INSTITUTE OF HEALTH SCIENCE

FACULTY OF PUBLIC HEALTH

DEPARTMENT OF ENVIRONMENTAL HEALTH SCIENCE AND TECHNOLOGY

MICROBIOLOGICAL REMOVAL EFFECTIVENESS OF COMMERCIALLY AVAILABLE POINT OF USE WATER TREATMENT DEVICES FOR HOUSEHOLD USE IN JIMMA TOWN, SOUTH WEST ETHIOPIA

BY MEKASHA BELETE

RESEARCH PAPER TO BE SUBMITTED TO DEPARTMENT OF ENVIRONMENTAL HEALTH SCIENCE AND TECHNOLOGY, FACULTY OF PUBLIC HEALTH, INSTITUTE OF HEALTH SCIENCE, JIMMA UNIVERSITY; IN PARTIAL FULFILLMENT FOR THE REQUIREMENT OF MASTERS OF SCIENCE IN ENVIRONMENTAL SCIENCE AND TECHNOLOGY

JANUARY 2022

JIMMA ETHIOPIA

JIMMA UNIVERSITY
INSTITUTE OF HEALTH SCIENCE
FACULTY OF PUBLIC HEALTH
DEPARTMENT OF ENVIRONMENTAL HEALTH SCIENCE AND TECHNOLOGY

MICROBIOLOGICAL REMOVAL EFFECTIVENESS OF COMMERCIALLY AVAILABLE POINT OF USE WATER TREATMENT DEVICES FOR HOUSEHOLD USE IN JIMMA TOWN, SOUTH WEST ETHIOPIA

BY MEKASHA BELETE

Advisors

Major Advisor: AbebeBeyene(Ph.D., Associate Professor)

Co-adviser: TesfalemGetahun (MSc., PhD. Candidate)

Approval sheet

As thesis research advisors, we hereby certify that we have read and evaluated this thesis prepared under our guidance by Mekasha Belete entitled as 'Microbiological Removal Effectiveness of Commercially Available Point of Use Water Treatment Devices for Household Use in Jimma Town, South West Ethiopia'. We recommended that it could be submitted as fulfilling the thesis requirement.

Name______________________________Signature: _________________ Date: ____________

Name______________________________Signature: __________________Date: ____________

As member of the board of examiners of the MSc. thesis open defense examination, we certify that we have read and evaluated the thesis prepared by Mekasha Belete and examined the candidate. We recommend that the thesis be accepted as fulfilling the thesis requirement for the degree of Master of Science in Environmental Science and Technology.

Name _______________________________ _________________ ______________

Chairperson Signature Date

Name ________________________________ ______________ _____________

Internal Examiner Signature Date

Name _________________________________ ___________________ ______________

External Examiner Signature Date

Department Head Department of Environmental Health Science and Technology appreciates the successful completion of his thesis.

Name __________________________________ Signature: ___________ Date: _____________

Abstract

Background: *Diarrhea is a major public health problem that disproportionately affects children in developing countries, including Ethiopia. Nowadays, numerous point-of-use devices are manufactured and sold all over the country for the prevention and control of waterborne disease. Even though many people have bought and installed point-of-use drinking water treatment devices, there is a lack of data on their type and applicability of devices at the household. Besides, little has known about the microbiological efficiency of these devices on quality of water for human consumption.*

Objectives: *To evaluate the microbiological removal effectiveness of commonly used and commercially available point of use water treatment devices for household use*

Method: *The study was conducted in Jimma city from June to August, 2021; laboratory based cross sectional study was designed and household survey at six Kebeles and 385 randomly selected households was conducted and four most accepted point of use water treatments ceramic, tulip, a new modified sand filter produced in Jimma University and Wuha -agar chemical disinfectants were identified. And then, microbial removal effectiveness; turbidity reduction and flow rate of these devices were evaluated using locally available water sources of municipality tap, rain, ground and spring in laboratory.*

Result and discussion: *The study result shown as among the commercially available water treatment devices, Tulip filter 75.15%, 81.99%, and 48.62%;35.59%;1.15l/h ceramic filter 62.91%, 49.16% and 62.18 %; 16.44%;1.06l/h an average value were registered for microbial (EC, FC and TC) removal effectiveness, turbidity reduction efficiency and flow rate respectively. And a chemical disinfectant Wuha- agar 89.37%, 48.66% and57.48%; was also registered average value of microbial (EC, FC and TC) removal effectiveness after 30-minute contact time. Microbial (EC, FC and TC) removal efficiency, turbidity reduction and flow rate of modified sand filter 83.17%, 55.88% and 52.59%; 30.89%; 1.83l/h average value was registered respectively. From regression analysis turbidity have significant effect on microbial removal effectiveness of devices but flow rate does not have significant effect at 99% confidential interval.*

Conclusion: *This study observed that Tulip/ceramic candle filter followed by chemical disinfectant Wuha- agar registered higher performance of microbial removal effectiveness.*

Keywords: water treatment devices, water treatment, microbial, removal, effectiveness,

Table of Contents

List of Figure

List of tables

List of Abbreviation and Acronym

CAWST……………………………. Centre of Affordable Water and Sanitation Technology

CDC…………………………………Centers for Disease Control

CFU………………………………… Coliform Forming Units

CSA…………………………………...Central statistics agency

CWFs..Ceramic Water Filters

FC…………………………………… Fecal Coliform

GGR …………………………………Gilgel Gibe River

HLL ………………………………… Hindustan Lever Limited

HWTS ....Household Water Treatment and Safe Storage

LRVs.. Log Removal Values

MASL…………………………………Metre Above Sea Level

MDG ………………………………… Millennium Development Goal

MoH …………………………………...Ministry of Health

MoWE ……………………………… Ministry of Water and Energy

MoWIE ……………………………… Ministry of Water, Irrigation and Energy

MWA ………………………………… Millennium Water Alliance

NaOcl...sodium hypochlorite

NGO ………………………………… Non-Governmental Organization

SDG………………………………… Sustainable Development Goals

TC…………………………………… Total Coliform,

TTC ……………………………………Thermo Tolerant Coliforms

UN ....United Nations

USEPA...United States Environmental Protection Agency

WG…………………………………… Water Guard

WHO ....World health organization

WSP ………………………………… Water Safety Plan

Acknowledgments

First of all I would like to thank Jimma University for this chance then I have an exceptional thanks to my research advisors Dr. Abebe Beyene and Mr. Tesfalem Getahun for their advice, support, comment and suggestions to shape me for the better way; in every step of the study. Then I am grateful to all of people from the communities of the study area because without their help and patience, none of the field research would have been possible.

I would like to acknowledge the support of Jimma City Trade Office, Municipality Water Resource Office, Woreda Health Centre, JU ESHT Laboratory Staff and SOS school assisting me in the field and laboratory water analysis as well as data gathering during the entire research period.

Finally, special thanks go to my family and friends for their constructive ideas and comments during the course of this program. I have thought that the research seems like a never-ending task but their constant encouragement, support and understanding has made it easier.

Chapter 1 Introduction

1.1 Background information

A community's wellbeing depends greatly on the availability of adequate and clean water (Troeger, 2021). Access to safe water is crucial to promote public health, social wellbeing, and nation's development as a whole. However, in many parts of the world, supplying water with consistent centralized treatment and safe distribution system is not practiced due to lack of adequate infrastructure (Peter, 2009). It is estimated by the World Health Organization that about 780 million people acquire their drinking water from unimproved surface, spring and ground water sources, and many more drinking water from improved sources that are still contaminated with pathogenic microorganisms (WHO, 2018). According to UNICEF (2016) diarrhoea is the second leading cause of death of children younger than five, with an estimated 526,000 children dying each year (Cohen & Colford 2017). In developing countries, access to drinkable water is difficult due to risk of contamination with pathogenic agents that might cause diarrheal diseases (Sobsey et al. 2008).

Treating water and safely storing it in the home are commonly referred to as "household water treatment and safe storage" (HWTS) or treating water at the "point of use" (UNICEF, 2012). Although it is not new, its recognition as a key strategy for improving public health is just emerging. A growing body of evidence demonstrates that the use of HWTS options improves the microbiological quality of household water and reduces the burden of diarrheal disease among users (Fewtrell, 2013). According to Clasen (2007) POU treatment devices do improve drinking water quality and reduce the risk of diarrhoea by an estimated 30% to 40%.

In Ethiopia, the prevalence and determinants of diarrhoea among under-five children in the country indicated that children from rural households were 1.9 times more likely to have diarrhoea than their urban counter parts (Alebel , 2018). About 80 % of the rural and 20 % of urban population have no access to safe water. Three-fourth of the health problems of children in the country are communicable diseases arising from the environment, especially water and sanitation. 46% of less than 5 years' mortality is due to diarrheal in which water related diseases occupy a high proportion. The Ministry of Health (MoH), Ethiopia estimated 6000 children die each day from diarrheal and dehydration (Ayenew, 2016).

Appropriately only 10-13 % of Ethiopian (across rural and urban settings) households treat their drinking water (MWA, 2014). According to (ICF,2016) Ethiopia's Health Transformation Plan stipulates that it is planned to achieve 35% coverage of water treatment methods in households by the end of 2020 (Geremew et al., 2018). However, the practice of point-of-use water treatment methods remains low. Although water treatment programs at the point of use have the potential to reduce diarrheal diseases by as much as 29–44% Cha et al. (2015), (CSA, 2020) only 7.9% of the rural population uses some kind of household water treatment, according to the 2016 Ethiopian Demographic Health Survey (EDHS).

Filtration mechanisms such as bio sand filter, solar disinfection, ceramic filtration, chlorination at point of use and combined flocculation/disinfection are the most practiced systems in Ethiopia (Tamene, 2021). The most used point of use (POU) filtration systems at household level are mesh like clothing in rural areas, membrane, and ceramic filter devices in urban areas Abraham et al. (2018), (Bayable ,2020). Wuha Agar, Bishan Gari, Agua tabs, PUR, Bio-sand filters, ceramic pot filters, siphon filters, Life straw family filters, Sawyer filters and Waryt filters are some of household water treatment devices well-known in Ethiopia (MWA, 2014). Ceramic filter devices can be made from locally available materials, affordable and used by individuals for household point of use (Enyew and Tesfaye, 2017).

Currently evidences showed that the distribution and implementation of POU water treatment devices in the country is increasing; there is a gap in the accessibility of ensuring and informing of removal effectiveness of these devices at the field. That is why this study was aimed to contribute a little base line to make survey on availability of commercially available water treatment devices at the study area, to evaluate the microbial removal effectiveness of those identified devices and also turbidity reduction and flow rate is evaluated using different water sources of; surface water, rain water and ground water in Jimma city. Since that there were no studies conducted to identify and make a solution for the problem in the area. And finally, the study would help the researchers for further investigation.

1.2 Statement of the problem

More than 11% of the world's population does not have access to improved water supply sources (Ren et al. 2013). According to (WHO,2016) estimation, around 1.8 billion people in the world use fecal contaminated drinking water source. Diarrheal illnesses and fatalities are prominent issues in many regions of the world (Harvey et al. 2015). Among the world's populations where poverty is most severe, diarrheal diseases are the second leading cause of death.

Improving the quality of drinking water and increased sanitation coverage could significantly decrease incidences of diarrhea (Escobar et al.; 2015, Santos et al., 2016). It has contributed to a reduction of 9.1% global disease burden and 6.3 % of deaths (WHO, 2016; Ronnie et al., 2017). Nevertheless, improving water quality at the source alone may not interrupt transmission since people can become infected with organisms that cause diarrhea through multiple pathways (Briscoe, 1984). Therefore, the prevention of diarrheal diseases should not only focus on improving water quality at source but also at the point-of-use (Fewtrell et al., 2005; Garen et al., 2017). Therefore, water supply intervention incorporates provision of an improved water supply whereas; water quality interventions include water treatment for the removal of microbial contaminants and/or clean storage, either at the source or at the household level (Fewtrell et al., 2005).

In developing countries, 75% of all industrial waste and up to 95% of sewage is discharged into surface waters without any treatment. Even though water may be clear, it does not necessarily mean that it is safe for us to drink. Diarrheal diseases were the cause of an estimated 1.39 million deaths in 2016 (WHO ,2017), and are among the leading causes of death among children under five years of age (UNICEF ,2012); (WHO ,2016), (WHO ,2017). Non-piped water supplies, such as roof catchments, surface waters and water collected from wells or springs, may often be contaminated with pathogens. Such sources often require treatment and protected storage to achieve safe water (WHO, 2008); (UNICEF, 2012). An increasing body of evidence is showing that water quality interventions have a greater impact on diarrhoea incidence, especially when interventions are applied at the household level (Clasen et al., 2007). To avoid the risk of poor-quality water consumption, different point of use water treatment and filtration technologies with variable microbial and other contaminant removal effectiveness have been developed and introduced to users. In many low-income nations, point of use filter devices made from locally available materials and/or available with inexpensive prices from venders used commonly as an intervention for household water treatment solutions (Angela, 2011).

In Ethiopia, about 80% of the majority (rural) and 20% of the urban population do not have access to safe fresh water (MoH, 2004); Warner et al. (2000). Meanwhile, the overall access to clean water is estimated to be between 10 and 20% of the total Ethiopian population Abera and Ahmed, (2005); Warner et al. (2000); (MoH, 1997). More than half of the urban population had access to piped water through centralized water treatment and piped distribution networks but majority of the rural population used untreated water from surface water sources (Usman et al., 2016). But quality of drinking water gets poorer in water distribution systems due to leakage through corrosion of pipes, intrusion of microbial contaminants and other physicochemical pollutants that cause diarrhea and other diseases Dawit (2015); Adane et al. (2017). The morbidity records indicated that there is still a high occurrence of communicable diseases which is related with water supply conditions in Ethiopia among which about 60% of the top ten diseases are related to poor quality and scarcity of household water consumption (WHO/UNICEF, 2012).

A case study in Eastern Ethiopia showed that point of use drinking water filtration devices is the most effective and recommended alternatives in removing several pollutants and water-borne pathogens and makes water safe for household consumption under proper usage (Abrham , 2018). According to Bayable (2020) in Addis Ababa; membrane filtration devices, hybrid filter devices and in some cases ceramic filters devices are the usual point-of-use household water filtration options people use for safe water consumption. Even though point of use water treatment devices has a significant contribution in removing microbial contaminants, physical and chemical pollutants and improves water quality and safety, there is limitation in knowing their efficiency in removing such contaminants at longer time usage. Despite point of use filtration devices have limitations, their attractiveness as interventions in removing waterborne microbes and unwanted pollutants from water are increasing in many countries where absence of treatment facilities and inefficient disinfection risks people's health (Jerome , 2018).

The Government of Ethiopia has invested heavily in health system strengthening, guided by the country's policies and strategies, resulting in significant improvements in the health status of Ethiopians. As a result, Ethiopia has done remarkably well in meeting most of the Millennium Development Goals (MDG) targets. Even though the nation has achieved impressive reductions in morbidity and mortality and increased overall access to primary health care, high regional disparities remain in the majority of health outcome indicators, driven by differences in the economic and educational status, access to basic utilities, poor network of roads and food security (EFSHPF, 2017).

HWT technologies are considered important as intervening and immediate solutions for communities where centralized treatment is difficult, expensive, or infeasible (Mintz et al. 2001; Zwane and Kremer 2007). They can also be effective in households with intermittent water supplies Bivens et al. (2017), or as temporary solutions in humanitarian crises (Martin-Simpson et al. 2015; Ramesh et al. 2015). There are several household treatment technology interventions that have been proven to significantly reduce the frequency of diarrheal occurrence (Reller et al. 2003; Crump et al. 2005; Enger et al. 2013; Abebe et al. 2014). However, there is a large degree of variation in reported effectiveness of HWT solutions between studies (Hunter 2009). According to Johnson, et al.(2008) the variation in the effectiveness between devices is thought to depend on the technology used, population served and local conditions, though more research is required to understand the impact of the different factors involved.

