

ASSESSMENT OF RURAL HOUSEHOLD WATER TREATMENT IN T/A CHIMALIRO, THYOLO DISTRICT, SOUTHERN MALAWI

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ABSTRACT

Access to drinking water from unsafe sources is widespread amongst communities in rural areas such as Thyolo District in Malawi. This situation puts many individuals and communities at risk of water borne diseases despite some households adopting household water treatment to improve the quality of the water. However, there still remains data gaps regarding the household water treatment methods used to improve public health and their effectiveness. This study was therefore, conducted to assess the efficacy of available rural household water treatment technologies in M'mina and Mangazi villages in Thyolo District, Malawi. A total of 20 randomly selected households were interviewed to determine their access to drinking water, water quality perception and household water treatment technologies among others. The majority of households (80%) in Mangazi and M'mina villages accessed water from boreholes while the 10% of the household access water from unprotected swallow wells and the remaining 10% from protected dug wells. All the respondents in both villages were females (Household mothers 60%, Adult females 35% and other adult females 5%). It was found out that only 45% ($\frac{9}{20}$ of the households) were observed to be practicing household water treatment techniques by boiling or solar disinfection and water storage in closed containers. Water samples from each household storage and water sources were collected for laboratory analysis. The levels of tested parameters were as follows; pH (6.83-8.5), temperature (25-32°C), Salinity (0.2-0.42ppt), Total Dissolved Solids (520-710mg/L) Electrical Conductivity (560-3500 μS/cm), turbidity (5-10NTU), Feacal Coliforms (3-728cfu/100 mL), Total coliforms (6-1042cfu/ 100 mL) - mainly in shallow wells, were found to be above the WHO water quality specifications. This study showed Solar disinfection (SODIS) to be more effective than boiling method in removal of total solids, pH neutralizing, turbidity and fecal coliforms. However, the effectiveness is to a less extent but significant as compared to the no treatment approach. These methods have shown that there's a need for improvement in order to meet WHO water quality standards. Further study is recommended for different other methods utilized to assess their effectiveness in removal of microorganisms, organics and to correlate their impact with clinical cases of reduction in diarrheal cases in rural communities.

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ACRONYMS/ABBREVIATION

EC- Electrical Conductivity

HWT- Household Water Treatment

HWTS- Household Water Treatment and Storage

MUST- Malawi University of Science and Technology

NTU- Nephelometric Turbidity Unit

pH- Power of Hydrogen

POU- Point of Use

SODIS- Solar Disinfection

TDS- Total Dissolved Solids

WASH- Water Sanitation and Hygiene

WHO- World Health Organisation

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CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

About 1.1 billion people worldwide lack access to improved drinking water supplies and use unsafe surface and groundwater sources (WHO, 2015 MDGs Endline Survey). Unimproved supplies are often contaminated with pathogens causing infectious diseases such as cholera, enteric fever, dysentery, and hepatitis. Lack of access to safe water contributes significantly to the global burden of disease and death resulting from infectious diarrhea and other enteric illnesses, as well as their sequelae and indirect health effects, such as neurological syndromes, reactive arthritis, malnutrition, and arrested growth and development (Palamuleni, 2010).

In 2015, the World Health Organization (WHO) estimated that diarrheal diseases kill 1.6 million people yearly, mostly children under five years of age. This disease burden falls disproportionately on those in developing countries, where children experience multiple episodes of diarrheal disease each year (WHO, 2015). Recent systematic reviews of water, sanitation, and hygiene interventions suggest that the beneficial effects of improving household drinking water quality at household level to reduce diarrhea disease risks had been previously underestimated (Fewtrell, L, 2012). There has been an estimated reduction (30-40%) in diarrheal disease by improving household drinking water quality at the household level, making such treatment more effective than improvements at the source (CAWST, 2009; Mwabi et al., 2012; WHO, 2011). The goal of household water treatment (HWT) and safe storage technologies is to empower people without access to safe water to improve water quality by treating it and storing it safely in the home. There are a number of different HWT technologies which policy-makers, implementers, and users can select as appropriate for particular circumstances and populations (Classen, et al. 2007).

Although a variety of HWT technologies have been suggested, tested, and disseminated, not all have an evidence base of effectiveness and sustained use (Stockman, 2007). One of the challenges to making informed choices about

widespread dissemination of these technologies is the lack of rigorous scientific evidence of sustained use, positive health impact, and water quality improvement over extended periods of use (5). The most common technology used is chlorination free chlorine (hypochlorite) treatment with Safe Storage. Although other technologies are available such as use of filters, boiling, Solar Disinfection (SODIS) etc., they lack scientifically sound evidence documenting their ability to improve water quality and reduce waterborne infectious disease. Thus, this study was examining available water treatment methods or technologies at household level and their efficacy to improve water quality.

1.2 PROBLEM STATEMENT

A billion people globally have gained access to an improved drinking water source since 1990, with about 96% of the global urban population using improved drinking water sources, compared to 84% of the rural population (United Nations World Water Assessment Programme (WWAP), 2016). Malawi is one of the countries in the Sub-Saharan region that has made fair progress in provision of safe and potable water by about 67% (National sanitation policy, 2008), Malawi through United nations Aid has established Water User Associations (WUA) for example the water kiosks projects in peri-urban areas mostly in the densely populated areas. The majority of Malawians in rural areas depend on groundwater for domestic purposes (Government of Malawi (GoM), 2007; GoM,2013). This is the case since most peri-urban and rural areas are not connected to piped water supplied by utility providers (Water Boards) due to limitation in capacity. In Malawi and other developing countries, water from contaminated sources is consumed directly without treatment or some few households treat their water using locally available technologies which include boiling, solar disinfection, chlorination, ceramic filters among others but there is no enough scientific evidence data for the effectiveness and sustainability of these methods. (Government of Malawi (GoM), 2011; WHO and UNICEF RADWQ, 2012).

An assessment in six pilot countries, found that 31% of drinking water samples from boreholes exceeded WHO guideline values (GV) and national drinking water standards in the pilot countries for faecal contamination, the leading source of infection and disease (Rapid Assessment of Drinking Water Quality -RADWQ 2006). At the household level, contamination of stored water is even more common. In one of the pilot countries, only 43.6% of samples from stored water were in compliance with the WHO guideline value and national standards, and more than half of household samples showed post-source contamination. This is consistent with a large body of research worldwide that has shown that even drinking water which is safe at the source is subject to frequent and extensive faecal contamination during collection, storage and use in the home (Wright, 2005). Currently, there is evidence that safe water for domestic use in the home can reduce diarrheal disease by 50%, independent of improved sanitation or hygiene (Water sanitation Framework, 2013). Despite the compelling benefits for personal health, only 32% of Malawian households are considered to treat their drinking water appropriately (Government of Malawi (GoM), 2013).

Information on household water treatment and safe storage practices in rural and peri-urban areas are not well documented for Thyolo District. However, such information is significant to aid policy formulation in water supply, sanitation and improved human health. Therefore, this study focused on evaluating the effectiveness of rural household water treatment methods in T district, Southern Malawi.

1.3 MAIN OBJECTIVE

The main objective of this study was to explore household water treatment in rural areas of Thyolo, Malawi.

1.3.1 SPECIFIC OBJECTIVES

1. To explore the methods of water treatment used at household level in M'mina and Mangazi Villages, T/A Chimaliro in Thyolo District
2. To assess the effectiveness and sustainability of the available household water treatment methods
3. To analyse the physical-chemical and biological quality of water for use before and after treatment

1.4 RESEARCH QUESTION

- What is the nature of household water treatment in rural Thyolo District, Malawi?
- What are the water treatment methods are used at household level?
- How effective and sustainable are these methods?
- What is the quality of the water for use from the sources at the household?
- What factors are related to the choice and preference of a particular treatment method used?

1.5 SIGNIFICANCE OF THE STUDY

This study has covered the gap of data paucity regarding to the assessment of rural household water treatment particularly for T/A Chimaliro in Thyolo District and it has added to the body of knowledge in policy making and realization of the global push towards Sustainable Development Goal number 6 of providing safe water for all, with special consideration for those in vulnerable situations of unsafe water.

CHAPTER 2: LITERATURE REVIEW

An assessment in six pilot countries, found that 31% of drinking water samples from boreholes exceeded WHO guideline values (GV) and national drinking water standards in the pilot countries for faecal contamination, the leading source of infection and disease (Rapid Assessment of Drinking Water Quality -RADWQ 2006). At the household level, contamination of stored water is even more common. In one of the pilot countries, only 43.6% of samples from stored water were in compliance with the WHO guideline value and national standards, and more than half of household samples showed post-source contamination. This is consistent with a large body of research worldwide that has shown that even drinking water which is safe at the source is subject to frequent and extensive faecal contamination during collection, storage and use in the home (Wright, 2005). Currently, there is evidence that safe water for domestic use in the home can reduce diarrheal disease by 50%, independent of improved sanitation or hygiene (Water sanitation Framework, 2013). Despite the compelling benefits for personal health, only 32% of Malawian households are considered to treat their drinking water appropriately (Government of Malawi (GoM), 2013).

