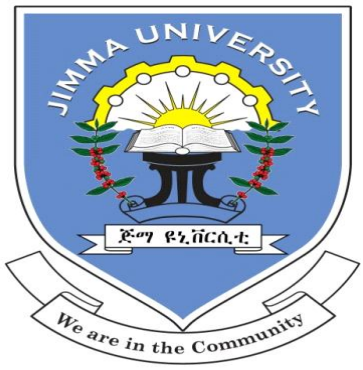

JIMMA UNIVERSITY COLLEGE OF PUBLIC HEALTH AND MEDICAL SCIENCES
DEPARTEMENT OF ENVIRONMENTAL HEALTH SCIENCE AND TECHNOLOGY

DETERMINANT FACTORS OF BACTERIOLOGICAL CONTAMINATION OF DRINKING WATER AT THE HOUSE HOLD LEVEL IN HIDI HORA, SERBO AND TURFE SEMI URBAN VILLAGES, OROMIA REGION, ETHIOPIA

BY: ELIAS AYANA

SEPTEMBER 2013
JIMMA, ETHIOPIA

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MASTER THESIS SUBMITTED TO THE DEPARTEMENT OF ENVIRONMENTAL HEALTH SCIENCE & TECHNOLOGY, COLLEGE OF PUBLIC HEALTH AND MEDICAL SCIENCES, SCHOOL OF GRADUATE STUDIES, JIMMA UNIVERSITY; IN THE PARTIAL FULFILLIMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ENVIRONMENTAL SCIENCE AND TECHNOLOGY, SPECIALITY IN ENVIRONMENTAL TECHNOLOGY

Name of the researcher: Elias Ayana

Advisors: Dr. Argew Ambelu (PhD)

Mrs. Sabilework Mokonnen (MSc, PhD fellow)

SEPTEMBER 2013

JIMMA, ETHIOPIA

DECLARATION

I, the undersigned, declare that this thesis is my original work from the data I obtained from Dr. Argaw project that has not been presented for a degree in this or any other university and that all sources of materials used for the thesis have been fully acknowledged. For further utilization of the data, I have to ask the data owner.

Name: Elias Ayana

Signature: _____

Name of the institution: Jimma University

Date of submission: 16/09/2013

This thesis has been submitted for examination with my approval as University advisor

Name and signature of the first advisor _____

Dr. Argew Ambelu (PhD)

Name and signature of the second advisor _____

Msr. Seblework Mekonnen(MSc, PhD fellow)

ABSTRACT

Water quality is a critical factor affecting human health and welfare. Studies showed that approximately 3.1% of deaths and 3.7% of disability-adjusted-life-years worldwide are attributable to unsafe water, poor sanitation and hygiene (WHO, 2005). Ethiopia is one of the countries which adopted the millennium development declaration to reduce the poverty of the country at 2015 (UNDP, 2008).Even if drinking water of poor urban communities is obtained from a safe source, it can become contaminated at the point-of-use (William et al., 2007). To know bacteriological contamination of house hold drinking water between source and point-of-use, 78 households' drinking water sample were taken from the three Sami urban villages, Oromia region, Ethiopia. The samples of the drinking water were examined for its bacteriological quality and associated the result with socio-demographic characteristics, the water collection, storage, handling, sanitary practices, walking distance of the source of water, total volume of water collected at a time, and time since water was collected. Standard methods were used to determine the presence of indicator organisms. Household water quality was characterized by relatively high levels of E. coli and F.coliform. Water from households has significantly more E. coli and F.coliform than water from the source. The arithmetic mean E.coli for all samples from the sampled households was 185.6 E.coli per 100 ml water and 199.8 F.coliform per 100ml of the house hold drinking water. Almost three quarters of the households, 74.4%, had water with greater than zero E. coli /100 ml of water and 89.74%, had water with greater than zero F.coliform/100ml of water. SPSS version 16 statistical analysis was used for the analysis of determinant factors of water recontamination at the house hold level in this study. According to the logistic regression analysis in this study, bacteriological contamination of water at the house hold level is significantly associated with the water collection, storage, handling, environmental sanitary practices, walking distance of the source of water from the house hold, total volume of water collected at a time and time since water was collected. This study points to the need to extend drinking water quality beyond the point of distribution to the point of consumption. A household questionnaire survey indicated an urgent need for education concerning the risk of waterborne diseases, the proper use of safe household water-storage devices and water treatment processes and improvement of hygiene and sanitation practices.