The main purpose of this study was to identify HWTS that is commonly used in Jimma town at household level. And then, microbial removal effectiveness; turbidity reduction and flow rate of commercially available devices tulip, ceramic filter and chemical disinfectant Wuha agar were evaluated using locally available water sources of municipality tap, rain, ground and spring water. Besides, a new and modified sand filter device which was produced in Jimma University also measured on its; microbial removal effectiveness; turbidity reduction and flow rate of the filter was evaluated.

1.3 Significance of the study

In Ethiopia even if; evidences showed that the distribution and implementation trained of POU water treatment devices in the country, there is a gap in the accessibility of ensuring and informing of removal effectiveness of these devices at the field.

- This study will give an insight on the type and applicability of these technologies in Jimma town.
- Besides, it will significant in microbial removal effectiveness and turbidity reduction of the most commonly practiced point of use water treatment.
- The study can be helpful to households in Jimma city, public health officials and public administrators to be informed and to take efficient and prompt actions to prevent any possible health outbreaks due to untreated drinking water.
- It can also be used as source information for NGOs working on water and sanitation, and concerned bodies works on quality standards of household water treatment devices, in the area and likewise the outcome will initiate other researchers for further studies.

1.4 Scope of the study

This study was mainly limited to assessment of microbiological removal effectiveness and turbidity reduction the most commonly used and commercially available water treatment devices using different drinking water sources such as ground, surface and rain water. It was also worthwhile to indicate that the study was conducted from June to August 2021.It was bounded six randomly selected Kebeles of Jimma city for the sake of time and budget problems.

Chapter 2 Literature review

2.1 Drinking water sources

According to (UNICEF,2012) we find our drinking water from different places depending on where we live in the world. Three sources that are used to collect drinking water are:

Groundwater - Water that fills the spaces between rocks and soil making an aquifer. Groundwater depth and water comes from the ground.

Surface water - water that is taken directly from a stream, river, lake, pond, spring or similar source. Surface water quality is generally unsafe to drink without treatment.

Rainwater -Water that is collected and stored using a roof top, ground surface or rock catchment.

The quality of rainwater collected from a roof surface is usually better than a ground surface or rock catchment. As water moves through the water cycle, it naturally picks up many things along its path (UNICEF, 2008).

2.2 Drinking water quality

Water quality will naturally change from place to place, with the seasons, and with the kinds of rocks and soil which it moves through Water can also be polluted by human activities, such as open defecation, inadequate wastewater management, dumping of garbage, poor agricultural practices (e.g., use of fertilizers or pesticides near water sources), and chemical spills at industrial sites (WHO, 2006). In developing countries, 75% of all industrial waste and up to 95% of sewage is discharged into surface waters without any treatment. Even though water may be clear, it does not necessarily mean that it is safe for us to drink. It is important to judge the safety of water by taking the following three types of parameters into consideration:

Microbiological - bacteria, viruses, protozoa and helminths (worms)

Chemical - minerals, metals

Physical - temperature, colour, smell, taste and turbidity (CAWST ,2013).

2.3 Microbiological hazards related with drinking-water

According to (WHO,2008) infectious diseases caused by pathogenic bacteria, viruses and parasites (e.g., protozoa and helminths) are the most common and widespread health risk associated with drinking water. The public health burden is determined by the severity of the illness associated with pathogens, their infectivity and the population exposed.

Fail in water supply safety may lead to large-scale contamination and potentially to detectable disease outbreaks. Other breakdowns and low-level, potentially repeated contamination may lead to significant regular disease, but is unlikely to be associated with the drinking-water source by public health surveillance. Quantified risk assessment can assist in understanding and managing risks, especially those associated with sporadic disease.

Non-piped water supplies, such as roof catchments, surface waters and water collected from wells or springs, may often be contaminated with pathogens. Such sources often require treatment and protected storage to achieve safe water (WHO, 2008; UNICEF, 2012).

An increasing body of evidence is showing that water quality interventions have a greater impact on diarrhoea incidence than previously thought, especially when interventions are applied at the household level (or point-of-use) and combined with improved water handling and storage (Fewtrell et al, 2005; Clasen et al, 2007).

2.4 Microbiological testing

According to (CAWST,2013) by far the most serious public health risk associated with drinking water is microbiological contamination, which makes it the priority for water quality testing. Pathogens in water; bacteria, viruses, protozoa and helminths; can cause a wide range of health problems, but the primary concern is infectious diarrheal disease transmitted by people drinking water contaminated with feces. Testing for microbiological contamination is usually the priority in most drinking water projects. Escherichia coli (E. coli) and/or thermo tolerant coliforms (TTC) are the standard for testing for microbiological contamination.

2.5 Commercially available point-use water treatment devices

Drinking water treatment technologies must be carefully evaluated before they are used as an intervention technology. Governmental and international organizations have provided frameworks by which household treatment technologies should be evaluated. Publications from the (WHO), United States Environmental Protection Agency (USEPA), and NSF International are commonly relied upon (Brown, 2019).

An effective water treatment device that can be commercially distributed on a wide scale would not only advance the important goals of promoting childhood survival (Millennium Development Goals goal 3) and safe drinking water (goal 7) but also goal 8, which calls for global partnerships, including cooperation with the private sector to make available the benefits of new technologies (Thomas Clasen, 2006).

Various methods for treating water in the home have been developed. Hindustan Lever Limited(HLL), the India-based affiliate of the multinational Unilever, has developed a microbiological water purifier known as 'Pure it ™', which the company hopes will provide the protection-meeting criteria established by the USEPA for water purifiers (6-log reduction of bacteria, 4-log reduction of viruses, and 3-log reduction of protozoan cysts) while being affordable and capable of achieving scaled-up and sustained adoption by vulnerable populations. Chlorine (Na DCC Tablets) Chlorine (Sodium Hypochlorite), P&G Purifier of Water (formerly known as PUR).

2.5.1 Ceramic water filters

CWFs are porous, clay-based filtration devices that retain microbiological pathogens through physical size exclusion and the development of a protective bio film. CWFs are low cost and are easily manufactured with minimal capital investment. The combination of these actors enables utilization of CWFs in many developing regions (Halem et al. 2009; Ren etal.2013; Mellor et al. 2014). Typical log removal values (LRVs) of Escherichia coli and other bacterial species are reported between two and four Abebe et al. (2015); Mikelonis et al. (2016), although some publications have reported LRVs between five and seven (Rayner et al. 2013; Yakub t al. 2013)

Bio sand Filter

A bio sand filter consists of a concrete box that is filled with layers of sand and gravel. A biological layer (often called a bio layer) of slime, sediment and microorganisms develops at the sand surface. According to Yilma (2009) the average efficiency of the filters at Chirecha Village was found to be between 85% and 99% for turbidity, iron, manganese, TC, and FC with mean flow rate of 4.4 ± 3.9 l/h. To use the filter, water is simply poured through the top and collected in another storage container at the base of the spout. Water slowly passes through the bio layer, sand and gravel. Pathogens and suspended material are removed through various physical and biological processes that occur in the bio layer and sand (CAWST,2013).

Ceramic Pot Filters

The filter element is an open-top clay cylinder. The filter is sometimes coated with colloidal silver. This helps to reduce the number of microorganisms in the water. The clay cylinder is placed in a plastic or ceramic receptacle with a lid and faucet.

The technology of using ceramic water filter is simple, affordable, and utilizes local materials and traditions (Atomissa, 2010). Pathogens and suspended material are trapped on the ceramic material as water is poured through the filter. If properly constructed and operated, a ceramic filter can be very effective in producing good quality water (CAWST,2011).

Ceramic Candle Filters

A candle filter consists of two containers and one or more ceramic filter elements, shaped like a thick candle, screwed into the base of the upper container. Water is poured into the upper container and then allowed to filter through the ceramic filter element into the lower collection vessel. Candle filters can have very low flow rates, so it is common to find filters with two or more candle filter elements (Dies, 2003).

Point -of -use Chlorination (POU)

The sodium hypochlorite (NaOcl) solution with 1.25 - 5.0 % concentration is the other form of POU water treatment technique. It is packaged in a bottle with directions instructing users to add one full bottle cap of the solution to the raw water (or two caps to turbid water) in a standard-sized storage container. The volume and the concentration of the bleach are various in different countries. According to (CDC ,2006) in Ethiopia, the Chlorine bleach solution is in 150 ml plastic bottle with chlorine concentration of 1.25 % which can treat up to 1000 litres of water and labelled as "water agar". Field tests have shown that POU chlorination can reduce the incidence of diarrhoeal disease in users by 22- 84%. Water Guard is imported. Wuha Agar is locally produced and similar to Water Guard. One 150ml bottle of liquid chlorine can be used to treat 250 gallons of water. It can treat 5 gallons of water in 30 minutes (MWA, 2014).

2.6 Point of use water treatment in Ethiopia

Before 2006 there was very little practice of HWTS, however awareness increased during 2006-2010 due to an outbreak of acute watery diarrhoea. Today, HWTS is included among ordinary household interventions utilised by the “community health worker” network which is a nation-wide scheme aimed at improving health outcomes. HWTS also has high visibility at the policy level: it is mentioned in the Health Sector Development Program IV for 2010-2015 with a set target to increase the proportion of households using HWTS from 7% to 77% by the year 2015 (WHO, 2011).

According to (ESSA ,2015) Ethiopia's water and sanitation coverage is also the lowest in the world. The water supply coverage in the country is 22 %, of which the rural coverage is only 11 percent. The sanitation coverage is 6 %, of which the rural coverage is 4 percent (JMP, 2010). The country's low health status, high population growth, and low literacy rates bring to bear a heavy burden on the state to increase delivery for water, health, education and other social services. In comparison with the neighbouring countries Ethiopia's water and sanitation coverage is even lower than Eritrea which has 57% water coverage and 9 percent sanitation coverage. Another neighbouring country, Kenya's water and sanitation coverage is much better than Ethiopia which is 62 and 48 percent respectively. Though, as the data taken from UNICEF and WHO show most Sub-Saharan African countries have the lowest coverage of water and sanitation of any world region, Ethiopia's water supply and sanitation coverage is the lowest (JMP, 2010).

Ethiopia has one of Africa's lowest rates of access to water supply, sanitation, and hygiene despite abundant surface and groundwater resources. According to the government in 2005, 40 percent of the population had access to safe water; however, according to the WHO and local nongovernmental organizations, the figure was closer to 22 percent. The WHO estimated that only 13 percent of the population had access to sanitation.

Ethiopia's Millennium Development Goals (MDGs) for improved water and sanitation access are 70 percent and 56 percent respectively. To reach the MDG targets, the government will need to help ensure local water supply and sanitation service providers continue to develop their capacity to manage operations. The government will also need to encourage consumer advocacy and hygiene awareness.

In most developing countries, in particular in Sub- Saharan Africa, the basic causes of more than 80% of the diseases are inadequate and unsafe water supply, and improper disposal of waste. Ethiopia is among the poorest countries in the world, ranking 170 out of 177 in the UN human development index and is the second most populous country in Africa. Yet, Ethiopia's rural populations are among the least served with rural water supply and sanitation access at only 24% and 8% respectively (ADF 2005). Even though all human beings have the right to life, the right to education, the right to food…etc, these fundamental human rights cannot be fully realized unless people have access to potable water and basic sanitation. Independent of the other basic human rights, all human beings also have the right to access potable water and basic sanitation (WWC, 2009). Since people in the developing countries are pain from lack of access to water and basic sanitation, we cannot talk much more about the so-called 'rights' before survival. Thus, the question of having access to potable water and basic sanitation goes beyond rights, rather it is a question of survival.

Filtration mechanisms such as bio sand filter, solar disinfection, ceramic filtration, chlorination at point of use and combined flocculation/disinfection are the most practiced systems in Ethiopia. The most used point of use filtration systems at household level are mesh like clothing in rural areas, membrane, and ceramic filter devices in urban areas (Abrham et al., 2018). Ceramic filter devices can be made from locally available materials, affordable and used by individuals for household point of use (Enyew and Tesfaye, 2017).

2.7 Conceptual frame work

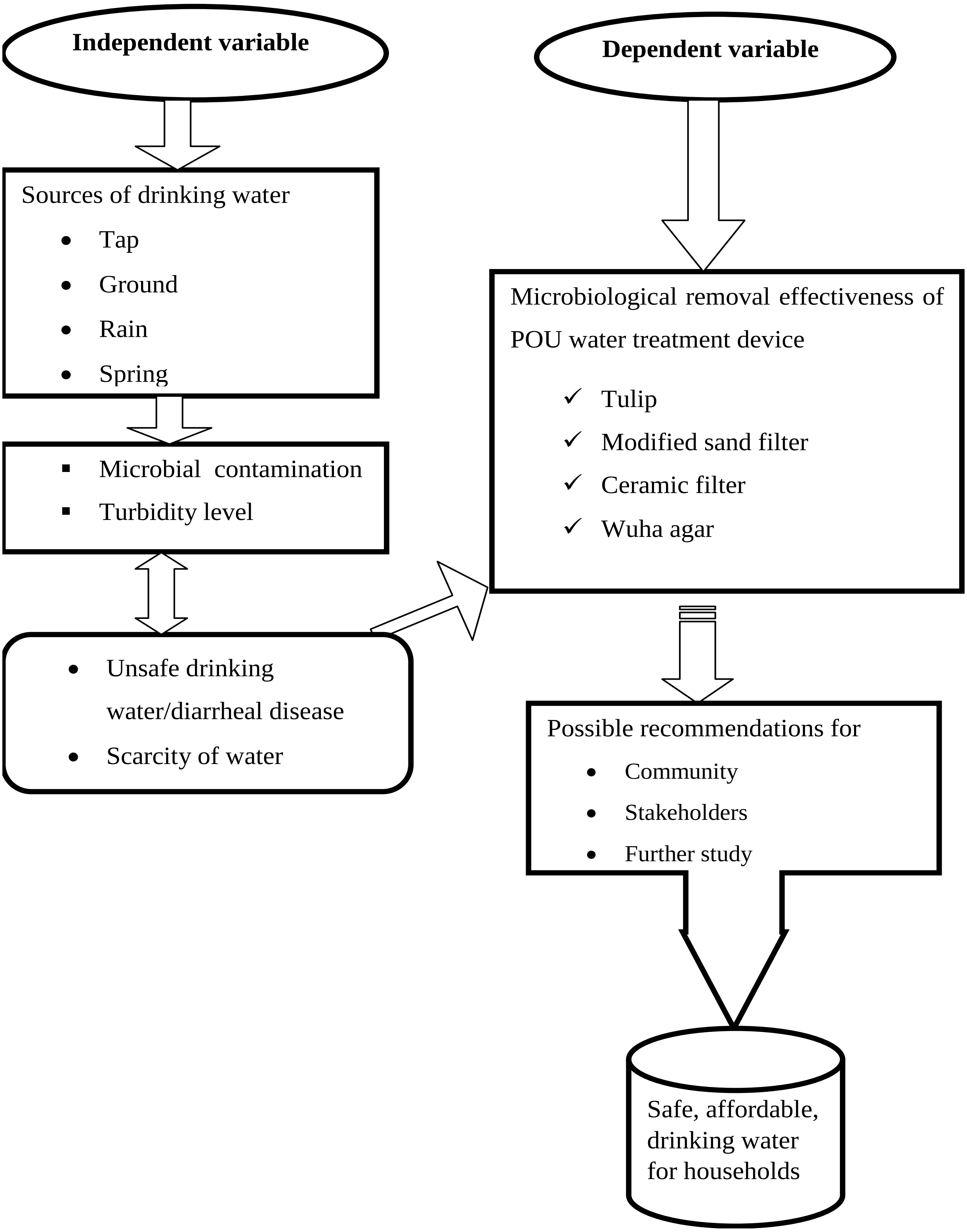

Figure 1 Conceptual framework for microbial removal effectiveness of commercially available POU water treatment devices for household use

Chapter 3 Objectives

3.1 General objectives

To evaluate the microbiological removal effectiveness of commonly used and commercially available point of use water treatment devices for household use

3.2 Specific objectives

1) To make an inventory on the most commonly used and commercially available point of use water treatment devices in Jimma town.
2) To evaluate microbial removal effectiveness of commonly used and commercially available water treatment devices using water sources in Jimma town.
3) To evaluate turbidity reduction and flow rate of commonly used and commercially available water treatment devices using water sources in Jimma town.

