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Determination of source-to-consumption waterhandling chains and their implications on water quality and human health in Babati town, Manyara, Tanzania

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DETERMINATION OF SOURCE-TO-CONSUMPTION WATERHANDLING CHAINS AND THEIR IMPLICATIONS ON WATER QUALITY AND HUMAN HEALTH IN BABATI TOWN, MANYARA, TANZANIA

Irene Prosper Tesha

A Dissertation submitted in partial fulfillment of the requirements for the Degree of Masters' in Life Sciences of the Nelson Mandela African Institution of Science and Technology

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ABSTRACT

Water safety is an important aspect in human health as it tends to decrease mobidity and mortality of infectious diseases that affect human populations. Improvements of water handling chains in rapidly urbanizing areas can contribute to inform policy and plans on sanitation and hygiene in these cities of tomorrow. A cross sectional study was conducted to obtain data on water handling and water storage practices done by communities in a northeastern town of Babati, Manyara Region in Tanzania. Using a stratified random sampling technique, water samples were taken from the common sources of water as well as from the downstream points in a given water handling chain. Water samples were collected in triplicate to test for two organisms (faecal coliforms, and *Salmonella typhi*. Descriptive and analytical tests (t-test and anova) were used to determine whether contamination levels differed among the chains. The main source of drinking water in Babati town is ground water. Five major sources of water were identified and consisted of wells, rivers, ponds, springs and lake. There were 4 reservoirs and 10 distribution points serving the 37 studied households. Three water-handling chains/patterns are characteristic of Babati town and consisted of: *untreated source* (untrS) *to treated reservoir* (trR) *and finally to households* (HH) abbreviated as '*untrS2trR2HH*'; *untreated source* (untrS) *to untreated reservoir* (untrR) *and finally to households* (HH) abbreviated as '*untrS2untrR2HH*'; and *untreated source* (untrS) *straight to households* (HH) abbreviated as '*untrS2HH*'. The number of users in these three chains was not statistically different (p = 0.5226) meaning that more or less all people in Babati source their waters from all the chains. The most contaminated chain was the one involving the untreated source to households. Most households (83%) did not treat the water they use for drinking making those using the untreated source to household chain (*untrS2HH*) most vulnerable to water-borne diseases. Comparison of education and usage of storage containers revealed that people who were educated were also not cleaning their storage container with water (p=0.01). Knowledge of unique water-handling chain from this study is an important tool in understanding the epidemiology and focusing the control of water-borne diseases in Babati town and in similar fast-growing small towns.

Key words: Hygiene, sanitation, microbial profiles, water handling chains, *E. coli, Salmonellatyphi*

DECLARATION

I, Irene Prosper Tesha do hereby declare to the Senate of Nelson Mandela African Institution of Science and Technology that this dissertation is my own original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

______________________ ______________________

Irene Prosper Tesha **Date**

Name and signature of candidate

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Dr. Emmanuel A. Mpolya **Date**

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Dr. Revocatus Machunda **Date**

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Prof. Karoli Njau **Date**

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CERTIFICATION

The undersigned certify that has read and hereby recommend for acceptance by Nelson Mandela African Institution of Science and Technology a dissertation entitled: “Determination of source-to-consumption water chains and their implications on water quality and human health in Babati town, Manyara, Tanzania”. The dissertation is submitted by Irene Prosper Tesha in partial fulfillment of the requirements for degree of Masters of Life Sciences and Bioengineering of Nelson Mandela African Institution of Science and Technology Arusha, Tanzania.

Approval of the Dissertation

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DEDICATION

I dedicate this work to the Almighty God, my family, friends and lecturers who have been keen to see my progress in academic life.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
BAWASA	Babati Urban Water Supply and Sanitation Authority
BLSW	Baloa surface water
BSW	Bagara surface water
BTC	Babati Town Council
CDC	Centre for disease and control
CFU	Colony Forming Unit
Covcle	Covered and clean,
Covdiry	Covered and dirty,
DALY	Disability Adjusted Life Year
E. coli	Esc*herichia coli*
GPS	Global Positioning System
HDW	Hangoni deep well
KAP	Knowledge, Attitude and Practices
MDG	Millennium Development Goal
MLSB	Membrane Lauryl Sulphate Broth
MRRSW	Mrara surface water
NDW	Nangara surface water
Notr	No treatment
NIMR	National Institute of Medical Research
SDG	Sustainable Development Goals
SIWI	Stockholm International Water Institute

uncovcle	Uncovered and clean
UNICEF	United Nations Children's Fund
untrS2trR2HH	Untreated source to treated reservoir to households
untrS2untrR2HH	Untreated source to untreated reservoir to households
untrS2HH	Untreated source to household
WaSH	Water, Sanitation and Hygiene
WHO	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 Background information

Clean and safe water is the most basic necessity to human life. More than one billion people in developing countries lack access to safe water (UNICEF, 2008) which is the heart of the poverty trap, especially for women and children who suffer in terms of illness and lost opportunities. In rural Africa, according to the World Bank, 40 million hours are lost each year in search of unsafe water and half of Africa's populations are without access to safe water (Black, 1998). In the year 2000, there was a study of water supply done by World Health Organization (WHO) in 91 countries which showed that only 14% of the rural population had access to sufficient and safe water (Hedman, 2009).

Worldwide, water demand is growing rapidly as between 1990 and 2012, a total number of 2.3 billion people gained access to an improved drinking water source (WHO, 2014) and in many low income countries the cost of developing new supplies is becoming prohibitive. Simultaneously, an increase in water pollution and mismanagement of catchment areas is worsening the imbalance between supply and demand. For these reasons, the efficient management of the limited water resources is critical for sustainable development (Black, 1998).

The term sanitation is defined as the control of all those factors in man's physical environment which may have a detrimental effect on his physical, mental, and social wellbeing". It entails the satisfaction of basic human needs with provisions for basic and healthy housing, drinking water, and waste management in all aspects including personal hygiene (Kumie *et al*., 1970). Clean water and sanitation are one of the most basic vital resource to maintain human health, and lack of these services is the main issue of many of African's current health, environmental, social, economic and political problems (Hedman, 2009)

The WHO and other major global public health organizations define safe water access as *reasonable access* through an *improved* or an *unimproved* source. An improved source of safe water consists of one of the following: a piped household connection, public standpipe, borehole, protected dug well or spring, and/or rainwater collection. An unimproved source is considered as any of the following: vendors, tanker trucks, surface water, bottled water (due to the inability to confirm source and quality), and unprotected dug wells and/or springs. Reasonable access to an improved source is defined as the availability of at least 20 liters a person a day from a source within one kilometer (0.6 miles) of the dwelling (Improved water source, 2011; Global Water, Sanitation, and Hygiene, 2012).

Drinking quality water is a big health concern to human as risks arise from infectious agents, toxic chemicals and radiological hazards (Hedman, 2009). Waterborne diseases are caused by pathogenic microbes that can be directly spread through contaminated water. These include amebiosis, buruli ulcer, cholera, cryptosporidiosis, cyclosporiosis, dracunculiosis (guinea-worm disease), typhoid fever, shigellosis, fascioliasis, giardiasis, hepatitis, leptospirosis, schistosomiasis. The majority of waterborne diseases result into diarrheal illnesses which are attributed to unsafe water supply, as well as insufficient hygiene and sanitation. Eighty-eight percent of diarrhea cases worldwide are associated with unsafe water, inadequate sanitation or insufficient hygiene (CDC, 2013). Hygiene related diseases, like diarrhea, kill around 2.2 million people every year with infant mortality being high in developing countries where around 90% of people who die from diarrheal disease are children below five years of age (WHO, 2005).

Water-borne diseases are among major problems facing most developing countries including Tanzania. Due to water shortage, most people living in squatter areas depend largely on ground water (well water). However, shallow well water may be highly polluted with faeces due to poor sewage system in most urban areas. In Tanzania, water pollution is cited as one of the major causes of water-borne diseases that kill both children and adults (Lyinto *et al*., 2007). On the other hand, improving of source water quality at the source alone does not always reduce diseases, drinking water also becomes contaminated after collection, either during transport or storage at the home (Hedman, 2009).

Globally, improving water, sanitation and hygiene has the potential to prevent at least 9.1% of the disease burden (Disability-Adjusted Life Years or DALY), or 6.3% of all deaths. Children, particularly those in developing countries, suffer a disproportionate share of this burden, as the fraction of total deaths or DALYs attributable to unsafe water, inadequate sanitation or insufficient hygiene is more than 20% in children up to 14 years of age (Bos *et al*., 2008). Global access to safe water, adequate sanitation, and proper hygiene education can reduce illness and death from diseases leading to improved health, poverty reduction, and socio-economic development (WHO, 2016).

Tanzania is facing a sanitation crisis. Almost 5 children die each hour due to poor hygiene and sanitation. At least 2.5 billion people still lack access to improved sanitation and over 1 billion have no access to any sanitation facilities and are forced to defecate in the open (Water, Sanitation and Hygiene, 2012). The United Nations International Children's Emergency Fund is collaborating with the government of Tanzania on a standard household package including access to improved sanitation facilities, hygiene promotion with focus on hand-washing with soap, household water treatment and storage (Hedman, 2009). These efforts are meant to ensure that the sanitation profile is up scaled and the coverage for both water and sanitation raised. It also indicated that access to sufficient sanitation reduced the rate of disease and brings relative comfort and ease to the daily routine of toilet use, thereby enhancing the quality of life (Jerry *et al*., 2013).

Currently, water and sanitation coverage stands at 58% and 13% respectively with greater variation between urban and rural areas. Only 47.9% and 9% of rural Tanzanians have access to improved safe water supply and sanitation services respectively, whilst access for the urban populations is at 80% water and 24% sanitation (Water Aid Report, 2013).

Babati town is the capital of Manyara region which is a newly established and fast growing in terms of population and infrastructure. The rapid growth is mostly due to population migrating from rural areas. Rapid migration and urbanization pose challenges such as availability and accessibility to social and health services, hygiene and sanitation, infrastructure and water supply. However about 50% of its population have access to safe water. A survey conducted in 2014 indicated that about 90% of people in Babati have a household toilet. Of those households that owned a toilet, 42% had traditional pit latrines, 30% had ventilated improved pit latrines, and 18% had septic latrines (Water Aid Report, 2013). With Migration flowing from rural areas, this intensifies the need for stable water supply and functioning sanitation facilities in the area. Due to water problems in Babati town it was observed that the shared latrines are not appropriate for it is difficult to maintain their cleanliness. As a result about half of the respondents during Water Aid survey use shared pit latrine, 40% use private pit latrines while five percent use private flush toilets and these are for the few who own houses and have high income (Lawi, 2013). Women's knowledge and perceptions are highly important when dealing with issues concerning waterborne diseases.
Furthermore, women's role in sanitation and water quality should be given due collection. They have a role in children's safety and ensure water is collected, stored and sometimes treated at household level (Watts, 2004).

1.2 Problem statement and justification

Water-borne diseases are among major problems facing most developing countries including Tanzania. According to the year 2010 Tanzania Demographic Health survey, about 60% of households in Tanzania do not treat their water (Hedman, 2009). Due to water shortage, water and sanitation coverage stands at 58% and 13% respectively with greater variation between urban and rural areas. Only 47.9% and 9% of rural Tanzanians have access to improved safe water supply and sanitation services respectively, whilst access for the urban populations is at 80% water and 24% sanitation (Water Aid Report, 2013). Most people living in squatter areas depend largely on surface water (well water). However, surface water may be highly polluted with faeces due to poor sewage system, animal deposits, non-use or lack of toilets or poor toilets in most urban rural areas. Water pollution is cited as one of the major causes of water-borne diseases that kill both children and adults (Lyinto *et al*., 2007).

The rapid growth of Babati town is mostly the result of population migrating in big numbers to the town especially after it was made the capital of Manyara region. Babati is now the center for administration, political, economic and social services. This rapid growth is subjected to several health and social associated risks. Health risk is associated with people use water from various sources, which leads to a possible increase in the prevalence of water borne diseases. Poor water, sanitation and hygiene (WaSH) perpetuate the transmission of disease agents. This occurs primarily through unsafe disposal of human faeces and wastes, thereby rising the pathogen load in the ambient environment.

From collection to usage water could be contaminated during collection, transportation or handling practices at the household level. Typically, this water is gathered and stored in vessels of various designs and materials. Such household water could be contaminated by various pathogenic viruses, bacteria and parasites linked with fecal wastes and other sources. Further contamination occurs due to a variety of unsanitary conditions and practices during storage and use. Microbial contamination of collected and stored household water is caused not only by the collection and use of feacally contaminated water but also by contamination of at first microbiologically safe water after its collection and storage (Sobsey, 2002).

This study focused on investigating water handling and storage practices among inhabitants of the Babati town in Tanzania in order to characterize those water handling patterns or chains and investigate the various hygienic practices in each chain as well as their microbial profiles so as to understand the possible health risks with each pattern or chain. Tracking microbial drinking water quality along different water supply "chains" to arrival in the household is a novel approach which allows for an understanding of the points at which highest fecal loading occurs. This approach thereby assists to inform the development of policies in the areas of household hygiene education, drinking water treatment, and water supply planning in rapidly growing urbanized towns in Tanzania and elsewhere/ developing countries.

We hypothesize that there are characterizable source-to-consumption chains of handling water, which might put people at various risks due to water contamination. So far there is no study that has explicitly characterized these chains. This work aims to investigate the presence of these chains and quantify their microbial profiles as well as the reasons for their adoption.

1.3 Objective of the research

1.3.1 Main objective

Investigation of domestic water handling practices and their implication to human health in a source-to-consumption water handling continuum/chain in Babati town.

1.3.2 Specific objectives

(i) To determine the common "source to consumption water handling chains" in the study area.
(ii) To assess microbial pathogens (*Salmonella* and *E. coli*) in domestic water at different "source-to-consumption chain".
(iii) To determine people's knowledge, attitude and practices related to water safety and quality.

1.3.3 Research questions

(i) What are the common "source-to-consumption water handling chains" in Babati town?
(ii) What is the microbial profile in a given source-to-consumption chain?
(iii) What are people's knowledge, attitude and practices relating to water safety and quality in relation to source to consumption water handling chains?

1.4 Scientific contribution of the study

This study will contribute to the updating of current data on water contamination levels in Babati, giving feedback to the town council, and acquisition of knowledge on different levels of contamination. Babati peoples' awareness on better and safe use of water from source to consumption will be enhanced. Knowledge on water safety access, adequate sanitation and proper hygiene will also be improved. Evidence from this research will guide the government to develop an action plan to improve health, reduce poverty, and develop socio-economic well being through reduction of illness and death from water related diseases. However households must have the motivation to treat their domestic water and boiling of drinking water maybe appropriate and sustainable.