Contaminated drinking water is a leading cause of disease in developing countries, especially among young children. Improving the quality of water can prevent waterborne disease, and interventions at the household level have proven more effective than interventions at the water's source.1 A project launched by PATH in 2006 will examine whether commercial market forces can help reduce the incidence of waterborne disease by delivering practical and affordable household water treatment and storage (HWTS) systems to poor families.

2.1 WATER QUALITY AND HEALTH IMPACTS

Unclean water can have different types and levels of contamination, and most contamination occurs due to anthropological activities (Jain, 2012). Typical water quality parameters important for public health include presence of microbiological indicators and pathogens, turbidity and suspended solids, and inorganic and organic

pollutants. Although each of these parameters can have associated health risks, many agree that microbial contamination poses the greatest health risk to humans in developing world settings in regards to drinking water contaminants (Howard, 2002; Jain et al., 2011; WHO, 2011; Jain, 2012; Prüss-Ustün et al., 2014). Exposure to pathogens may be associated with the stomach flu, diarrhea, and vomiting (Pathak et al., 2006). Independently, turbidity itself is not a health risk; however, turbidity is associated with the concentration of suspended solids (SS) to which harmful microorganisms or other pollutants can be attached (Howard, 2002). Turbid and odorous water can also be aesthetically unpleasing resulting in rejection by the user (WHO, 2011). Heavy metal contamination may cause acute or chronic health issues; this contamination can result from leaching from premise plumbing materials like galvanized iron and lead pipes, copper pipes, steel pipes, brass fittings and taps (Akers et al., 2015; Masters et al., 2016; Ab Razak et al., 2016).

Many different types of water sources can be contaminated, and drinking water quality can be sacrificed for many different reasons. Although improved drinking water sources theoretically provide safe drinking, limited monitoring, inadequate treatment, poor maintenance, and short-term contamination can result in these improved sources failing to provide users with an adequate supply (Howard et al., 2012). More information and research can help further the understanding of the health risks of possibly contaminated water sources like harvested rainwater (Kwaadsteniet et al., 2013). Still, unimproved sources such as shallow wells and surface water have been shown to have higher microbial contamination and reduced risk of illness (Dean et al., 2012; Abraham et al., 2015). Improved water sources can be contaminated after distribution or construction, but supplying agencies hold responsibility for these technologies supplying safe water (WHO, 2011). Given that water can be contaminated and pose a health risk, disinfection is highly recommended in order to ensure safe drinking water (WHO, 2011).

2.2 HOUSEHOLD WATER TREATMENT TECHNOLOGIES

Promoting household water treatment and safe storage (HWTS) helps vulnerable populations to take charge of their own water security by providing them with the knowledge and tools to treat their own drinking water (Household, Treatment, In, & Wash, 2008). Laboratory and field evidence document that free chlorine, coagulation/chlorination, solar disinfection, ceramic filtration, and bio-sand filtration are effective for improving water quality and reducing diarrheal disease burdens in households and communities of developing countries. However, the controlled intervention studies that document such positive impacts typically last only months and do not address critical issues of long-term sustainability and continued technology performance in homes and communities. It is essential to establish the key criteria for sustained access to and use of microbiologically safe water, and to rigorously evaluate and compare technologies in meeting these requirements.

Free chlorine, coagulation/chlorination, and solar disinfection can in principle improve the microbiological quality of water and reduce diarrheal disease, but the available evidence suggests that they do not achieve sustainable, long-term, continuous use by populations once intervention studies end. For chlorination and coagulation/chlorination, the need to continuously repurchase a consumable product may cause households to forego treating water when financial resources are inadequate. Once interrupted, it may be difficult for households to start treating water again. For technologies producing relatively small quantities of water, such as solar disinfection and coagulant-disinfectant products, the required time and effort to treat sufficient water quantities for all daily household uses may contribute to declining use rates and consumption of both treated and untreated water, undermining their overall effectiveness (Ashlee K. V, 2012)

A review of literature recommends further work to better understand the role of education, behavior change, individual and group perceptions and attitudes of the aesthetic qualities of water, and the social-cultural drivers that influence household water treatment choices and practices of individuals, households, and communities. Understanding the human behavioral factors that drive people to adopt and

continue using household level is also crucial for widespread adoption and continued effective use.

PHYSICAL TREATMENT METHODS

Physical treatment methods Physical treatment methods include boiling, heating, settling, filtration and exposure to ultraviolet radiation from sunlight (Gilman 2012). Boiling is widely used since it is easy to use and effective in destroying bacteria, viruses and protozoa in all types of water (Sobsey, 2002). However, the collection of firewood is time consuming, could lead to deforestation and is an expensive method for general use (Gilman and Skillicorn, 1985; Barau and Merson, 1992). A further concern is that water is often transferred to storage containers for cooling and thus can become re-contaminated (Sobsey, 2002). Solar disinfection such as the SOLAIR and SODIS systems, which makes use of plastic water collection bottles which is left in the sun, have been widely tested in rural African communities (Conroy et al, 2001). Both these systems inactivates pathogens by disinfecting small quantities 47 of water for consumption, requires relative clear water (turbidity< 30 NTU) and the effectiveness of the inactivation is dependant on exposure times (Conroy et al., 1996; Conroy et al., 1999; McGuigan et al., 1999; Meyer and Reed, 2000; Conroy et al., 2001; Rijal and Fujioka, 2001; Sobsey, 2002; Mascher et al., 2003; Oates et al., 2003). Sedimentation and settling is used for very turbid water (Sobsey, 2002). The turbidity is usually due to the presence of sand particles (mud) (Sobsey, 2002). After the water is collected, the container is left undisturbed for a few hours (Sobsey, 2002). The large dense particles (sands and silts) together with large microorganisms will settle out (sediment) due to the effect of gravity (Sobsey, 2002). The upper cleaner water is carefully removed without disturbing the sedimented particles (Sobsey, 2002). Unfortunately, sedimentation is not very effective in reducing microbial pathogens in stored household water (Sobsey, 2002). Filtration is a widely used method to remove particles and some microorganisms from water samples (Potgieter, 1997; Sobsey, 2002). Several types of filter media and filtration processes are available for household treatment of water (Sobsey, 2002). However, the effective removal of microorganisms, the cost and the availability of the filter media in

developing countries varies from easy to moderate to difficult (Sobsey, 2002). Granular type of filters includes bucket filters, barrel or drum filters and roughing filters and filter cisterns which can rapidly reduce turbidities and enteric bacteria by >90% and larger parasites by >99% efficiency, and enteric viruses by 50% to 90% (Sobsey, 2002; Clasen and Bastable, 2003). Slow sand filters, fibre, fabric and membrane filters, porous ceramic filters and diatomaceous earth filters are alternative filters that have been tested and used for household water treatment in developing countries (Sobsey, 2002; Clasen and Bastable, 2003). Many of these studies have showed to reduce turbidity by 90% and bacteria by 60%, although the cost of the filters is high (Sobsey, 2002; Clasen and Bastable, 2003). A study by Clasen and co-workers (2004) in Bolivia, indicated a reduction of diarrhoea of 70% and a 100% reduction of thermotolerant coliforms in households using ceramic filters compared to control households not using ceramic filters. Unfortunately, little information is available on the effectiveness of these filter systems in the reduction of viruses from household water (Sobsey, 2002).

CHEMICAL TREATMENT METHODS

Various chemical methods are available for the treatment of drinking water at the household level and include methods such as coagulation-flocculation, precipitation, adsorption, ion exchange and chemical disinfection with agents such as sodium hypochlorite (Mintz et al., 2013). Unfortunately, most of these methods are expensive, requires technical skilled persons, regular monitoring, specific materials and the efficacy varies (Sobsey, 2002). Chemical disinfectant agents have proved to be the most successful types of treatment and include free chlorine (which will be discussed in more detail), chloramines, ozone and chlorine dioxide (Sobsey, 2002). Several factors might play a role in the effectiveness of a chemical disinfectant. These factors include pH, turbidity, temperature, degree of microbial contamination and the contact time of the disinfectant to the water and microorganisms (LeChevallier et al., 1981; Reiff et al., 1996). According to Reiff and co-workers (1996), an ideal chemical disinfectant should have the following qualities:

• The disinfectant must be reliable and effective in the inactivation of pathogens under a range of conditions likely to be encountered;

• The disinfectant must provide an adequate residual concentration in the water as to assure safe microbial quality throughout the storage period;

• The disinfectant must not introduce nor produce substances in concentrations that may be harmful to health, nor otherwise change the characteristics of the water so as to make it unsuitable for human consumption;

• The disinfectant must be reasonable safe for household storage and use;