Chapter 4 Methods and Materials

4.1 Description of the study area

Jimma town is located at 354 Km Southwest of Addis Ababa. The geographical coordinates are approximately 7°40'N latitude and 36°50'E longitude. The town has an altitude of 1750-2000m above sea level, temperature range of 20-30 °C and average annual rainfall of 800-2500mm3. According to CSA (2007) the national census of 2007, the projected total population of the town is 174, 396 (86,326 males and 88,070 females). There are 36,333total households. There are 5 public health institutions (3 health centers & 2 hospitals) and 18 private clinics (6 higher and 12 medium clinics) in the town.

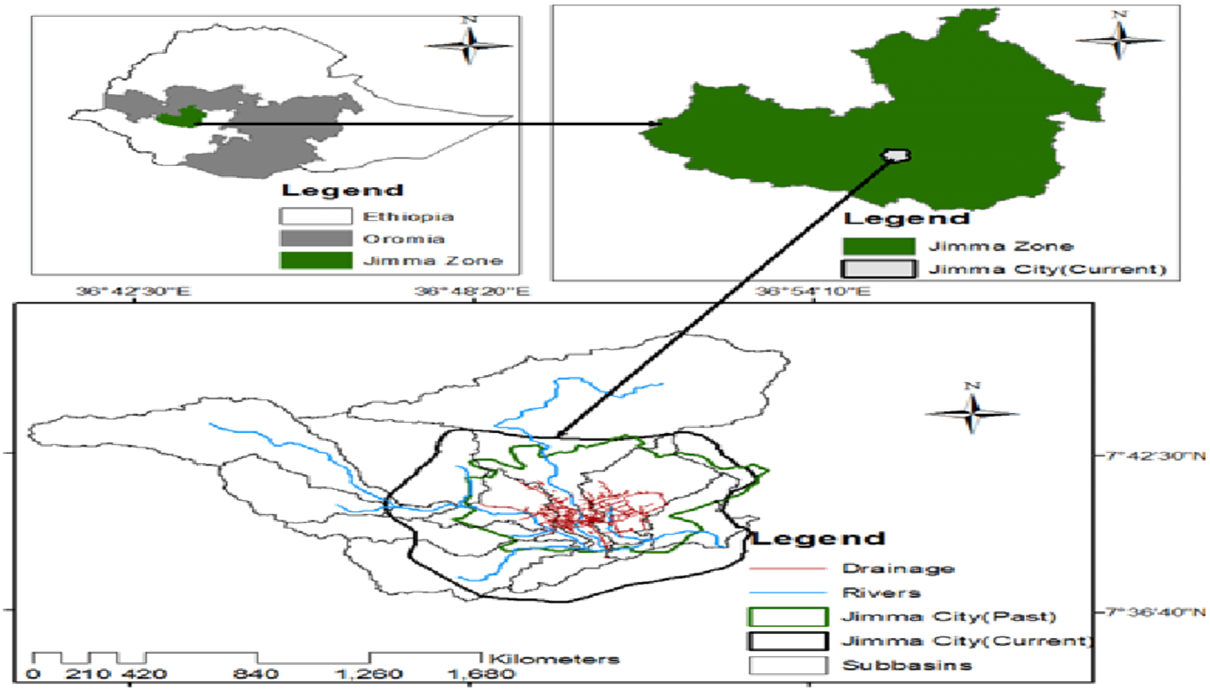

Figure 2 Map of Jimma city

4.2 Study design

The study employed cross sectional study for household survey and laboratory based approach to evaluate the bacterial removal effectiveness of point of use filter devices using municipal tap, rain, spring and ground water samples from June to August, 2021.

4.3 Sample size determination technique for HH survey

To determine sample size of households a sample technique which was developed by (Cochran ,1977) to determine sample size (n) with the desired degree of precision (d) for general population was used

$$n = \frac{\left[Z_{\alpha/2} \sqrt{P\,(1-P))} \right]^2}{d^2}$$

Where: n = Sample size z = critical value 1.96 p = binomial parameter to estimate a population proportion is to be, 0.5 d = precision (marginal error) = 0.05. In calculating a sample size for a proportion, a value of 0.5 was used for the estimate of the population proportion; p=0.5 gives the largest sample size relative to any other value of p (unknown population proportion).

Based on this assumption, the actual sample size for the study was computed using one-sample population proportion formula as indicated below. Thus, the sample size is,

$$n = \frac{\left[Z_{\alpha/2} \sqrt{P\,(1-P))} \right]^2}{d^2} = \left[\frac{1.96}{0.05} \right]^2 0.5 \times 0.5 \approx 385$$

4.4 Sampling technique

The study was conducted in Ginjo, Becho Bore, Bosa Kito, Hermata Mentina, Awetu Mendera and Seto Semero Kebeles from June 10- June 30, 2021 which among the17Kebeles' in Jimma town. They have 3023, 3857, 3268, 4170, 3825 and 3642 households respectively in the area.

Table 1 Sample size distribution in each selected Kebeles

Kebele	Total Number of households	Proportion of sample size
Ginjo	3023	3023*385/21785=54
Becho Bore	3857	3857*385/21785=68
Bosa Kito	3268	3268*385/21785=58
Hermata Mentina	4170	4170*385/21785=74
Awetu Mendera	3825	3825*385/21785=67
Seto Semero	3642	3642*385/21785=64
Total	21785	385

4.5 Sampling of water sources

For experimental study, 6 water samples from Ginjo, Becho bore; Bosa Kito, Hermata Mentina, Awetu Mendera and Seto Semero were collected from four water sources of ground, spring, tap and rain water for microbial removal effectiveness, turbidity reduction of the devices.

4.6 Study variables (dependent and independent variables)

4.6.1 Dependent variable

Microbiological removal effectiveness of household water treatment devices

4.6.2 Independent variables

Sources of water

Contamination level

Turbidity

Flow rate of devices

Microbial load

Device type

4.7 Operational definition

Household water: the water used at the house of the participants for drinking, preparing food, and washing

Collection: fetching of drinking water from the source

Contamination: poor bacteriological quality

Household: family selected for this specific study

Point-of-use**:** place where the water is used for specific purpose

Treatment**:** to make the water safe for drinking

Storage: putting water in the container for future use

Survey instrument: Questionnaire used for this study

Disinfection effectiveness: (Lethal dose of Wuha agar/ chemical)

Tulip/ceramic candle: types of ceramic filters which is structurally different

4.8 Methods of data collection

A structured questionnaire and checklist were prepared and pre-tested before being administered then, refining and corrections were made in accordance to the respondents' perception to conduct house hold assessment. Both the primary and secondary data were used to collect data. Four skilled data collectors were used; who are capable to perfectly communicate with local language.

In this study, three POU filter devices two of them commercially available and one was produced in Jimma university from local material and one chemical disinfectant were selected; ceramic filter, Tulip, modified sand filter and Wuha- agar were set in the laboratory. The filter devices and chemical disinfectant were obtained from the local market of Jimma city.

4.8.1 Household survey

Household level visit was conducted from June 15- June 30, 2021to assess and identify the most commonly used household water treatment devices in the city by using check list and organized questionnaire in 385 \randomly selected households from six Kebeles.

4.8.2 Water sample collection

A total of 5 water samples were collected; ground water from SOS school 1 water samples, tap water from HHs 2 samples from two sites, rain water from households gutter 2 samples from two sites, spring water from Tulema 1 sample from one site for laboratory analysis.

Table 2 summery of water samples collected from different sources

No	Water source	Number samples collected / device				
		Tulip	Wuha agar	CF	MSF	Total number of sample
1	Ground water	1	1	1	1	1
2	Municipality tap water	2	2	2	2	2
3	Rain	2	2	2	2	2
4	Spring	1	1	1	1	1
	Total	6				

4.8.3 Test of microbial removal effectiveness of household water treatment devices

The filters were tested for the removal effectiveness of microbiological indicators (total Coliform, fecal coliform and E. coli). Filter paper with 0.45 μm pore size was placed on the filter support base by using sterile tweezers. The whole apparatus was moved in a swirling motion to stir the sample by pouring 100 ml of the diluted sample water. The dilution was different from sample to sample depending on the nature of the water source and; in the case of water sample collected from ground water from SOS it was complex to count in the first trial and corrected on the second trial. And the dilution was corrected as follows 100, 200, 200, 100 and ml of the sample taken 1, 0.5, 0. 5 and 1Tap, spring, ground and Rain water respectively.

The filter membrane was removed carefully with sterilized tweezers and the membrane was then transferred to Membrane Lauryl Sulphate Broth media on Petri dish for in a rolling motion. The Petri dishes were inverted and placed into incubator set at 37 °C for 48h and 44.5 °C for 24 h for growth of colony of total coliform and E. coli. The numbers of coliform forming units (CFU) were counted under magnifying glass and were expressed as CFU/100 ml.

4.8.4 Evaluating disinfecting effectiveness of Wuha agar (chemical disinfectant)

The standard recommended dosage was to pour one capful of water guard into 25 litres of jerry can of water indicated on producer manual. Based on the volume obtained, the corresponding volume of water guard was weighed out on a measuring balance and added to the cylinder and thoroughly mixed for two minutes and shaken. The WG-treated water was allowed to stand for thirty minutes before samples were taken for analyses. Using the same water samples listed above the effectiveness of the chemical evaluated after 30 minutes' contact time and disinfecting rate of microbial was tested.

4.8.5 Microbial removal effectiveness of a new designed sand filter

The filter was made from locally available materials two buckets, selected sand and plastic packed water container used. The buckets used one at the top to fill untreated water and one at the bottom to collect filtered water passing through the sand layer attached on the center. The device is cost effective and not need more skill to implement if promotion and training is given well for rural also households at low level incomes. Microbial removal effectiveness, turbidity reduction and flow rate of modified sand filter was measured using water samples collected from municipality tap, spring, and ground and rain water in Jimma university laboratory.

Figure 3 Modified sand with ceramic candle filter

4.9 Quality control

Critical and great attention was given to sample collection, transportation and experimental works to reduce an error occurred by it. Time to test, laboratory equipment handling, storing of collected sample, data counting and recording was as a guidance of (WHO, 2004,UNICEF, 2008, UNEP/WHO, 1996)**.** Also the performances of the devices were checked at each batch according to (CDC,2010) using blank control sample; steralized distiled waterpackedwater). Sodiumthio-sulphate(WHO, 1997) was used to reduce residue effects for tap water.

4.10 Data analysis

Data was stored in a Microsoft Excel spread sheet and analyzed with SPSS version 23 statistical software. Mean, median and frequency was summarized in the form of descriptive statistics tables, figures and pie chart (Liben, 2016). Multi linear regression model was performed for identification of relation between flow rate and microbial removal effectiveness of HWTDs, turbidity and removal effectiveness. Bacteriological analysis for total coliforms (TC) and fecal coliforms (FC) were determined and enumerated by Millipore filtration method using the membrane filter technique as outlined in (APHA ,1999)and as per the procedure by (Krishnanet al., 2007).All data were entered twice to ensure consistency and accuracy of data input.

$$\% \text{ Microbial removal effectiveness} = \frac{\text{C before} - \text{C after}}{\text{C before}} \times 100$$ Source (CAWST,2013)

%Reduction = (Influent - Effluent / Influent) × 100

4.11 Ethical issues

This study and its means for obtaining informed consent from participants was reviewed and approved by the Ethical committee of Jimma University and administrative of Jimma city.

4.12 Dissemination plan

Following the analysis of the data, a report will be presented to the Faculty of public health and Medical Sciences, Jimma University. The result of the study will also be disseminated to the concerned offices of the Jimma city and other concerned bodies through the reports and possible publications in journal.

Chapter 5 Result

5.1 An inventory result of commercially available water treatment device

5.1.1 Household survey

Among385 surveyed households 377 (97.92%) response rates were observed. Among these 250 (66.31%) of the households were users. Regarding to the types of devices 125 (50%), 57(22.8 %), 10(4%) of them were used ceramic filter, Tulip/ceramic candle filter and other (WARYT, boiling) respectively. Chemical flocculants and disinfectants such as Wuha-agar (15%) and Bishangari (8.2%) were also observed at the household level in the study area.

Table 3 Household level water treatment devices in Jimma town south west Ethiopia

Types of devices	Frequency	Percent
Ceramic filter	125	50.0
Tulip	57	22.8
Chemical	58	23.2
Other	10	4.0
Total	250	100.0

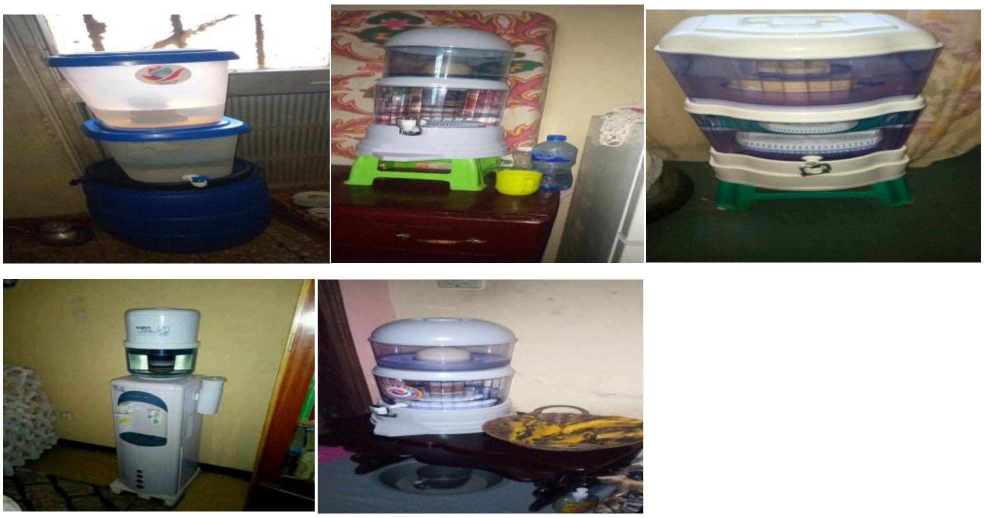

Figure 4Water treatment devices observed at household level in Jimma town Ethiopia.

5.2 Physico- chemical water quality measurement

5.2.1 Turbidity

Onsite measurement indicated that, the mean value of turbidity of rain, ground, spring, and municipality tap water samples were 4.6,6 ,4.05, and 6.23 NTU respectively.

5.2.2 Temperature

The mean value of temperature of rain, ground, spring, and municipality tap water samples were 20.4, 20.7, 19.8, and 20.2 °c respectively.

5.2.3 Dissolved oxygen

The mean value of DO of rain water, ground water, spring water and municipality tap water samples were 7.8, 3.87, 5.35 and 8.14 mg/l respectively.

5.2.4 Electrical conductivity

The mean value of EC of rain water, ground water, spring water and municipality tap water samples were 15.3, 780.5, 182.2, and 89.95 µs/cm respectively.

