculosis in the setting of HIV hyperendemicity at a tertiary hospital in Durban, South Africa. *Southern African Journal of Infectious Diseases*, 33 (3): 57-64.

Guerrini, A., Vigolo, V., Romano, G. and Testa, F. 2018. Levers supporting tariff growth for water services: evidence from a contingent valuation analysis. *Journal of Environmental Management*, 207: 23-31.

Heibati, M., Stedmon, C. A., Stenroth, K., Rauch, S., Toljander, J., Säve-Söderbergh, M. and Murphy, K. R. 2017. Assessment of drinking water quality at the tap using fluorescence spectroscopy. *Water Research*, 125: 1-10.

Heligman, B. T., Zhao, A., Bartilson, E., Gupta, A., Hannan, J., Diop, M. and Read, R. L. 2019. The design and usage of a portable incubator for inexpensive in-field water analysis. *Journal of Humanitarian Engineering*, 6 (2).

Hellberg, S. 2017 Water for survival, water for pleasure-a biopolitical perspective on the social sustainability of the basic water agenda. 10: 65-80.

Hemson, D. 2016. Water, sanitation and health: South Africa's remaining and existing issues. *South African Health Review*, 2016 (1): 25-34.

Hlongwa, M., Peltzer, K. and Hlongwana, K. Risky sexual behaviours among women of reproductive age in a high hiv burdened township in Kwazulu-Natal, South Africa 2020, Page 1-9, https://bmcinfectdis.biomedcentral.com/track/pdf/10.1186/s12879-020-05302-1.pdf (Accessed 01 May 2020)

Hurst, C. J. 2018. Understanding and estimating the risk of waterborne infectious disease associated with drinking water. In: *The Connections Between Ecology and Infectious Disease*. Springer, 59-114.

Hurst, C. J. 2019. Options for Providing Microbiologically Safe Drinking Water. In: *The Structure and Function of Aquatic Microbial Communities*. Springer, 185-260. https://doi.org/10.1007/978-3-030-16775-2_8 (Accessed 28 October 2019)

Hurst, C. J. 2019. Understanding Aquatic Microbial Communities. In: *The Structure and Function of Aquatic Microbial Communities*. Springer, 1-12. https://doi.org/10.1007/978-3-030-16775-2_1 (Accessed 28 October 2019)

Kandel, P., Kunwar, R., Lamichhane, P. and Karki, S. 2017. Extent of fecal contamination of household drinking water in Nepal: Further Analysis of Nepal Multiple Indicator Cluster Survey 2014. *The American Journal of Tropical Medicine and Hygiene*, 96 (2): 446-448.

Kelava, I., Šutić, I., Pavišić, V., Salać, N. and Aleksandar, B. 2018. Health safety of water for human consumption in the City of Cabar in the period of 2012-2016. *International Journal of Sanitary Engineering Research*, 12 (1/2018): 27. Page 1-7.

Khalil, K. U. R., Sarwar, A., Hamayun, M., Naeem, W. and Ahmad, M. 2017. Bacteriological quality of drinking water in schools of Peshawar, Khyber Pakhtunkhwa. *Journal Of Medical Sciences*, 25 (4): 433-436.

Kostyla, C., Bain, R., Cronk, R. and Bartram, J. 2015. Seasonal variation of faecal contamination in drinking water sources in developing countries: a systematic review. *Science of the Total Environment*, 514: 333-343.

Kurui, E. J., Ogendi, G. M., Moturi, W. N. and Nyawanga, D. O. 2019. Household Water Handling Practices in the Arid and Semi-Arid Lands in Kenya. In: *The Relevance of Hygiene to Health in Developing Countries*. . https://www.intechopen.com/books/the-relevance-of-hygiene-to-health-in-developing-countries/household-water-handling-practices-in-the-arid-and-semi-arid-lands-in-kenya

Li, J., Zhuge, X., Li, Y. and Yuan, C. 2019. The water-soluble Indolium-based fluorescence probes for detection of the extreme acidity or extreme alkalinity. *Tetrahedron*, 75 (48): 130688.

Melariri, P., Steenkamp, L., Williams, M., Mtembu, C., Ronaasen, J. and Truter, I. 2019. Water, Sanitation and Hygiene practices in early childhood development (ecd) centres in low socio-economic areas in nelson mandela bay, South Africa. *Journal of Water, Sanitation and Hygiene for Development*, 9 (1): 164-171.