CHAPTER TWO

LITERATURE REVIEW

2.1 Water, Sanitation and Hygiene

The word WASH is an acronym for Water, Sanitation and Hygiene. It is a word used in public health campaigns to address issues regarding access to sufficient and safe water for drinking, sanitation and hygiene practices. According to WHO and UNICEF, access to drinking water means that, the water source is less than 1 kilometer away from its place of use and it is possible to get at least 20 liters per member of household per day. Water can be used for domestic purposes, drinking, cooking and personal hygiene. Access to safe water is the proportion of people using improved drinking water sources such as household connections, public standpipes, boreholes, protected wells or springs and rainwater (WHO/UNICEF, 2004).

It is a problem in underestimation of people served by unsafe water. Often the assumptions of safe water do not take into concern important well-documented problems, this leads to the fact that current numbers of people using unsafe water are probably low. One big problem is the so called protected or improved water sources, such as boreholes and treated urban supplies, the fact is that this water can still be unsafe and cause diseases. But there are factors that lead to contaminated water when it reaches the consumer's tap or collection point, poor water distribution systems, irregular water pressure due to power outages and other disruptions, and illegal connections to the distribution system do often in the end lead to unsafe water (Hedman, 2009)

There are lots of factors which need to be considered when planning for and dealing with safe water sources. Factors like increasing populations, urban growth and expansion, peri-urban settlement among others affect the water in terms of increasing pollutant transport into ground and surface water due to deforestation, global climate change, recurring disastrous weather events and increasing coverage of the earth's surface with impervious materials (Sobsey, 2002).

2.2 Water as a resource to human consumption

Safe and sufficient drinking-water, along with adequate sanitation and hygiene have implications across all Millennium Development Goals (MDGs) – from eradicating poverty and hunger, reducing child mortality, improving maternal health, combating infectious diseases, to ensuring environmental sustainability. Much progress has been achieved over the past decade:

(i) A total number of 2.3 billion People gained access to improved drinking-water between 1990 –2012.

(ii) The number of children dying from diarrhoeal diseases, which are strongly associated with poor water, inadequate sanitation and hygiene, have steadily fallen over the two last two decades from approximately 1.5 million deaths in 1990 to just above 600 000 in 2012.

As the world turns its attention to the formulation of the post-2015 Sustainable Development Goals (SDGs) much remains to be done particularly to reduce inequalities across populations:

(i) About 2.5 billion People lack access to improved sanitation.

(ii) About 1 billion people practice open defecation, nine out of ten in rural areas.

(iii) A total number of 748 million people lack access to improved drinking-water and it is estimated that 1.8 billion people use a source of drinking-water that is feacally contaminated.

(iv) Hundreds of millions of people have no access to soap and water to wash their hands, preventing a basic act that would empower them to block the spread of disease.

2.3 Water as a source of pathogen exposure and diseases

Water and sanitation are serious determinants for survival in the initial stages of a disaster. People affected by disasters are generally much more susceptible to illness and death from diseases, which are linked to a large extent to inadequate sanitation, inadequate water supplies and poor hygiene. The most significant of these diseases are diarrheal diseases and infectious diseases transmitted by the faeco-oral route.

Diminishing the ingestion of pathogens has the potential to prevent mortality and morbidity from diarrheal illness, an advantage not conferred by oral rehydration treatment, which only prevents the consequences of dehydrating diarrhea once it occurs. Diarrheal and intestinal parasitic diseases can result in poor growth through decreased absorption of nutrients and increased requirements, thus contributing to general protein-energy malnutrition and also specific nutrient deficiencies like vitamin A deficiency from Ascaris and Giardia and iron deficiency from hookworm and Schistosomes (Burger *et al*., 1995).

Diseases related to inadequate water, sanitation and hygiene are a huge burden in developing countries. It is estimated that 88% of diarrheal conditions is caused by unsafe water supply, and inadequate sanitation and hygiene (Global WASH-Related Diseases, 2012). Many schools serve communities that have a high prevalence of diseases related to inadequate water supply, sanitation and hygiene (mainly lack of hand washing), and where child malnutrition and other underlying health problems are common. If every person in the world had access to a regulated piped water supply and sewage connection in their houses, 1863 million days of school attendance would be gained due to less diarrheal illness (Adams *et al*., 2009).

The most important hygiene messages to impart knowledge on preventing infections are the essential issues such as hand washing, proper disposal of feces, and protection of drinking water (EHP 1999). Several studies in different parts of the world, in day care centers, and community settings, have indicated that frequent hand washing, with or without soap, results in fewer diarrhea cases. Collectively, these studies reported a 33% reduction in diarrhoea cases from hand washing alone (Esrey *et al*., 1991; Huttly *et al*., 1997). Proper disposal of feces, which is not guaranteed by the mere presence of latrines, is also critical for realizing the potential benefits of sanitation. Improvements in water, sanitation and hygiene (WaSH) education and awareness are expected to reduce the burdens of disease and improve the overall health of the general population. Reductions in morbidity, due to diarrhoea, are expected to improve nutritional status by preventing dehydration, fever and mal absorption of nutrients (Staley, 2009).

2.4 Water as a source of improving economic status

Investments in improved water and sanitation will contribute to economic growth and eradicate poverty in countries where water challenges occur. Among the poor countries, those with access to clean water and sanitation experience greater economic growth. Stockholm International Water Institute (SIWI) states that investing in water is a good business due to increased production and productivity within economic sectors, and meeting the Millennium Development Goal on water supply and sanitation that will result in economic benefits.

Stockholm International Water Institute further argues that water issues should be a public and private investment strategy that also allows individuals and households to explore new livelihood opportunities and businesses to reach new markets with increased production and productivity. Improved water is a question about people's health. Improving health not only provides immediate economic benefits, it also safeguards future economic gains (Sanctuary *et al*., 2005). A healthier adult population is more productive and improvements in WaSH can improve income and the capacity to acquire food and other services (Bergeron and Esrey, 1993).

2.5 Water storage system at Household level

Collection and storage of household water by WHO (2002) revealed that such water often comes from feacally contaminated sources and therefore poses infectious disease risks to consumers (Thompson *et al*., 2003). Furthermore, regardless of whether or not collected water is of acceptable quality, it often becomes contaminated during transport and storage due to unhygienic storage and handling practices. Higher levels of microbial contamination were associated with storage vessels having wide openings (e.g., buckets and pots), leading to vulnerability to introduction of hands, cups and dippers that can carry faecal contamination, and lack of a narrow opening for dispensing water (Sobsey, 2002; Seino *et al*., 2007). In general, the contamination levels are substantially higher in household water containers than in water sources taps (Sobsey, 2002). Children may, in particular, cause contamination when they put their feacally contaminated hands or utensils into the household water container (Laurent, 2005).

2.6 Indicator organisms for feacal contamination

Indicator organisms, particularly bacterial indicators, are widely used to assess contamination of water sources by human and animal excreta. *Escherichia coli* and thermotolerant coliform bacteria have been used extensively as indicators of faecal contamination to monitor drinking water quality.

The presence of bacteria like *Escherichia coli, and Salmonella* etc. in water is one of the root cause of various diseases and infections (Bharadwaj, 2016). *Escherichia coli* is a gram-negative, facultative anaerobic, rod-shaped bacterium of the genus *Escherichia* that is commonly found in the lower intestine of warm-blooded organisms (endotherms).

Escherichia coli is expelled into the environment with fecal matter. The presence of *E. coli* in water is a strong indication of faecal contamination.

Salmonella is an ubiquitous enteric pathogen with a worldwide distribution that comprises a large number of serovars characterized by different host specificity and distribution. This microorganism is one of the leading causes of intestinal illness throughout the world as well as the etiological agent of more severe systemic diseases such as typhoid and paratyphoid fever (Levantesi *et al*., 2012)

Thermotolerant coliforms comprised of those which are able to ferment lactose at 44.5 °C. The group contains bacteria like *Escherichia coli* and *Klebsiella pneumoniae*. The detection of thermotolerant coliforms indicates contamination of water sources with faecal material (Bitton, 2005). Several studies showed that faecal coliforms are not potent indicators of faecal contamination as a result of the presence of species that are found in nature like *Klebsiella* (Alonso *et al*., 1999; Ashbolt *et al*., 2001; Leclerc *et al*., 2001). So, their presence can be used as a secondary indicator to assess the effectiveness of water treatment plants and they are generally easy to detect (WHO, 1997).

Escherichia coli are species of thermotolerant coliform distinguished by producing endole from tryptophan, and also possess β-galactosidase and β-glucuronidase enzymes. *Escherichia coli* is predominantly found in the gastrointestinal tract of warm-blooded animals (Krieg and Holt, 1984). Nevertheless, some findings showed that *E. coli* can also be found, multiply and persist in the environment especially in tropical soils and waters rich with organic matter (Jimenez *et al*., 1989; JMP, 2012). The majority of *E. coli* strains are non-pathogenic, even though some serotypes, like *E. coli* 0157:H7, can cause serious illnesses in humans (Wilson *et al*., 2011).

2.7 Water collection from the source water supply

In many developing countries, water is collected from communal sources which are either exposed (e.g. unprotected wells, unprotected springs, and rivers) or improved (e.g. protected wells, boreholes and public standpipes) (WHO/UNICEF, 2000; Sobsey, 2002). The primary source of human pathogens in water sources is from human waste. Animal waste also carries pathogens that affect people as well as other animals. Discharge of domestic wastes into surface waters allows pathogenic bacteria to be dispersed downstream (Goel *et al*., 2004).

In many developing countries the task of collecting water falls to women. In rural Africa women often walk ten miles or more every day to fetch water (Sobsey, 2002). The work involved in fetching may differ in each region, it may vary according to the specific season, and it depends on the time spent on the queue at the source, the distance of the house from the source and the number of household members for which water must be collected. Water for domestic use may be collected either by dipping the container inside the water supply, collecting rainwater from a roof catchment system or by collection using different varieties of pumps (Potgieter, 2007)

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of the study area

The study was conducted within the 8 wards which constitute the Babati Town Council namely; Bagara, Maisaka, Bonga, Mutuka, Singe, Sigino, Nangara and Babati (Fig. 1). Babati town lies between latitudes 3^0S and 4^0S longitudes 35^0E and 36^0E. According to the National census of 2012, the town covers an area of 471.33 square kilometers and density of 197.5 square inhabitants per kilometers and had a population status of 93 108 based on gender. Out of which 47 313 were male and 45 795 were females. The main economic activities in Babati town are fishing, livestock keeping, tourism, and agriculture production. Babati town was selected due to the fact that it is one of the urban centres experiencing a rapid population increase with a high rate of urbanization. Lying along the shores of Lake Babati and being surrounded by small mountains the area is potentially vulnerable to environmental and water pollutions due to its landscape and social economic activities around the lake.

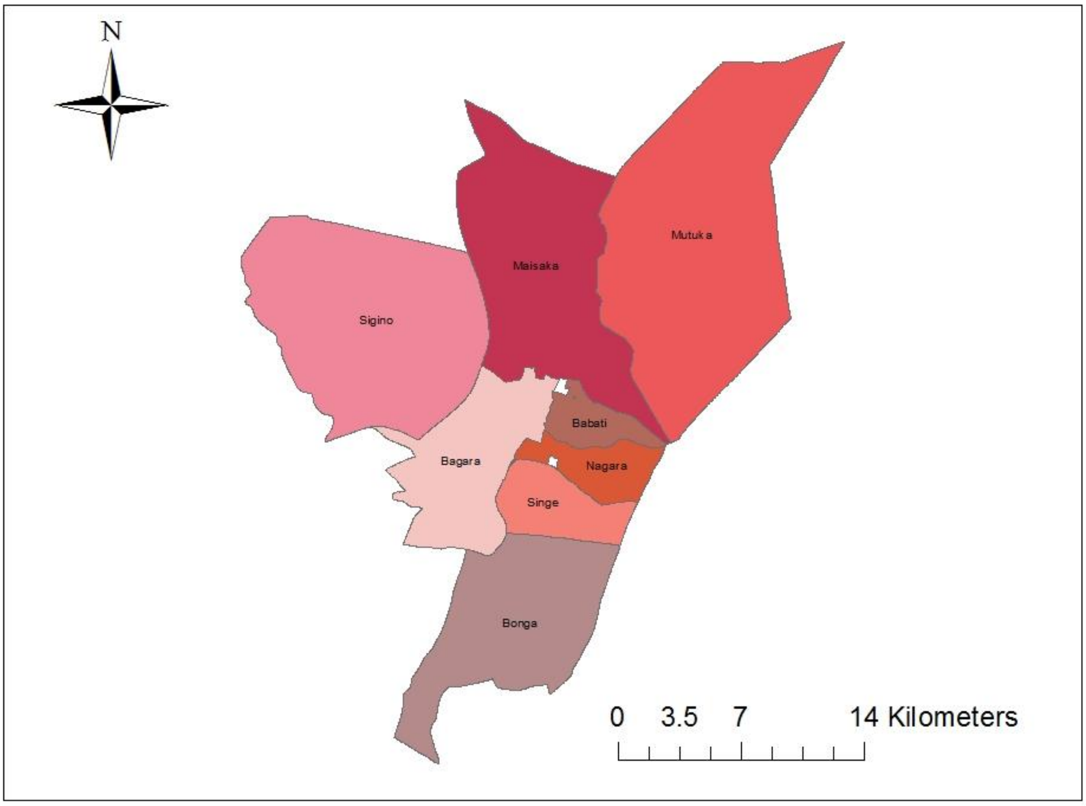

Figure 1: Eight wards in Babati town Council

3.2 Study design

In this study the unit of analysis was a water sample collected from various water-collection points along the source-to-consumption water-handling chain. We employed a cross-section study using a multi-stage sampling as follows. Babati town has eight wards listed from the largest to the smallest as: Babati, Bagara, Maisaka, Nangara, Sigino, Bonga, Singe and Mutuka. In this multi-stage stratified sampling, a random sample of households per ward were selected as follows; seven households from Babati ward, six households from Bagara, then four households from each of Maisaka, Nangara, Singe, Bonga, Sigino and Mutuka. This made a random sample of 37 households. At the last level of sampling water handling points among these 37 household had their water sampled to produce our unit of analysis. The number of water collection points which would be powerful to detect any differences in the water-handling chains if they existed was calculated as follows;

$$n = \frac{\text{deff}}{r} \cdot \frac{z^2 \hat{P}\left(1-\hat{P}\right)}{e^2}$$

Since the population of Babati at the time was about 93 000 the population correction factor was dropped as it evaluated to 1. In this formula: d.eff is design effect = 1.5 for multi-stage sampling, r is response rate = 1, z is the 97.5% percentile point of the normal distribution in which 95% of the area of the curve lies = 1.96 and p, binomial probability which has maximum variance (for maximum sample size) = 0.5. This yielded a total of 564 water samples (collected from the same numbers of water collection points).