5.2.5 PH

The mean value of pH of rain, ground, spring, and municipality tap water samples were 9.22, 8.37, 6.3 and 7.9 respectively.

Table 4 summary of onsite measurements of Physio-chemical

No	Water sources	PH	EC µs/cm	DO		Temp. °c	Turbidity NTU
				mg/l	Percent%		
1	Rain	9.22	15.3	7.8	107	20.4	4.6
2	Ground	8.37	780.5	3.87	54.1	20.7	6
3	Spring	6.3	182.2	5.35	71.9	19.8	4.05
4	Tap	7.9	89.95	8.14	110.8	20.2	6.23

5.3 Microbial removal effectiveness of Tulip filter

The microbial removal effectiveness of Tulip filter was measured log values of the device before treatment 3.73,4.05,3.25 and 3.98log and after treatment 2.69,3,3 and 3.39 log using indicator bacteria of E. coli result registered was 90.7, 91.22, 44.44 and 74.23% tap, spring, ground and rain water respectively. The mean value of removal effectiveness of E. coli on Tulip filter was 75.86%.

Table 5 E.coli removal effectiveness of ceramic candle/ tulip

No	Sources of water	E.coli (bf)	E.coli (af)	Log10 (bf)	Log10(af)	LRV(log10 (bf)-log10(af)	% ecol reduction(bf af)/(bf)*100
1	Tap	5400	500	3.73	2.69	1.04	90.7
2	Spring	11400	1000	4.05	3	1.05	91.22
3	Ground	1800	1000	3.25	3	0.25	44.44
4	Rain	9700	2500	3.98	3.39	0.59	74.23

Fecal coliform indicator bacteria were also counted to measure the removal effectiveness the pre and post treatment result showed log values of 3.95, 5.31, 4.17 and 3.74log and 2.95, 4.62, 3.73 and 2.95 log of Tulip filter using water samples collected from municipal tap, spring rain and ground water. The result was registered as 90, 90.32, 64 and 83.63% municipal tap, spring, ground water and rain respectively. The mean value of removal effectiveness of Tulip filter for fecal coli-form was 81.99 %.

Table 6 fecal coliform removal effectiveness of ceramic candle /tulip

No	Sources of water	F coli (bf)	F coli (af)	Log10 (bf)	Log10(af)	LRV(log10 (bf)-log10(af)	% fcol reduction(bf af)/(bf)*100
1	Tap	9000	900	3.95	2.95	1	90
2	Spring	18600	1800	4.26	3.25	1.01	90.32
3	Ground	15000	5400	4.17	3.73	0.44	64
4	Rain	5500	900	3.74	2.95	0.79	83.63

The effectiveness of Tulip filter on removing of total coliform was measured the pre and post treatment result showed log values of 4.35,4.78, 4.59 and 4.34log and 4.05,4.45,4.35 and 4.06log by using the same water sample listed above and registered 50.2, 53.92, 42.85, and 47.5% municipal tap, spring, ground and rainwater respectively. The mean removal effectiveness value of Tulip filter for total coliform was 48.62%.

Table 7 total coliform removal effectiveness of ceramic candle /tulip

No	Sources of water	T. coli (bf)	T.coli (af)	Log10 (bf)	Log10(af)	LRV(log10(bf)-log10(af)	% T.col reduction(bf af)/(bf)*100
1	Tap	22700	11300	4.35	4.05	0.30	50.2
2	Spring	61200	28200	4.78	4.45	0.43	53.92
3	Ground	39200	22400	4.59	4.35	0.24	42.85
4	Rain	22100	11600	4.34	4.06	0.28	47.5

5.3.1 Turbidity reduction of tulip filter

The effluent water turbidity was tested after passing through the developed filters. Turbidity reduction 6.23, 4.05, 6 and 4.6 NTU; 3.5, 2.95, 2.65 and 3.9NTU pre and post treatment registered. Percent turbidity reduction effectiveness of the device was registered as follows 44.14, 27.16, 55.83 and 15.22% tap, spring, ground and rain water respectively.

Table 8 Turbidity reduction effectiveness of ceramic candle filter/tulip

No	Sources of water	Tur (bf)	Tur(af)	%tur reduction(turb -tura) /turb*100
1	Tap	6.23	3.5	44.14
2	Spring	4.05	2.95	27.16
3	Ground	6	2.65	55.83
4	Rain	4.6	3.9	15.22

Flow rate

The flow rate of collected water samples was also measured on tulip tabletop filter and results were registered on different water sources 1.2, 0.9, 1.1, and 1.4 lit/h tap, ground, spring and rain respectively.

5.4 Microbial removal effectiveness of Ceramic filter

The microbial removal effectiveness of ceramic filter was measured using indicator bacteria of E. coli using different drinking water source result registered; log values of the device before treatment 4.37, 5.45, 5.4 and8.6 log and after treatment 3.9, 4.6, 4.2 and 7.12 log using indicator bacteria of E. coli municipality tap, ground, spring and rain water sample respectively.57.14, 72, 62.5 and 60 %of municipal tap, ground, spring, and rain water respectively. Mean value of removal effectiveness of ceramic filter 62.91 % on E. coli.

Table 9 E.coli removal effectiveness of ceramic filter

No	Sources of water	E.coli (bf)	E.coli (af)	Log10 (bf)	Log10(af)	LRV(log10(bf)-log10(af)	% E.col reduction(bf af)/(bf)*100
1	Tap	700	300	2.84	2.47	0.37	57.14
2	Ground	2200	600	3.34	2.77	0.57	72
3	Spring	1600	600	3.2	2.77	0.43	62.5
4	Rain	1500	6100	3.17	2.77	0.40	60

Calculation based on (CAWST,2013)

Fecal coliform indicator bacteria were also counted to measure the removal efficiency of ceramic filter using water samples collected from municipal tap, spring, ground and rain water. The result showed log values of 3.11, 3.89, 4.43 and 3.32log and 2.47, 3.73, 3.53 and 3.23log fecal coliform counted before and after treatment respectively. Percent of reduction was registered as 88.46, 30.77, 58.36 and 19.04 % municipal tap, ground, spring and rain respectively. Mean value was 49.16 %.

Table 10 Fecal coliform removal effectiveness of ceramic filter

No	Sources of water	F coli (bf)	F coli (af)	Log10 (bf)	Log10(af)	LRV(log10(bf)-log10(af)	% fcol reduction(bf af)/(bf)*100
1	Tap	1300	300	3.11	2.47	0.64	88.46
2	Ground	7800	5400	3.89	3.73	0.16	30.77
3	Spring	110000	45800	4.43	3.53	0.90	58.36
4	Rain	2100	1700	3.32	3.23	0.09	19.04

Calculation based on (CAWST,2013)

The effectiveness of the device on removing of total coliform was measured the pre and post treatment result showed log values of 4.11,5.77,5.04 and 5.36 log and 4.02,4.94,4.66 and 4.99 log total coliform by using the same water sample listed above and registered 19, 85.18, 87.4

and 57.14 % municipal tap, ground, spring and rain respectively. Mean removal effectiveness was registered 62.18%.

Table 11 total coliform removal effectiveness of ceramic filter

No	Sources of water	T. coli (bf)	T.coli (af)	Log10 (bf)	Log10(af)	LRV(log10(bf)-log10(af)	% T.col reduction(bf af)/(bf)*100
1	Tap	13,100	10600	4.11	4.02	0.09	19
2	Ground	594,000	88000	5.77	4.94	0.83	85.18
3	Spring	27000	3400	5.04	4.66	0.38	87.4
4	Rain	231000	99000	5.36	4.99	0.37	57.14

Calculation based on (CAWST,2013)

5.4.1 Turbidity reduction effectiveness of ceramic filter

Then turbidity reduction effectiveness of the device was registered as follows 10.75, 15.59, 22.22 and 17.21% municipal tap, ground, spring, and rain water respectively. Mean value of turbidity reduction was 16.45%.

Table 12 Turbidity reduction effectiveness of ceramic filter

No	Sources of water	Tur (bf)	Tur(af)	%tur reduction(turb -tura) /turb*100
1	Tap	4.37	3.9	10.75
2	Ground	5.45	4.6	15.59
3	Spring	5.4	4.2	22.22
4	Rain	8.6	7.12	17.21

Calculation based on (CAWST,2013)

Flow rate

The flow rates of tap, ground, spring and rain resulted 1.1, 1.1, 0.95 and 1.1 lit/h on ceramic filter respectively.

5.5 Microbial removal/disinfecting effectiveness of Wuha agar

The microbial disinfecting effectiveness of Wuha-agar was measured log values of the device before treatment 3.73, 4.05, 3.25 and3.98 log and after treatment 2.84, 2.77, 2.6, and 2.3logusing indicator bacteria of E. coli with different drinking water source and result registered was 87.03, 94.74, 77.77 and 97.93% tap, spring, ground and rain water respectively. The mean value of disinfecting effectiveness of E. coli was registered 89.37%.

Table 13 E.coli dis infectiveness of Wuha agar

No	Sources of water	E.coli (bf)	E. coli (af)	Log10 (bf)	Log10(af)	LRV(log10(bf)-log10(af)	% E.col reduction(bf af)/(bf)*100
1	Tap	5400	700	3.73	2.84	0.89	87.03
2	Spring	11400	600	4.05	2.77	1.28	94.74
3	Ground	1800	400	3.25	2.6	0.65	77.77
4	Rain	9700	200	3.98	2.3	1.68	97.93

Calculation based on (CAWST,2013)

Concentration of Fecal coliform was also counted before treatment and after treatment result showed log values of 3.95,4.26,4.17 and 3.74 log and 3.77, 4.11,3.92 and 2.84log to measure the disinfecting effectiveness of Wuha-agar. The result was registered as 33.33, 30.11, 44 and 87.22 % municipal tap, spring, ground and rain respectively. 48.66 % of mean disinfecting value was registered.

Table 14 Fecal coliform dis infectiveness of Wuha -agar

No	Sources of water	F coli (bf)	F coli (af)	Log10 (bf)	Log10(af)	LRV(log10 (bf)- log10(af)	% fcol reduction(bf af)/(bf)*100
1	Tap	9000	6000	3.95	3.77	0.18	33.33
2	Spring	18600	13000	4.26	4.11	0.15	30.11
3	Ground	15000	8400	4.17	3.92	0.25	44
4	Rain	5500	700	3.74	2.84	0.90	87.22

Calculation based on (CAWST,2013)

The effectiveness of Wuha- agar on disinfecting of total coliform was measured by using the same water sample listed above and registered log removal values of 4.35, 4.78, 4.59 and 4.34log and 3.95, 4.5, 4.25 and 3.86log before and after treatment respectively. Reduction percent was 60.35, 48.03, 54.08, and 66.96% municipal tap, spring, ground, and rain respectively. Mean value of 57.35 % of disinfecting effectiveness was registered.

Table 15 Total coliform dis infectiveness of wuha agar

No	Sources of water	T. coli (bf)	T.coli (af)	Log1 0 (bf)	Log10(af)	LRV(log10 (bf)- log10(af)	% T.col reduction(bf af)/(bf)*100
1	Tap	22700	9000	4.35	3.95	0.40	60.35
2	Spring	61200	31800	4.78	4.5	0.28	48.03
3	Ground	39200	17800	4.59	4.25	0.34	54.59
4	Rain	22100	7300	4.34	3.86	0.48	66.96

5.6 Removal effectiveness of Modified sand filter

The microbial removal effectiveness of modified sand filter was measured log values of the device before treatment 3.73, 4.05, 3.25 and3.98 log and after treatment 2.77, 3.34, 2.3 and 3.39 log using indicator bacteria of E. coli using different drinking water source result registered was 88.88, 80.7, 88.88and 74.23% tap water, spring, ground and rain water respectively. The mean value of removal effectiveness of E. coli on modified sand filter was 83. 17%.

Table 16 E.coli removal effectiveness of modified sand filter

No	Sources of water	E. coli (bf)	E. coli (af)	Log10 (bf)	Log10(af)	LRV(log10(bf)-log10(af)	% E.col reduction(bf af)/(bf)*100
1	Tap	5400	600	3.73	2.77	0.96	88.88
2	Spring	11400	2200	4.05	3.34	0.71	80.7
3	Ground	1800	200	3.25	2.3	0.95	88.88
4	Rain	9700	2500	3.98	3.39	0.59	74.23

Calculation based on (CAWST,2013)

Fecal coliform indicator bacteria were also counted before treatment and after treatment of water samples after incubating and reached countable to measure the removal effectiveness of the device the result showed log values of 3.95,4.26,4.17 and 3.74 log and 3.25, 3.99,3.91 and 3.43 log. CFU was counted using water samples collected from municipal tap, spring, ground and rain water. The result was calculated in reduction percentage and registered as 80, 47.31, 45.33 and 50.9 % municipal tap, spring, ground and rain water respectively. The mean value of removal effectiveness of modified sand filter was 55.88 %.

Table 17 Fecal coliform removal effectiveness of modified sand filter

No	Sources of water	F coli (bf)	F coli (af)	Log10 (bf)	Log10(af)	LRV(log10(bf)-log10(af)	% fcol reduction(bf af)/(bf)*100
1	Tap	9000	1800	3.95	3.25	0.70	80
2	Spring	18600	9800	4.26	3.99	0.27	47.31
3	Ground	15000	8200	4.17	3.91	0.26	45.33
4	Rain	5500	2700	3.74	3.43	0.31	50.9

Calculation based on (CAWST,2013)

The effectiveness of MSF on removing of total coliform was measured; the pre and post treatment result showed log values of 4.35,5.37,4.59 and 4.34 log and 4.16,5.23,4.33 and 3.77 log by using the same water sample listed above and percent of reduction was registered 36.12, 55.55, 45.41, and 73.3% municipal tap, spring, ground and rainwater respectively. The mean removal effectiveness value of MSF on total coliform was 52.59%.

Table 18 Total coliform removal effectiveness of modified sand filter

No	Sources of water	T. coli (bf)	T. coli (af)	Log10 (bf)	Log10(af)	LRV(log10 (bf)-log10(af)	% T.col reduction(bf af)/(bf)*100
1	Tap	22700	14500	4.35	4.16	0.19	36.12
2	Spring	61200	27200	4.78	4.43	0.35	55.55
3	Ground	39200	21400	4.59	4.33	0.26	45.41
4	Rain	22100	5900	4.34	3.77	0.57	73.3

Calculation based on (CAWST,2013)

5.6.1 Turbidity reduction effectiveness of modified sand filter

Turbidity reduction 6.23, 4.05,6 and 4.6 NTU and 4, 3.5, 3.3 and 3.35NTU pre and post treatment was registered. Then turbidity reduction effectiveness of the device was registered as follows 35.79, 13.58, 45 and 27.17 % tap, spring, ground and rain water respectively. The mean value of reduction effectiveness of MSF on turbidity was 37.96%.

Table 19 Turbidity reduction effectiveness of modified sand filter

No	Sources of water	Tur (bf)	Tur(af)	%tur reduction=(turb) -(tura) /turb*100
1	Tap	6.23	4	35.79
2	Spring	4.05	3.5	13.58
3	Ground	6	3.3	45
4	Rain	4.6	3.35	27.17

Flow rate

The flow rate of water samples on filter media of MSF prepared in Jimma University was also measured and a result as follows 2.2,1.5,2 and1.6 lit/h using tap, ground, spring and rain respectively.

Figure 5 Water samples after treatment

Figure 6 Bacteria count in the lab before and after treatment

5.7 Factor affecting microbial removal effectiveness of POU water treatment devices

5.7.1 Flow rate

After frequent trial and measurement, the study obtained mean value of flow rate for each device as follow 1.15, 1.06 and 1.83l/h tulip, ceramic filter and modified sand filter respectively.