Murphy, J. 2017. Prevalence and Risk Factors for Diabetes Mellitus among newly-diagnosed HIV-infected South African Adults. University of Washington, Page 1-25.

Murwirapachena, G. and Dikgang, J. 2018. An empirical examination of reducing status quo bias in heterogeneous populations: evidence from the South African Water Sector. School of Economics and Development Studies, Nelson Mandela University, Port Elizabeth, South Africa., Public and Environmental Economics Research Centre (PEERC), School of Economics, University of Johannesburg, Johannesburg, South Africa: Page 1-39.1

Musoke, D., Ndejjo, R., Halage, A. A., Kasasa, S., Ssempebwa, J. C. and Carpenter, D. O. 2018. Drinking water supply, Sanitation, and Hygiene promotion interventions in two slum communities in Central Uganda. *Journal of Environmental and Public Health*, 2018.

Navab-Daneshmand, T., Friedrich, M. N., Gächter, M., Montealegre, M. C., Mlambo, L. S., Nhiwatiwa, T., Mosler, H.-J. and Julian, T. R. 2018. *Escherichia coli* contamination across multiple environmental compartments (soil, hands, drinking water, and handwashing water) in urban Harare: Correlations and Risk Factors. *American Journal Tropical Medicine Hygiene* 98 (3), 803−813

Ngasala, T. M., Gasteyer, S. P., Masten, S. J. and Phanikumar, M. S. 2019. Linking cross contamination of domestic water with storage practices at the point of use in urban areas of Dar es Salaam, Tanzania. *Journal of Environmental Engineering*, 145 (5): 04019017.

Nicholson, K. N., Neumann, K., Dowling, C. and Sharma, S. 2017. *E. coli* and Coliform bacteria as indicators for drinking water quality and handling of drinking water in the Sagarmatha national park, Nepal. *Environmental Management and Sustainable Development*, 6 (2): 411-428.

Odonkor, S. T., Kitcher, J., Okyere, M. and Mahami, T. 2019. Self-assessment of hygiene practices towards predictive and preventive medicine intervention: A Case Study of University Students in Ghana. *BioMed Research International Journal*, 2019. 3868537

Onda, K., Crocker, J., Kayser, G. L. and Bartram, J. 2014. Country clustering applied to the Water and Sanitation sector: a new tool with potential applications in research and policy. *International Journal of Hygiene and Environmental Health*, 217 (2-3): 379-385.

Otsuka, Y., Agestika, L., Sintawardani, N. and Yamauchi, T. 2019. Risk factors for undernutrition and diarrhea prevalence in an urban slum in Indonesia: focus on Water, Sanitation, and Hygiene. *The American Journal of Tropical Medicine and Hygiene*, 100 (3): 727-732.

Prüss-Üstün, A. and Corvalán, C. 2006. Preventing disease through healthy environments. *Towards an estimate of the environmental burden of disease. Geneva: World Health Organization*. *The American Journal of Tropical Medicine and Hygiene.*

Rayner, J., Murray, A., Joseph, M., Branz, A. and Lantagne, D. 2016. Evaluation of household drinking water filter distribution programs in Haiti. *Journal of Water, Sanitation and Hygiene for Development*, 6 (1): 42-54.

Reddy, B., Kusuma, Y. S., Pandav, C. S., Goswami, A. K. and Krishnan, a. 2017. Water and Sanitation Hygiene practices for under-five children among households of Sugali tribe of Chittoor district, Andhra Pradesh, India. *Journal of Environmental and Public Health*, 2017, Page 1-9.

Roche, R., Bain, R. and Cumming, O. 2017. A long way to go–estimates of combined Water, Sanitation and Hygiene coverage for 25 Sub-Saharan African countries. *PloS one*, 12 (2): e0171783.

Rubino, F., Corona, Y., Jiménez Pérez, J. and Smith, C. 2019. Bacterial contamination of drinking water in Guadalajara, Mexico. *International Journal of Environmental Research and Public Health*, 16 (1): 67.

Sacchetti, R., De Luca, G., Guberti, E. and Zanetti, F. 2015. Quality of drinking water treated at point of use in residential healthcare facilities for the elderly. *International Journal of Environmental Research and Public Health*, 12 (9): 11163-11177.