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ACRONOMY AND ABBREVIATIONS

AAWSA: Addis Ababa Water and Sewerage Authority

AOR: Adjusted odd ratio

ANOVA: Analysis of Variance

COR: Crude odd Ratio

CI: Confidence Interval

E. coli: *Escherichia coli*

EPA: Environmental Protection Authority

FC: Feacal coliform

HACCP: Hazard and Critical for Critical Control Point

HWTS: Household Water Treatment and Safe Storage

ISO: International Standard Organization

MDG: Million Development Goal

MF: Membrane Filtration

MLSB: Membrane Lauryl Sulfate-Based medium

MPN: Most Probable Number

P/A: Presence/Absence

TC: Total Coliform

TTC: Thermo tolerant coliform

UN-WATER/WWAP: United Nations Water/World Water Assessment Program

USEPA: United State Environmental Protection Agency

USA: United state of America

WASH:water and sentation hygiene

CHAPTER ONE: INTRODUCTION

1.1. Background

Water quality is a critical factor affecting human health and welfare. Studies showed that approximately 3.1% of deaths (1.7 million) and 3.7% of disability-adjusted-life-years (DALYs) (54.2 million) worldwide are attributable to unsafe water, poor sanitation and hygiene (WHO, 2005). Ethiopia is one of the countries which adopted the millennium development declaration to reduce the poverty of the country at 2015 (UNDP, 2008). This resulted in prioritizing accessibility to improved water supply. Many researchers have shown that access to clean water is the significant element for poverty alleviation (Water Aid, 2009). Access to safe drinking water and sanitation is a global concern. However, developing countries, like Ethiopia, have suffered from a lack of access to safe drinking water from improved sources (WHO, 2006). As a result, people are still using unprotected water sources such as rivers, streams, springs and hand dug wells. These sources are open, they are highly susceptible to flood and birds, animals and human contamination. In addition, most sources are found near gullies where open field defecation is common and flood-washed wastes affect the quality of water. Additionally, water-borne infectious diseases create more poverty and slow economic growth. The International Water Decade's goal, to be achieved by 2015, is to reduce by half the proportion of people who regularly obtain their drinking water from unsafe sources. The goal also calls for better access to basic sanitation. Without safe drinking water basic sanitation is unthinkable. Despite the consensus on the critical need for clean water to improve child and population health, simple provision of clean water through municipal or private piped systems has not yielded the expected immediate health improvements in most developing countries (Clasen & Cairncross, 2004). Recent systematic reviews and meta-analyses of interventions to improve water quality suggest that, although such interventions are generally effective in preventing diarrhea, the substantial variation across water improvement trials points to still unknown factors that influence water quality and diarrhea (Clasen et al., 2007). This suggests to us that detailed research is needed on how household socio-demographic and sanitation factors influence water quality by structuring access to, and use of, different types of water source. These structuring factors include spatial factors such as origin of, as well as distance to water sources, especially in rural areas (Jagals et