• The disinfectant must have an accurate, simple and rapid test for measurement of the disinfectant residual in the water, which can be performed, when required;

• The disinfectant must have an adequate shelf life without significant loss of potency;

• The disinfectant must have a cost that is affordable for the household. A chemical disinfectant that has been used effectively since 1850, is chlorine (sodium hypochlorite) (White, 1999). During a cholera outbreak in London, chlorine was used Chapter 2 49 to disinfect water supplies (White, 1999). During the 1890's, Europe used hypochlorites against epidemics of typhoid (White, 1999). Only in the early 20th Century Great Britain and New Jersey City began treatment of potable water supplies on a continuous basis. Since then chlorine has become the most widely used water treatment disinfectant because of its potency, ease of use and cost effectiveness (White, 1999). Chlorine reacts with water to form hypochlorous acid (HOCl) and hydrochloric acid (HCl) (Carlsson, 2003). The HOCl dissociates further into a hypochlorite ion (OCl-) and a hydrogen atom (H+) which are commonly referred to as the free chlorine residual (Carlsson, 2003). The main problem to overcome when chemical treatment is used is the differences in resistance of bacteria, viruses and parasites to these chemical disinfectants (Sobsey, 1989; Sobsey, 2002). The resistance of waterborne microbes to be inactivated by chemical disinfectants is influenced by several factors: (1) their physical status; (2) their physiological status; (3) the presence of microorganisms within microbial aggregates (clumps); and (4)

microorganisms embedded within other matrices such as a membrane, a biofilm, another cell, or fecal matter (Sobsey, 1989; Sobsey, 2002). The microorganisms could be protected against chemical disinfectants and by the oxidant demand of the material in which they are located (Sobsey, 1989; Sobsey, 2002). Consequently, it has been showed that bacteria are more susceptible to chlorine than viruses or enteric parasites (Sobsey, 1989; Sobsey, 2002).

WATER SOURCE SUPPLIES

The World Health Organization (WHO) classifies source water supplies as either improved or unimproved (WHO, 2000; Gundry et al., 2004). Improved water sources include public standpipes, household connections, boreholes, protected dug wells, protected springs, boreholes and springs connected via a pipe system to a tap, as well as rainwater collection (WHO, 2000; Gundry et al., 2004). Unimproved water sources include unprotected wells, unprotected springs, vendor-provided water, rivers as well as tanker truck provision of water (WHO, 2000; Gundry et al., 2004). Several studies carried out in developing countries have determined the microbiological quality of these improved and unimproved water sources and depending on the water source, different results were obtained (Pournadeali and Tayback, 1980; Obi et al., 2002; Sobsey et al., 2003; Gundry et al., 2004; Obi et al., 2004). Studies conducted in Iran (Pournadeali and Tayback, 1980) and in northern Sudan (Musa et al., 1999) have both showed that water at communal taps were microbiologically of a better quality than untreated irrigation canal water. Contrary to these findings, a study in Burma (Han et al., 1989) has showed that tube well and shallow well water supplies were microbiologically of a better quality than municipal tap water and pond water source supplies. In South Africa, studies in the Limpopo Province (Verweij et al., 1991) have showed that communal standpipes were microbiologically less contaminated than borehole and unprotected spring water sources. Another study in the rural Kibi area of the Limpopo Province of South Africa (Davids and Maremane, 1998), have indicated that spring and borehole water sources were microbiologically less contaminated than river water sources. In addition three recent studies conducted in the Vhembe region of the Limpopo

Province in South Africa indicated that rivers and fountains used by rural communities for domestic water were all contaminated by enteric pathogens including E. coli, Plesiomonas shigelloides, V. cholera, Enterobacter cloacae, Shigella spp, Salmonella spp, Aeromonas hydrophila, Aeromonas caviae and Campylobacter spp (Obi et al., 2002; Obi et al., 2003; Obi et al., 2004). Escherichia coli isolates obtained from the Chapter 2 28 different rivers during this study were typed using molecular techniques to determine the presence of virulent genes (Orden et al., 1999; Kuhnert et al., 2000; Obi et al., 2004). Enterotoxigenic E. coli isolates (11.8%) contained heat stable and heat labile genes; Shigatoxin producing E. coli (4.4%) isolates contained stx1 and stx2 genes; Necrotoxigenic E. coli (35.6%) contained cnf1 and cnf2 genes and Enteropathogenic E. coli (34.1%) isolates contained BfpA and EaeA genes (Obi et al., 2004). Necrotoxigenic E. coli may play a role in possible zoonotic transmission since it has been shown that human and animal strains share similar serogroups and carry the same genes coding for fimbrial and afimbrial adhesion (Mainil et al., 1999). All of these studies indicated that the water sources used by communities in developing countries are microbiologically contaminated and pose a health risk to the consumers (Pournadeali and Tayback, 1980; Obi et al., 2002; Sobsey et al., 2003; Gundry et al., 2004; Obi et al., 2004). 2.5.1 Water collection from the source water supply in most developing countries, women are responsible for the collection of water (Sobsey, 2002). The work involved in fetching the water may differ in each region, it may vary according to the specific season, it depends on the time spent queuing at the source, the distance of the household from the source and the number of household members for which the water must be collected (WHO, 1996b; WHO, 1996c).

2.3 RELATED STUDIES ON RURAL HOUSEHOLD WATER TREATMENT METHODS

Assessment of drinking water quality and rural household water treatment in Balaka District, Malawi.

This study revealed that several households in Njerenje, Balaka accessed water from shallow wells and rivers for domestic use whilst in Phimbi, Balaka majority of residents rely on borehole water. There was general satisfaction in borehole drinking water availability, safety and quality in Phimbi area. However, dissimilar views regarding the state of current and future access to reliable, safe and good quality drinking water were raised among Njerenje residents. Generally, several water quality parameters (75%, n 1⁄4 12) measured in the two areas registered values within the WHO (2011) and MBS (MS 733:2005) for boreholes and shallow well drinking water. Several water sources in one village (Njereje) were deemed unsafe due to elevated levels of FC and FS above limits. By and large, several water sources (73%, n 1⁄4 11) were classified as "Intermediate risk" with FC counts of 11e100 cfu/100 mL e posing a threat to human health when consumed untreated. Results of this study provide a general representation of water quality in the two areas and probably depict similar trends in other parts of Balaka District. However, no categorical statements can be drawn on the safety of the water sources since other equally important water quality parameters were not assessed due to study limitations. This, then calls for periodical and further monitoring studies on water quality in the two areas and entire district. Further studies are also needed on Mg and Ca to validate the water hard- ness perception by respondents. Spatial-temporal assessment of ground and surface water sources with substantial sample size and number of water quality parameters will also be significant to influence policy decisions in provision of safe water and continual dissemination of HWTS practices and basic sanitation practices in the area. Follow up studies could be done on efficiency of the HWTS practices in the study area in line with public health. The continued use of water drawn from the unprotected shallow wells with high levels of Feacal Coliforms calls for a need to increase improved water supply coverage and functionality rate in the study areas through borehole drilling and rehabilitation. Further studies could be con-

ducted on water demand and non-functionality of borehole infrastructures.

Effective water treatment for rural communities in Suriname: a comparison of point-of-use ceramic filters and centralized treatment with sand filters.

The Suriname clay assessed in this study is appropriate for the production of ceramic water filters. Results from the physical properties testing of the various mixtures showed that the plasticity, shrinkage, and porosity were within reasonable ranges, indicating that manufacture and production of filters would be viable. In addition, the hydraulic conductivity achieved by the 20% rice husk mixture was within an acceptable range (Ashlee K. Vincent,2013).

The Bendekonde system as a whole was more effective than both the Suriname clay mixtures at removing E. coli but was less effective at removing total coliform. However, the ceramic point- of-use filter would likely result in less contamination in household water as the treated water would travel less distance after treatment. In addition, by including colloidal silver in the filter 50 design, the treatment effectiveness ceramic filter could be improved (Lantagne 2001; Oyanedel- Craver 2008).

Relying on local materials, ceramic water filters provide a simple technology that should be considered for remote communities like those along the Upper Suriname River. Not only do they offer an alternative to the currently installed and commonly failed centralized treatment options, ceramic filters could also create revenue for locally trained artisans in a region mostly devoid of economic opportunities. The implementation of a ceramic filter workshop or factory would require a significant amount of work and investment before any production could begin, but in the long run, the factory could eventually become completely self-sustaining without any outside aid or subsidy.

Consistency of use and effectiveness of household water treatment practices among urban and rural populations claiming to treat their drinking water at home: A case study in Zambia

The lack of consistency and microbial effectiveness of HWT practices among those identified as HWT users according to current monitoring standards important questions about the potential contribution of HWT in low and middle-income countries in reducing the risk of waterborne diseases.