The study was also carried out by investigation through house to house visit. Information was collected by interviewing the available adult family member at the time of visit, and also, physical examination of storage facilities was observed.

3.3 Data collection and processing

A total number of 564 samples were collected from the various points constituting different patterns, which included water sources, reservoirs, and taps and households storage containers for bacterial analysis. In sampling from open ground water sources, the inverted containers were immersed beneath the water surface and turned upright before removal to minimize surface contamination. Tap water sources were sampled after allowing the water to run for 20-30 seconds. Samples were collected in labeled sterile containers and transported in cooler bags to the laboratory. Sample processing started within six to eight hours after collection. Sample was not taken if a village was too remote to permit timely refrigeration and analysis. If incubation was delayed beyond 48 hours, the sample was discarded because multiplication or death or competing organisms might interfere with coliform testing.

A questionnaire was administered during household visit to a person who was involved in domestic activities in the house so as to gather information on demographic details, water handling practices, treatment methods, storage and sanitation. Data for the women’s knowledge, attitude and practices regarding water usage was collected to the fifty two randomly selected households. Interview was administered using structured questionnaires to one adult female in each household. Women are the primary caregivers involved in domestic duties such as fetching water, cooking, hygiene and sanitation.

A retrospective documentary review was also performed where data were collected from Mrara hospital which services the whole study area so as to have a good picture of what had happened in the past. Retrospective data dated from January to December 2016 was collected.

3.4 Laboratory analysis

Water samples were analyzed using (membrane filtration technique) which is a quantitative method used to quantify the actual number of faecal coliforms. For chlorinated samples, Sodium thiosulphate was added to the sample container to neutralize chlorine. Sterile distilled water (100 ml) was used as a negative control

3.4.1 Membrane filtration technique:

(i) Thermo tolerant coli form *(E. coli)* detection

Potatest field kit (Wagtech International, PTW10020) based on the field kit manual was used. The membrane filtration method was used to determine bacteriological water quality for *E. coli* counts. Potatest filtration sets were used to filter 100 mL of water sample through a 0.45 µm pore size filter which retains bacteria that were present in the water sample. Samples were manually vacuum-filtered. The filter was then transferred to a petri dish containing absorbent pad and growth medium Membrane Lauryl Sulphate Broth (MLSB). Membrane Lauryl Sulphate Broth contains Lactose as the major carbon source, which during incubation is degraded to acid by E. *coli* and coliform bacteria. Petri dish lid was then replaced and labeled with sample identification. Petri dishes were placed into the petri dish rack ready to be incubated for 18 hours at different temperatures. An incubation temperature of 44°C was used for thermotolerant coliforms (*E. coli*). After incubation yellow colonies grown on a plate were counted manually and the concentration was reported as CFU/100 mL.

(ii) *Salmonella typhi* detection

Potatest filtration sets were used to filter 100 mL of water sample through a 0.45 µm pore size filter which retains bacteria that were present in the water sample. Samples were manually vacuum-filtered. The filter was transferred to a prepared nutrient agar (a wet Bismuth- Sulphite Nutri disk) from Potatest field kit. Nutri disk lids were then replaced and labeled with sample identification and then placed into the petri dish rack ready to be incubated for 40-48 hours at 35°C incubation temperature. After incubation, Salmonella pathogens were identified as black colonies with a surrounding metallic sheen resulting from hydrogen sulphide production and reduction of sulphite to black ferric sulphide. The concentration was reported as colony forming unit per 100 ml of water (CFU/100 ml).

3.5 Statistical analysis

Data analysis was entered into Excel and cleaned. Descriptive statistics (qualitative analysis) was used to analyze the data obtained from knowledge, attitude and practices done in the represented households using statistical package for social sciences (SPSS programme). Quantitative analysis was used to analyze data obtained in colony counts in the laboratory using R package and Prism 3.0. Analysis of variance ANOVA was used to compare microbial counts from different water handling chains from different points (sources, reservoirs, taps, and storage containers). Results at $p < 0.05$ were considered statistically significant.

3.6 Ethical consideration

The study project was approved where the study is registered. Authorization to conduct the study was obtained from the National Institute of Medical Research (NIMR), Babati town council (BTC) and Babati Urban Water Supply and Sanitation Authority (BAWASA). Ethical clearance permission to conduct this research and consent for publication was granted by the National Institute of Medical Research (NIMR) of Tanzania permission number: NIMR/HQ/R.8a/Vol.IX/2335. In each of the study communities, a selected participant received a letter informing that a research project was being conducted, a description of the study, the voluntary nature of participation, and assurance of privacy and confidentiality was given to the participants. Consent forms were given to the participants to sign before conducting a research. All participation was voluntary and withdrawal from the study was possible on request at any point in the study. No financial incentives were provided for participation in this study as it had no harm on the participants. All data collected was treated as strictly confidential and maintained under locked storage and only available to the research team.

CHAPTER FOUR

RESULTS AND DISCUSSION

A total of 471 water sources were first identified through transect walk by using GPS readings where by 24 spring water sources, 9 rivers and 437 wells (protected and unprotected wells) and one lake were obtained in Babati town. Three unique water handling chains were commonly determined in the study area. The chain includes water taken from the main water source then collected from the reservoirs and then directed to the distribution points (taps) to be collected to the storage containers and be ready for human consumption. The main water sources were not treated. Untreated sources include water sources such as dug wells, boreholes and surface waters collected using gravity or electric pumps

Figure 2: Borehole (deep well) and water storage containers used

Figure 3: Surface water (spring water)

Figure 4: Reservoir used

(Reservoir is where treatment process is taking place. Some of the reservoirs were not treated).

Three unique water-handling chains were determined in this study. These chains were derived from analysis of the chains of water handling that the studied households reported using. From Fig. 2, the chains are namely; untreated source – untreated reservoir – household, shortened as *untrS2untrR2HH*. The second chain is untreated source – treated reservoir – household, shortened as *untrS2trR2HH*, and the third one was untreated source – household, shortened as *untrS2HH*. In chain (A), (*untrS2trR2HH*) represents the water sources like boreholes and surface water which water is collected using gravity or electric pump and flows through pipeline to the reservoir for treatment process to be taken and then distributed to the distribution points (taps) directly to be collected to the households for domestic uses and storage purposes for drinking. In chain (B) (*untrS2untrR2HH*) represents water sources like surface water being distributed through pipeline to the reservoir where it is not treated before distribution to the households. In chain (C) (*untrS2HH*) represents the water from sources like surface water, dug wells, and boreholes is obtained by various ways including dipping bucket to the wells to fetch water or using pump (foot/hand pump) and then taken to the households.

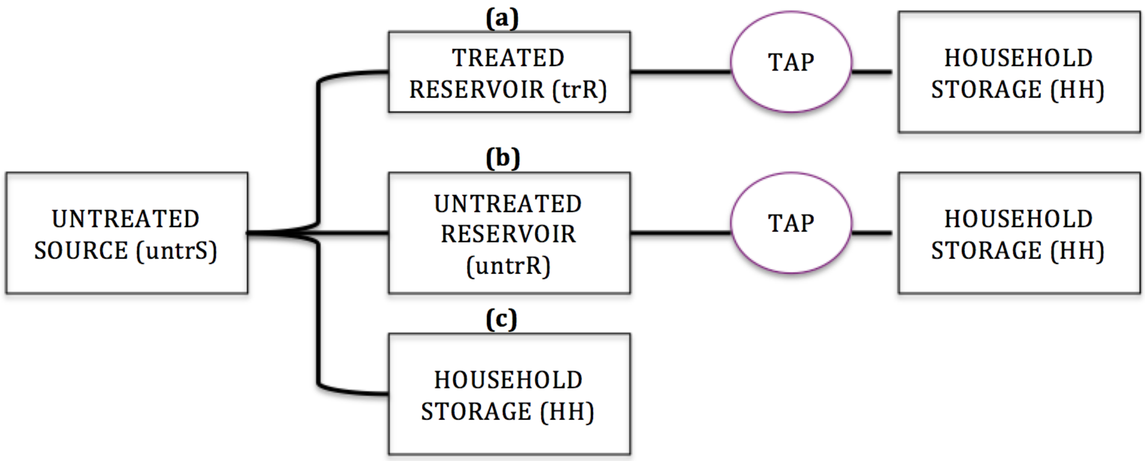

Figure 5: Water handling patterns commonly found in Babati town

Figure 5 Three water-handling chains in Babati Town. They include; untreated source to treated reservoir to households (*untrS2trR2HH*), untreated source to untreated reservoir to households (*untrS2untrR2HH*) and untreated source to households (*untrS2HH*).

Chain (a) includes: - Mrara (MRRSW) surface water, Nangara (NDW) borehole

Chain (b) includes: - Baloa water source (BLSW) surface water,

Chain (c) includes: - Hangoni (HDW) shallow well , Bagara (BSW) shallow well

4.1 Distribution of water handling chains

After specifying the water-handling chains we analyzed the distribution of users of these chains. From Fig. 6, we find that households were using all chains, depending on the situation. Most of the time, households were using the untreated source to household (*untrS2HH*) chain. Statistically it was found that there was no evidence that the number of households using each chain differed (x^2=5.2973, *df*=2, *p*=0.07) meaning that households more or less involve themselves equally in employing the various water-handling chains. Numerically, a high proportion of consumers (46%) are in the chain involving untreated water sources taken directly to the household for domestic use. It was found that most people taking water from untreated source straight to households chain (*untrSHH*) were more vulnerable to infectious disease compared to the other chains because the water they consumed was never treated thus was unsafe to human consumption as reported in other studies (Uhuo *et al*., 2014; Okereke *et al*., 2014; Packiyam *et al*., 2016). Sourcing water from untreated sources could potentially put consumers at risk of water borne infections due to direct access of people and animals to such water sources (Thomas, 2013; Huang *et al*., 2014). Equal percentages of households (27%) are using water from untreated and treated reservoirs.

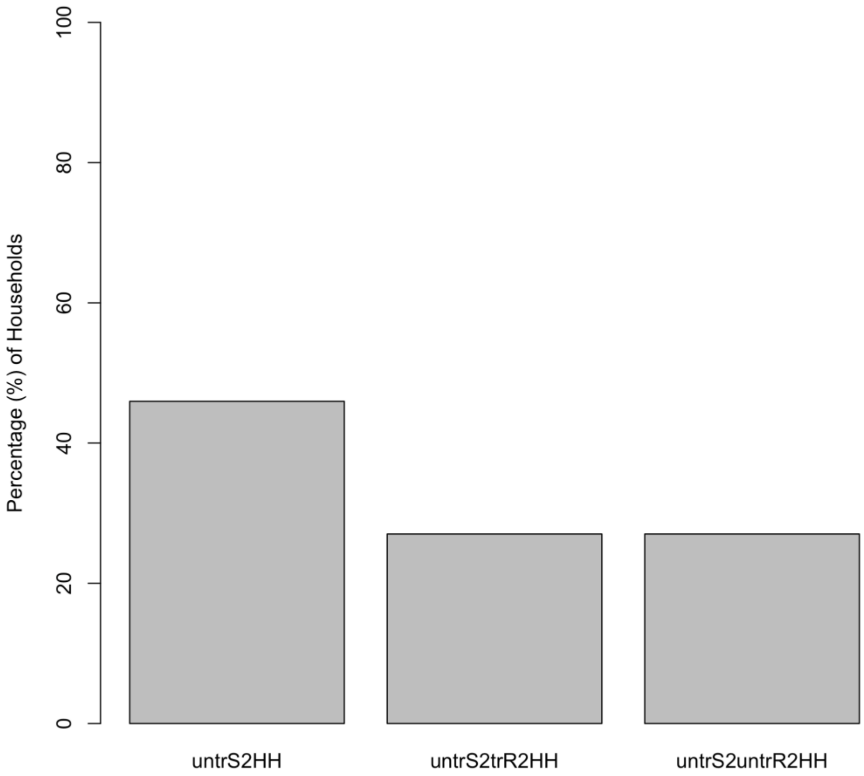

Figure 6: Number of households involved in the chains

(*UntrS2HH*- untreated source to households, *untrS2trR2HH*-untreated source to treated reservoir to households, *untrS2untrR2HH*- untreated source to untreated reservoir to households) Households are involved in multiple chains

4.2 Distribution of types of containers used by various households

Households stored their water in three types of containers (Fig. 7). There was a statistically significant difference of the number of households using various types of containers (x^2=51.27, df=2, *p*=7.359e-12*)* where 72% of the respondents stored their water in buckets while 22% and 7% from the households stored their water predominantly in drums and pots respectively. Households could use multiple storage containers. These buckets are commonly used in developing countries to store water but these storage containers could allow contamination into the water and affects water quality by dipping hands into uncovered storage containers when fetching water for household, which was also found in 2% of studied households in other finding (Sobsey, 2002). Also infrequent cleaning of the containers before refilling water could be one of the factors to microbial contaminants especially to the large storage containers like drums where contaminated water which is inside the drum may not be empted rather refilled hence increase the bacterial load in water. This was also observed in Ethiopia were they found more contamination in storage containers compared to the distribution points and reservoir which was likely due to bacterial re-growth (Wright *et al*., 2004; Gundry *et al*., 2006; Sharma *et al*., 2013).