Saleh, M. A., Abdel-Rahman, F. H., Woodard, B. B., Clark, S., Wallace, C., Aboaba, A., Zhang, W. and Nance, J. H. 2008. Chemical, microbial and physical evaluation of commercial bottled waters in the greater Houston area of Texas. *Journal of Environmental Science and Health Part A*, 43 (4): 335-347.

Salisbury, F., Brouckert, C., Still, D. and Buckley, C. 2018. Multiple criteria decision analysis for sanitation selection in South African Municipalities. *Multiple criteria decision analysis for sanitation selection in South African Municipalities*, 44: 448-458.

Shields, K. F., Bain, R. E., Cronk, R., Wright, J. A. and Bartram, J. 2015. Association of supply type with faecal contamination of source water and household stored drinking water in developing countries: a bivariate meta-analysis. *Environmental Health Perspectives*, 123 (12): 1222-1231.

Suiter, E. and Johnston, I. 2014. Resolving water and sanitation access in Niger. Factor 9. Water and Sanitation Page 1-8. https://www.worldfoodprize.org/documents/filelibrary/images/youth_programs/research_papers/2014_papers/Johnston_ESuiter_IA_DEC76B3FC3E0A.pdf , (Accessed 28 October 2019)

Tenza, O. T. 2018. Assessing the provision of interim services role in promoting livelihood strategies in informal settlements: case of Amaoti Mozambique in iNanda,University of Kwazulu Natal, Page 1- 150.

Troeger, C., Forouzanfar, M., Rao, P. C., Khalil, I., Brown, A., Reiner Jr, R. C., Fullman, N., Thompson, R. L., Abajobir, A. and Ahmed, M. 2017. Estimates of global, regional, and national morbidity, mortality, and aetiologies of diarrhoeal diseases: a systematic analysis for the global burden of disease study 2015. *The Lancet Infectious Diseases*, 17 (9): 909-948.

Umar, M., Kambai, J., Mohammed, I., Oko, J., Obafemi, A., Murtala, I., Ajiya, K., Yaya, A., Abdulkarim, I. and Akafyi, D. 2019. Bacteriological quality assessment and antibiogram profile of bacteria associated with sachet drinking water sold at Zaria, Northern Nigeria. *International Journal of Pathogen Research*: 1-13.

WHO 2015. *Water Sanitation & Hygiene for accelerating and sustaining progress on neglected tropical diseases: A global strategy 2015-2020*. http://apps.who.int/iris/bitstream/10665/182735/1/WHO_FWC_WSH_15.12 (Accessed 22 November 2017)

WHO 2017. *Guidelines for drinking-water quality*. World Health Organization. Second Addendum, Microbiological agents in drinking water: Page 1-142.

WHO and UNICEF 2017 progress on drinking water, sanitation and hygiene: 2017 update and SDG Baselines: Page 1- 108.

Wolfe, M., Kaur, M., Yates, T., Woodin, M. and Lantagne, D. 2018. A systematic review and meta-analysis of the association between Water, Sanitation, and Hygiene exposures and cholera in case–control studies. *The American Journal of Tropical Medicine and Hygiene*, 99 (2): 534-545.

Wright, C. J., Sargeant, J. M., Edge, V. L., Ford, J. D., Farahbakhsh, K., Shiwak, I., Flowers, C., Harper, S. L. and Team, I. R. 2017. Water quality and health in Northern Canada: stored drinking water and acute gastrointestinal illness in Labrador Inuit. *Environmental Science and Pollution Research*: 1-13.

Xaba, N. A., Chetty, N. and Karodia, A. M. 2016. The management of water quality along the umlazi l-section stream, KwaZulu-Natal province-republic of South Africa. *Singaporean Journal of Business, Economics and Management Studies*, 51 (3415): 1-29.

Annexure A: A letter of application to the Municipal councillor

ANNEXURE A

DUT DURBAN UNIVERSITY OF TECHNOLOGY

23 November 2018

EThekwini Municipality
The Councillor
Mezzanine Floor Shell House
PO Box 1014
Durban 400

Herewith a request to conduct a research project in the informal settlements at Umlazi P section, the study will focus on contamination of domestic water stored within the households of the informal settlements. I will conduct questionnaires with an aim to get information on handling and storage of water that has been collected from the main source. I will also collect water samples that will be tested in an approved laboratory for waterborne pathogens and chemical substances suspended in water.