al., 1999), and the location of households along the rural to urban continuum (Wright et al, 2004). Urban places with high population densities may not have access to safe drinking water, and water transported long distances may not be safety to use(Wright et al., 2004).Household socio-economic status measures such as education and occupation may be associated with exposure to, and perceived salience of, health education about water quality and sanitary habits. For example, detailed evidence from behavioral studies of water use and quality indicates the roles played by variations in household storage of water and sanitary habits, such as hand washing, on microbiological contamination of household water supply (Clasen & Bastable, 2003; Brick et al., 2004; Trevett et al., 2005). Household social and economic variables are also associated with types of toilet facility and waste disposal pattern, which directly affect water quality (Wright et al., 2004; Cronin et al., 2006). Despite the demonstrated importance of more proximate individual behavioral factors on water quality, socio-demographic studies of household water quality may help answer questions about variations at community and household level in water acquisition, use and quality. As investments are made to establish modern water systems, such research can lead to more efficient design and targeting of household and community training about water sources, safe use and storage at the house level as well as waste disposal. The purpose of this paper is to examine associations between social and demographic characteristics, water sources, sanitation factors and household drinking water quality in a representative sample of residents of the three villages in the three districts of Oromia, one of the nine administrative regions in Ethiopia. This study focuses on determinants of bacteriological water quality at the house hold level such as hand-washing facility, water storage system, socio-economic variations between communities and households that contribute to household water quality levels and which may produce health inequalities, such as differences in diarrhea risk. As infrastructure improvements proceed as part of economic development, attention must be paid to the link between socioeconomic and health inequalities for etiologic understanding and applied interventions (Braveman & Tarimo, 2002; Marmot, 2005).

1.2. Statement of the problem

Diseases caused by contaminated water consumption and poor hygiene practices are the leading causes of death among children worldwide (WHO, 2004). Lack of safe drinking water, absence of basic sanitation and hygienic practices are associated with high morbidity and mortality from excreta related diseases (WHO, 2003). Water may be contaminated with pathogens at the source but contamination may also occur during distribution, transportation, or handling in households or other working places (WHO, 2004). If raw water is used without any more treatment, it brings a sanitary risk (WHO, 1996). Insufficient protection of water collection and storage containers and unhygienic conditions contribute to contamination at house hold (Nath et al., 2006).The provision of water, sanitation and good hygiene services is vital for the protection and development of human resources (Fewtrell et al., 2000).Ethiopia is one of the countries in the world with the worst of all water quality problems. It has the lowest water supply and sanitation coverage in Sub-Saharan countries with only 42% and 28% for water supply and sanitation, respectively (WHO, 2002). Most of the population of Ethiopia does not have access to safe and reliable sanitation facilities. Still further, most of its population does not have access to safe and reliable sanitation facilities. On top of these, majority of the households do not have sufficient understanding of hygienic practices regarding food, water and personal hygiene. As a result, over 75 % of the health problems in Ethiopia are due to communicable diseases attributed to unsafe and inadequate water supply, and unhygienic waste management, particularly human excreta (UN-WATER/WWAP, 2004). There are a number of pollution sources that continuously deteriorate the bacteriological quality of surface and groundwater as well as water at the households' level in this study area. The majorities of the pit latrines are often badly constructed and improperly maintained and frequently overflow to affect the quality of the water at the household level.

In Ethiopia no published work has been found on examining the determinant factors that can affect the quality of drinking water at the house hold level. Although on other aspects of drinking water, governments' agencies, non-governmental organizations (NGOs) and private drinking water companies, do have reports on the bacteriological quality of the drinking water at the source, but they fail to conduct a research-based study that could then be published on bacteriological contamination of water at the house hold level. In other developing countries such studies are found but in a very small number. However, no study has been done on the

determinant factor of bacteriological contamination of drinking water at the house hold level. The aim of this study was therefore to analyze the key determinant factors of bacteriological contamination of drinking water at the household level in the randomly selected study areas.

1.3 Significance of the study

The research has the following significances in our country:

- The study shows the degree of bacteriological contamination of drinking water at the house hold level.
- It helps the Ministry of water and energy, Ministry of health to develop systematic strategy to bring behavior change communication to improve hygiene, sanitation, and water handling practices.
- It helps the Ministry of water and energy, and Ethiopian ministry of health as input to teach the community to use household water treatment to improve water quality and reduces diarrheal disease in our country.

CHAPTER TWO: LITRATURE REVIEW

2.1. Water quality parameters

Drinking water or potable water is defined as having acceptable quality in terms of its physical, chemical, bacteriological parameters so that it can be safely used for drinking and cooking (WHO, 2004).WHO defines drinking water to be safe if and only if no any significant health risks during its lifespan of the scheme and when it is consumed. This thesis focuses on bacteriological water quality for drinking and domestic uses.