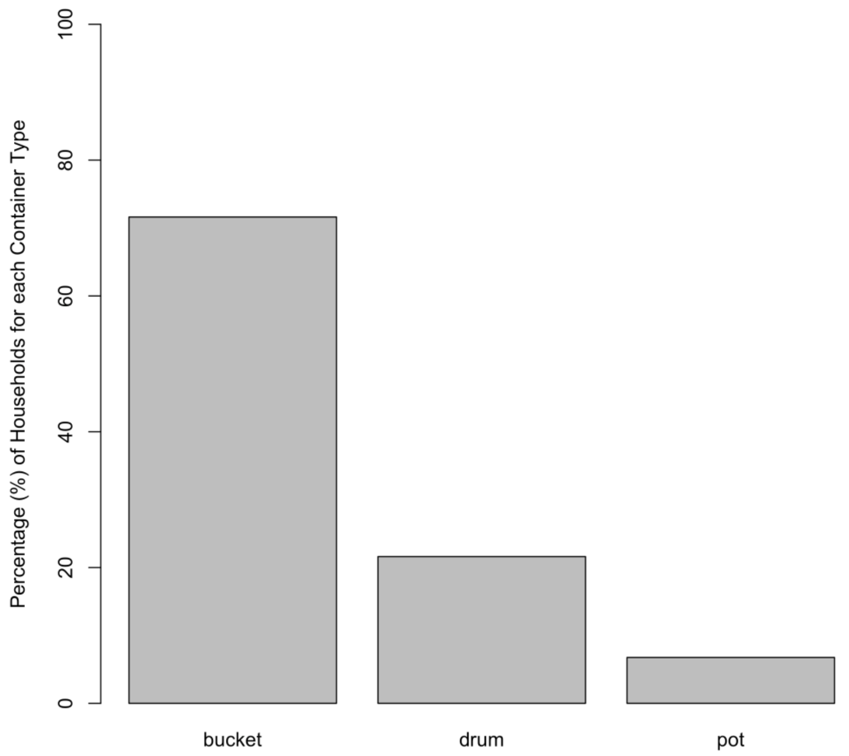

Figure 7: Type of containers used by households

4.3 Condition of containers for each households

The condition of containers observed in various households was whether the water containers were covered and clean (covcle), covered but dirty (covdiry) and uncovered but clean (uncovcle) (Fig. 8). From Fig. 8, there was enough evidence to suggest that the number of households using each type of containers differ where a high percentage (92%) of containers used by the households were found covered and clean and 3% were found uncovered but clean (x^2=114.27, p<2.2e-16). These Findings revealed that few people were using uncovered containers implying some adherence to hygienic behaviors at the household. The way communities use water-handling containers has important implications to hygiene as reported by Sobsey (2002), Singh *et al*. (2009), Peckering *et al*. (2011) and Devamani *et al*. (2014) who reported poor hygiene as an important factor for disease spread within the communities where water quality was affected by dipping hands into water when fetching. About 5% of the containers were found covered but dirty. This reflects a high awareness among households in terms of ensuring that their water containers are kept clean and covered. The fourth category of uncovered and dirty was not observed as being used for water storage and hence the absence in our analysis.

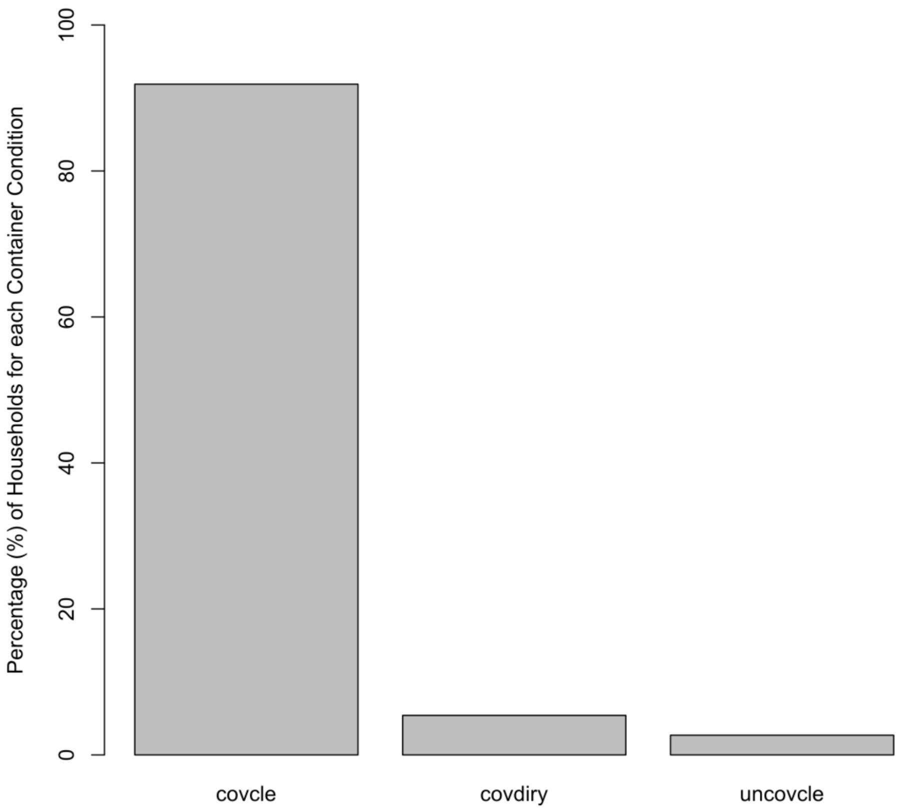

Figure 8: Conditions of the storage containers in the households

covcle = covered and clean, *covdiry* = covered and dirty, *uncovcle* = uncovered and clean

4.4 Distribution of water treatment means by households

Water treatment is any process that removes contaminants and undesirable components from water making it more acceptable for a specific end-use. Among the studied households, about 86% of them reported not treating their water (x^2 = 39.405, *df = 1*, $p<0.001$) (Fig. 9) but the remaining studied households who treated water, still 11% and 20% of the treated water samples were free from *E. coli* and *Salmonella typhi* which was about three times lower than 36% detected in Bolivia and Nigeria (Rufener *et al*., 2010; Asifamabia *et al*., 2015). This situation of storing untreated water could pose a high risk of contamination due to high concentration of microbes in this stationary water, a situation also reported by Wright *et al*. (2004), Gundry *et al*. (2006) and Sharma *et al*. (2013). These commentators reported that contaminations were mostly found in storage containers compared to the distribution points and reservoirs mainly because of fresh bacterial contamination of the storage vessels. Indeed, there is evidence from Lesotho for the fecal contamination in domestic storage vessels being of human origin, while that in public water supply is more likely to be predominantly of animal origin (Feachem *et al*., 1978). Similar risks must be befalling households involved in storing water without treating.

A similar study in Zimbabwe reported that 65% of the households' abstracted water from protected sources yet only 32% treated their water before use by boiling, chlorination or biosand filtration (Kanda *et al*., 2013). Due to water treatment process such as boiling being important as a public health importance, the communty still rely on drinking untreated water. The low numbers of households treating their water in Babati is striking and qualitative methods would probably give more definitive answers as to why many people do not treat their water. In the literature, there are several reasons for people not treating their water ranging from being tasteless to being smelly and at times just costly (Yallew *et al*., 2012; Kangamba *et al*., 2006). When water treatment behaviors were studied in the identified water handling chains it was found that most households using various chains did not treat their water before drinking (Fig. 10). Respondents were asked to give reasons for not treating the water and most of them preferred not to treat water because it was expensive, or because it was rendered the water tasteless and/or made water to have smell (for chlorinated water). Chlorination was found in the untreated source-to-treated reservoir-to household chain (*untrS2trR2HH*), which is the evidence that chlorination was the method of choice in treating waters in reservoirs in Babati town. On the other hand boiling of water was practiced by households getting their water from the untreated source-to- household chain (*untrS2HH*) or from the untreated source-to-untreated reservoir-to households (*untrS2untrR2HH*) chain (Fig. 9).

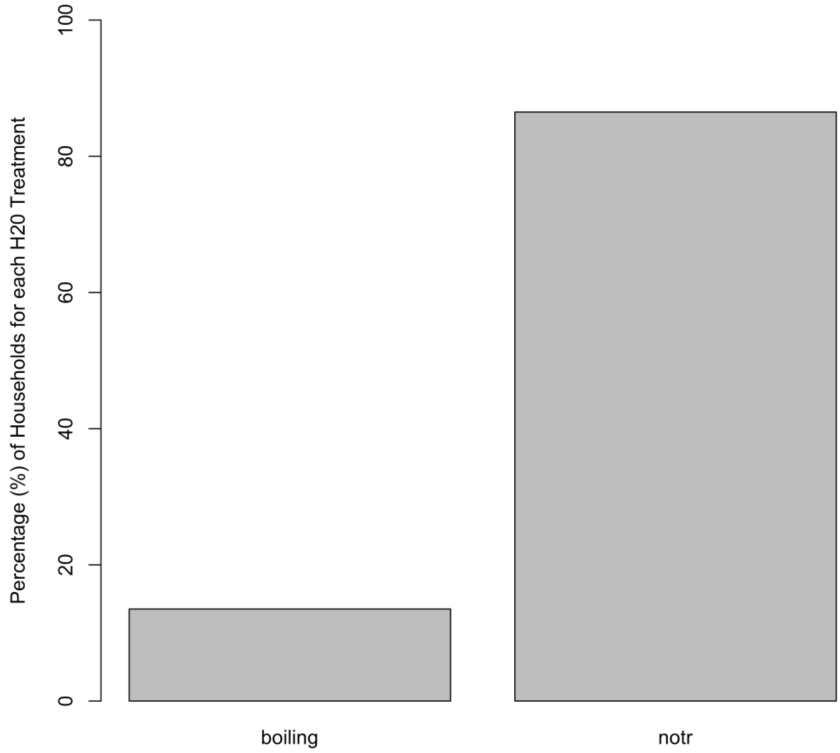

Figure 9: Water treatment methods used in the households; notr= no treatment

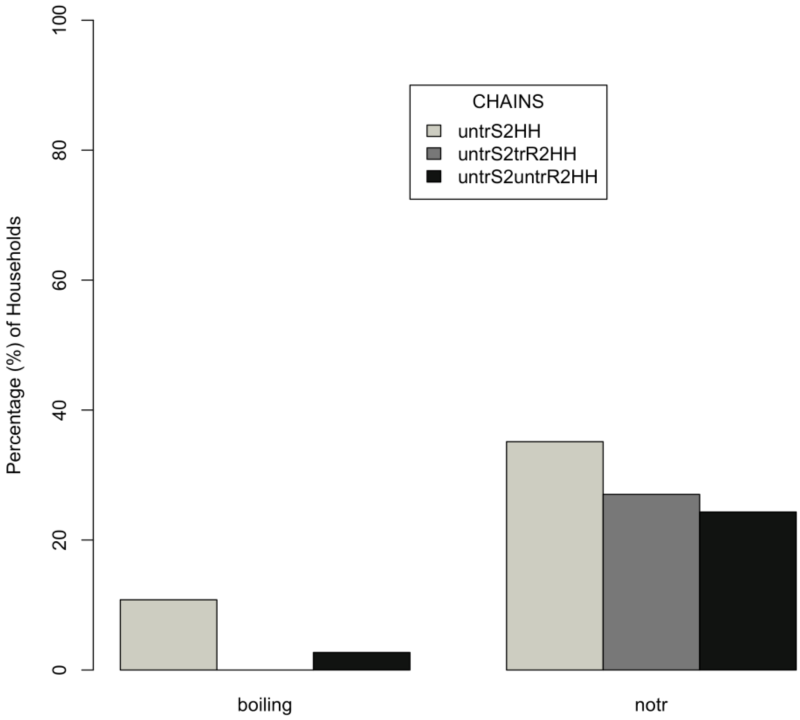

Figure 10: Water treatments practices in water handling chains

(notr= notreatment, *untrS2HH*= untreated source to households, *untrS2trR2HH*=untreated source to treated reservoir to households, *untrS2untrR2HH*=untreated source to untreated reservoir to households)

4.5 Water-handling chains and types of containers

A breakdown of water-handling chains with regards to types of containers shows that the bucket is the most used water container followed by water drums (Fig. 11). Pots are only moderately used. Despite the fact that majority use buckets for water handling, the difference was not statistically significant (x^2*=8.8891, df = 4, p= 0.06393).*

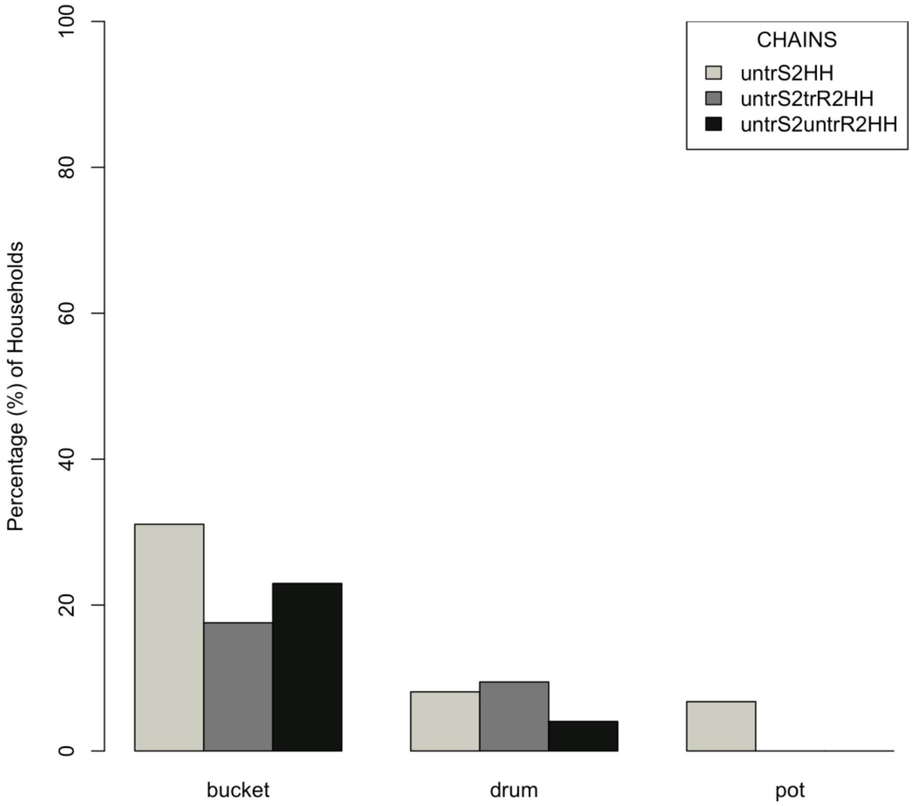

Figure 11: Water storage types in different chains

4.6 Microbiological water quality

The results in water handling patterns indicated that majority of the parameters assessed for microbiological quality which included water sources, reservoirs, taps and household storage containers in the study area, exceeded the WHO recommended guideline value of 0 cfu/100 ml for faecal coliform and *Salmonella typhi* bacteria counts in drinking water. Out of 564 water samples collected, above 70% of the samples were found contaminated and only 14% were free from all two microbial counts (i.e., faecal coliforms and Salmonella). Specifically, 85% were positive for faecal coliforms and 70% for *Salmonella typhi* count which highlight the precautionary measures that should be taken during on-site risk assessment from collection to point of use to prevent cases of water borne infections. These findings from this study were consistent with the findings from Nepal which showed that 94% of samples collected from source to reservoir and taps were positive for *E. coli* counts (Kenea, 2016). We further compared the amounts of these contaminations in the water-handling chains to see the level of risk among the chains. Figure 12 shows that faecal coliforms counts were found to be significantly more concentrated within the chains of untreated source to households (*untrS2HH*) compared to the other chains (p=0.00944). The water-handling chain from untreated source to treated reservoir to households (*untrS2trR2HH*) had the lowest median levels of faecal coliforms of the three chains (Fig. 12) though the difference between this chain and the untreated source to untreated reservoir to households was not statistically significant.