2.4 STUDY AREA

2.4.1 Thyolo District

Thyolo district is the main study area in which samples were collected from M'mina and Mangazi villages. M'mina village is under the authority of T/A Chimaliro and these villages are composed of different water sources such as the Nansadi river officially known as Luchenza river, boreholes (that enables the people of this village to have access to groundwater), shallow wells and protected dug well just behind MUST campus fence.

2.4.2 The Geology of Thyolo Area

This area largely lies within the Thyolo administrative district. The greater part of Thyolo district is underlined by what is referred to as the Malawi Basement Complex (Malunga, 2018). The Basement complex of Thyolo is composed of the high-grade magmatic gneisses and granulites which lie in the Precambrian to Lower Palaeozoic Mozambique Belt (Malunga, 2018). Biotite-hornblende gneisses and charnokitic granulites are the dominant rock types in this area. This is also composed of other rocks which occur in subordinate amounts such as the Quartzo-feldspathic and Calc-silicate granulites, ultramafic rocks and perthitic gneisses and syenites (Habgood, 1973).

Thyolo is also filled with a swarm of dolerite dykes which cuts the basement complex rocks on a NE – SW (north-east to south-west) trend. These alkaline dykes of the late Jurassic to early cretaceous are assigned to the Chilwa Alkaline Province and these

dolerite dykes act as the groundwater traps and can be essential for conducting groundwater surveys (Habgood, 1973). Thyolo area is also entitled to a generous amount of rainfall that supply water to this area. Thyolo is composed of zones of weathered gneiss and unconsolidated deposits of the shire valley with faults which are used for the construction of boreholes (Habgood, 1973).

CHAPTER 3: METHODOLOGY

3.1 RESEARCH DESIGN AND DATA COLLECTION

This study was specifically conducted in two villages M'mina and Mangazi in the Group Village Headman Mangazi of T/A Chimaliro in Thyolo District. The two villages were purposively selected because they are not connected to the piped water system and some households consume water from these sources directly without treatment and some few households use local means to treat the water and hence the need for evaluation of the available household water treatment methods. Qualitative and quantitative research methods were both used to collect relevant data in this study. Household surveys and moderate participant observation were used to help the researchers obtain in-depth knowledge of the problems in water, sanitation and hygiene (WASH) experienced in the study area. Data on accessibility to safe drinking water sources, the household water treatment and storage that used in the area were evaluated by the household surveys using semi-structured questionnaires.

Out of the total 20 households a sample size of 6 households were randomly selected from the study area. Water samples from each household storage and water sources were collected for laboratory analysis of water quality to evaluate chemical, physical and biological parameters to compare with the national and international water quality standards. This was essential to evaluate if the method used at household level was effective or not. The water quality parameters at the water point source were measured, then after each household water treatment method the parameters were also measured and lastly, the water quality parameters were also measured. This was to compare the effectiveness of the each of the methods. The methods were boiling, solar disinfection and settling.

(a)  (b) 

Figure 1: (a); Sample collection and (b) data collection through questionnaires

3.2 MATERIALS AND METHODS

Qualitative data was collected by administering questionnaires in the 20 households, 10 from each village. Respondents were asked about their main water source, distance and time to and fro the water source, the use of water from that source, people responsible for water collection, if water is treated in any way before consumption, type of water containers and if water is properly stored with containers. The responses were recorded on the questionnaire.

Out 9 households that were found to be treating water before consumption either by solar disinfection, adding chlorine (mostly in rain season) or boiling, 6 households were randomly selected to collect water samples for measuring water quality variables. Water samples were measured for temperature and pH at household using the pH meter. Water samples were then collected in 1L plastic bottles for other variable measurements which are turbidity, Total Dissolved Solids (TDS), Electrical conductivity (EC) and salinity using multi probe aqua meter in the laboratory (MUST Environmental Quality Laboratory). These tests were meant to be done on insitu but due to the lack of enough equipment like the aquameter so the water samples were transported in a cooler box under ice to preserve them. It was a 10 minutes' distance

from the point of collection to the laboratory. Bottles with water sample before boiling were labeled as B_0 and B_1 for water samples after boiling. Those bottles with water samples before and after solar disinfection were labeled as SD_0 and SD_1 respectively. Bottle for no treatment which was used as a control were labeled as NT_0 for water samples after abstraction and NT_1 and being stored without treatment.

Autoclaved 3.3 250ml glass bottles were used to collected water samples for microbiological analysis (Total and feacal coliforms), the bottles were autoclaved in order to kill all the living organisms that might have infected the bottles hence avoiding compromising the results. All the bottles were also labeled same as those of the physical chemical parameters explained above. Microbiological analysis was done by filtration. Water samples from each household for each treatment method was filtered through a membrane and then add reagents that helps with microorganism growth. In the laboratory total coliforms are grown in or on a medium containing lactose, at a temperature of 37 °C. They are provisionally identified by the production of acid and gas from the fermentation of lactose. For feacal coliforms in the laboratory thermotolerant coliforms are grown on media containing lactose, at a temperature of 44 °C. They are provisionally identified by the production of acid and gas from the fermentation of lactose. Counting of colonies was done after incubating for 24 hours

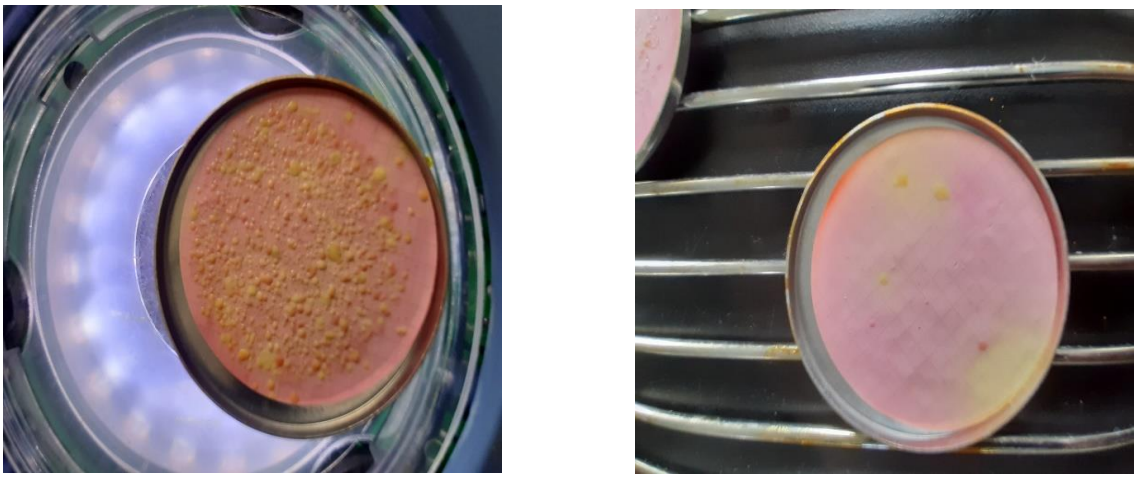


Figure 2: Showing colonies for samples before and after treatment

Multi-probe aquameter was able to conduct all the field measurements is called a multi-parameter water monitoring instrument by the name AQUAMETER, Aquaprobe-800 (AP-800) (figure 1) under the supervision of Mr. Yapuwa. This instrument was manufactured by the Aquaread Limited which focuses on monitoring a number of water parameters including those that were tested for in this project. The instrument is made up of three probes that are able to conduct the measurements of all the mentioned parameters.

(a)



(b)

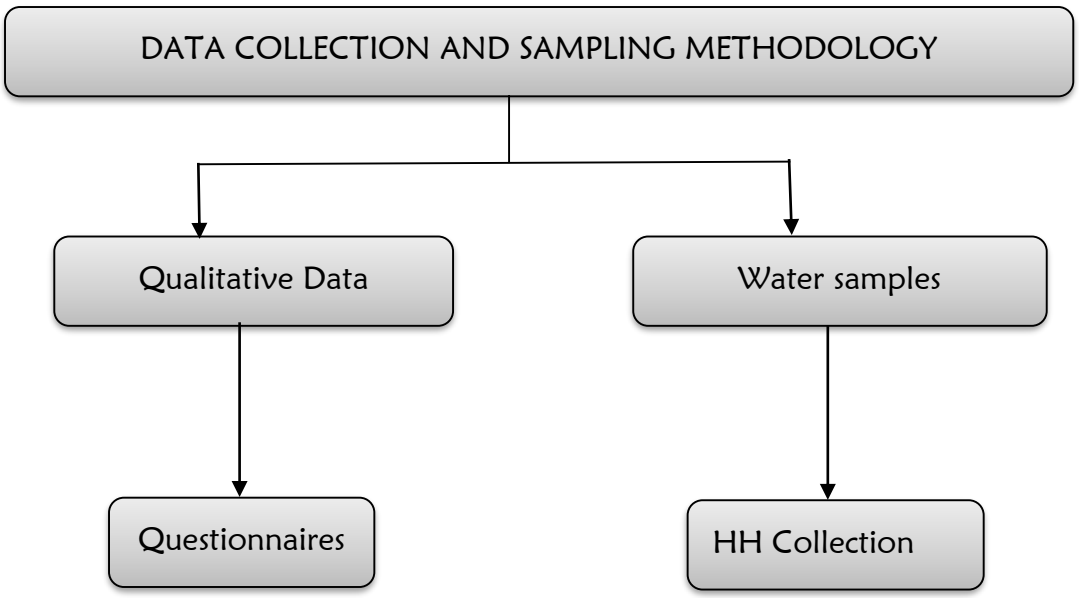


Figure 3: (a) Multi-probe Aquameter used for testing water quality variables, (b) Methodology

3.3 STUDY AREA

3.3.1 Thyolo District

Thyolo district is the main study area in which samples were collected from M'mina and Mangazi villages. M'mina village is under the authority of T/A Chimaliro and these villages are composed of different water sources such as the Nansadi river officially known as Luchenza river, boreholes (that enables the people of this village to have access to groundwater), shallow wells and protected dug well just behind MUST campus fence.