The Title of my topic is: The evaluation of the quality of sanitation and stored water for domestic use in the Umlazi P section informal settlement.

This study will be conducted after a full ethical approval has been obtained from Durban University of Technology. The results obtained in the study will indicate whether the water used for all domestic purposes is not contaminated in the storage containers. The results will be made available online sources and available through publications.

Thanking you for your consideration in this regard

Sincerely

Applicant: Mr Simangaliso Shangase

Date: 26/11/2018

Community Representative:

Date 26/11/2018

Signature

Stamp

Annexure B: A letter of acceptance of the research project application

ANNEXURE B

EThekwini Municipality
The Councillor
Mezzanine Floor Shell House
PO Box 1014
Durban 400

Councillor A.N Shabalala

0731887759

26 November 2018

To whom it may concern

I, councillor A.N Shabalala Ward 87 Umlazi write this letter to confirm that I have given Mr Simangaliso Idiom Shangase, ID 7907275452083 permission to conduct a research project "Evaluation of the quality of stored water for domestic use" within ward 87.

Should you require any clarity please feel free to contact my office on 031-9075766.

Yours in community development

Councillor A.N Shabalala

26/11/2018

Annexure C: Letter of information for consenting participants

ANNEXURE C

LETTER OF INFORMATION

Title of the Research Study: The evaluation of the quality of sanitation and stored water for domestic use in the Umlazi P section informal settlement.

Principal Investigator/s/researcher: Simangaliso Shangase. B.Tech Biomedical Technology

Co-Investigator/s/supervisor/s: Dr P Pillay (PHD) & Ms T S Ndlovu (M Tech)

Brief Introduction and Purpose of the Study:

You are invited to participate in a research study that will be based on testing stored water in your households. The water that you use for drinking, cooking and washing should be free of contamination. Due to the lack of adequate water taps this results in our communities storing water inside the houses. The failure to use correct water storage methods and also storing water in a humid temperature as well as failure to adhere hygienic practices, gives rise to various infections like diarrhoea, Urinary tract infections and fever which can lead to health problems. The purpose of this research is to test the quality of stored water collected for domestic use and to investigate how community members handle the stored water.

Outline of the Procedures: We intend to collect and test water samples from water storage containers within your homes. These water samples will be tested to see if your stored water is fit for all domestic purposes which is drinking, washing, cooking and bathing. The first stage will be to conduct a questionnaire which is aimed at gathering information about the overall living conditions, knowledge and practices relating to safe water storage methods. Laboratory analysis of samples for microorganisms will be done at a Mangosuthu University Biomedical Science Laboratory. Chemical suspensions will be tested in water samples using quantitative analytical methods.

Risks or Discomforts to the Participant: None. This research will pose no discomfort to you, as we will be working with storage water only.

Benefits: This study seeks to assess the quality of stored water for domestic purposes within this community and also advise on any unhygienic practices on handling and storing water to prevent contamination.

Reason/s why the Participant May Be Withdrawn from the Study: The participation on this research is voluntary, however you will be requested to sign an informed consent as an official agreement between a researcher and a participant to work together on this research project. You must also be willing the researcher to conduct a questionnaire. You must allow the researcher access inside your homes to collect samples of water from storage containers.
Remuneration: No remuneration will be given to you.

Costs of the Study: There will be no costs will have to be covered by a participant

Confidentiality: Results obtained will be published though the Department of Water and Sanitation after submitting the results, and any sensitive information will be kept confidential. The information will be accessible online through official written request and a special pin code will be granted. Hard copies will be kept on a locked cupboard accessible through a written request.

Research-related Injury: We don't anticipate any injuries to occur as we will be only working with water samples but contact numbers are provided in an event of an injury.