2.2. Health hazards associated with contaminated water

The Health hazards of water can be divided into four categories based upon the source of the involved Pathogen and the route by which human recipients come in contact with that pathogen. Those categories could be defined as follows:

- Water-borne diseases: caused by water that has been contaminated by human, animal or chemical wastes. Examples include cholera, typhoid, meningitis, dysentery, hepatitis and diarrhea. Diarrhea is caused by a host of bacterial, viral and parasitic organisms most of which can be spread by contaminated water (WHO, 2006). Poor nutrition resulting from frequent attacks of diarrhea is the primary cause for stunted growth for millions of children in the developing world (Gadgil, 1998).
- Water-related vector diseases: These are diseases transmitted by vectors, such as mosquitoes that breed or live near water. Examples include malaria, yellow fever, dengue fever and filariasis. Malaria causes over 1 million deaths a year alone (WHO, 2006). Stagnant and poorly managed waters provide the breeding grounds for malaria-carrying mosquitoes.
- Water-based diseases: These are caused by parasitic aquatic organisms referred to as helminthes and can be transmitted via skin penetration or contact. Examples include Guinea worm disease, filariasis, paragonimiasis, clonorchiasis and schistosomiasis.
- Water-scarce diseases: These diseases flourish in conditions where freshwater is scarce and sanitation is poor. Examples include trachoma and tuberculosis.

The World Health Organization estimates that 80% of all illness in the world was attributable to insufficient water supplies or sanitation. Over 250 million new cases of waterborne diarrhea are reported worldwide each year, resultant in more than 10 million deaths. Today there are many recognized waterborne pathogens. All are present in large numbers in human or animal waste; sporadically both are commonly resistant to environmental decomposition. Many of these pathogens are proficient in causing infections even when ingested in extremely small numbers(Skraber1 et al., 2005).Several types of microorganisms are pathogenic. Typhoid, cholera and gastroenteritis are bacterial diseases, which are commonly waterborne. Similarly, viral diseases such as hepatitis, parasitic worms such as Schist soma (bilharzias) and some tape worms, together with protozoan diseases such as amoebic dysentery, are waterborne. In the production of potable water, all water-borne organisms but especially water-borne pathogens are of concern. The majority of these pathogens affects the gastro-intestinal tract and can be bacteria, viruses, protozoa and sometimes fungi. Viruses, bacteria and protozoa are the three principal groups of microorganisms that can be transmitted via drinking water. They are all transmitted by the fecal-oral route, and so largely arise either directly or indirectly by contamination of water resources by sewage or possibly animal wastes (LeChevallier et al., 1996).Ingress of pathogens into the distribution system can rapidly lead to an infection of thousands of people (Boe-Hansen, 2002). Most health-related water-quality problems are the result of microbial contamination (Smith et al., 2006). Bacteria that cause illness in most individuals is called primary pathogens while those that cause illness mainly in sensitive sub-populations (immuno-compromised, elderly, children) are called opportunistic pathogens. Pathogens are microorganisms that can cause disease in other organisms or in humans, animals and plants. They may be bacteria, viruses, or parasites and are found in sewage, in runoff from animal farms or rural areas populated with domestic and/or wild animals, and in water used for swimming and/ or drinking water. Fish and shellfish contaminated by pathogens, or the contaminated water itself, can cause serious illnesses (Ring, 2003). The majority of waterborne outbreaks are classified as. Acute gastrointestinal illness and etiologic agents include Salmonella, Shigella, Campylobacter, Guardia, Cryptosporidium and viral agents. In addition, there are a number of newly recognized etiologic agents for which there is some evidence of an association with waterborne disease, such as enteric waterborne emerging pathogens which include caliciviruses, E.coli 0157:H_7, Helicobacter sp., Mycobacterium avium complex and protozoa Cryptosporidium sp., Cyclospora