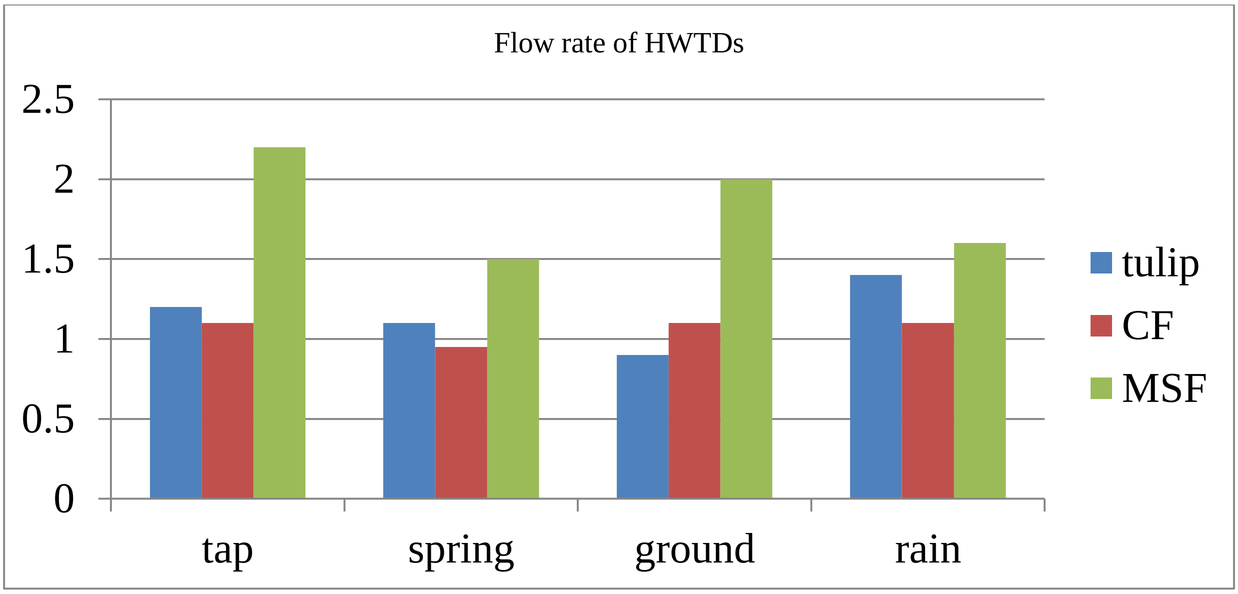

Figure 7 summary of flow rate of HWTDs by different water samples

5.7.1.1 Effects of flow rate on microbial removal effectiveness of Ceramic filter

From table 20 the relation between flow rate and microbial removal effectiveness of ceramic filter show that the R^2value was 0.286 this indicates that factors included flow rate in the regression model of removal effectiveness of TC, FC and EC in all selected water sources can explain 28.6% of the variation on removal effectiveness.

Table 20 Regression model of flow rate and ceramic filter

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.534[a]	.286	-.429	.51696

a. Predictors: (Constant), CF

From ANOVA table significance difference in the effect of the three independent variables in removal effectiveness of TC, FC, EC (p=0.641). This indicates that factors affecting removal effectiveness was not providing predictive ability of the relation between dependent and independent variables.

Table 21 ANOVA table for flow rate and ceramic filter

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.107	1	.107	.400	.641[b]
	Residual	.267	1	.267		
	Total	.374	2			

a. Dependent Variable: Flow rate
b. Predictors: (Constant), CF

The relation between flow rate and microbial removal effectiveness of ceramic filter device was analyzed as (p=0.641) using all the water sources listed. The result indicates there is no significant relationship at 99 % confident interval between flow rate of water samples and removal effectiveness of ceramic filter for EC, FC and TC. The relation between microbial removal effectiveness and flow rate on ceramic filter devices showed that list effect since the coefficient of variation was (B= 0.030).

Table 22 linear regression model summary of flow rate and ceramic filter

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
CF	.030	.047	.534	.632	.641

5.7.1.2 The relation between flow rate and microbial removal effectiveness on Tulip device

The relation between flow rate and microbial removal effectiveness of tulip filter/CCF show that the R^2value was 0.992 or 99.2% indicates that factors included (flow rate) in the regression model of removal effectiveness of TC, FC and EC can explain 99.2% of the variation on removal effectiveness on all water samples.

Table 23 Regression model of flow rate and tulip

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.996[a]	.992	.983	.05567

a. Predictors: (Constant), tulip

From ANOVA table significance difference in the effect of the three independent variables in removal effectiveness of TC, FC, EC (p=0.058). this indicates that the factors or flow rate of water though the filter media affecting removal effectiveness was not providing predictive ability of the relation between dependent and independent variables at 99% CI.

Table 24 ANOVA table for flow rate and tulip

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.371	1	.371	119.718	.058[b]
	Residual	.003	1	.003		
	Total	.374	2			

a. Dependent Variable: flow rate

b. Predictors: (Constant), tulip

The relation between flow rate and microbial removal effectiveness of POU water treatment device was analyzed as (p=0.058) using all the same type of water sources listed. The result indicates there was no significant relationship at 99% confident interval between flow rate of water samples and removal effectiveness of Tulip filter for EC, FC and TC. The relation between flow rate and microbial removal effectiveness of tulip indicates negative variation. This indicates the relation was weak.

Table 25 Linear regression result of flow rate and tulip

	Un standardized Coefficients		Standardized Coefficients		
Model	B	Std. Error	Beta	t	Sig.
tulip	-.024	.002	-.996	-10.942	.058

5.7.1.3 The relation between flow rate and microbial removal effectiveness of MSF

The regression model resulted R^2=0.239 value which indicates that the relation between filtration time and removal effectiveness of modified sand filter for microbial EC, FC and TC was 23.9% variation.

Table 26 Regression model for flow rate and modified sand filter

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.488[a]	.239	-.523	.53370

a. Predictors: (Constant), MSF

The ANOVA result showed that the significance difference in the effect of the three independent variables in removal effectiveness of TC, FC, EC (p=0.675). This indicates that the factors affecting removal effectiveness was not providing predictive ability of the relation between modified sand filter and microbial TC, FC and EC.

Table 27 ANOVA table for flow rate and modified sand filter

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.089	1	.089	.313	.675[b]
	Residual	.285	1	.285		
	Total	.374	2			

a. Dependent Variable: Flow rate

b. Predictors: (Constant), MSF

The relation between flow rate and microbial removal effectiveness of MSF was analyzed as (p=0.675). The result indicates there is no significant relationship at 99 % CI between flow rate of water samples and microbial removal effectiveness of modified sand filter for EC, FC and TC. The relation between microbial removal effectiveness of flow rate and modified sand filter showed negative relation which means that flow rate has less effect on the removal microbial.

Table 28 linear regression result of flow rate and modified sand filter

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.172	1.494		1.454	.384
	MSF	-.013	.023	-.488	-.560	.675

5.7.2 Effects of Turbidity on microbial removal effectiveness of HWTS device

In this study turbidity was analyzed as; its effect on the removal effectiveness of household water treatment devices.

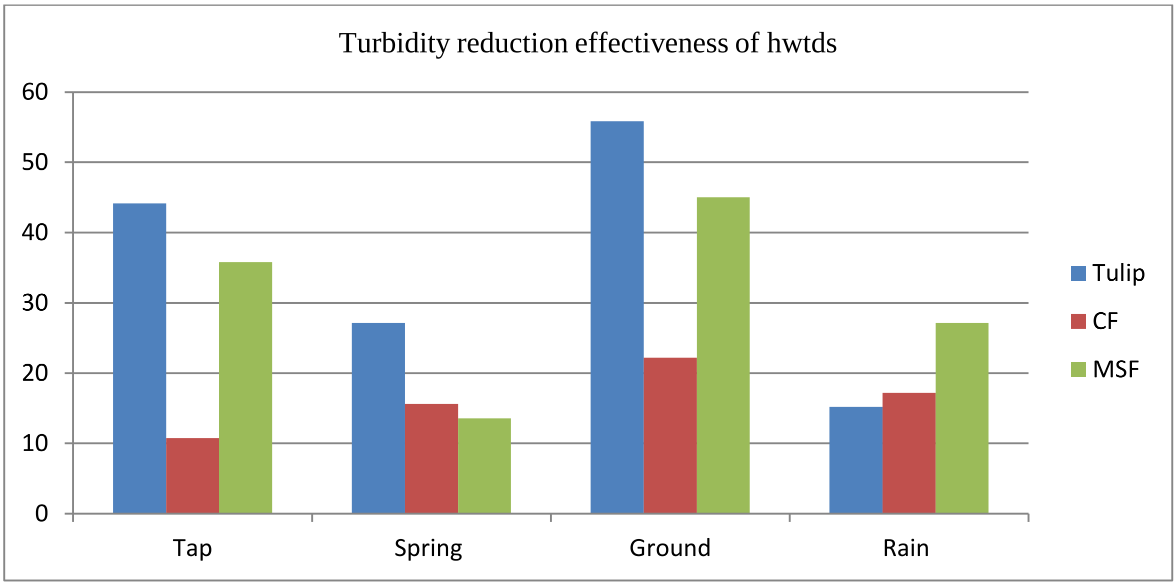

Figure 8 Turbidity reduction effectiveness of HWTDs

5.7.2.1 The relation between turbidity and microbial removal effectiveness of devices

This study observed the relation between turbidity and its potential effect on removal effectiveness of selected; household level water treatment devices Tulip, modified sand filter and ceramic filter from different water sources on load of E. coli, fecal coliform and total coliform.

From table 29 the relation between turbidity and microbial removal effectiveness of HH water treatment devices showed that the R^2value was 1 or 100% this indicates that turbidity of water sources analyzed in the regression model of removal effectiveness of Tulip, modified sand filter and ceramic filter can explain 100 % of the variation on removal effectiveness of microbial. This means turbidity has significant effect on microbial removal effectiveness at 99% confidence interval.

Table 29 Regression model summary of turbidity and microbial removal effectiveness of HWTDs

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000[a]	1.000	.	.

a. Predictors: (Constant), TULIP, CF, MSF

From the ANOVA table below significance difference in the effect of the three independent variables (CF, MSF and Tulip) in removal effectiveness of TC, FC, EC (p=0.00). This indicates that the factors affecting removal effectiveness was providing predictive ability of the relation between dependent and independent variables.

Table 30 ANOVA table for turbidity and microbial removal effectiveness

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.935	3	.312	.	.[b]
	Residual	.000	0	.		
	Total	.935	3			

a. Dependent Variable: turbidity

b. Predictors: (Constant), TULIP, CF, MSF

The relation between turbidity and microbial removal effectiveness of POU water treatment device was analyzed as (p=0.00), (p=0.00) and (p=0.00) for, modified sand filter ceramic filter and Tulip respectively. The result indicates that there is significant relationship at 99 % confident interval between turbidity of water samples and removal effectiveness of devices for EC, FC and TC. The effect of turbidity on CF and tulip microbial removal effectiveness (B=-0.048, B=-0.002) from this it can be conclude that turbidity on CF and tulip has less effect on microbial removal effectiveness.

Table 31 linear regression model summary for turbidity and microbial effectiveness

		Un standardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	4.615	.000		.	.
	MSF	.024	.000	.165	.	.
	CF	-.048	.000	-.883	.	.
	TULIP	-.002	.000	-.048	.	.

Chapter 6 Discussion

6.1 House hold survey and Market assessment inventory of commercially available HWTDS in Jimma Town

6.1.1 Household survey

This study observed 66.31% of the households use the device in Jimma town. This indicates that the majority of selected households used the ceramic filter, Tulip and Wuha-agar. With the increased promotion and dissemination of water treatment products, the percentage of people using HWT in 2014 is between 10 and 13%. Of this, around 6-7% is boiling, 3-5% is using a chlorine product, and 1% is using some kind of a household water filter (EDHS, 2011). This study showed more dissemination performance of the system in the city than the previous study this was because of the information was gathered from only urban populations dwelling in the study area while the previous showed the rural and urban status. The National Hygiene and Sanitation Strategic Action Plan (2011- 2015) aimed for an increase of families practicing some kind of HWTS from 8% (base year 2010) to 77% in 2015 (MWA, 2014).

6.2 Physico-chemical measurement

On site measurement of turbidity indicated that 4.05-8 range. According to the national (CES, 2013) recommendation maximum permissible level of turbidity is 5NTU and also the WHO recommendation is less than 5NTU. Comparing with the standards only municipality water (6.23 NTU) was fulfilling the recommendation. It was due to the seasonal factors (data was collected at summer) affecting the turbidity level of water quality. For effective disinfection, median turbidity should be below 1 NTU although turbidity of less than 5NTU is usually acceptable to consumers (WHO, 2004).

Temperature was also measured onsite and resulted19.8-21.1 ^{o}c range in this study. The most attractive temperature for drinking water is between 4^{o}C and 10^{o}C. Temperatures above 25^{o}C (77^{o}F) are usually objectionable (CAWST, 2013). Water temperature was also measured by another researcher before in this study area by (Deneke, 2007) and reported 26^{o}C tap water sources. And also previous study conducted (Manyazewal., 2019) on deep well was registered 16.65^{o}C on previous study conducted in Jimma city. Comparing with this study all the results were not had much difference and in both cases it was above the standards. It was beyond the recommended unit of WHO <15^{0}C (2004c), nationally it has no guideline value (since it is not health-based problem, non-Objectionable, ES, 2001).

In this study PH was measured onsite and registered 6.3-9.22range. Comparing it, according to the WHO, the minimum and maximum allowable PH ranges from 6.5 to 8.5for potable water. According to (CES,2013) the Ethiopian national standard edition maximum permissible level is 6.5-8.5. After measuring the result obtained it was compared with both standards ranges from 6.3 to 9.22 and ground and municipality tap were between the permitted levels while spring and rain water samples scored under and above the permitted level. Also PH was reported by Deneke(2007) 7.2 tap water sources; also previous study Manyazewal(2019) 7.61 also registered on deep well at the same study area. comparing with the current study tap water showed almost the same result it was below the recommendation level on previous study and also; regarding to deep well observation the second researcher and the current also registered accepted result of the recommendations.

6.2 Removal effectiveness of HH water treatment devices

6.2.1 Evaluating the microbial removal effectiveness of Tulip filter

The current study conducted on four water sources; was registered the mean value of removal effectiveness of E. coli 75.86%. The microbial removal effectiveness of the device on a single indicator E. coli was measured and compared with previous studies conducted by others. According to MENON(2007) previous study reported 99.99% removal effectiveness CCF using single water sample and also similar filter named Pelican in Kenya also performed well with regard to removing coliforms. The average percent removals of E. coliform these filters were and 99.98%, (Amber, 2005). This indicates that there was a difference in the removal performance of the device since concentration of suspended matter, level of bacteriological contamination varies and the numbers of water samples tested were not the same.

The average removal effectiveness for fecal coliform was registered 81.99 %. A previous study conducted Amber (2005) was reported 99.9 % removal effectiveness on fecal coliform. There was a variation between these two studies and the reason behind might be the difference with number and type of water samples used for test.

The current study conducted the mean microbial removal effectiveness of Tulip filter on total coliform was 48.62% was registered. According to Amber (2005) average percent removals of total coliforms99.89% by similar device on a single water source on its previous study. By comparing it with this might be because of the variation in the number of water samples tested; differences with pore sizeand supporting materials used. Porous ceramic filters are widely used for household treatment of water, most commonly in the form of candle filters. Ceramic filter pore size varies widely, but most can reduce turbidity and parasites by at least 90% and substantially lower bacterial concentrations (Sobsey, 2002).