Persons to Contact in the Event of Any Problems or Queries:

Dr Pavitra Pillay
Senior Lecturer, Department of Biomedical and Clinical Technology, Faculty of Health Sciences, Durban University of Technology, Tel: 031-3735423/031-3735411, email: pillayp@dut.ac.za

Ms T S Ndlovu
Lecturer, Department of Biomedical and Clinical Technology, Faculty of Health Sciences, Durban University of Technology, Tel: 031-3735298/031-3735411, email: ndlovuts@dut.ac.za

Full Name of Participant **Date** **Time** **Signature**

Full Name of Participant **Date** **Time** **Signature**

Annexure D: Laboratory permission from Mangosuthu University of Technology

ANNEXURE D

Mangosuthu
University of Technology

UMLAZI - KWAZULU NATAL
P.O. Box 12363 Jacobs 4026 Durban Tel: 031 907 7111 Fax: 031 907 2892

23 May 2018

To whom it may concern

Permission to use the Biomedical Sciences Laboratories for Masters Project – Mr SI Shangase

This letter serves to confirm that permission has been granted to Mr Simangaliso I. Shangase, 7907275452083 to use the Department of Biomedical Sciences Laboratories to conduct his practicals for his Masters research project.

Permission is granted on condition that students' practicals will take priority

Sincerely

Dr Zilungile Kwitshana
Head of Department: Biomedical Sciences
Faculty of Natural Sciences
Mangosuthu University of Technology
P.O. Box 12363
Jacobs , Durban
4026
Tel: 031 8199273
Email: kwitshanazl@mut.ac.za
Skype Zilungile.Kwitshana
"Strong people lift others up, weak and insecure people put others down ....MP Watson"

Annexure E: Water and Sanitation evaluation form Annexure E

Title: The evaluation of the sanitation and quality of stored water for domestic use in the Umlazi P section informal settlement: Monitoring at Household Level Questionnaire.

Note for the head of the Household:

A quantitative study for testing the quality and the fitness of domestic water, testing water samples for the presence of pathogenic microorganisms and other corrosive elements that can be present in water within the informal settlements in Umlazi section P (Mphathi Luthuli circle). The study will be conducted by Mr Simangaliso Shangase. The information gathered using the questionnaire will remain to be strictly confidential.

HOUSE NUMBER		**WARD**	
AREA CODE		**OWNED?**	
TOWNSHIP		**RENTED?**	
DISTRICT		**STREET**	
Family Information			
FAMILY	**Family Name**		
MEMBERS	Total number of family members		
MALES	Total male members		
FEMALES	Total Female members		
CHILDREN	**Total children (less than 5 years old)**		
EMPLOYMENT	**Are you employed?**	1. Yes	2. No
Shelter/House Information (conditions)			
HOUSE SIZE	AREA: Total area of the shelter (m^2)	…………………………………	
HOUSE TYPE	TYPE:	1) Apartment 2) Separate house 3) Asbestos / Metal roof house 4) Other	
EDUCATION	What is the level of your education?	1) None 2) Primary school 3) High School 4) Tertiary Education 5) Don't know	
Water			
W1	What is the primary source of drinking water for your household?	1)Municipal piped water 2)Water vender – tanker delivery or 3)River 4)Private tap 5)Other	
W2	How many litres of drinking water storage capacity do you have?		………..Litre
W3	How does your drinking water taste?	1)Excellent 2)Good 3)Acceptable 4)Unacceptable	
W4	What is the primary source of water for domestic use in your household? e.g. cooking	1)Municipal piped water 2)Water vender – tanker delivery or 3)River 4)Private tap 5)other	
S1	What is the stored water used for in the house?	1)Domestic water 2)Drinking water 3)Both	
S2	Do you keep water buckets closed all the times		1 Yes 2 No
S3	Do you use dipping utensils to access water in the storage container?		1 Yes 2 No
S4	How often do you go collect water for storage?	1)Everyday 2) times a week 3)Once a week 4)Once a month	
S5	How often do you clean you buckets for water storage	1)Not at all 2)All the time 3)Once a week 4)Once a month 5)Less than once a week	