sp. and Taxoplasma sp (OECD/WHO, 2003). Waterborne disease outbreak usually involves, source contamination and the breakdown of the treatment barriers, contamination of the distribution system and the use of untreated water (WHO, 2004b).Access to clean water is not only just an issue for developing countries. Despite wealthy economies and access to proven drinking water-treatment technologies significant outbreaks of waterborne intestinal disease have occurred in North America and Western Europe over the last 10–15 years. Faulty distribution systems are a significant cause of waterborne outbreaks. For example, a review of waterborne outbreaks in the United States from 1991 shows that 38.7% of outbreaks were caused by problems within the distribution system (FPTSDW, 200; Smith et al., 2006). Epidemiological and microbiological characteristics of reported outbreaks of waterborne infectious intestinal disease affecting 4321 people in England and Wales over the period 1992–2003 (Smith et al., 2006). A large waterborne-infection outbreak of infection that occurred during August 2000 in a local community in France was investigated initially via a rapid survey of visits to local physicians (Gallay et al., 2006).The major prevalent water quality problems in Ethiopia are those related to physical, chemical, as well as microbiological parameters, the possible causes of which are natural, anthropogenic or both.

Many infectious diseases are associated with faecally contaminated water and are a major causes of morbidity and mortality worldwide (Leclerk et al., 2002:Theron and Cloete, 2002).Waterborne diseases are caused by enteric pathogens such as bacteria, viruses and parasites that are transmitted by the faecal oral route(Leclerc et al., 2002;Theron and Cloete, 2002).Waterborne spread of infection by these pathogenic microorganisms in the water environment, the infectious dose of the microorganisms required to cause a diseases in susceptible individuals, the microbiological and physical-chemical of quality of the water, the presence or absence of water treatment and the season of the year(Deetz et al., 1984;Leclerc et al., 2002;Theron and Cloete, 2002).

Table 1: Waterborne pathogens and their associated diseases

Waterborne pathogens and their associated diseases (Leclerc et al., 2002; Theron and Cloete, 2002; Yatsuyanagi et al., 2003; NRC, 2004).

	Pathogens	Diseases
Bacteria	Campylobacter spp	Diarrhea and acute gastroenteritis
	Enteropathogenic Escherichia coli	Diarrhea
	Escherichia coli coli 0157;H_7	Bloody diarrhea and haemolytic uremic syndrome
	Salmonella spp	Typhoid fever, diarrhea
	Shigella spp	Dysentery, diarrhea
	Vibrio cholera	Cholera, diarrhea
	Yersinia spp	Diarrhea, gastrointestinal infections
Viruses	Adenoviruses	Diarrhea, respiratory diseases, Conjuctivities
	Astroviruses	Diarrhea
	Coxsackie viruses(Enter viruses)	Respiratory,meningitis,diabetes, diarrhea,vomiting,skin rashes
	Echo viruses(Enter viruses)	Meningitis, diarrhea, myocarditis
	Enter viruses 68-71	Respiratory,meningitis,diabetes, diarrhea,vomiting,skin rashes, acute enter viral hemorrhagic conjunctivitis
	Hepatitis viruses(A,E)	Hepatitis(jaundices), Gastroenteritis
	Caliciviruses	Diarrhea, vomiting
	Polioviruses(Enter viruses)	Poliomyelitis
	Rotaviruses	Diarrhea ,vomiting
	Small round structured viruses	Diarrhea ,vomiting
Protozoan parasite	Cryptosporidium parvum	Cryptosporidiosis, diarrhea
	Entamoeba histolytica	Amoebic dysentery
	Guardia	Giardiasis, diarrhea
Helminthes	Dracunalis medinensis	Guinea worm(Dracunculiasis)
Emerging opportunistic pathogens	Antinobacter spp	Septicemia, meningitis,endocarditis
	Aeromonos spp	Diarrhea, gastroenteritis
	Cyclospora spp	Diarrhia,abdomenial cramping, fever
	Isospora spp	Diarrhea
	Legionella spp	Legionnaires diseases,pontiac fever
	Micro sporidia spp	Gastrointestinal infections, diarrhea
	Non tuberculosis Mycobacterium	Skin infections, cervical lymphadenitis, non tuberculosis mycobacterium diseases
	Pseudomonas aeruginosa	Septicemia, wound and eye infections