6.2.1.1 Turbidity reduction effectiveness

The mean percent turbidity reduction effectiveness of Tulip filter was 35 .59%and 2.65-4.03 NTU result after treatment for current study. Comparing it with previous study Mwabi (2011) done on ceramic candle filter it was registered 95% which confirms the effectiveness of the device in turbidity reduction and the same filters possessed an average turbidity removal of 98.3% (Amber, 2005). Also comparing it with the standards of; WHO less than 5NTU and national fits to provide the permissive level of turbidity.

6.2.1.2 Flow rate of ceramic candle /Tulip filter

The current study was registered 1.15 l/h of average value of different water sources. A previous study on average value of flow rate on ceramic candle filter of 1.5 L/h Mwabi (2012); it indicates a little variation between the result of the studies which might be because of the difference in water sources, the number of water samples collected and seasonal variation.

6.2.2 Evaluating the removal effectiveness of Ceramic filter

The current study was registered mean value 62.91 % of E. coli removal effectiveness. A previous study reported 99 % removal effectiveness of ceramic water purifier on its field test Brown (2007) the difference might be it was tested by using only 2 water samples rain and surface water.

The removal effectiveness of ceramic filter for fecal coliform was 49.16 % on average. This result was compared with previous study conducted by another researcher Bayable (2020) which was registered 24% reduction effectiveness less than the current. The difference was the previous study considered the time variation on removal effectiveness of the device and it was critical for further study.

The removal effectiveness of the device for total coliform in this study different values and mean value of 62.18%was registered. Although the greater result was registered than the previous study 48%by Bayable (2020) both were not compatible with the national and WHO recommendations. Comparing with the previous study it is important to know in both cases different challenging factors affecting microbial removal effectiveness of the devices were investigated and an average values taken.

According to Chaudhuri (1994) comprehensive study in Cambodia demonstrated that locally-produced ceramic filters, used regularly, can significantly improve household water quality up to 99.99% less E. coli and reduce diarrhoea morbidity (households using the filter reported nearly half the cases of diarrhoea compared to control households).

6.2.2.1 Turbidity reduction effectiveness of ceramic filter

Turbidity the current study registered mean value of 16.45%turbidity reduction. According to (EPA, 1999) turbidity is a key parameter used to measure the quality of a water source. In several parts of the sub Saharan region the water turbidity can be caused by organic waste, silt, bacteria and other germs, and chemical precipitates (Doulton, 2009). A previous study conducted by SAGARA(2000) was registered 96.2% of reduction effectiveness. This difference might be because of the difference in the number of water samples, the quality difference in water samples tested (MWA, 2014) strengths the reduction effectiveness; depending on quality, they remove turbidity and 99-99.99% of bacteria.

6.2.2.2 Flow rate result of ceramic filter

This study tested the flow rates on each of water samples collected and registered an average value of 1.06 l/h; a previous study Amber(2005) reported 0.20l/h, Albert (2020) was reported flow rate of 1.5 l/h on average and nationally (MWA,2014) suggests for ceramic filter it can treats 1-3 letters/hour. The difference might be because of variation in level contamination, turbidity level and difference of pore size.

6.2.3 Microbial disinfecting effectiveness of Wuha- agar (chemical disinfectant)

This study observed the mean value of disinfecting effectiveness of Wuha agar on E. coli was registered 89.37%. According to Küng(2011) previous researcher chlorination with wuhaagar was reduced E.coli on half of the influent water; for E. coli, Wuha agar recorded the highest disinfection efficiency of 99.9% (Sojobi, 2015).Comparing with this study it was less performed this may because of the difference in selected materials(container) to do the experiment,dosage, the number of water samples tested and recontamination after treatment. Also (WHO,2011) disinfectingdose of chemical treatment method is a critical for better performance.

On the other hand, for faecal coliform the current study 48.66 % of mean disinfecting effectiveness value was registered. Wuha-agar recorded the highest disinfection effectiveness of 87.5% Sojobi (2015); another study conducted by Albert(2020) reported 95%.

The removal effectiveness of wuha agar on total coliform was registered an average value of 57.48 %. Total coliform disinfecting effectiveness of 75%were reported by previous study conducted by (Sojobi, 2015). Also the previous study Küng(2011) reported no change was seen on the removal effectiveness of wuha agar on total coliforms. It contradicts with this study the previous reported no change; the reason might be the dose applied to test, turbidity level of water samples since it is basic for chemical disinfection (UNICEF,2012) and also recontamination after treatment.

6.2.4 Microbial removal effectiveness of Modified sand filter produced in JU

Microbial removal effectiveness of sand filter on the current study was registered83.17% of mean value. Comparing with the previous studies conducted before Mwabi (2011) microbial effectiveness was registered 40 % removal effectiveness. Also (OSHO ,2009), Küng, (2011) reported that on their previous studies household sand filter not reduces E. coli rather increased number was observed after treatment. As Sobsey(2002) reported that bucket filters are not estimated to reduce bacteria by more than 90%, approximately 50% reduction was expected. The current study conducted on modified sand filter was performed greater than the estimation.

This study; mean value of 56% removal effectiveness. Comparing with the study conducted before Mwabi (2011) microbial effectiveness was registered 38% removals which is less than the current. According to Sobsey(2002) reported that rapid sand filters are not estimated to reduce bacteria by more than 90%, approximately 50% reduction was expected. The current study conducted on modified sand filter was performed greater than the estimation.

From this study mean value of 53% observed. Comparing with study conducted before Mwabi(2011) microbial effectiveness was registered 20% removals. Also (OSHO, 2009; Küng, 2011) reported that on their previous studies HH sand filter reduces TC under 50% and it had capacity to remove TC more than EC. All the above studies were reported less performance than this study.

Rapid sand filtration alone can remove large pathogens (e.g., Giardia cysts, helminths) and bacteria (50%-90%), but viruses are small enough to pass through the filter beds. If the filter media is chemically modified to give the surface a positive charge, removal of bacteria and viruses can increase to > 99%. This can be done by combining sand or anthracite with metal salts such as alum, iron, lime or manganese (Sobsey, 2002).

6.2.4.1 Turbidity reduction effectiveness of Modified sand filter

The mean value of reduction effectiveness of modified sand filter on turbidity was 38%. According to Mwabi(2011) 90% reduction efficiency was registered from his previous study and also Sobsey(2002) depending on the turbidity, to achieve 90% to >99% reduction in suspended solidswhich is more effective than this study. The reason for the variation in result might because of the difference in test samples, variation in filter design, and quality of filter materials.

6.2.4.2 Flow rate of modified sand filter

Modified sand filter produced in Jimma University by another researcher was tested on the flow rate and registered an average value of 1.83 l/h. Comparing it with Sobsey(2002) rapid sand filtration average; flow rate 12 l/h the current registered lower performance. This might be because of the current was done on different water samples which had quality variation, also there was a variation on structure the current used one narrow inlet to filter layer, variation in container size, also might variation in material quality used.

6.3 The relation between flow rate and microbial removal effectiveness on Ceramic filter

From table the relation between flow rate and microbial removal effectiveness of HH water treatment devices show that the R^2value was 0.286% this indicates that factors included in the regression model of flow rate on removal efficiency of TC, FC and EC in all selected water sources can explain 28.6 % of the variation on removal efficiency.

From ANOVA table significance difference in the effect of the three independent variables in removal efficiency of TC, FC, E. coli (p=0.641). This indicates that the factors flow rate affecting removal efficiency was not providing predictive ability of the relation between dependent and independent variables.

Using all the water sources listed. The result indicates there is no significant relationship at 99 % confident interval between flow rate of water samples and removal effectiveness of ceramic filter for EC, FC and TC.

6.4 The relation between flow rate and microbial removal effectiveness on Tulip device

The relation between flow rate and microbial removal effectiveness of tulip filter HH water treatment devices show that the R^2value was 0.992 indicates that factors included (flow rate) in the regression model of removal effectiveness of TC, FC and EC can explain 99.2 % of the variation on removal effectiveness on all water samples.

From ANOVA table significance difference in the effect of the three independent variables in removal effectiveness of TC, FC, EC (p=0.058). This indicates that the factors or flow rate of water though the filter media affecting removal effectiveness was not providing predictive ability of the relation between dependent and independent variables at 99%confidence interval.

The result indicates that there was no significant relationship at 99 % confident interval between flow rate of water samples and removal effectiveness of Tulip filter for EC, FC and

TC. This indicates the relation was weak. On the contrary other researcher was investigated with reduced filter rate an increase of microbial reduction (Stauber, 2007).

6.5 The relation between flow rate and microbial removal effectiveness of Modified sand filter

The regression model resulted R^2=0.239of R value which indicates that the relation between filtration time and removal effectiveness of modified sand filter for microbial EC, FC and TC was 23.9% variation.

The ANOVA result showed that the significance difference in the effect of the three independent variables in removal effectiveness of TC, FC, EC (p=0.675). This indicates that the factors affecting removal efficiency was not providing predictive ability of the relation between modified sand filter and microbial TC, FC and EC.

Using all the water sources listed. The result indicates there was no significant relationship at 99 % confident interval between flow rate of water samples and microbial removal effectiveness of modified sand filter for EC, FC and TC. A previous study by Kati (2018) a reported no significant difference was registered on microbial removal of rapid sand filter with relation on flow rate which agrees with this study.

6.6 The relation between turbidity and microbial removal effectiveness of devices

This study analyzed the relation between turbidity and its potential effect on removal effectiveness of selected household level water treatment devices Tulip, modified sand filter and ceramic filter load of E. coli, fecal coliform and total coliform.

The relation between turbidity and microbial removal effectiveness of HH water treatment devices showed that the R^2value was 1 this indicates that turbidity of water sources analyzed in the regression model of removal effectiveness of Tulip, modified sand filter and ceramic filter can explain 100 % of the variation on removal effectiveness of microbial. This means turbidity has significant effect on microbial removal effectiveness at 99% confidence interval. From the ANOVA table significance difference in the effect of the three independent variables (ceramic filter, modified sand filter and Tulip) in removal effectiveness of TC, FC, EC (p=0.00). This indicates that the factors affecting removal effectiveness was providing predictive ability of the relation between turbidity and the treatment devices.

The effect of turbidity on MSF microbial removal effectiveness (B= -0.048, B=-0.002) from this it can be conclude that turbidity on MSF has less effect on microbial removal effectiveness. The results of this study oppose the findings of Mwabi, et.al.(2012) observed that high microbial removal effectiveness at high turbidity level from this study it can be conclude that the load of turbidity of water samples indicates high microbial load rather than organic, inorganic and dissolved matter.

6.7 Comparing the microbiological removal effectiveness of POU devices

Microbiological removal effectiveness of selected devices was compared using load of EC, FC and TC indicators measuring pre and post treatment variations. The average values of removal effectiveness of each device were compared. As showed before in this study 68.6, 65.2, 64 and 58.1% of average microbial removal effectiveness tulip, Wuha-agar, modified sand filter and ceramic filter was registered respectively.

From this point of view, the study suggests using Tulip filter provides high effectiveness followed by chemical disinfectant Wuha-agar; from four different water sources; having different character, contamination and turbidity level and also not for a single bacterium it was also evaluated on average removal values of three indicators which make the result influential. Therefore, a device that improves water quality and removes turbidity and bacteria under various water source conditions will provide the communities with high-quality water regardless of the quality of the source water, as reported by (Sobsey, et al., 2008).

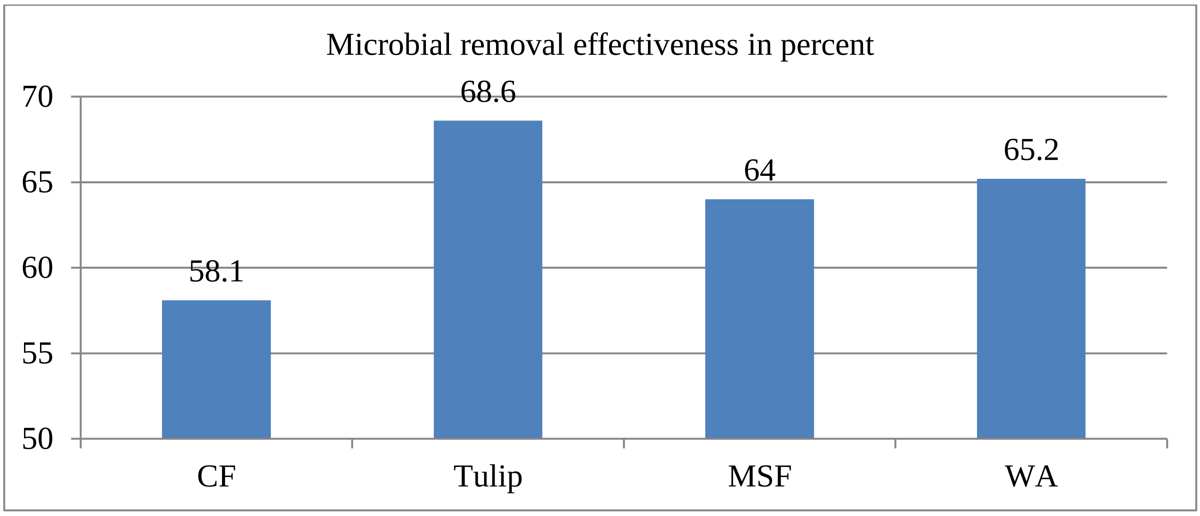

Figure 9 average microbial removal effectiveness of HWTDs

6.8 Limitations of the study

This study was conducted from June to August which is limited on a single season though additional study with seasonal variation is important. Laboratory tests were conducted on water samples collected from the study area; this may not give full information on the effectiveness of the devises; evaluating its efficacy using water samples prepared in the laboratory is essential. The removal effectiveness of the device on other contaminants; since the current was limited on EC, FC and Total coliforms CFU it needs further investigation.

Chapter 7 Conclusion and recommendation

7.1 Conclusion

In this study 68.6, 65.2, 64 and 58.1% of average microbial removal effectiveness tulip, Wuha-agar modified sand filter and ceramic filter was registered respectively. From these commercially available water treatment devices, Tulip filter followed by Wuha agar was removed higher and registered good performance in this study. Therefore, the study suggests using Tulip filter provides high effectiveness followed by Wuha-agar; from four different water sources; having different character, contamination and turbidity level and also not for a single bacterium it was also evaluated on average removal values of three indicators which make the result influential.

Also regression analysis of factors affecting the microbial removal effectiveness of devices with flow rate and turbidity was analyzed and turbidity affects at 99% significant level while flow rate not affects at 99% significant level. This shows that there are also other factors that can influence microbial removal effectiveness of these household water treatment devices for future study.

7.1 Recommendation

This study identified the commonly used POU water treatment devices in Jimma town and evaluated the microbial removal and turbidity reduction effectiveness of those devices. Based on the investigation it is recommended that

- for the community to use ceramic candle/tulip filter followed by chemical disinfectant Wuha agar since resulted better performance in removal effectiveness
- to create awareness on implementing, handling and its health impact of POU water treatment devices in the area; for health professionals
- Further studies on removal effectiveness of chemical contaminants; cleaning method of these POU water treatment devices.

Reference

A. O. Sojobi S. I. Dahunsi and A. O. Afolayan ASSESSMENT OF THE EFFICIENCY OF DISINFECTION METHODS FOR IMPROVING WATER QUALITY [Journal]. - [s.l.] : Nigerian Journal of Technology (NIJOTECH), 2015.

Abrham G Bezatu M, Esayas A, Daniele SL, Jonathan M, Geremew S Point-of-use water chlorination among urban and rural households with under-five year children: A comparative study in Kersa Health and Demographic Surveillance Site, Eastern Ethiopia. Journal of Water Sanitation and Hygiene for Development [Journal]. - 2018a.