		6)Other	

S6	What method do you use when washing your buckets?	1)Rinsing with cold water 2) Rinsing with boiling water 3)washing with soap 4)Washing with Chemical detergents 5)Other	
S7	Do you sometimes have to top up water vessels?	1) Yes 2) No	
Sanitation			
WW1	What sort of toilet do you have?	1)Sit down toilet with water flush 2)Squat toilet with water flush 3)Pit latrine 4)Other	
WW2	Do you have stagnant or sewage water near your house?	1 Yes 2 No	
Solid Wastes			
SW1	Do you have solid waste piles near your house?	1) Yes 2) No	
SW2	How frequently is the solid waste collected from outside your household?	1)Collected once every week or more 2)Collected every two weeks 3)Collected every month 4)We deal with it ourselves by	
Hygiene practice			
PC1	Have you ever received any basic health education on water storage?	1)Yes 2)No 3)Maybe 4)Other	
PC2	When do you usually wash your hands with soap? (more than one answer is possible)	1)After mealtimes 2)At prayer times 3)After using the toilet 4)Before bed 5)Before cooking 6)Before mealtimes	
PC3	Do you understand anything about water contamination??	1) Yes 2) No 3) Other	
PC4	Do you have pets or animals that walk into the house at any time?	1)Yes 2) No 3) Does not apply	
Prevalent Clinical Symptoms			
H1	Has anyone in your household >5 year of age had unusual diarrheal symptoms (water/bloody diarrheal for a few days) in the past four weeks?	1)Yes 2) No 3) Does not apply	
H2	Has anyone in your household >5 year of age had unusual diarrheal symptoms (water/bloody diarrheal for a few days) in the past four weeks?	1)Yes 2). No 3) Does not apply	

Source: UNICEF
Water Sanitation and Hygiene
Monitoring at Household Level – GAZA STRIP 2009

Annexure F: Letter of information in Isizulu

LETTER OF INFORMATION

Title of the Research The evaluation of the quality of sanitation and stored water for domestic use in the Umlazi P section informal settlement

Principal Investigator/s/researcher: Simangaliso Shangase.
B.Tech Biomedical Technology

Co-Investigator/s/supervisor/s: Dr P Pillay (PHD) & Ms T S Ndlovu (M Tech)

Injongo Yocwaningo :

Siyakumema ukuba uhlanganyele nathi ocwaningweni esizolwenza olumayelana nokuhlolwa kwamanzi esiwagcina ezindlini zethu. Ngenxa yokuntuleka kwengqalasizinda efana nompompi wamanzi, sizithola sesiwagcina ezigujini ezahlukahlukene amanzi ethu, ezinye zezigubhu azihlanzekile ngokwanele ukugcina amanzi esiwasebenzisela ukuphuza, ukupheka nokuwasha. Nendawo esibeka kuzo izigubhu zamanzi kuyenzeka zithole ukushisa beseze kuphazamisa ukuphuzeka kwamanzi aphephile. Lokhu kungagcinwa kahle kwamanzi kungaholela ekutheni amanzi abenamagciwane angasibangela izifo ezifana nohudo, Isinye esibuhlungu, izifo ezimayelana nokuphefumula nokunye okuningi

Indlela Esizosebenza ngayo:
Sizobe sithatha amasampula amanzi ezigujini enigcine kuzo amanzi emakhaya, bese siyowahlola ezindlini zocwaningo, ukubheka ukuthi ngabe amanzi okuphuza, ukuwasha, ukupheka nokugeza ngabe aphephile na. Sizophinde senze inhlolovo kubahali basezabelweni ukuthi lunjani ulwazi lwabo makuza kwezokuphathwa nokulondolozwa kwamanzi. Ukuhlola kwethu kuzosebenzisa uhlelo oluphezulu lwasocwaningweni nolwamukelekile iNingizimu Afrika yonke.

Ubungozi obungadalwa yilolucwaningo:
Alukho uhlobo lobungozi olungabangwa ucwaningo ngoba sizobe sihlola amanzi alondolozwe ezigujini kuphela hhayi abantu esisebenzisana nabo

Okuzohlonyulwa ngocwaningo:
Ucwaningo luzosikhanyisela ukuthi bungakanani ubungozi esingabhekana nabo ngokwezempilo ngokugcina amanzi ezigujini isikhathi eside ezindlini zethu. Luzosisiza futhi ukuba sizithuthukise olwazi lwethu lwezokugcinwa kwamanzi ehlanzekile.

Izizathu zokuhoxisa esisebenza nabo ocwaningweni
Umcwaningi uzofika ephethe incwadi kaMaspala emgunyazayo ukusebenza esigcemeni sakwa P Emlazi. Ucwaningo alunayo impoqo kulabo abafisa ukuba yingxenye yocwaningo, nalabo abafisa ukuhoxa ocwaningweni ekuhambeni kwesikhathi nabo bavumelekile.