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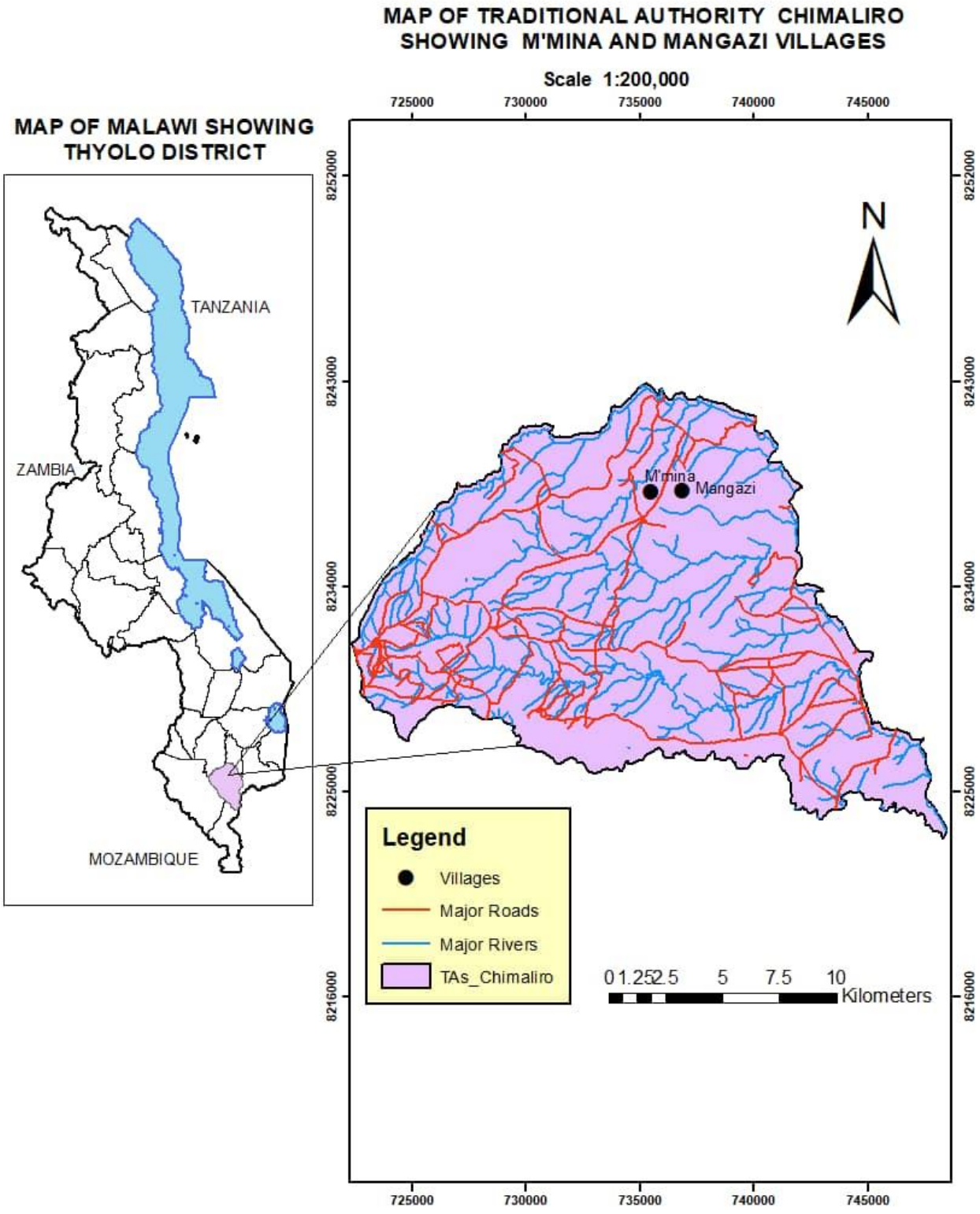


Figure 4: Map of Malawi showing Thyolo District; M'mina and Mangazi Villages

3.4 DATA ANALYSIS

Data was analysed using SPSS v22 and Microsoft Excel 2016 for presentation of data with graphs and tables. Laboratory analyses were presented on Excel graphs. For qualitative data, recorded audio was transcribed and coded to identify emerging themes.

3.5 ETHICAL APPROVAL

To ensure code of ethics and professional conduct of the study (Dawson, 2002), ethical principles and clearance were observed by seeking consent from relevant authorities in the study area with valid supporting documents from Malawi University of Science and Technology. Furthermore, participants were verbally asked for their voluntary participation and withdraw at any time without harming their relationship with the researchers or in any other way receive a penalty or loss of benefits. Participants' confidentiality, ages and other sensitive information were respected at all times. Questionnaires were presented in English and translated into local language (Chichewa) for easy understanding.

CHAPTER 4:

CHAPTER 5: RESULTS AND DISCUSSION

5.1 CHARACTERISTICS OF STUDY PARTICIPANTS

All the respondents from both villages were females. The age of the respondents was in range from 20 to 65 years (mean age 36.9±12.3 years). Majority of them which is 60% were household mothers, 35% other adult females and the 5% were adult females constituting to 100% of the respondents. This is because most water duties are performed by females in most rural. Pie chart below describes the characteristics of the respondents

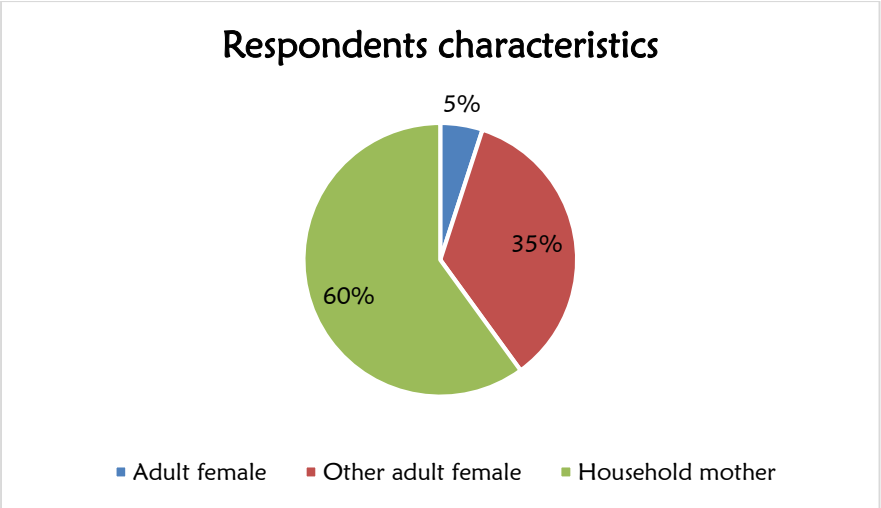
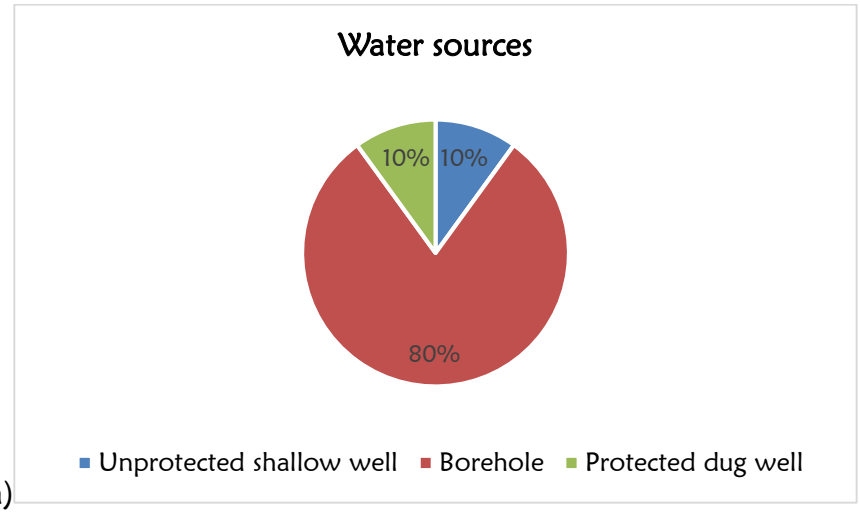


Figure 5: Pie chart showing respondent characteristics

5.2 SOURCES OF WATER

Majority of population from M'mina and Mangazi get their water from boreholes and few of them from the protected dug well and the unprotected shallow wells in Linchenza river. Statistically it was found that 80% of the selected households get their water from boreholes this is because of the newly constructed borehole in M'mina village by Islamic well-wishers, 10% from the protected dug well and the remaining 10% from the unprotected shallow wells. The pie chart below summaries all.