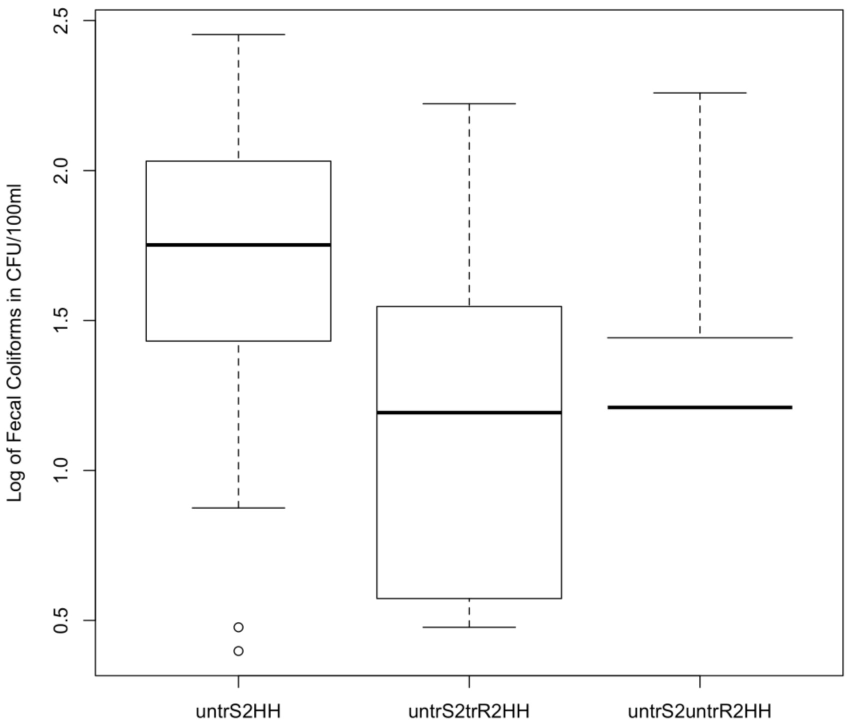

Figure 12: Faecal coliform counts in various water handling chains

Comparison of fecal coliforms among water handling chains revealed that the largest difference was between the untreated source to untreated reservoir to household (*untrS2untrR2HH*) chain and the untreated source to household (*untrS2HH*) chain, followed by the untreated source to treated reservoir to household (*untrS2trR2HH*) and the untreated sources to household (*untrS2HH*) chain. The least difference is between the *untrS2untrR2HH* and the *untrS2trR2HH* chains providing evidence that the treatment of water that is usually done at the reservoir and household behaviors around water treatment are effective in reducing the fecal coliforms (Fig. 13).

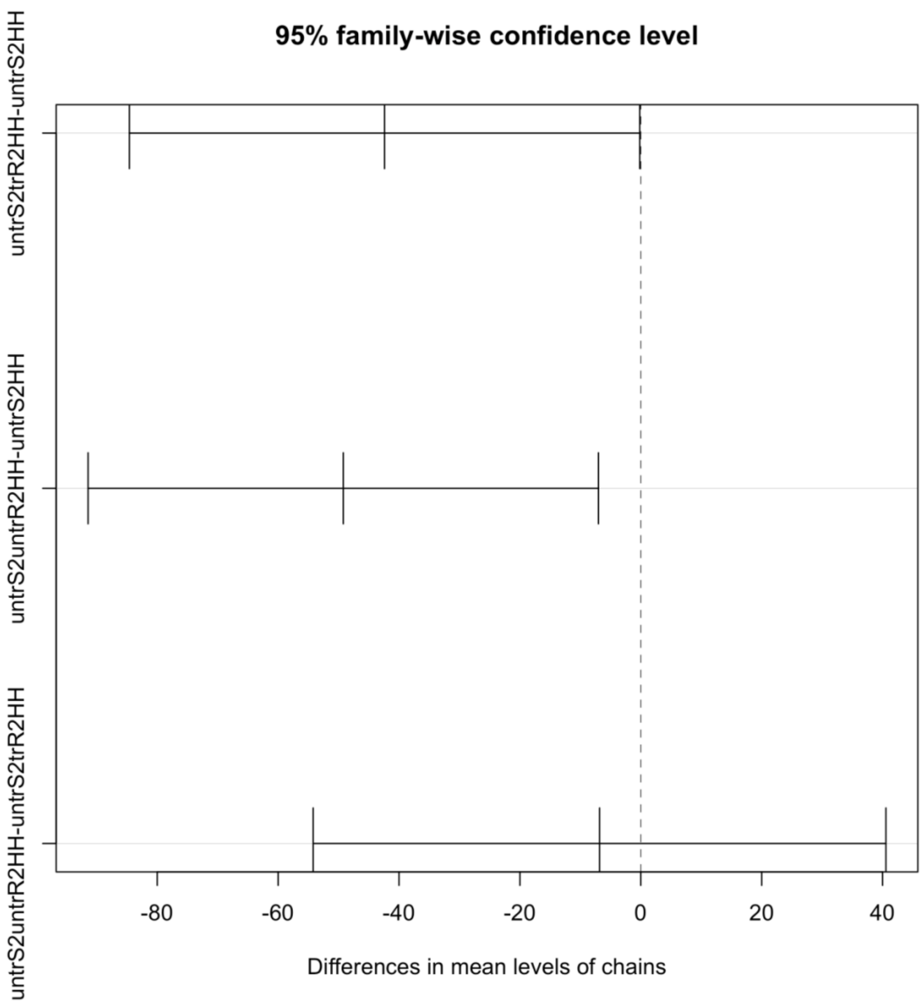

Figure 13: Pair wise comparison of faecal coliforms among chains

In terms of *Salmonella typhi*, the chain with untreated source to household had the highest counts compared to other chains. However, the difference was not statistically significant (p=0.06) (Fig. 14). The chain with the lowest count was the one with untreated source to treated reservoir to households again pointing to the evidence of effectiveness of water treatment.

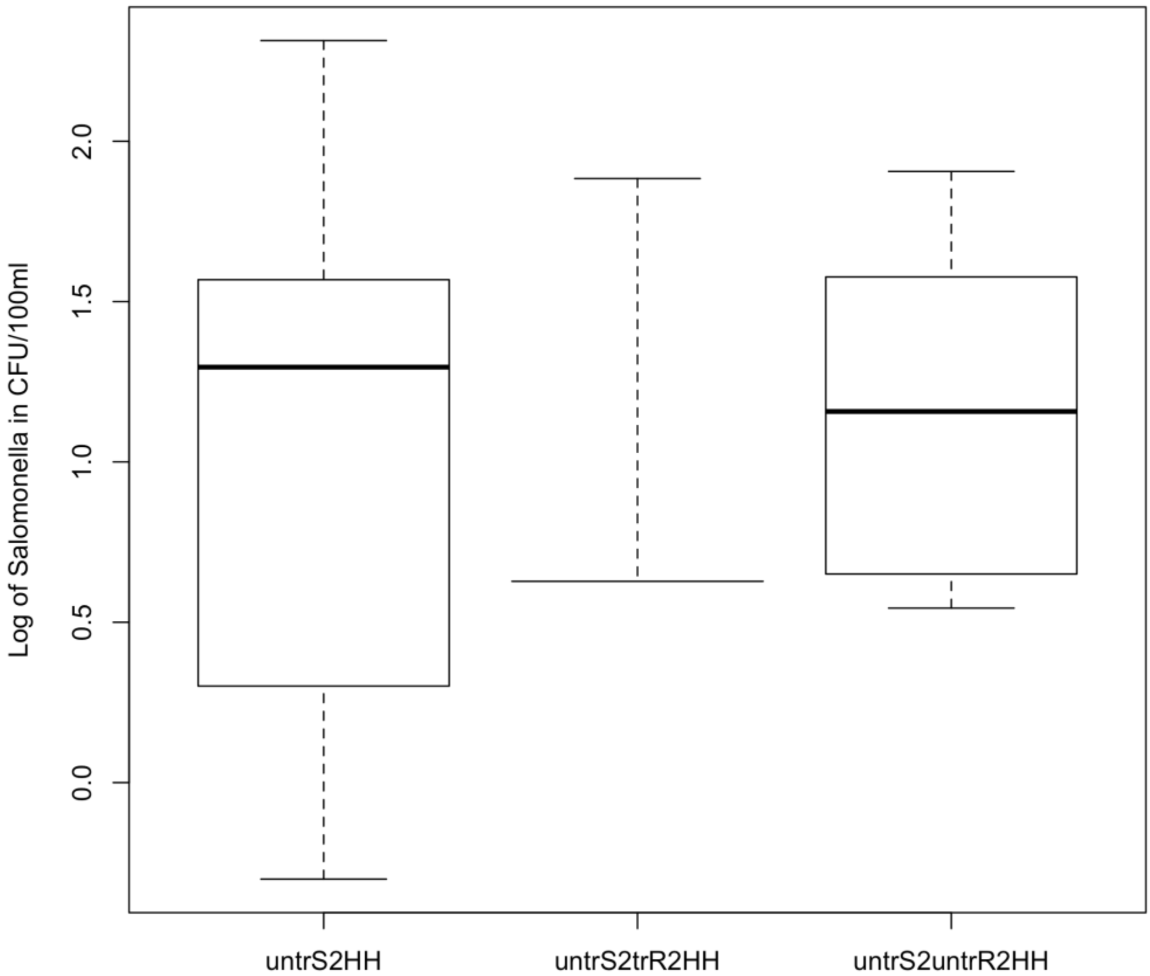

Figure 14: Logarithm of *Salmonella typhi* counts in water handling chains

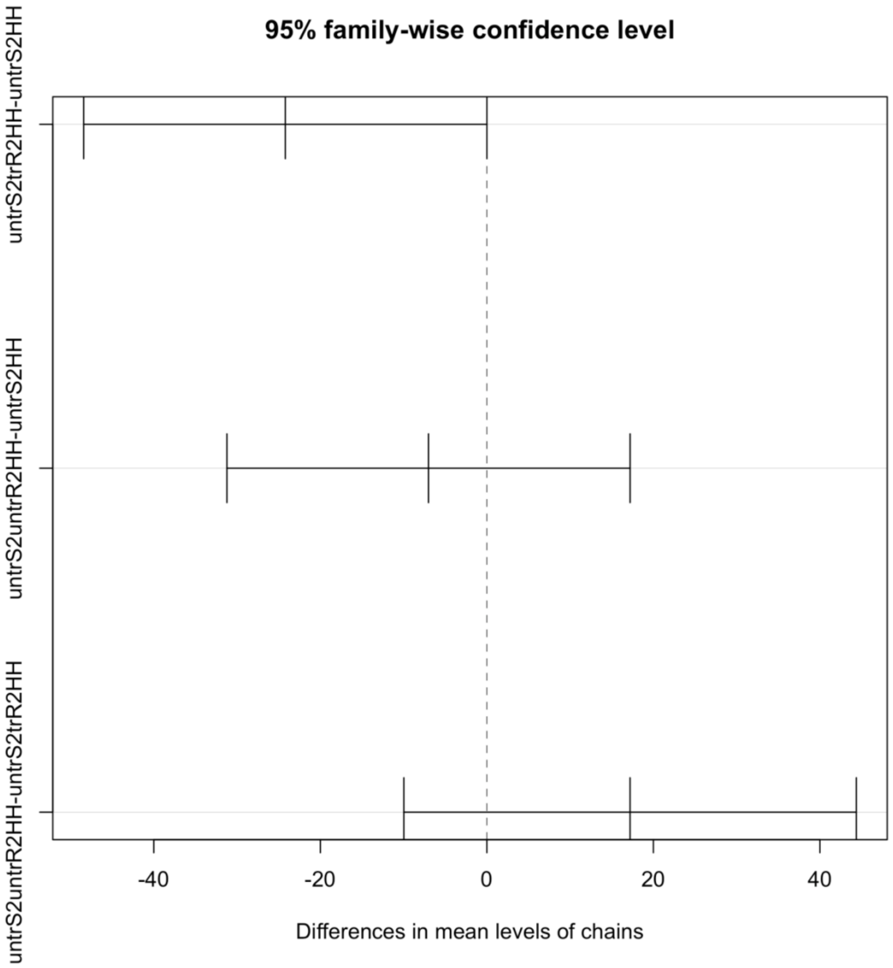

Figure 15: Pair wise comparison of *Salmonella typhi* counts among chains

A comparison of levels of salmonella for each chain revealed that the *untrS2trR2HH-untrS2HH* pair and the *untrS2untrR2HH- untrS2trR2HH* pair had the largest difference (Fig. 15) with the lowest difference being between the *untrS2untrR2HH- untrS2HH* chains. People involved in the *untrS2HH* chain are having the most exposure to *Salmonela typhi*.

4.6.1 Role of water-handling chains and type of containers in the contamination profile

The chain with the lowest count of microbial profile was the untreated source to treated reservoir to the household (*untrS2trR2HH*) pointing to the possible effectiveness of the routine water treatment. Figure 16 shows the relationships between the salmonella contamination, water containers and the water-handling chains. The chain *untrS2trR2HH* is therefore a baseline and the roles of container types and container conditions with respect to the two other chains (*untrS2HH* and *untrS2untrR2HH*) are shown. We see that within the *untrS2untrR2HH* chain the drum had the most concentrations of *Salmonela typhi* whereas within the *untrS2HH* chain the culprits were buckets and drums (Fig. 16).