Umholo : Awukho umholo ohlelwelwe lolucwaningo

Uzokhokhani: Labo abazoba ingxenye yocwaningo angeke bakhokhiswe lutho

Ulwazi oluyimfihlo : Konke esikuphothule ocwaningweni siyo kunikezela eMnyangweni wezamanzi nokuthuthwa kwendle

Imininingwane egcwele ngocwaningo ingatholakala kulamahhovisi

Dr Pavitra Pillay
Senior Lecturer, Department of Biomedical and Clinical Technology, Faculty of Health Sciences, Durban University of Technology, Tel: 031-3735423/031-3735411, email: pillayp@dut.ac.za

Ms T S Ndlovu
Lecturer, Department of Biomedical and Clinical Technology, Faculty of Health Sciences, Durban University of Technology, Tel: 031-3735298/031-3735411, email: ndlovuts@dut.ac.za

Okunye Ngocwaningo

Abafisa ukubayingxenye yowaningo bazokwenza lokho ngokuzinqumela kwabo hhayi ngokuphoqwa.

Amasampula azocwaningwa abalelwa ku 269 azothathwa emizini eyahlukahlukene

DUT DURBAN UNIVERSITY OF TECHNOLOGY — INSTITUTIONAL RESEARCH ETHICS COMMITTEE

CONSENT

Isivumelwano phakathi ko Mcwaningi nasebenzisana nabo ocwaningweni

Mina : Ngiyavuma ukusebenzisana Mr Simangaliso Shangase ocwaningweni alwenzayo. Ngichazeleke kahle ngakho konke okuzokwenzeka ocwaningweni.

Ngichazelekile ngolwazi lonke oludingekayo ukuze ucwaningo luhambe kahle

Ngichazelekile ukuthi kuzokwenzakalani ngemiphumela yokuhlolwa kwamasampula amanzi

Ngichazelekile ukuthi ulwazi oluyimfihlo olumaqondana name ngeke ludalulwe ngaphandle kwemvume yami

Ngilinikeziwe ithuba lokubuza imibuzo mayelana nocwaningo

Ngichazelekile ukuthi nginalo ilungelo lokuhoxa ocwaningweni uma ngifisa kanjalo.

Ngiyavuma ukuba yingxenye yocwaningo olungenayo inzuzo yemali noma ukuthenjswa umsebenzi

_______________________ ___________ _______ _________________

Igama Nesibongo **Usuku** **Isikhathi** **Signature /**

Thumbprint

Mina Simangaliso Shangase ngiyakuqinisekisa ukuthi engisebenzisana nabo ocwaningweni bachazeleke kahle mayelana nakho konke okuzokwenzeka ocwaningweni

Okunye okumele ukwenze

Yazisa umcwaniningi konke okuyisikompilo okungacishe kuphazamise ucwaningo kusanesikhathi
Uma ungakwazi ukubhala gxiviza ngesithupha okuzoba uphawu lwesivumelwano

Uma kwenzeke iphutha ekugcwalisweni kwama formu siyocela ukuba agcwaliswe kabusha

Igama eliphelele lomcaningi_____ **Usuku**
Sayina lapha

Igama likafakazi **Usuku**
Sayina lapha

Igama lobhekelele omncane ngeminyaka **Usuku**
Sayina lapha

References

Department of Health: 2004. Ethics in Health Research: Principles, Structures and Processes

Department of Health. 2006. *South African Good Clinical Practice Guidelines*. 2nd Edition

Annexure G: Letter of Ethical approval

DUT
DURBAN
UNIVERSITY OF
TECHNOLOGY

Institutional Research Ethics Committee
Research and Postgraduate Support Directorate
3rd Floor, Berwyn Court
Gate 1, Steve Biko Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2375
Email: [illegible]@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

22 February 2019

Mr S Shangase
Z1751 Umlazi

Dear Mr Shangase

The evaluation of the quality of sanitation and stored water for domestic use in the Umlazi P section informal settlement.

The Institutional Research Ethics Committee acknowledges receipt of your final data collection tool for review.

We are pleased to inform you that the data collection tool has been approved. Kindly ensure that participants used for the pilot study are not part of the main study.

In addition, the IREC acknowledges receipt of your gatekeeper permission letter.

Please note that FULL APPROVAL is granted to your research proposal. You may proceed with data collection.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the IREC according to the IREC Standard Operating Procedures (SOP's).