(a)



(b



Figure 6: (a) Pie chart for respondent characteristics and (b)Water sources for Mangazi and M'mina Villages

5.3 WATER TREATMENT METHODS UTILIZED

This study found out that the only household water treatment methods utilized by the participants during the period of study were physical water treatment at point of use such as Solar Disinfection (SODIS) and Boiling methods. The majority which is 55% of the households were not doing anything to make the water safe before using it. For the purposes of this study, two (2) households were sampled which used SODIs and two (2) households that used boiling and two (2) households that didn't do anything to the water in order to compare the quality

of the water before and after treatment or settlement (in case of no treatment samples).

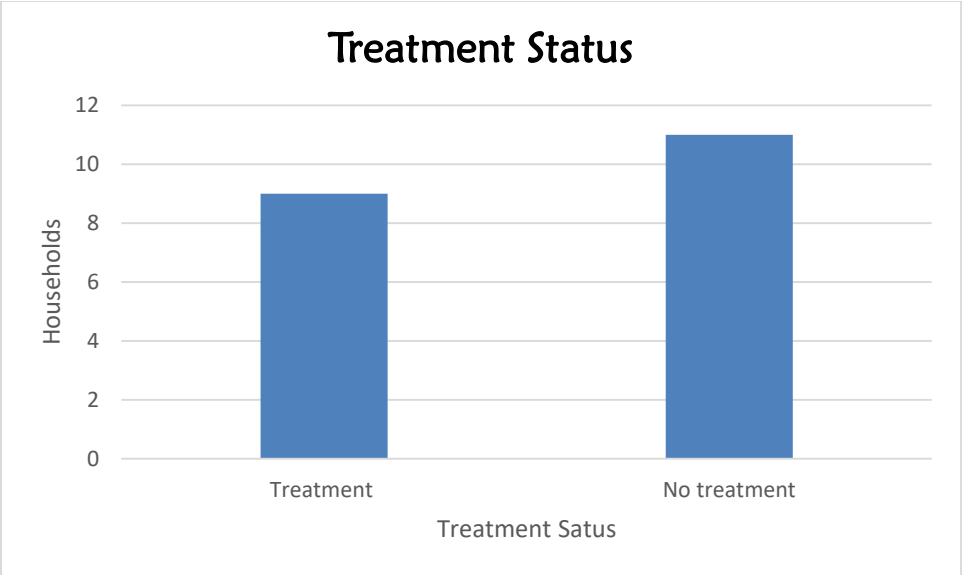


Figure 7: Bar graph representing treatment status

WATER QUALITY PARAMETERS

The study aimed at evaluating effectiveness of the household water treatment practiced at household level water samples were tested from water sources and stored at household level, before and after treated. The parameters which were assessed were limited according to availability of resources. However, this study tested the presence of fecal coliforms, total coliforms, total dissolved solids, turbidity, salinity, temperature, pH and Electrical Conductivity of the water both before and after water was treated and we compared the results with the samples with no treatment used. The following table illustrates the findings.

Table 1: Summary of the analysis of the parameters of the water samples

	Boiling		SODIS		No Treatment		
Parameter	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	WHO
Temperature (°C)	26.6	31.6	30.8	32	30.4	25.8	25
pH	6.93	7.5	6.83	7.67	7.11	6.95	8.5
Turbidity (NTU)	6	6	8	7	12	10	5
EC (μS/cm)	992	900	990	730	1008	560	3500
Salinity (ppt)	0.42	0.32	0.41	0.31	0.48	0.24	0.2
TDS (mg/L)	650	600	710	520	690	381	600
Total coliforms (counts per 100ml)	6	16	156	20	1042	588	50
Feacal coliforms (counts per 100ml)	3	12	588	3	728	728	50

These physical methods have one parameter in common, namely change in temperature because they were within the range of room temperature. Table below illustrates this.

Tables 2: Variation in temperature changes in the samples

Sample	Treatment Used	Treatment	Temperature (°C)
HH1	Boiling	Before boiling	24.4
		After boiling	26.6
HH2	Boiling	Before boiling	25.3
		After boiling	31.6
HH3	SODIS	Before SODIS	26.8
		After SODIS	30.8
HH4	SODIS	Before SODIS	24.7
		After SODIS	32
HH5	No treatment	Before abstraction	23.5
		After settling	30.4
HH6	No treatment	Before abstraction	22.6
		After settling	25.8

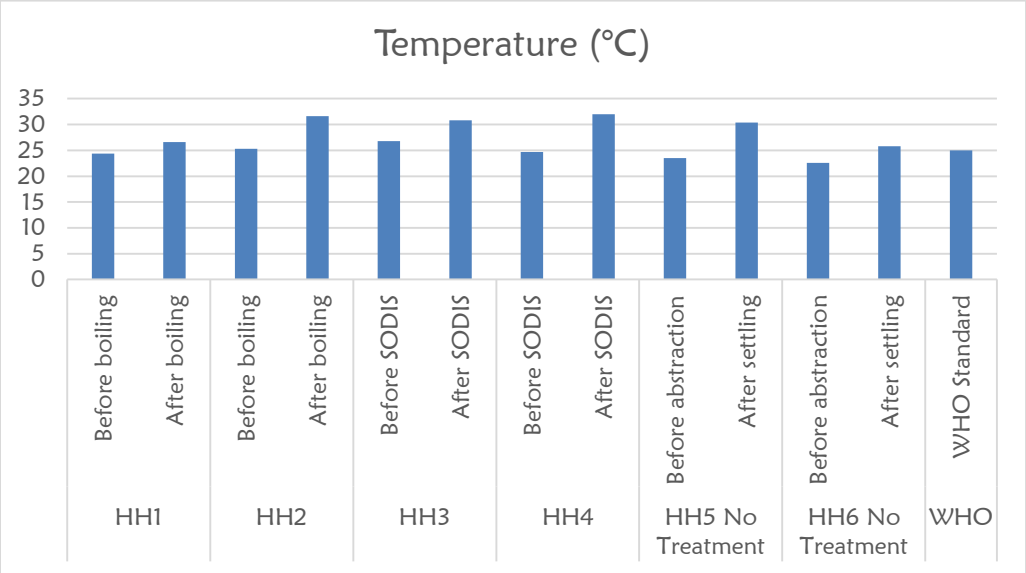


Figure 8: Bar graph representing temperature variations before and after each treatment method

Boiling as a water treatment – increases water temperature however, it still keeps the water at room temperature and may not be effective in removal of other microorganisms. This however, depends on the duration of the time the water is exposed to temperature as well as the magnitude of the heat is exposed.

SODIS in this study seems to increase water temperature, but it is as well subjective to weather changes, and duration it is exposed to.

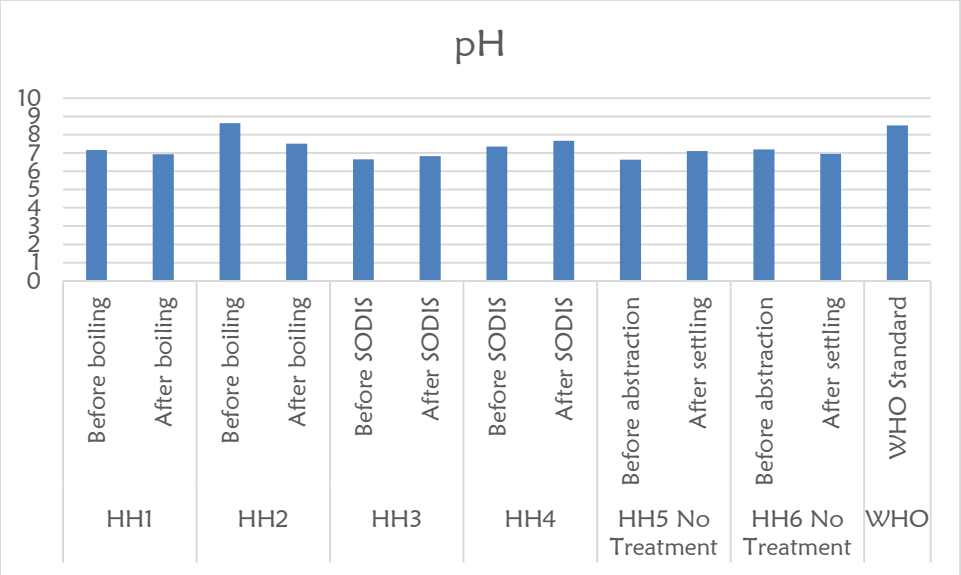


Figure 9: Bar graph representing pH values before and after each treatment method