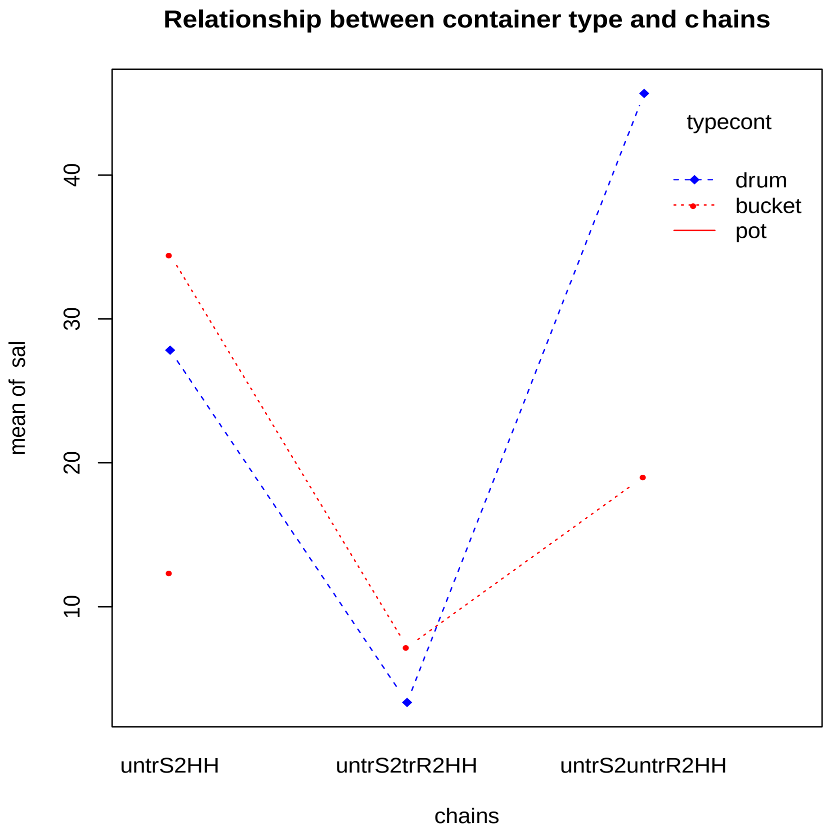

Figure 16: Interaction between container type and water handling

In terms of the condition of containers, as can be seen from Fig. 17, containers that were covered and clean also had a substantial count of salmonella in this chain, this is an interesting observation since we would expect what is ‘clean and covered’ to have the lowest amount of contamination. Surprisingly, containers that were covered and dirty had lower amount of contamination. Moreover, within the *untrS2HH* chain, covered and clean container actually had the highest counts of salmonella in comparison to the covered and dirty containers (Fig. 17). These seemingly contradictory findings underscore our hypothesis that the safety of water is a function of the entire activities happening in the entire water handling chain. Contamination can happen at many points within the chain making it possible that even covered and clean containers can have higher contaminations than uncovered and dirty containers.

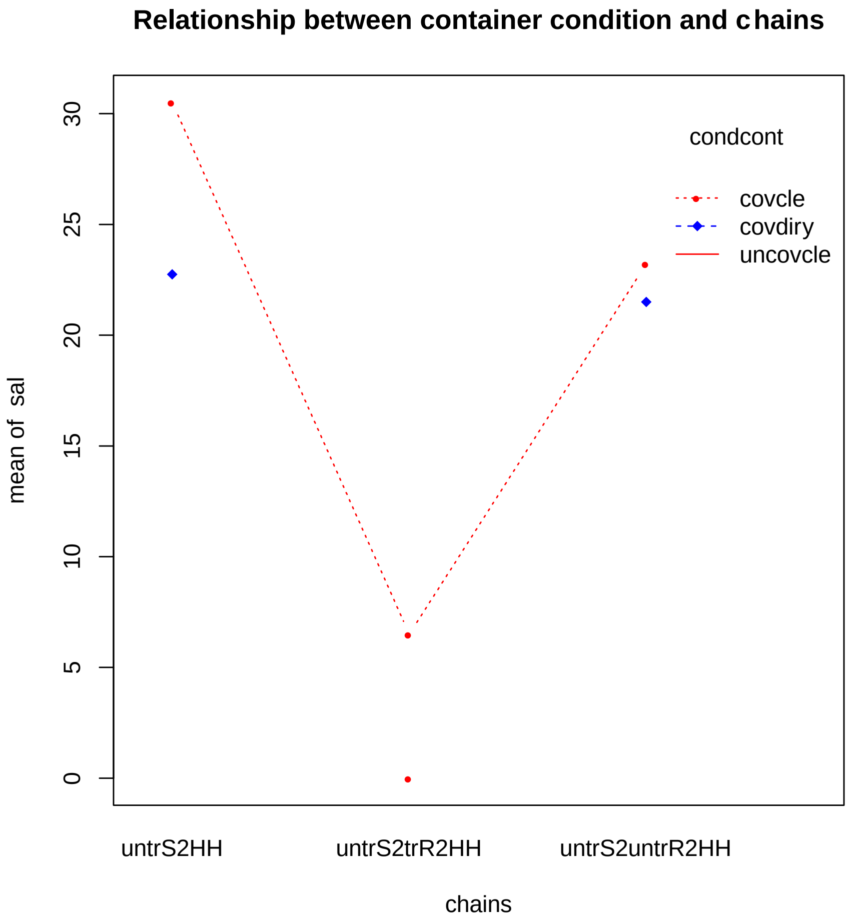

Figure 17: Interaction between container condition and water handling chains

Figure 18 summarizes the mean microbial profiles of various water handling chains from the studied area. Faecal coliforms were highest in the source and reservoir, falling significantly in the tap water and rising significantly in the storage containers while Salmonella count seems to fall from the source to the storage containers. The deterioration of microbial quality of drinking water from the source to point of use through water handling factors has also been addresed to other countries where hands (poor hygiene) were seen as important vector of diseases to the community (Singh *et al*., 2009; Peckering *et al*., 2011; Devamani *et al*., 2014). This finding is significant because it points to the fact that treating water in the reservoir and source only may not be enough because of this evidence of recontamination during collection, transportation, storage and dispensing of the water.

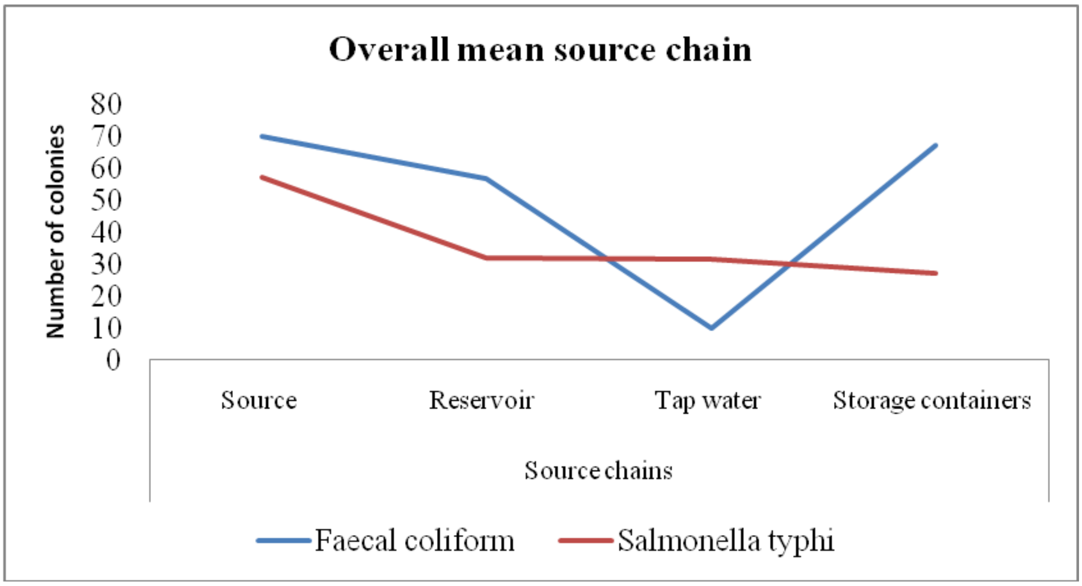

Figure 18: Overall mean counts along water handling chains

4.7 People's knowledge, attitude and practices relating to water safety and quality on source to consumption chains in water handling and reason for adopting such chains

Retrospective clinic records from Mrara Hospital were reviewed to identify patients with diarrhoea diseases reported in 2016 for the whole Babati town. Out of 44 229 first visit cases, 7382 (16.69%) cases were identified as diarrhoea diseases from Babati town (Fig. 19). About 3401 (46.07%) diarrhea cases were children under five years. However, clinic records did not specify diarrhoea diseases in monthly bases, and instead reported the symptoms of diarrhoea diseases in quarterly bases.

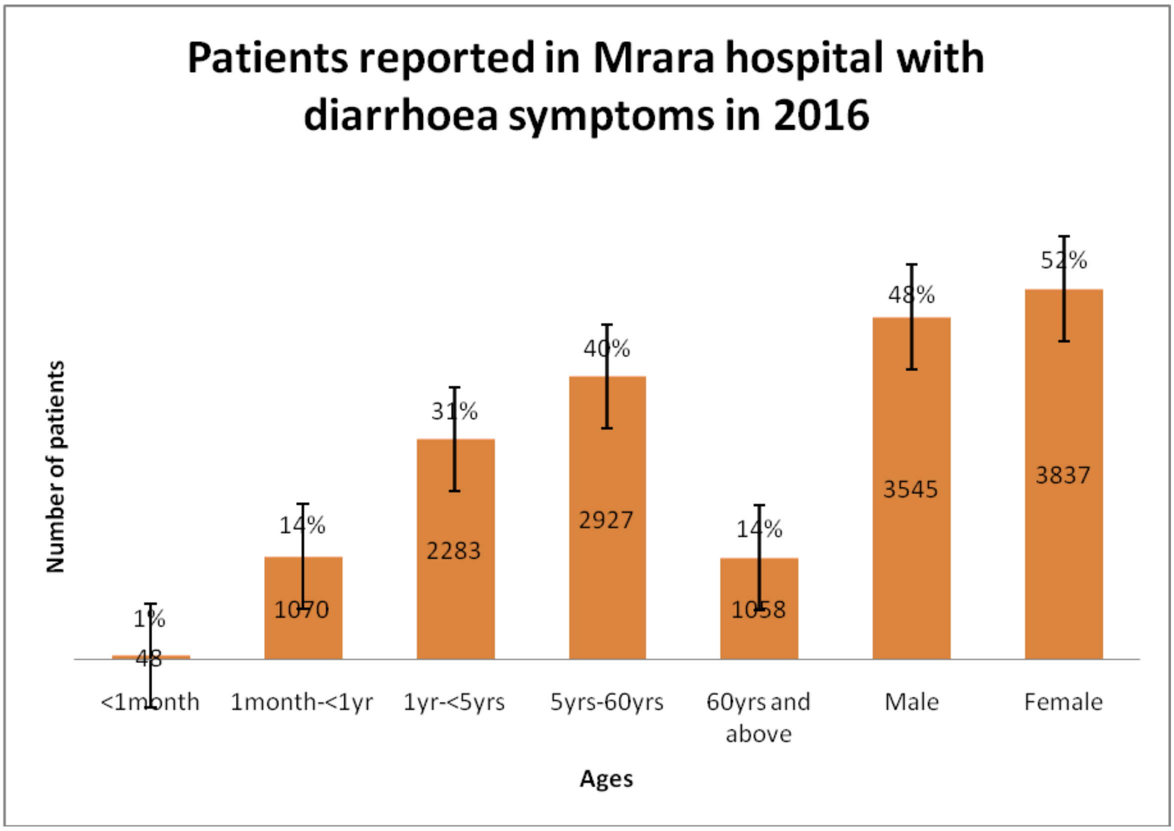

Figure 19: Demographic data of patients reported in Mrara hospital for Babati town in 2016 with diarrhoea symptoms (N=7382).

Figure 19 shows the frequency distribution of the individuals identified to have had symptoms of diarrhoea diseases. It also shows the proportion of symptoms distributed across the age groups. The majority of patients, who visited the clinic with diarrhoea diseases (2927, 40%), were within 5-60 years of age followed by 2283 (31%) who were children aged between one and under five years. Figure 20 specifically reported 66% of diarrhea cases with no dehydration, 17% of diarrhea cases with some dehydration, 10% of cases with typhoid, 3% of diarrhea cases with severe dehydration and dysentery respectively, and 1% of cholera cases. The graph also shows the sex distribution of the symptoms of diarrhoea diseases. It also indicates that 52% of the symptoms of diarrhoea diseases victims were females, whereas 48% were males.

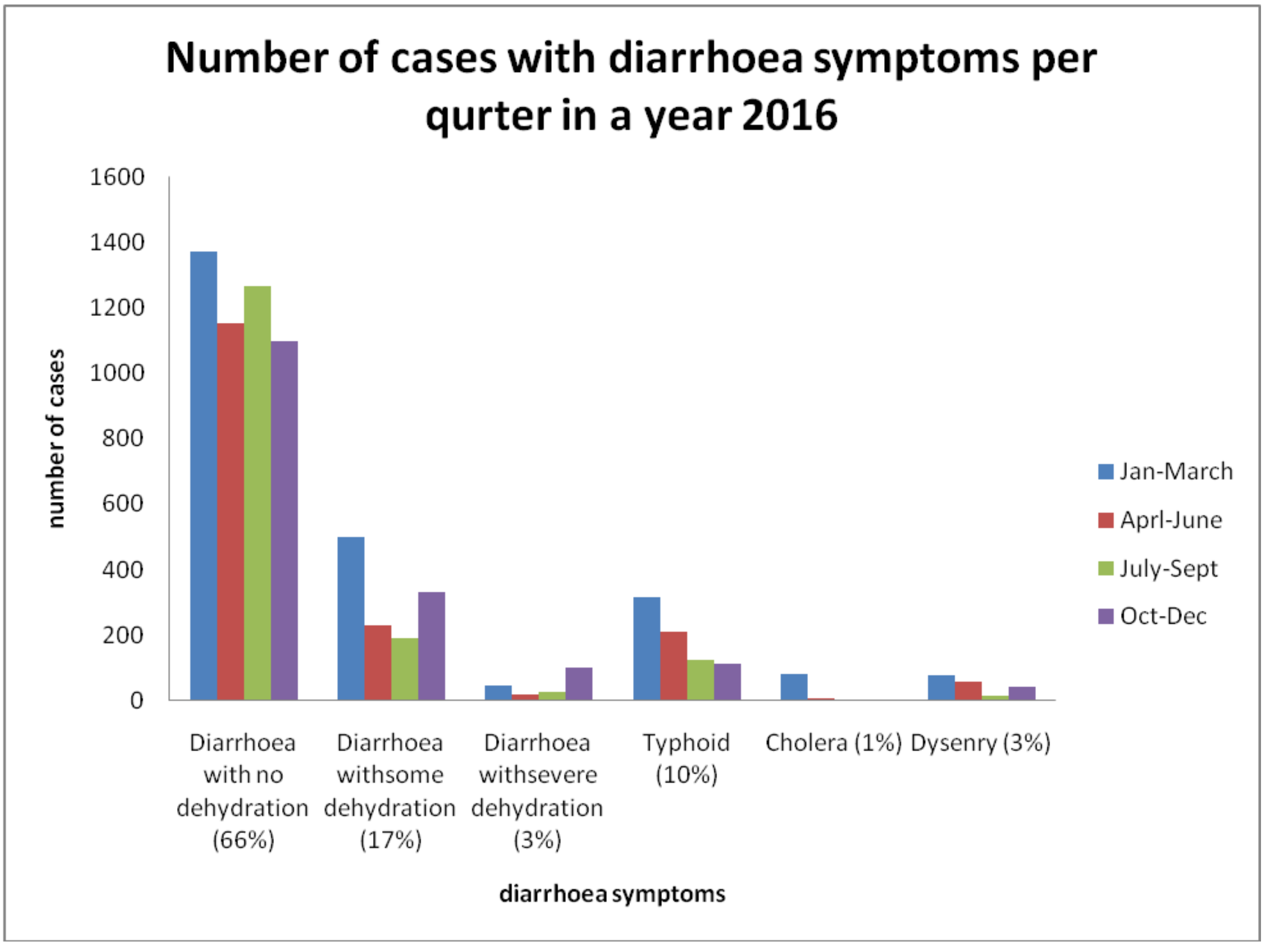

Figure 20: Number of cases with diarrhea symptoms per quarter in a year 2016

Figure 20 also illustrates the general quarterly data of the number of diarrhoeal diseases cases in the clinic from the study areas. The number of iarrhea cases varies remarkably among the months of a year. On the whole, there is higher incidence of diarrhoeal diseases during the months of January-March, in the short season of rain (September-December) and in July after the big rain season (March-June), than other months in Northern highlands. Cholera cases occurred during the month (January-March) which was after the short season of rain and within the big season of rain (March-June).