Alebel A Tesema C, Temesgen B, Gebrie A, Petrucka P, Kibret GD Prevalence and determinants of diarrhea among under-five children inEthiopia: a systematic review and meta-analysis. [Journal] // PLoS One. - 2018.

Alex Saturday George Lukoye Makokha, Anthony Macharia Performance of Household Water Treatment Methods for Microbial Removal under Household Conditions in Kabale District, Uganda [Journal] // Journal of Environment and Health Science (JEHS). - 2016.

Amber Franz A PERFORMANCE STUDY OF CERAMIC CANDLE FILTERS IN KENYA INCLUDING TESTS FOR COLIPHAGE REMOVAL [Journal]. - [s.l.] : MIT, 2005.

Atomissa Kelbessa Gutema Development of Ceramic Pot Water Filter for Household Drinking Water Treatment forRemoval of Total and Fecal Coliform Bacteria [Journal]. - Addis Ababa : Addis Ababa University, 2010.

Ayenew Yirdaw Meride and Bamlaku Drinking water quality assessment and its effects on residents health in Wondo genet campus, Ethiopia [Journal] // Environmental System Research aspringerOpen Journal. - 2016. - p. 2.

Bayable Atnafu Kassa Adey Feleke Desta and Fassil Assefa Evaluating the efficacy of household filters used for the removal of bacterial contaminants from drinking water [Journal] // African Journal of Microbiology Research. - 2020. - p. 274.

Bayable Atnafu Kassa Adey Feleke Desta and Fassil Assefa Evaluating the efficacy of household filters used for the removal of bacterial contaminants from drinking water [Journal] // African Journal of Microbiology Research. - 1 June, 2020. - p. 273.

Brown Joseph Mark EFFECTIVENESS OF CERAMIC FILTRATION FOR DRINKING WATER TREATMENT IN CAMBODIA [Journal]. - Chapel Hill : University of North Carolina Chapel Hill, 2007.

CAWST Biosand Filter Manual: Design, Construction, Installation, Operation [Journal]. - [s.l.] : CAWST, 2008.

CAWST Household Water Treatment and Safe Storage [Book]. - Canada : [s.n.], June,2011.

CAWST Introduction to Drinking Water Quality Testing [Book]. - Canada : [s.n.], October,2013.

CAWST Introduction to Drinking Water Quality Testing [Journal]. - 2013.

CDC Preventing Diarrhoeal Disease in Developing Countries: The Safe WaterSystem Program, US Centres for Disease Control and Prevention [Journal]. - USA : [s.n.], 2006.

CES-58 Compulsory Ethiopian Standard for drinking water [Journal]. - 2013.

Chaudhuri M., S. R. Verma, et al. Performance Evaluation of Ceramic Filter [Journal]. - [s.l.] : Journal of Environmental Engineering-Asce, 1994.

Clasen et.al. Interventions to improve water quality for preventing diarrhoea: [Journal]. - 2007.

CSA Population projections for Ethiopia 2007–2037 [Journal]. - [s.l.] : CSA, 2020.

D. Brown C. Farrow, E. A. McBean, B. Gharabaghi and J. Beauchamp Advancing performance evaluation standards for household water treatment technologies [Journal] // Journal of Water and Health. - 2019.

Daba Desissa QUALITY ASSESSMENT OF RURAL DRINKING WATER SUPPLY SCHEMES FROM SOURCE TO -POINT OF- USE. (A CASE STUDY OF ADA"A WOREDA, IN OROMIA REGIONAL STATE OF ETHIOPIA). [Report]. - [s.l.] : ADDIS ABABA UNIVERSITY, December, 2016. - p. 6.

Deneke Israel Assessment of Drinking Water Quality and Pollution Profiles along Awetu stream (Jimma) [Journal] // Addis Ababa University School of Graduate Studies Environmental Science Programme. - 2006. - p. 15.

Deneke Israel Assessment of Drinking Water Quality and Pollution Profiles Along Awetu Stream (Jimma) [Report]. - Adis Abeba : Addis Ababa University School of Graduate Studies Environmental Science Programme, 2007.

Deneke Israel Assessment of Drinking Water Quality and Pollution Profiles Along Awetu Stream (Jimma) [Journal]. - [s.l.] : Addis Ababa University, 2007.

Doulton Doulton Water Filter Ceramic Candle & Cartridge Technologies [Journal]. - 2009.

ECSA Drinking Water Quality in Ethiopia [Journal]. - [s.l.] : Central Statistical Agency of Ethiopia Ministry of Water, Irrigation and Electricity (MOWIE),LSMS, World Bank, UNICEF, WHO, and JMP, December 2017.

Edessa Negera Geritu Nuro and Mulugeta Kebede Microbiological assessment of drinking water with reference to diarrheagenic bacterial pathogens in Shashemane Rural District, Ethiopia [Journal] // African Journal of Microbiology Research. - 6 January, 2017. - p. 255.

EFSHPF Ethiopia F. School-Health-Program-Framework. . [Report]. - 2017.

EPA In EPA Guidance Manual, Turbidity Provisions; [Journal]. - USA : Environmental Protection Agency, 1999.

ESSA MANYAWKAL BIREDA ASSESSMENT OF WATER ACCESS AND PREVALENCE OF WATERBORNE DISEASES IN RURAL COMMUNITY: A CASE OF ENDEGAGN WOREDA, GURAGE ZONE, SNNPR,ETHIOPIA [Journal] // Indira Gandhi National Open University. - 2015. - p. 12.

Fewtrell L., Kaufmann, R. B., Kay, D., Enanoria, W., Haller, L. &Colford, J. M. Water, sanitation, and hygiene interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis [Journal] // Lancet. - 2013.

Group World Bank World Bank Document [Report]. - 2011.

Hailegebriel Belay Zewdu Dagnew and Nurilign Abebe Small scale water treatment practice and associated factors at Burie Zuria Woreda Rural Households, Northwest Ethiopia,2015: cross sectional study [Journal] // BMC Public Health. - 2016. - p. 2.

ICF CSA and Ethiopia Demographic and Health Survey 2016 [Journal]. - [s.l.] : Central Statistical Agency and ICF International, 2016.

J.K. Mwabi F.E. Adeyemo , T.O. Mahlangu , B.B. Mambab, B.M. Brouckaert c, C.D. Swartz c,G. Offringa d, L. Mpenyana-Monyatsi a, M.N.B. Mombaa,⇑ Household water treatment systems: A solution to the production of safe drinking water by the low-income communities of Southern Africa [Journal]. - South Africa : Elsevier Ltd, 2011.

Jackson Water in changing world, Issues in Ecology. [Journal] // Washington,. - 2001. - pp. pp 1–16.

Jeff A lbert Jill Luoto and David Levine End-User Preferences for and Performance of Competing POU Water Treatment Technologies among the Rural Poor of Kenya [Journal]. - [s.l.] : ENVIRONMENTAL SCIENCE & TECHNOLOGY, 2020.

Jerome N Chuanwu X, Azhar S, Annette V, Basem S Influence of Household Water Filters on Bacteria Growth and Trace Metals in Tap Water of Doha, Qatar. [Journal]. - 2018.

Johnson D.M. [et al.] Feasibility of water purification technology in rural areas of developing countries [Journal]. - [s.l.] : J. Environ. Manag., 2008.

K. Mwabi, et.al.,2012 Removal of Escherichia coli and Faecal Coliforms from Surface Water and Groundwater by Household Water Treatment Devices/Systems: A Sustainable Solution for Improving Water Quality in Rural Communities of the Southern African Development Community Region [Journal]. - [s.l.] : International Journal of Environmental Research and Public Health.

Kati Martikainen Ari Kauppinen , Ville Matikka , Anna-Maria Veijalainen ,Eila Torvinen , Tarja Pitkänen , Ilkka T. Miettinen and Helvi Heinonen-Tanski Efficiency of Private Household Sand Filters in Removing Nutrients and Microbes from Wastewaterin Finland [Journal]. - [s.l.] : Water, 2018.

Küng Nina Household drinking water in rural Ethiopia -impact of defluoridation filters on microbial drinking water quality in the Rift Valley [Journal]. - [s.l.] : eawag, 2011.

Liben Bulti K. Fufa and Melkam D. Bacteriological quality of drinking tap water in selected districts of north showa zone, Amhara, Ethiopia [Journal] // Scholars Research Library. - 2016. - p. 24.

Manyazewal. Tewodros Tewodros Manyazewal. Bacteriological and Physico-Chemical Quality of Deep Well Water Source in Jimma, Southwest Ethiopia [Journal]. - [s.l.] : JOJ Pub Health, 2019.

MENON THOMAS CLASEN & SHASHIKALA Microbiological performance of common water treatment devices for household use in India [Journal] // International Journal of Environmental Health Research. - 2007.

MENON THOMAS CLASEN AND SHASHIKALA Microbiological performance of common water treatment devices for household use in India [Journal]. - [s.l.] : International Journal of Environmental Health Research, 2007.

Micheal2 Alemu Lelago Bulta1* and Geremew Arega W. Evaluation of the efficiency of ceramic filters for water treatment in Kambata Tabaro zone, southern Ethiopia [Journal] // Environmental system research. - 2019.

Ministry of Water Irrigation and Electricity (MOWIE),LSMS, World Bank, UNICEF, WHO, and JMP Drinking Water Quality in Ethiopia [Journal]. - [s.l.] : Central Statistical Agency of Ethiopia, December 2017.

Momba Resoketswe Charlotte Moropeng and Maggy Ndombo Benteke Assessing the Sustainability and Acceptance Rate of Cost-Effective Household Water Treatment Systems inRural Communities of Makwane Village, South Africa [Journal]. - [s.l.] : Crystals, 2020.

MWA HWTS in Ethiopia: The State of Art and Ideas to Scale Up [Report]. - [s.l.] : Millennium Water Alliance, 2014.

MWA HWTS in Ethiopia: The State of Art and Ideas to Scale Up [Journal]. - 2014.

OSHO Possible field sites for RP and IP: Results od the field trip in November 2009 [Journal]. - Modjo : [s.n.], 2009.

SAGARA JUNKO STUDY OF FILTRATION FOR POINT-OF-USE DRINKING WATER TREATMENT IN NEPAL [Journal]. - [s.l.] : MASSACHUSETTS INSTITUTE OF TECHNOLOGY, 2000.

Salvato J.A. Sanitation Handbook [Journal]. - [s.l.] : UNICEF / USAID, 1997.

Sobsey M. [et al.] Point of use household drinking water filtration: A practical, effective solution for providing sustained access to safe drinking water in the developing world [Journal] // Environ. Sci. Technol. - 2008. - pp. 42, 4261-4267.

Sobsey M.D., Managing Water in the Home: Accelerated Health Gains from Improved Water Supply [Journal]. - Geneva : WHO, 2002.

Sobsey Managing Water in the Home: Accelerated Gains from Improved Water Supply [Journal]. - Geneva, Switzerland : WHO, 2002.

Stauber Christine E. THE MICROBIOLOGICAL AND HEALTH IMPACT OF THE BIOSAND FILTER IN THE DOMINICAN REPUBLIC:A RANDOMIZED CONTROLLED TRIAL IN BONAO [Journal]. - [s.l.] : Core, 2007.

Thomas Clasen Suresh Nadakatti and Shashikala Menon Microbiological performance of a water treatment unit designed for household use in developing countries [Journal] // Tropical Medicine and International Health. - [s.l.] : Tropical Medicine and International Health, 2006.

Thomas Clasen1 Suresh Nadakatti2 and Shashikala Menon3 Microbiological performance of a water treatment unit designed for household use in developing countries [Journal] // Tropical Medicine and International Health. - 2006.

Troeger et al. Quantifying risks and interventions that have affected the burden of diarrhoea among children younger than 5 years: an analysis of the Global Burden of Disease Study 2017 [Journal]. - [s.l.] : Risk Management and Healthcare Policy, 2021.

UNEP/WHO Water Quality Monitoring - A Practical Guide to the Design and Implementation of Freshwater QualityStudies and Monitoring Programmes [Book]. - London, UK : [s.n.], 1996.

UNICEF [Book Section] // UNICEF Handbook on Water Quality.. - New York, USA : UNICEF, 2008.

UNICEF One Is Too Many: Ending Child Deaths from Pneumonia and Diarrhoea [Journal]. - 2016.

UNICEF WHO Water safety planning for small community water supplies: Step-by-step risk management guidance for drinking-water supplies in small communities [Journal]. - [s.l.] : UNICEF, WHO, 2012.

Wakene Alemu Gizaw Comparative Study on Biogas Production Potential of Sewage, Slaughterhouse, Fruit-Vegetable Wastes and their Co-digestion [Journal]. - 2016.

WHO Combating waterborne disease at the household level. WHO/The International Network to Promote Household Water Treatment and Safe Storage [Journal]. - [s.l.] : WHO, 2007.

WHO EVALUATING HOUSEHOLD WATER TREATMENT OPTIONS: Health-based targets and microbiological performance specifications [Book]. - 2011. - p. 8.

WHO Guideline for Drinking Water Quality [Journal]. - 2004.

WHO Guidelines for drinking-water quality [Journal] // WHO. - 2004.

WHO GUIDELINES FOR DRINKING-WATER QUALITY THIRD EDITION INCORPORATING THE FIRST AND SECOND ADDENDA Volume 1 Recommendations [Book]. - Geneva : [s.n.], 2008. - p. 121.

WHO National Household Water Treatment and Safe Storage Strategies and Integrated Household Environmental Health Interventions [Report]. - [s.l.] : Water Institute at the University of North Carolina at Chapel Hill, 2011.

Yilma Zewditu Evaluation of Household Bio-Sand Filters for Pathogen and Inorganic Substances Removal Efficiency in Ada'a Woreda,Oromia Region [Journal]. - Addis Ababa : Addis Ababa University School of Graduate Studies, 2009.