Apparently, boiling decreases water pH than SODIS and no treatment but both of the pH values for each treatment method are in the range of WHO which is 6.5-8.5

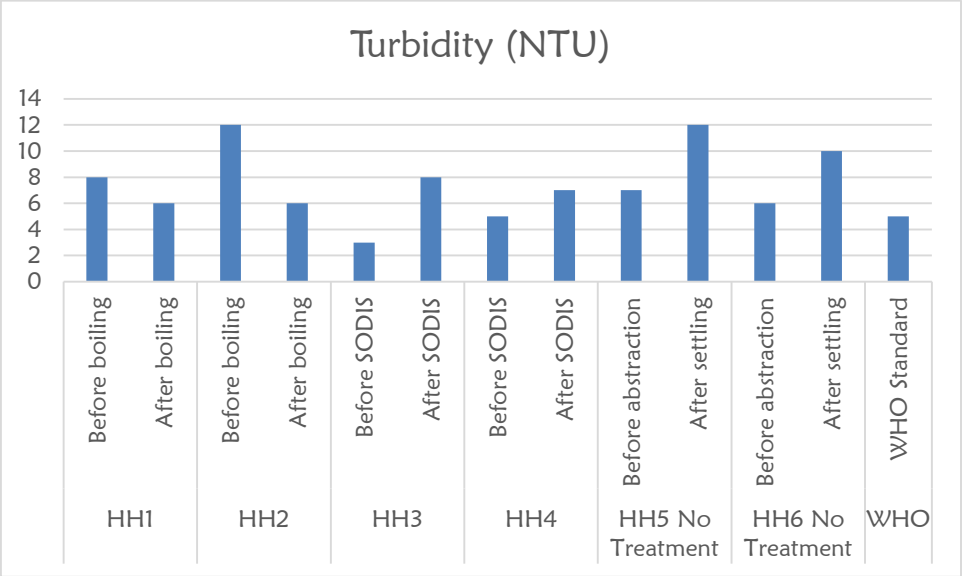


Figure 10: Bar graph representing turbidity of water samples before and after each treatment method

Turbidity decreases steadily due to boiling and followed by no treatment and finally SODIS. In this study, seems SODIS and letting water to settle may have the same effectiveness in reducing water turbidity. Boiling methods is effective in correlating with WHO standards on turbidity.

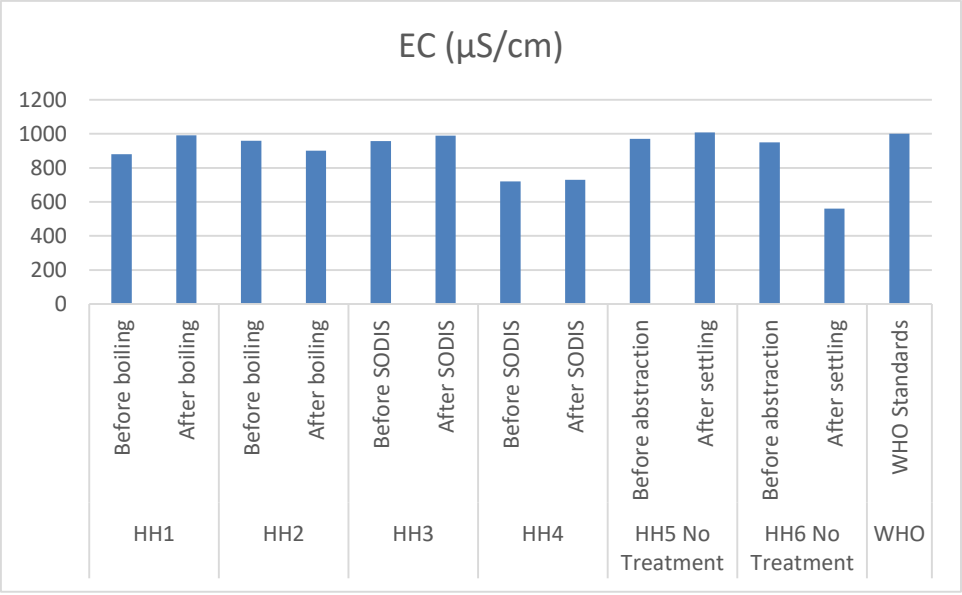


Figure 10: Bar graph representing EC of water samples before and after each treatment method

Solar disinfection is not effective in treating EC as compared to boiling.

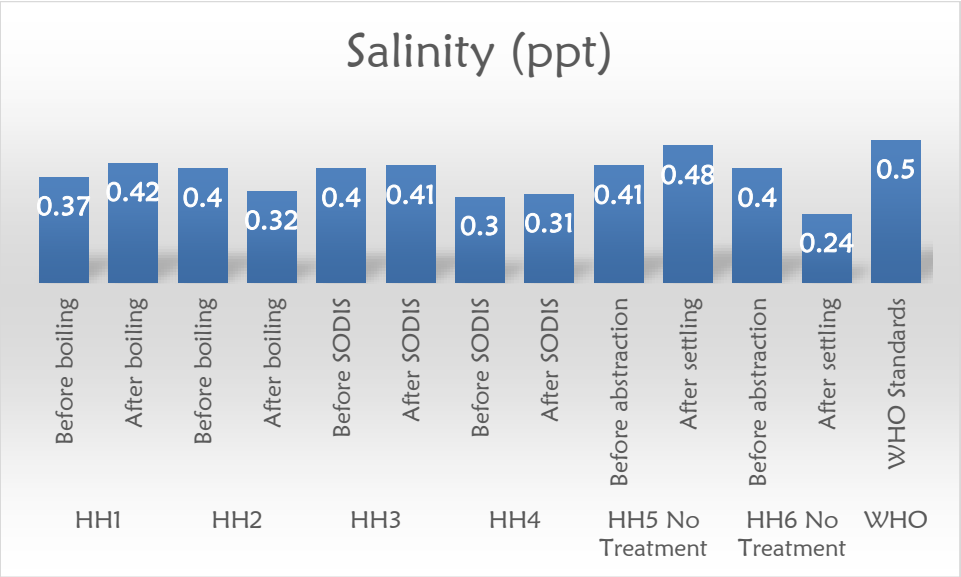


Figure 11: Bar graph representing salinity of water samples before and after each treatment method

Both boiling and solar disinfection are both effective in treating salinity since the salinity of water samples were both complying with the WHO standard which is 0.5ppt.

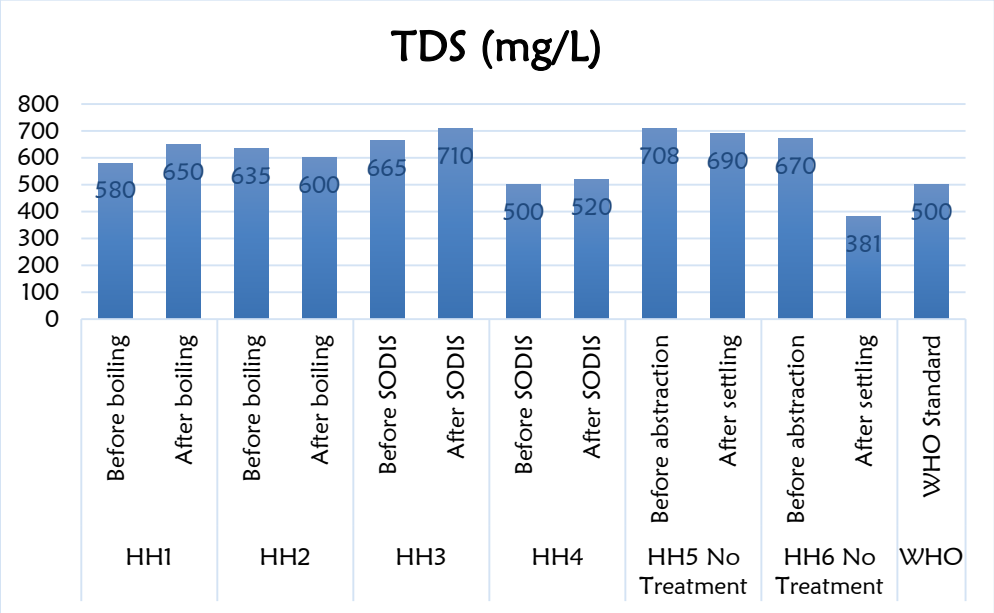


Figure 12: Bar graph representing TDS of water samples before and after each treatment method