4.7.1 Knowledge, attitude and practices (KAP) survey

(i) Demographic information of the study households in Babati town (N=52)

The respondents were female aged between 20 to 55 years as in most cases (91%) water is collected by females (Sharma *et al*., 2013). The majority of the respondents (73%) had primary education as their highest education while only 10% secondary education,14% had some college education and only 3.8% had no education. The average Tanzanian household has 5 members (MoHCDGEC, 2015), according to the studied site a total of 328 people lived in the 52 interviewed households and the average number of people per household was 6. About 75% of the heads of the houses' occupation were farmers and 15% privately owned their businesses while only 10% were government and private employees.

Table 1: Household demographics in Babati town

Data	N	%
Age of the mother (N=52)		
20-29	9	17.3
30-39	12	23.1
>40	31	59.6
Age of the father (N=47)		
20-29	3	6.4
30-39	11	23.4
>40	33	70.2
Marital status (N=52)		
Single	2	3.8
Married	47	90.4
Widower	3	5.8
House hold head occupation (N=52)		
Farmer	39	75
Business	8	15
Others	5	10
Education of father (N=47)		
No education	3	6.4
Primary education	37	78.7
Secondary education	2	4.3
College/University	5	10.6
Education of mother (N=52)		
No education	2	3.8
Primary education	38	73.1
Secondary education	5	9.6
College/University	7	13.5

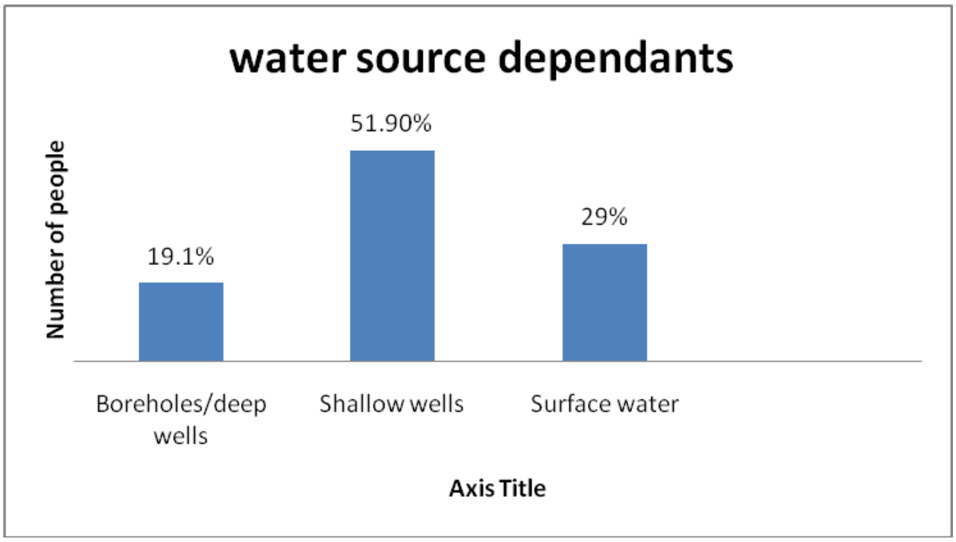

Figure 21: water source dependants (N=52)

The main source of water in Babati town is ground water. About 52% of household respondents indicated that their source of water was ground water (shallow well water) while 29% used surface water and 19% used boreholes (deep wells). This is relevant as a significant number of people rely on these water sources particularly shallow wells and springs for domestic use (Elisante *et al.*, 2016). Some of the people in the study areas had to walk long distances to reach the water sources as it was similarly reported that about 40% of Tanzanian households spend on average of 30 minutes or longer to obtain drinking water (MoHCDGEC, 2015). Seventy three percent of the respondents, the sources of water were located at less than 50m to their houses. About 16% walked between 50 to 500 m to get water while for 11% of the respondents had to travel for more than 500 m from their houses to the source of water. This is particularly relevant as water transported manually over long distances is prone to increased contamination (Uwimpuhwe, 2012)

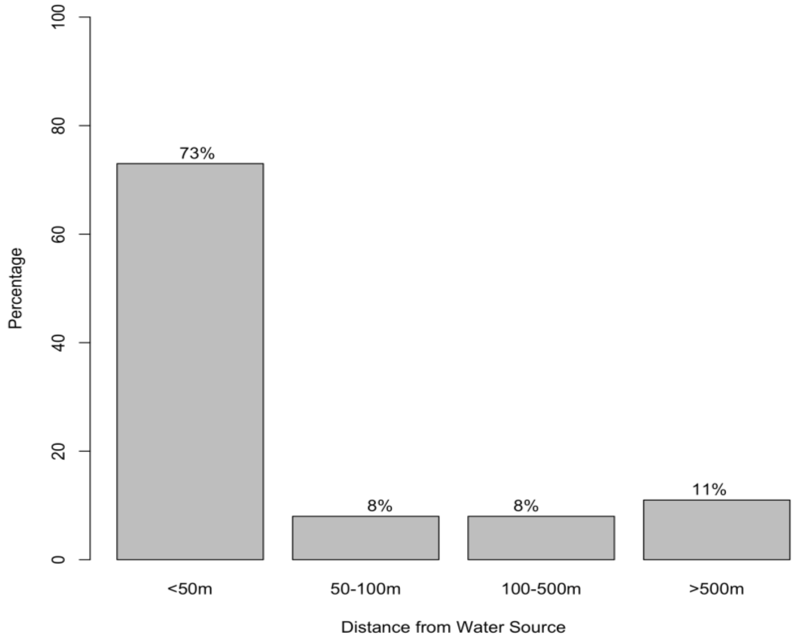

Figure 22: Distance between the study households to source of water (N= 52)

4.7.2 Water usage, storage practices and treatment used by the study households in Babati town.

Improvement of water quality through improved water supplies, house hold water treatment and safe storage at point of use can give a positive health impact to the society without forgetting continual health education and hygiene promotion which can also sustain behavioral change (Uwimpuhwe, 2012). A summary of water storage and treatment practices is shown in Table 2.

Of all the 52 households investigated, about 89% of the respondents used plastic containers (bucket) for both water collection and storage for drinking water while the remaining 12% of the respondents used clay pots. About 96% of respondents indicated that they cover their water storage containers. The other 4% of respondents used uncovered storage containers which could be one of the risk factors for diarrhea diseases.

All the respondents indicated that they kept their water storage containers indoors. In terms of the cleanliness 85% of the containers were clean. About 73% of the respondents clean their storage containers using water and soap while only 27% used water only to clean the storage containers. Most of the respondents (94%) indicated that they used separate containers for drinking purposes and for cooking, washing and cleaning of kitchen utensils. Almost 81% of the main water sources used were not treated. With regard to water treatment before use, 81% of the study households did not treat water before use as most of them believed that the water they used was clean and safe, only 15% boiled drinking water before using it. The reported low numbers of people boiling water is similar to what was reported in Ethiopia where 3% of the households use boiling process to treat water before consuming (Sharma *et al*., 2013). A similar study in Zimbabwe reported that 65% of the households' abstracted water from protected sources yet only 33% treated their water before use by boiling, chlorination or biosand filtration (Kanda *et al*., 2013). All of the respondents were satisfied with the treatment used and because of the availability of water in the society, 96% of the respondents reported that an average person consumes about 20 litres of water per day.

Table 2: Water usage, storage practices and treatment used by the study households in Babati town (N=52

Data	N	%
Availability of water throughout the year	52	100
Type of storage container	46	88.5
Plastic	0	0
Metal	6	11.5
Other		
Means of collection from the storage container	50	96.2
Mug	2	3.8
Tap attach to the container		
Container storage conditions	50	96.2
Closed	2	3.8
Open		
Cleaning storage containers with	38	73.1
Water and soap	14	26.9
Water only		
Observation if the containers are clean	44	84.6
Yes	8	15.4
No		
Separate container for drinking water		
Yes	49	94.2
No	3	5.7
Treating water at the main source		
Yes	1	1.9
No	43	81.1
I don’t know	9	17
Treating water at point of use	8	15.4
Yes	42	80.8
No	2	3.8
I don’t know		
Satisfied with the treatment	52	100
Yes	0	0
No		
Liters per day used per person		
20 ltr per day	50	96.2
Less than 20 ltr per day	2	3.8

4.7.3 Sanitation and hygiene related information

Basic hygiene practices, especially hand washing, and access to sufficient sanitation are effective interventions in the reduction of waterborne diseases in developing countries (Uwimpuhwe, 2012; Jerry *et al*., 2013). Poor basic hygiene like women dipping their hands into storage containers when fetching water for household use can affect water quality. Therefore hygiene interventions that target the female heads of households may help develop household hygiene practices through influencing the habits of children who are usually involved in the collection and handling of drinking water (Kanda *et al*., 2013). Several studies have indicated that *E. coli* can survive for 10 minutes, *Klebsiella spp* for 2.5 hours and *Shigella sonnei* for up to 3 hours on unwashed hands. The Tanzania National Household Budget Survey in 2007 reported that 97 % of households have a basic latrine in urban areas (Thomas, 2013). This was also observed in Babati town where all the respondents (100%) indicated that they had a toilet at home.

Majority 67% used pit latrines, 23% pour flash toilets and only 10% used flashed system toilets. The respondents were also asked the importance of having a latrine, the majority of the respondents (77%) indicated that they used a latrine for privacy; while 23% expressed that the latrine is important to prevent them from getting diseases. Hand washing at critical times in Tanzania has been reported to be a rapid and reliable indicator of general hygiene behavior in households (Thomas, 2013). With regards to hand washing practices 87% of the respondents wash hands with soap and water. About 35% of the respondents indicated that they washed hands before eating, 34% of the respondents washed hands after using a toilet, while only 20% of the respondents washed hands before they prepared food and 11% washed hands after touching dirty things. This was seen also in Kilombero valley in Tanzania where a good number of people washed hands before preparing food and 62% in low income urban areas washed hands after coming from the toilet (Thomas, 2013) which is key in reducing diarrhoea diseases.

Regarding the importance of washing hands, most of the respondents (62%) indicated that they just washed hands to be clean (remove stains), 39% of the respondents said washing hands was important in preventing diseases by killing bacteria. On observation, 27% of the respondents' nails were dirty and not cut while 89% had their hair neatly cut and 81% were having neat clothes.

Table 3: Summary of hygiene and sanitation practices in the study households in Babati town (N=52)

Data	N	%
Presence of toilet at the household		
Yes	52	100
No	0	0
Type of toilet		
Pit latrine	35	67.3
Pour flash	12	23.1
Flashed toilet	5	9.6
Reasons of having a toilet at home		
Privacy	40	76.9
To prevent diseases	12	23.1
Wash hands with soap and water		
Yes	45	86.5
Not all the time	7	13.5
Hand washing practices		
Before eating and feeding child	51	35.2
Before food preparation	29	20
After using toilet	49	33.8
After touching dirty things	16	11
Importance of hand washing		
To be clean (remove stains)	32	61.5
To kill bacteria	20	38.5
Observation of nails cut and clean		
No	14	26.9
Yes	32	73.1
Observation of hair cut and neat		
No	6	11.5
Yes	46	88.5
Observation clothes clean		
No	10	19.2
Yes	42	80.8

Pearson's chi-square tests were performed to determine whether water handling practice, hand washing practices, and their prevention was dependent on educational level of respondents. As presented in Table 4, the results showed that people who went to secondary school and above were not cleaning their storage containers with water (p=0.01) as this was also reported from other studies on the process of household cleaning and sanitizing (Mutyaba, 1997) which revealed the importance of using soap and water when cleaning could decrease diseases associated to hygienic behaviour. There was also a significant association for people cleaning their storage containers before refilling another drinking water (p=0.03). This was also reported in South Africa where this process was also adapted to the households so as to reduce contamination of the stored drinking water (Nala *et al*., 2003). The use of mug as a means of drawing water was statistically significant to 80% of women who had primary level of education (p=0.05). This observation was not supported in the other studies as the use of mugs was seen as one of the probable source of contamination when drawing water (wright *et al*., 2004). No significant associations were identified for hand washing behavior, water treatments at household level, type of storage container, preservation of water stratified by level of education of the respondents.