Annexes

Annex 1: Experimental Procedures for membrane filter treatment

1. All the materials listed above necessary for the study were sterilized
2. Some samples were diluted to make them easily countable
3. Aseptically the filter paper was removed and putted in the sterilized filtration apparatus
4. 100ml of diluted sample was taken and added to the filtration apparatus
5. The pump was turned on to filter the sample
6. Aseptically removed the filter paper with bacteria using sterile forceps and putted on absorbent pad containing 2ml sterile m-lauryl sulphate Broth and the Petri dish was covered
7. All the Petri dish were labeled
8. Incubated at temperature 37 ^{o}c for 48 hours for total coliform and 44.5^{o}c for 24hour for fecal coliform and E. coli
9. After incubation all the CFU were counted identifying by color and the result was recorded
10. Finally number of CFU were calculated per 100ml of sample using the following formula

Annex 2: Materials and chemical used for microbial removal efficiency test of (HHWTD)

Membrane filter paper
Absorbent pad
Petri dish
Autoclave
Incubator
Membrane filtration apparatus
Forceps
Pipettes
Pipette tips
Magnifying glass
Sterilized bottles
Cold box
Turbidity meter
Multi parameter probe

Ceramic filter

Tulip

Modified sand filter

Refrigerator

Bucket

Balance

Chemicals used

Wuha agar

Culture or growth media M-lauryl sulphate Broth

Alcohol 70%

Sodium thio- sulphate

Annex 3: summarized result for experimental work

Tulip hh water treatment device effectiveness using different water sources

No	Sources of water	E.coli (bf)	E.coli (af)	Log10 (bf)	Log10(af)	LRV(log10(bf)-log10(af)	% ecol reduction(bf af)/(bf)*1	Tur(bf	tur(af)	%tur reduction(turb
1	Tap	5400	500	3.73	2.69	1.04	90.7	6.23	3.5	44.14
2	Spring	11400	1000	4.05	3	1.05	91.22	4.05	2.95	27.16
3	Ground	1800	1000	3.25	3	0.25	44.44	6	2.65	55.83
4	Rain	9700	2500	3.98	3.39	0.59	74.23	4.6	3.9	15.22

Tulip hh water treatment device effectiveness using different water sources

No	Sources of water	F coli (bf)	F coli (af)	Log10 (bf)	Log10(af)	LRV(log10(bf)-	% fcol reduction(bf af)/(bf)*100	Tur(bf	tur(af)	%tur reduction(
1	Tap	9000	900	3.95	2.95	1	90			
	Spring	18600	1800	4.26	3.25	1.01	90.32			
3	Ground	15000	5400	4.17	3.73	0.44	64			
	Rain	5500	900	3.74	2.95	0.79	83.63			

Tulip hh water treatment device effectiveness using different water sources

No	Sources of water	T. coli (bf)	T.coli (af)	Log10 (bf)	Log10(af)	LRV(log10(bf)-log10(af)	% T.col reduction(bf	Tur(bf	tur(af)	%tur reduction(
1	Tap	22700	11300	4.35	4.05	0.30	50.2			
	Spring	61200	28200	4.78	4.45	0.43	53.92			
3	Ground	39200	22400	4.59	4.35	0.24	42.85			
	Rain	22100	11600	4.34	4.06	0.28	47.5			

Ceramic filterhh water treatment device effectiveness using different water sources

No	Sources of water	E.coli (bf)	E.coli (af)	Log10 (bf)	Log10(af)	LRV(log10(bf)-log10(af)	% E.col reduction(bf	Tur(bf	tur(af)	%tur reduction(turb
1	Tap	700	300	2.84	2.47	0.37	57.14	4.37	3.9	10.75
2	Ground	2200	600	3.34	2.77	0.57	72	5.45	4.6	15.59
3	Spring	1600	600	3.2	2.77	0.43	62.5	5.4	4.2	22.22
5	Rain	1500	6100	3.17	2.77	0.40	60	8.6	7.12	17.21

Ceramic filterhh water treatment device effectiveness using different water sources

No	Sources of water	F coli (bf)	F coli (af)	Log10 (bf)	Log10(af)	LRV(log10(bf)-log10(af)	% fcol reduction(bf af)/(bf)*1	Tur(bf	tur(af)	%tur reduction(turb
1	Tap	1300	300	3.11	2.47	0.64	88.46			
2	Ground	7800	5400	3.89	3.73	0.16	30.77			
3	Spring	110000	45800	4.43	3.53	0.90	58.36			
4	Rain	2100	1700	3.32	3.23	0.09	19.04			

Ceramic filterhh water treatment device effectiveness using different water sources

No	Sources of water	T. coli (bf)	T.coli (af)	Log10 (bf)	Log10(af)	LRV(log10(bf)-log10(af	% T.col reduction(bf af)/(bf)*100	Tur(bf	tur(af)	%tur reduction(turb -tura)
1	Tap	13100	10600	4.11	4.02	0.09	19			
2	Ground	594000	88000	5.77	4.94	0.83	85.18			
3	Spring	27000	3400	5.04	4.66	0.38	87.4			
	Rain	231000	99000	5.36	4.99	0.37	57.14			

Modified sand effectiveness using different water sources

No	Sources of water	E. coli (bf)	E. coli (af)	Log10 (bf)	Log10(af)	LRV(log1 0(bf)-	% E.col reduction(bf	Tur(bf	tur(af)	%tur reduction(turb
1	Tap	5400	600	3.73	2.77	0.96	88.88	6.23	4	35.79
3	Spring	11400	2200	4.05	3.34	0.71	80.7	4.05	3.5	13.58
5	Ground	1800	200	3.25	2.3	0.95	88.88	6	3.3	45
6	Rain	9700	2500	3.98	3.39	0.59	74.23	4.6	3.35	27.17

Modified sand effectiveness using different water sources

No	Sources of water	F coli (bf)	F coli (af)	Log10 (bf)	Log10(af)	LRV(log1 0(bf)- log10(af)	% fcol reduction(bf	Tur(bf	tur(af)	%tur reduction(turb -tura)
1	Tap	9000	1800	3.95	3.25	0.70	80			
2	Spring	18600	9800	4.26	3.99	0.27	47.31			
3	Ground	15000	8200	4.17	3.91	0.26	45.33			
4	Rain	5500	2700	3.74	3.43	0.31	50.9			

Modified sand effectiveness using different water sources

No	Sources of water	T. coli (bf)	T. coli (af)	Log10 (bf)	Log10(af)	LRV(log1 0(bf)- log10(af)	% T.col reduction(bf	Tur(bf	tur(af)	%tur reduction(turb
1	Tap	22700	14500	4.35	4.16	0.19	36.12			
3	Spring	61200	27200	4.78	4.43	0.35	55.55			
5	Ground	39200	21400	4.59	4.33	0.26	45.41			
6	Rain	22100	5900	4.34	3.77	0.57	73.3			

Wuha agar effectiveness using different water sources

No	Sources of water	E.coli (bf)	E. coli (af)	Log10 (bf)	Log10(af)	LRV(log10(bf)-	% E.col reduction(
1	Tap	5400	700	3.73	2.84	0.89	87.03
3	Spring	11400	600	4.05	2.77	1.28	94.74
5	Ground	1800	400	3.25	2.6	0.65	77.77
6	Rain	9700	200	3.98	2.3	1.68	97.93

Wuha agar effectiveness using different water sources

No	Sources of water	F coli (bf)	F coli (af)	Log10 (bf)	Log10(af)	LRV(log10(bf)-log10(af)	% fcol reduction(bf af)/(bf)*100
1	Tap	9000	6000	3.95	3.77	0.18	33.33
3	Spring	18600	13000	4.26	4.11	0.15	30.11
5	Ground	15000	8400	4.17	3.92	0.25	44
6	Rain	5500	700	3.74	2.84	0.90	87.22

Wuha agar effectiveness using different water sources

No	Sources of water	T. coli (bf)	T.coli (af)	Log10 (bf)	Log10(af)	LRV(log10(bf)-log10(af)	% T.col reduction(bf af)/(bf)*100
1	Tap	22700	9000	4.35	3.95	0.40	60.35
3	Spring	61200	31800	4.78	4.5	0.28	48.03
5	Ground	39200	17800	4.59	4.25	0.34	54.59
6	Rain	22100	7300	4.34	3.86	0.48	66.96

Annex 4 Questionnaire

Maqaan koo ___________________tessoo___________________

Ani barrattaa___________________.Yeroo amma kana

qo’anno__________________.

Gaaffif-deebii kana irratti gaaffilee akka hawwas-dinagdee, beekkumsa fi maloota mana kessatti bishaan qulqqullesu dhaaf fayyadamtanu isinan gaaffadha. Deebi issin laattanus waraqaa gaaffano qopha’e kana irratti kan galmaa’u ta’aa. Ragaan asirra arggamu kun koodiin itti kennamee akka iccittin isa eggamu ta’aa; enyummaa namas akka hin ibsinne ni taassifamaa.Hirmaannan issin qo’anno kanna irratti qabdan heyyama kessan irratti kan hundaa’u ta’aa. Qo’anno kanna irratti wan hirmaattannnif midhaan issin irra qaqqabu hin jiru. Akkasumas faayyidaan issin kallatti dhaan arggattan hin jiru garuu bu’aa qo’anno kannan booda dhufu irra fayyadamo ta’u danddessu. Faayidaan qo’anno kanna oddeffanno galtee karoora hojiilee mana kessatti bishaan yaalanii fayyadamu danddessisan akka naannottis ta’ee akka biyyattis jajjabessu fi akka kallaqaman kallatti aggarsisu dhaaf shoora guddaa taphataa. Gaaffif-deebbin kun daqqiqaa 20-30 fudhachu danda’aa. Yeroo kanattis wanti issintti hin tolle yoo jiraate yaada kessan ibsachun gaaffiif-deebbi addan kuttun beellama qabattani yeroo biraa itti fufuu danddessu. Yoo issin yaada kana irratti walligaltatan gaaffif-deebbi Kenya itti fufu danddenyaa.

Qo’anno kana irratti hirmaachuf heyyamamo dha? eyyee/lakkii

Yoo eyyee ta’ee

I. Gaaffanoo manaa-manatti hojjatamu

Guyyaa___________________________

Yeroo/sa’aati___________________________

Maqaa abba warra___________________________Umurii_______Saala________

Saddarkaa barnnoota__________________Amantii____________________

Baay’ina maati_______________Galii waggaa qarshii ___________________________

Tesso(naanno/Godina/magaala/ganda___________________________

GPS Baha_________________ Kaabaa___________________

I. Hubbanno,Ilaalcha fi gocha qulqullina fi bishaan faalame yaalu irratti qaban

1. bishaan dhugaati madda kam irra arggattu?

A. malkaa B. Burqaa C. bolla/ birii D. kan biro_________________

2. Gosoota qulqullina dhaban/Faalama bishaani irratti hubbanno qabdu?

    A. Eyyee B. Lakkii

3. Gaaffii 2ffaa tiif deebin isaani yoo “eyyee” ta’ee gosoota faalama bishaani isaan beekan tarressi

B. Baayolojiikaala ykn lubbu qabeeyyi B. Cheemikaalota summii qaban C. sabbaboota bishaan borressan D. kan biroo_________________

4. Ilaalcha issin bishaan dhugaatiif fayyadamaa jirttan irratti qabdan

    A. Gaarii/qulqullu B. Giddu gallessa/ C. qulqullu miti D.

5. Malloota/tooftaan issin mana kessatti bishaan dhugaati faayyidaaf olchu kessaniin dura raawwattan jiraa ?A. Eyyee B. Lakkii

    Deebin gaaffi 5ffaa “lakkii” yoo ta’ee isa itti aanutti darbii

6. Deebin gaaffi 5ffaa “eyyee” yoo ta’ee tooftaale issaan fayyadaman fi bu’aa arggamu/e tarressi

    Tooftaan fayyadaman bu’aan argamu/e

    a. ___________________________ ___________________________

    b. _________________________ _________________________________

    c. _________________________ ________________________________

    Tooftaalen gaaffi 6ffaa irratti tarrefaman kessa yeroo baay’ee isa kammin fayyadamtu? __________________sababbi kessan maali? __________________tarttiiba hojiichaa ibsii

7. Yeroo hundaa mana kessatti tooftaa bishaan yaalu ni fayyadamtu? A. Eyyee B. Lakkii

8. Yeroo haammamiif tursitani faayyidaaf olchitu? Daqiqaa/sa’aatii ______________

9. Tooftaa kana yeroo haammamiif fayyadamtu?

    A.guyyaatti_____________ B. torbeetti _____________C.guyyaatti si’a tokko D.torbee kessa al-tokko

10. Guyyyaatti bishaan hammam yaaltu ? barmeelii______________

11. Madda bishaani gosa kamiin fayyadamtu?

12. Erga meshaa kana fayyadamttani booda qulqqulinna bishaani irratti garaaggarumaan /jijjiramni jiraa jettani yaaddu?eyyee/ lakkii

    Jijjiramni mul’ate maalii?

    a. Dhandhamaa b. foolii c.qulqqullina d. kan biroo

13. Tooftaa kana fayyadamuuf wanti rakkisu maali? moo salphaa dha? Tooftaa kana bishaan dhugaatiin ala tajaajjila biraatif ni fayyadamtu?
14. Tooftaan kun maati kessanif gahaa dha jettani yaaddu?eyyee/lakkii
15. Yeroo akkamii mana kessatti bishaan teeknoloojiin yaalanii fayyadamu dhaabdu/dhistu ? [deebii fi yaada bal'aatu kennama waan ta'ef, bifa "kan biraan?" jechun gaafadhu]
    a. Yeroo birraa b.yeroo ganna c .yeroo maallaqa dhaban d .yeroo hundaa e. yeroo hojiin baay'atu f. kan biroo______________
16. Teeknoloojii mana kessatti bishaan yaalani fayyadamu maalif hin fudhanne? [deebii fi yaada bal'aatu kennama waan ta'ef, bifa "kan biraan?" jechun gaafadhu]
    b. Dhandhama aja qaba b.foolii aja qaba c. beekkumsa dhabu d.hiraanfachu/daggachu e.yeroo dheraa waan fudhatuf f. waan cabuuf g. maallaqa guddaa wan gaaffatuf h. kan biroo______________
17. Teeknolojii mana kessatti bishaan yaalu akkamitti fudhttani? [deebii fi yaada bal'aatu kennama waan ta'ef, bifa "kan biraan?" jechun gaafadhu]
    A. Qulqquluman isaa wan egamuf B. qulqullu waan ta'uf C.dhukkuba ittisa waan ta'ef D. nama irra dhagaheen E. kan biroo______________
18. Teeknolojii kana ilaalchisee leenjii ykn erga darbu fudhattani/dhaggessanni beektu ?
    A. Eyyee B. Lakkii
19. Leenjii gosa akkammi fudhattanii? [deebii fi yaada bal'aatu kennama waan ta'ef, bifa "kan biraan?" jechun gaafadhu]

A. Walga'ii ummataa B. daawwi mana- manaa C.Saggantaa beekssisa raadiyoo irra D.Ergaa bilbbila irra E.tiyaatrii iira F. kan biroo: ______________

20. Qaama kamtu leenjise? [deebii fi yaada bal'aatu kennama waan ta'ef, bifa "kan biraan?" jechun gaafadhu]
    a.qaamota beeksisa hojjatan irra b.hojjattoota eksteenshinii fayyaa irra c.dhaabata miti- moottuma irra d. abbooti ammantaa/gaggesitoota ummata irra e.hiriyaa,olla, irra f. kan biroo: ______________
21. Osoo meshaan issin itti fayyadamaa jirttan kun issin jalaa cabee iddo gurggurtaa /suphaa meshaa kanaaf olanu ni beektuu?
    a. Eyyee b. lakkii
22. Bishaan yaalame fayyadamun dirqamma kooti jettani yaaddu?
    A. Eyyee b. haamma ta'ee c. lakkii d. hin beeku

23. Guyyoota 15n darban kessatti maati kessan kessaa namni garaa –kaasaa dhukkubsate jiraa?

    A. Eyyee B. Lakkii

    Deebiin gaaffi 23 ffaa eyyee yoo ta'e mana kessa nama meeqatu dhukkubsate?

    a.1 b.2 c.3 d. 4

24. Dhukkuboota sababa qulqqulin dhabu/faalamu bishaanitiin maddan isa kammin beektu ?

    1. Ameebaa
    2. Garaa-kaasaa
    3. Jaardiyaa
    4. Kan biroo____________________

25. Teeknoloojii mana kessatti bishaan yaalanni fayyadamu waggaa meeqaaf hojii irra olchittani ?

    a. Waggaa 1 b. Waggaa 2 c. Waggaa 3 d. Waggaa 4 fi isa ol

26. Teeknoloojii mana kessatti bishaan yaalanni fayyadamun barbaachisa akka ta'e nammoota kan biraatiif muxxanno kessan dabbarsittani beektu ?

    A. eyyee B. lakkii

Galatooma!

Declaration

I declare that this is an original work and has not been submitted, in whole or in part, in any previous application for a degree or professional qualification in any other institution. I confirm that due references have been provided on all supporting literature and contributor to any resources in this work has been appropriately acknowledged.

Name: Mekasha Belete Signature: __________ Date: _________

Institution: Jimma University, Institute of Health, Jimma, Ethiopia

This thesis work has been undertaken under our supervision as advisors, I confirm the finalization of his MSc. thesis work.

Name:______________________________Signature: __________ Date: _________

Name:______________________________Signature: __________ Date: _________