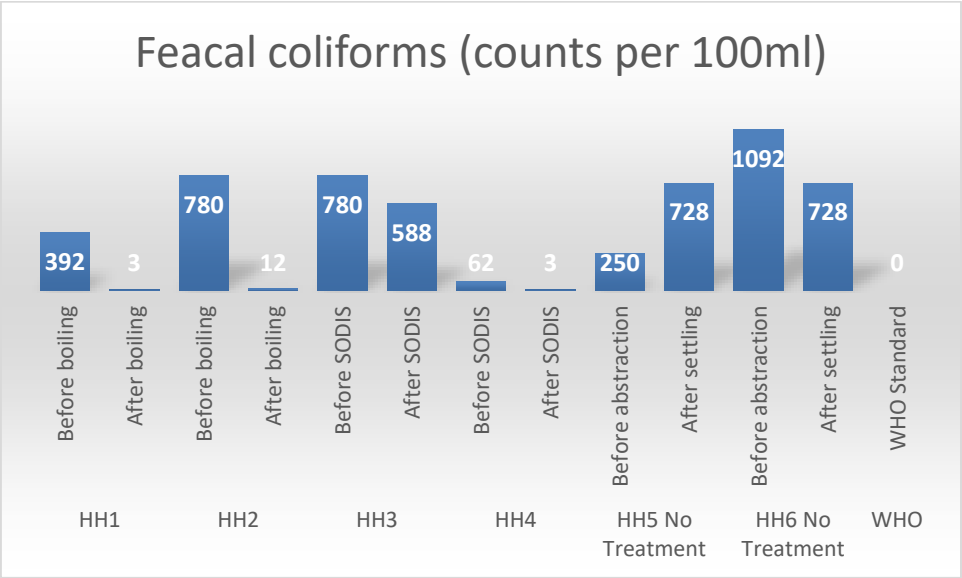


Figure 13: Bar graph representing feacal coliforms of water samples before and after each treatment method

The graph indicates that boiling methods is effective in correlating with WHO standards on removal of feacal coliforms.

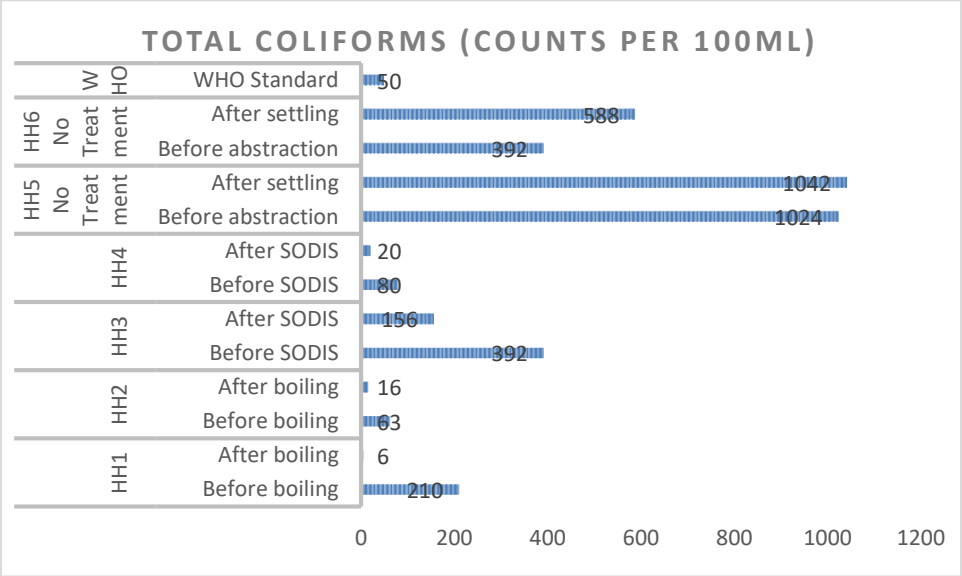


Figure 14: Bar graph representing total coliforms of water samples before and after each treatment method.

The graph indicates that boiling methods is effective in correlating with WHO standards on removal of feacal coliforms.

5.4 THE EFFECTIVENESS OF THE METHODS

Four samples utilized the boiling and SODIs methods to treat their water. Physical parameters were tested and compared with WHO standards. For each method, two samples were taken in order to have unbiased results. A careful analysis indicates very minimal differences of using these methods from the two samples with no treatment method. This may be due to the extent of the heat supplied during boiling, the time taken to heat the water, the heat of the sun, and also the water sources themselves. As noted above, some samples were taken from the boreholes, wells and river. These sources have different concentration of the parameters. That is to say, the variations maybe due to different sources used, not specifically the effectiveness of each method. A good example of this is on salinity. Some water sources have water with high salinity concentration due to the groundwater and environmental sources in the area and this may not be exactly with other locations, even though the same method of treatment is used.

5.4.1 BOILING

Two samples were taken from the storage containers and were tested for water quality parameters before boiled and after boiling to evaluate the level of effectiveness in terms of turbidity, removal of fecal coliforms, presence of dissolved solids, changes in pH and salinity. Figure 15 below illustrates the findings from two samples that were treated with boiling method.

Boiling method

The graphs above indicate that boiling methods is effective in correlating with WHO standards on temperature, pH, turbidity and removal of feacal and total coliforms, however, it is less effective for EC, salinity and total dissolved solids. This, as explained above maybe due to other environmental factors as other research studies confirm (Lakudzala, 2012).

5.4.2 SOLAR DISINFECTION

Some households utilize solar disinfection to treat their water. In this case, a water container is left on the sun for some time before use. Two samples were taken and tested before and after the treatment.

According to this study, SODIS treatment indicates to be more effective than boiling method in treating water towards reaching WHO water quality threshold. However, it is less effective on EC, total dissolved solids and fecal coliforms. In research studies conducted by Mann, et al. (2010), SODIS was reported to significantly decrease diarrheal disease in children in Africa and India, with reductions of 26-37%.

5.4.3 NO TREATMENT

Many households in the study area were not using any method to treat their water. For the purposes of this study, two samples were collected from households which do not treat their water to closely examine as a control to closely examine the defectiveness of other methods.

As indicated area, the no treatment samples were taken after collection and then after settling and tested for the parameters as other samples. Since the above methods have to do with exposing heat to the water, there's an insignificant difference with no treatment since the temperature from no treatment to boiling is within the room temperature which water is usually left (23 - 31°C). This would be better compared if other methods were utilized such as use of ceramic filters, bio-sand, chlorine, etc. However, there's a slight change in pH and turbidity when the water settles. This indicates that no treatment of water is unsafe water since all fecal coliforms, total coliforms, salinity, total dissolved solids, EC are not removed. This is the case for all water sources.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

Solar disinfection indicates to be more effective than boiling method in removal of total solids, pH neutralizing, turbidity and fecal coliforms. However, the effectiveness is to a less extent but significant as compared to the no treatment approach. These methods have shown that there's a need for improvement in order to meet WHO water quality standards. Although point of use (POU) technologies may demonstrate effectiveness both in laboratory and field studies, this does not necessarily mean that they will do so over long periods of time in actual use. The effectiveness of POU technologies will be seriously undermined and waterborne disease risks and burdens will remain high if people treat water intermittently, go for long periods without treating, treat only some of the water they consume, or provide treated water to only some household members while others consume contaminated water. People must be sufficiently motivated and committed to integrate POUs into their daily lives long after intensive study interventions have ended.

6.2 RECOMMENDATION

This study makes the following recommendations with consideration to sustainability, cost-effectiveness, ease of access and duration of treating the water:

6.2.1 SUSTAINABILITY AND COST-EFFECTIVENESS OF THE METHODS

The overarching need for any Point of Use (POU) technology is that it is sustainable: it becomes a part of the daily routine of every household member, who uses it for drinking and other high-level purposes (e.g., food preparation and handwashing) all of the time. Key features of a sustainable POU technology are as follows:

1. Able to consistently produce sufficient quantities of microbiologically safe water to meet daily household needs.
2. Effective for treating many different waters sources and quality levels including turbid and high organic content waters.

3. Requires relatively small user time to treat water, thereby not significantly contributing to already substantial household labor time burdens.
4. Low cost; relatively insensitive to income fluctuations, not causing households to stop treating water because they cannot afford to purchase the technology or continuously replace it.

6.2.2 EASE OF PROCESS USE AND TIME TREATING WATER.

Adoption and consistent use of POU technology by households is influenced by both ease of treatment process performance and the time required of the household member tasked with treatment. The more straightforward the operation and maintenance of the technology, the greater the likelihood that it will be adopted and used successfully. This criterion is based on the sum of scores for three elements: process ease, process duration, and process maintenance requirements.

6.3 NEED FOR FURTHER STUDY

Further study is recommended for different other methods utilized to assess their effectiveness in removal of microorganisms, organics and to correlate their impact with clinical cases of reduction in dirrahoeal cases in rural communities.

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