2.3. The microbiological quality of water

Water supplies in developing countries are devoid of treatment and the communities have to make use of the most convenient supply(Sobsey, 2002).Many of these supplies are unprotected and susceptible to external contamination from surface runoff ,windblown debris, human and animal faecal pollution and unsanitary collection methods(Chidavaenzi et al., 1998;WHO, 2000;Moyoet al., 2004).Detection of each pathogenic microorganisms in water is technically difficult ,time consuming and expensive and therefore not used for routine water testing procedures(Grabow, 1996).Instead ,indicator organisms are routinely used to assess microbiologically quality of water and provide an easy, rapid and reliable indication of the microbiological quality of water supplies(Grabow, 1996).In order for microorganisms to be used as an indicator organism of pollution, the following requirements should be fulfilled (Grabow, 1986; WHO, 1993; NRC, 2004).

- The concentration of the indicator microorganism should have a qualitative relationship to risk of disease associated with exposure (ingestion /recreational contact) to the water.
- The indicator organisms should be present when pathogens are present.
- The persistence and growth characteristics of the indicator organisms should be similar to that of pathogens.
- Indicator organisms should not reproduce in the environment.
- The indicator organism should be present in higher numbers than pathogens in contaminated water.
- The indicator organisms should be at least as resistance to adverse environmental conditions, disinfection and other water treatment processes as pathogens.
- The indicator organisms should non pathogenic and easy to quantify
- The test for the indicator organisms should be easy, rapid, inexpensive, practice, have adequate sensitivity, quantifiable and applicable to all types of water.
- The indicator organism should be specific to a faecal source or identifiable as to the source of origin of fecal pollution.

2.4. Microbial Indicators

The standard method for measuring microbiological contamination of water involves in the measuring concentration of a microorganisms in the drinking water. Such a test typically entails an indicator organism, such as total coliforms. Total coliform bacteria comprise a diverse array of aerobic and facultative nonaerobic, gram-negative, non-spore forming bacilli that readily grow at 35-37 degrees Celsius given a variety of media broths (WHO, 2006). In terms of diseases stemming from contact with contaminated water, indicator microorganisms are used for their ability to identify likelihood of fecal contamination. Fecal contamination is directly inferred through the presence of two widely used indicator organisms, Escherichia coliform and thermo tolerant coli forms, which are both coliforms of direct fecal origin and part of the total coliform family. Thermo tolerant coli forms are culturable at higher temperatures that are lethal to other coliforms (44.5°C), whereas E.coli can be cultured at body temperature (35° C). Both thermo tolerant coli forms and E.coli cannot grow outside of the body, and thus infer direct fecal contamination of the water tested (WHO, 2004).

2.4.1 Total Coliform Bacteria

Disease-causing organisms can be present in water in small numbers and pose a human health risk. Because of this, indicators of disease-causing organisms present in higher concentrations were initially developed to assess drinking water safety. Because there are numerous coli form bacteria in the intestinal tracts of humans, and each person discharges between 100billion and 400 billion per day, this group was initially chosen as the indicator organism for drinking water safety. The total coli form test is defined by the laboratory method, and not the biology. In the United States, total coli form bacteria are species of Gram-negative rod bacteria that, at 35 degrees Celsius, either ferment lactose with gas production (for most probable number and presence/absence testing); or, produce a distinctive colony on a suitable medium (for membrane filtration testing).This definition includes members of the Escherichia, Klebsiella, Citrobacter, and Enterobacter families. Escherichia is most commonly associated with waterborne disease. Although total coli form bacteria have historically been the standard used for drinking water safety, the WHO has moved away from the use of this indicator to assess human health risk. This is because total coli form bacteria are naturally present in the environment, especially in tropical

countries, and thus does not always indicate presence of human and animal wastes. However, total coli form bacteria are still a valuable indicator for some purposes, including: routine sampling in a treatment process with a history of compliance to regulations; determination of the efficiency of a treatment process if both pre- and post-treatment waters are collected; and risk assessment in lower-risk waters when E. coli is not present.