Please note that any deviations from the approved proposal require the approval of the IREC as outlined in the IREC SOP's.

Yours Sincerely,

Professor J K Adam
Chairperson: IREC

DUT DURBAN UNIVERSITY OF TECHNOLOGY
2019 -02- 2
INSTITUTIONAL RESEARCH ETHICS COMMITTEE
P O BOX 1334 DURBAN 4000 SOUTH AFRICA

Annexure H : SANS 241 drinking water

SOUTH AFRICAN NATIONAL STANDARD
Drinking water (SANS 241 :2015)

Parameter	Unit	Risk	Standard limit
pH at 25 ^{0} C	pH Unit	Operational	≥ 5.0 - ≤ 9.7
Conductivity at 25 0 C	mS/m	Aesthetic	170
Turbidity	NTU	Operational	1
		Aesthetic	5
Free Chlorine	mg/L	Chronic Health	5
Colour	mg/L	Aesthetic	15
Calcium as Ca	mg/L	Aesthetic/Operational	150
Magnesium as Mg	mg/L	Aesthetic/Health	70
Sodium as Na	mg/L	Aesthetic	200
Potassium as K	mg/L	Operational / Health	50
Zinc as Zn	mg/L	Aesthetic	5
Chloride as Cl	mg/L	Aesthetic	300
Fluoride as F	mg/L	Chronic Health	1.5
Sulphate as SO_4^{2-}	mg/L	Acute Health Chemical	500
		Aesthetic	250
Total Dissolved Solids	mg/L	Aesthetic	1,200
Nitrate and Nitrite Nitrogen as N	mg/L	Acute Health Chemical	12
Ammonia Nitrogen as N	mg/L	Aesthetic	1.5
Iron as Fe	µg/L	Chronic Health	2,000
		Aesthetic	300
Manganese as Mn	µg/L	Chronic Health	400
		Aesthetic	100
Aluminium as Al	µg/L	Operational	300
Total Coliforms count	cfu/100mL	Operational	10
E.Coli (<1 taken as 0)	cfu/100mL	Acute Health Micro	0
Heterotrophic Plate Count	cfu/ mL	Operational	1,000
Cytopathogenic Viruses	cfu/10 L	Acute Health Micro	0
Cryptosporidium Species	cfu/10 L	Acute Health Micro	0
Gardia Species	cfu/10 L	Acute Health Micro	0
Chloroform	mg/L	Chronic Health	0.3
Bromodichloromethane	mg/L	Chronic Health	0.06
Dibromochloromethane	mg/L	Chronic Health	0.1
Bromoform	mg/L	Chronic Health	0.1
Combined Trihalomethanes	mg/L	Chronic Health	1
Phenols	µg/L	Aesthetic	10
Nitrate as N	mg/L	Acute Health Chemical	11
Nitrite as N	mg/L	Acute Health Chemical	0.9
Antimony as Sb	µg/L	Chronic Health	20
Arsenic as As	µg/L	Chronic Health	10
Cadmium as Cd	µg/L	Chronic Health	3
Chromium as Cr	µg/L	Chronic Health	50
Cobalt as Co	µg/L	Chronic Health	500
Copper as Cu	µg/L	Chronic Health	2,000
Lead as Pb	µg/L	Chronic Health	10
Mercury as Hg	µg/L	Chronic Health	6
Nickel as Ni	µg/L	Chronic Health	70
Selenium as Se	µg/L	Chronic Health	40
Vanadium as V	µg/L	Chronic Health	200
Cyanide	µg/L	Acute Health Chemical	200
Total Organic Carbon as C	mg/L	Chronic Health	10

www.swartland .org.za

LIST OF ABBREVIATIONS

°C:	The degree Celsius
DOH:	Department of Health
DUT:	Durban University of technology
DWS:	Department of water and Sanitation
E. coli:	*Escherichia coli*
EHEC:	*Enterohemorrhagic E.coli*
ETEC:	*Enterotoxigenic E. coli*
ETKM:	EThekwini Municipality
GR:	Ground water
mg/l:	Milligrams per litre
MUT:	Mangosuthu University of Technology
NHLS:	National Health Laboratory services
pH:	Measure of how acidic/basic water is
SANS :	South African National Standards
WS:	Waste water
WHO:	World health organisation