Table 4: Hygiene practices stratified by level of education

Water handling practices		Primary	Secondary and above	P value
Type of storage container	Plastic	35(76.1%)	11(23.9%)	0.39
	Clay pot	5(83.3%)	1(16.7%)	
Condition of storage container	Not covered	3(100%)	0(0)	0.45
	Covered	37(75.5%)	12(24.5%)	
What is used to clean storage container	Water only	14(100%)	0(0)	**0.01**
	Soap and water	26(68.4%)	12(31.6%)	
Method of drinking water treatment	Boiling	5(71.4%)	2(28.6%)	0.62
	Not boiling	35(79.54%)	0(0)	
Duration of cleaning storage container	Before refilling	28(70%)	12(30%)	**0.03**
	Once per week	10(100%)	0(0)	
	Once dirty	2(100%)	0(0)	
Means of drawing water	Mug	40(80%)	10(20%)	**0.05**
	Tap attached to container	0(0)	0(0)	
Hand washing practices	Washing hands before food preparation	20(69%)	9(31%)	0.09
	Washing hands after toilet	38(77.6%)	11(22.4%)	0.14
	Washing hands before eating and feeding child	39(76.5%)	12(23.5%)	0.77
	After touching dirty things	10(62.5%)	6(37.5%)	0.1
Importance of washing hands	Remove stains	15(71.4%)	6(28.6%)	0.5
	Kill bacteria	25(80.3%)	6(19.4%)	

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In this study we found that three patterns of water handling were commonly practiced in the studied area with a revelation of poor water storage and handling as evidenced by the microbial profiles performing poorly against national and WHO standards. The water-handling patterns did harbor active population of microorganisms that could threaten the public health. Even though treated water may be free of fecal indicator organisms, water handling practices done from source, collection and transportation to reach to the households may hinder water quality and hence increase vulnerability to water borne diseases. Tracking microbial drinking water quality along different water supply "chains" to arrival in the household is a novel approach which allows for an understanding of the points at which highest fecal loading occurs. This approach thereby assists to inform the development of policies in the areas of household hygiene education, drinking water treatment, and water supply planning in rapidly growing urbanized towns in Tanzania and elsewhere/ developing countries. Our study has shown that it is possible to determine the actual water-handling chains that households regularly use in obtaining and consuming water, this knowledge can better guide public health and policy interventions to reduce to health impact of water-borne diseases.

The traditional pit latrine in the studied area also seemed to be the most favored sanitation option although it is regarded as an unimproved technology on the sanitation ladder. Having inadequate sanitation could be one of the potential health risks to the community. Ventilated improved pit latrine appeared to be less popular due to financial constraints, as this is the major barrier in adopting an urban sanitation option.

5.2 Recommendation

From the study, the following recommendations were made, that an appropriate health education on hygiene, water treatments i.e; boiling water before drinking are recommended so as to prevent waterborne diseases to reoccur in the community.

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APPENDICES

Appendix 1: Questionnaire

Questionnaire on water handling practices from source to point of use at household level in Babati town for research titled: "Determination of source- to- consumption water chains and their implication on water quality and human health in Babati Town, Tanzania".

	A questionnaire on WASH for people living in Babati town **Date:……………District……………………Ward…………………Street……** **household no:**……………… **Sample ID**…………………….	Code
	Socio-Demographic	
1.	Age of the father………… (Years) (01). 16 to 19, (02). 20 to 29, (03). 30 to 39, (04). >40	
2.	Age of the mother………… (Years) (01). 16 to 19, (02). 20 to 29, (03). 30 to 39, (04). >40	
3.	What is your Marital Status? (01). Single, (02). Married, (03). Divorced, (04). Cohabiting (05). Separated, (06). Widower , (07). Widow	
4.	If a man, How many wives do you have?	
5.	Type of Household (01). Father headed ………. (02). Mother Headed…………	
6.	Education level (Number of years gone to school) Father……………. Mother……………..	
7.	What is the occupation of (a) Mother………….. (b)Father………….	
8.	How many children do you have?	
9.	How many children are under 5 years?	
10.	How many are you in the family including yourself?	

11.	What is your Religion? (01). Christian, (02). Muslim, (03). No religion,(04).Others	
B: Water, Sanitation and Hygiene Practices		
	Water adequacy and safety	
12.	Is Water available in your village? (01). Yes, (02). No (03). I don`t know	
13.	What is the main source of the water? 01. Bore holes, 02. Wells, 03. Rain water, 04. Surface water, 05. Tape water, 06. Others	
14.	What causes you to adopt a given source? 01. Very busy in the office, 02.Water sources are not available, 03.Economic status, 04.Dirty water at that place	
15.	How far is it from home to the water source? 01. Half a kilometer, 02. One kilometer, 03. More than a kilometer	
16.	How many minutes do you take to collect water from the source? 01.15 minutes, 02. 15 to 30 minutes, 03. 30 to 1 hour, 04. More than one hour	
17.	Is the water treated? 01. Yes, 02. No, 03. I don`t know, (If the answer is yes go to question number 20)	
18.	Do you treat water at home? 01. Yes, if Yes, go to question no.19 02. No, if No, go to question no.20 03. I don`t know	
19.	What kind of treatment do you use? 01. Boiling, 02. Filtering, 03.Let it stand and settle, 04. Others (specify)	
20.	How much water does your household use per day? 01. 20 litters, 02. Less than 20 liters, 03. I don`t know	
21.	What causes you to adopt a given water source? 01. Financial status, 02. It is too far 03. I don`t know	
22.	Do you use the same water source to feed your animals? 01. Yes, 02. No,	

	03. I don`t know	
23.	Do you use the main source all year or only part of the year? 01.Whole year, 02.Dry season, 03.Wet season only	
24.	Who in the Household usually goes to collect water? 01.Adult woman 02.Adult man 03.Female child under 15 years 04.Dont know	
25.	Why do you store your drinking water 01.Prevent contamination, 02.Keep clean, 03.Limit/Reduce water treatment, 04.Keep safe, 05.Other specify	
26.	How long does the drinking water in the storage container stay stored before it is refilled? 01.Every day, 02.Every week, 03.Every two weeks, 04.Every month, 05.Every six months, 06.Other specify	
27.	Do the storage containers get cleaned? 01. Yes 02. No	
28.	If Yes, When was the last time they were cleaned? 01.Today/This week, 02.This week, 03.More than a month ago, 04.Dont know, 05.Other /specify	
29.	What kinds of water storage containers are observed? 01.Narrow mouthed, 02.Wide mouthed, 03.Both types, 04.Other specify	
30.	Are the storage containers covered? 01.All are covered, 02.Some are covered, 03.None are covered, 04.Other specify	
31.	Is the water in the storage containers clean? 01.All are clean and covered, 02.Some are clean and covered, 03.All are dirty and covered, 04.Some are dirty and covered, 05.Water is turbid, 06.Algae growth in water	
32.	Observe for different types of water treatment practices/ equipment 01.Boil 02.Add bleach and chlorine 03.Strain through a cloth 04.Water filters 05.Let it stand and settle 06.Other specify	
	HYGIENE PRACTICES	
33.	When do you wash your hands?……………………………………………	
34.	Do you wash hands using soap? 01. Yes, 02. No	
35.	If the answer is yes, in which occasion do you use soap?	

	01. Before eating/feeding a child, 02. Before preparing food, 03. After coming from the toilet, 04. after touching dirty things, 05. After coughing or sneezing, 06. Others………………………………	
36.	What do you think is the reason for using soap? ………………………………………………………………………………………	
37.	Observation checklist 1. Nails cut and clean 01. Yes, 02.No 2. Hairs cut and neat 01.Yes, 02.No 3. Clothes clean 01.Yes, 02. No 4. Looking clean generally 01.Yes, 02.No	
	D. ENVIRONMENTAL HYGIENE & SANITATION	
38.	Do you have a Toilet/Latrine 01.Yes, 02.No	
39.	If Yes, What type of toilet do you have in the household? 1. Pit latrine 2. Flashed toilet 3. No toilet 4. Others (specify)	
40.	If No (you don`t have a toilet), give a reason why? ……………………………………………………………………………………… ………………………………………	
41	Where do you go then?	
42.	How far is the defecating area from water source?	
43.	How far from the household to the toilet/defecating area?	
44.	Where do you urinate? ………………………………………………………………………………………	
45.	How do you dispose other household waste? ………………………………………………………………………………………	
46.	Do you share a single toilet with other Household? (01).Yes (02). No	
47.	How many other Household share this toilet	

48	What specific do you encounter with your latrine? 01.Bad smell, 02.Flies insects, 03.Flooding, 04.Difficult in cleaning, 05.Lack of water	
49	What are the diseases or illness your family experienced during the last three weeks? 01. Diarrhoea among <5 years. Number of family members sick………. 02. Diarrhoea Number of family members sick………. 03. Dysentry Number of family members sick………. 04. Malaria Number of family members sick……….	
50	How do you protect your family from the above diseases? 01.Keeping clean 02.Use safe drinking water 03.Use and clean latrine 04.Follow the health advice 05.Wash hands and personal hygiene 06.Mosquito net 07.Environmental cleaning	

Appendix 2: Informed Consent

This informed consent form is for Households/Institutions in the BABATI community and who we are inviting to participate in research, titled "Achieving Universal Access to adequate, sustainable and equitable sanitation services in the Cities of Tomorrow ".

Institutions that conduct the research project: The Nelson Mandela African Institution of Science and Technology (NM-AIST) and SHARE-II, WaterAid UK and WaterAid Tanzania

This Informed Consent Form has two parts:

Part:Information Sheet (to share information about the study with you)

Part II: Certificate of Consent (for signatures if you choose to participate)

You will be given a copy of the full Informed Consent Form

Part I: Information Sheet

Introduction

I am________________________________, working for the NM-AIST, a university based in Arusha, working with the support of WaterAid, an international development organization with a country office in Dar es Salaam, to conduct this study. I am collecting this data on behalf of the research partners on the household and institutional sanitation and hygiene practices, infrastructure and services in Babati Town. Your views and those of others in your community would help the researchers work with the community and Babati Town Council to prepare a sanitation and hygiene plan for Babati.

I am going to give you information and invite you to be part of this research. Before you decide if you would like to participate in the research, you can talk to anyone you feel comfortable with about the research. This consent form may contain words that you do not understand. Please ask me to stop as we go through the information and I will take time to explain. If you have questions later, you can ask them of me or another researcher

Purpose of the research

We are conducting a survey and would appreciate your participation. I would like to ask you a few questions about your access to water, and hygiene practices.

Participant Selection

You have been asked to participate in this study because your personal views and experience as community member is important to us.

Voluntary Participation

Your participation in this research is entirely voluntary. It is your choice whether to participate or not. The choice that you make will have no bearing on your job or on any work-related evaluations or reports. You may change your mind later and stop participating even if you agreed earlier. Participation in this survey is voluntary and you can choose not to answer any individual question or all of the questions. However, we hope that you will participate in this survey since your views are important.

Procedures

Whatever information you provide will be kept strictly confidential. We are asking you to help us learn more about Water, Sanitation and Hygiene in your community. We are inviting you to take part in this research project. If you accept, you will be asked to participate in one or more sessions that will involve interviews, focus group discussion and or in-depth interviews which will be held by myself and some of our project team members.

Duration

The survey will take 40-45 minutes to complete

Risk

We are asking you to share with us some very personal and confidential information, and you may feel uncomfortable talking about some of the topics. You do not have to answer any question or take part in the discussion/interview/survey if you don't wish to do so, and that is also fine. You do not have to give us any reason for not responding to any question, or for refusing to take part in the interview"

Benefits

There will be no direct benefit to you, but your participation is likely to help us find out more about how to participate in a city wide sanitation and hygiene plan development.

Reimbursements
You will not be provided any incentive to take part in the research

Confidentiality

The research being done in the community may draw attention and if you participate you may be asked questions by other people in the community. We will not be sharing information about you to anyone outside of the research team. The information that we collect from this research project will be kept private. Any information about you will have a number on it instead of your name, to help protect your identity.

Part II: Certificate of Consent

I have been invited to participate in research, titled "Achieving Universal Access to adequate, sustainable and equitable sanitation services in the Cities of Tomorrow". I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions I have asked have been answered to my satisfaction. I consent voluntarily to be a participant in this study

Name of Participant____

Signature of Participant ____

Date ____

Day/month/year

Statement by the researcher/person taking consent

I have accurately read out the information sheet to the potential participant, and to the best of my ability made sure that the participant understands that the following will be done:

1. ____

2.____

I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily. A copy of this ICF has been provided to the participant.

Print Name of Researcher/person taking the consent________________________

Signature of Researcher /person taking the consent__________________________

Date ___________________________________ Day/month/year

Appendix 3: Clearance certificate

THE UNITED REPUBLIC OF TANZANIA

National Institute for Medical Research
3 Barack Obama Drive
P.O. Box 9653
11101 Dar es Salaam
Tel: 255 22 2121400
Fax: 255 22 2121360
E-mail: headquarters@nimr.or.tz

Ministry of Health, Community Development Gender, Elderly & Children
6 Samora Machel Avenue
P.O. Box 9083
11478 Dar es Salaam
Tel: 255 22 2120262-7
Fax: 255 22 2110986

NIMR/HQ/R.8a/Vol. IX/2335

27th October 2016

Prof Karoli Nicholaus Njau
The Nelson Mandela African Institution of Science and Technology
Department of Water Environmental Science and Engineering
P O Box 447, TENGERU, ARUSHA

CLEARANCE CERTIFICATE FOR CONDUCTING MEDICAL RESEARCH IN TANZANIA

This is to certify that the research entitled: Achieving Universal Access to Adequate, Sustainable and Equitable Sanitation Services in the Cities of Tomorrow, in Tanzania (Njau K N *et al)* has been granted ethical clearance to be conducted in Tanzania.

The Principal Investigator of the study must ensure that the following conditions are fulfilled:

1. Progress report is submitted to the Ministry of Health, Community Development, Gender, Elderly & Children and the National Institute for Medical Research, Regional and District Medical Officers after every six months.
2. Permission to publish the results is obtained from National Institute for Medical Research.
3. Copies of final publications are made available to the Ministry of Health, Community Development, Gender, Elderly & Children and the National Institute for Medical Research.
4. Any researcher, who contravenes or fails to comply with these conditions, shall be guilty of an offence and shall be liable on conviction to a fine. NIMR Act No. 23 of 1979, PART III Section 10(2).
5. Site: Babati Town Council, Manyara Region

Approval is for one year: 27th October 2016 to 26th October 2017.

Name: Dr Mwelecele N Malecela

Signature
CHAIRPERSON
MEDICAL RESEARCH
COORDINATING COMMITTEE

Name: Prof. Muhammad Bakari Kambi

Signature
CHIEF MEDICAL OFFICER
MINISTRY OF HEALTH, COMMUNITY DEVELOPMENT, GENDER, ELDERLY &CHILDREN

CC: RMO **MANYARA**

DED Babati
DMO Babati