2.4.2 Thermo tolerant Coliform Bacteria

To provide a more accurate indicator of human health risk, the fecal coli form group was developed. This group is also defined by the laboratory method, and includes those Gram-negative rod bacteria that, at 44 degrees Celsius, either ferment lactose with gas production (for MPN and P/A testing), produce a distinctive colony on a suitable medium for MF testing. This subgroup includes the genus Escherichia, and some species of Klebsiella, Enterobacter, and Citrobacter. The terms fecal coli form bacteria and thermo tolerant coli form bacteria are used interchangeably. The fecal coli form test has also fallen into some disfavor for the assessment of human health risk for many of the same reasons as the total coli form group, primarily their presence in the normal microbiological indicator testing in developing countries, environment in tropical countries. However, fecal coli form bacteria are still a valuable indicator for some purposes, including: routine sampling in a treatment plant with a history of compliance to regulations; determination of the efficiency of a treatment process; and secondary assessment of human health risk after E. coli. The WHO guideline values consider both E. coli and thermo tolerant coli form acceptable tests for drinking water safety.

2.4.3 Escherichia coli

It is bacteria that colonizes the gastrointestinal tract of humans and other mammals shortly after birth and is considered part of our normal intestinal flora. Some types of E.coli, such as E. coli possess virulence factors and can cause diarrheal disease in humans, but most types of E. coli are harmless. A single gram of fresh feces may contain as many as 1billion E. coli. The mammalian gut is the normal habitat for E. coli, and, unlike other coli form bacteria, they are not normally found in uncontaminated waters. This makes E. coli an ideal indicator for human health risk. The presence of E. coli in water always indicates potentially dangerous contamination requiring immediate attention (WHO, 1993).Due to its high prevalence and disease-causing properties,E. coli is a solid microbiological indicator. However, in some less contaminated environments, there is not enough E. coli present to calculate treatment process efficiency. When sampling for both human health risk and treatment efficiency a combined total coli form/fecal coli form bacteria test and E. coli test may need to be completed.

2.5. Why we test for microbiological indicator contaminants

The goal of household water treatment programs, like the CDC Safe Water System, is to reduce diarrheal disease in users by improving the microbiological quality of stored household water. Thus, testing for microbiological contaminants is useful to determine if:

- household drinking water is contaminated before program initiation; and,
- An intervention improves the microbiological quality of stored household water.

Microbiological indicators are bacteria shown to be associated with disease-causing organisms, but do not cause disease themselves. Testing the bacterial contaminants in water can be simplified by utilizing the presence of an indicator organism. An indicator organism may not necessarily pose a health risk but it can be easily isolated and enumerated, is present in large numbers, is more resistant to disinfection than pathogens, and does not multiply in water and distribution systems (Gadgil, 1998). Traditionally, total coli form bacteria have been used to indicate the presence of fecal contamination; however, this parameter has been found to exist and grow in soil and water environments and is therefore considered a poor parameter for measuring the presence of pathogens (Stevens et al., 2003). Studies also show that due to their ability to grow in drinking water distribution systems and their unpredictable presence in water supplies during outbreaks of waterborne disease, the sanitary significance or quality of water is difficult

to interpret in the presence of total coli forms (Stevens et al., 2003). An exception is Escherichia coli, a thermo tolerant coli form, the most numerous of the total coli form group found in animal or human feces, rarely grows in the environment and is considered the most specific indicator of fecal contamination in drinking-water (WHO, 2004). The presence of E. coli provides strong evidence of recent fecal contamination (WHO, 2004; Stevens et al., 2003). The risk of coli form presence can depend on the health or sensitivity of the consumer. The risks of E. coli presence, slightly greater than WHO Guideline zero count per 100ml may be of only low or intermediate risk.

According to USEPA, 2006 about risk classification for thermo tolerant coli forms or E. coli of drinking water is shown below.

Table 2: Water quality counts per 100ml of drinking water and the associated risk

Count per 100ml of water	Risk category
0	In conformity with WHO guide lines
1-10	Low risk
1-100	Intermediate risk
101-1000	High risk
>1000	Very high risk

2.6. Bacteriological requirements of the drinking water

Bacteriological requirement for the bottled drinking water shall conform to the level specified in table (IBWA, 2001)

Table 3**: Bacteriological level of the drinking water**

Organisms	Maximum permissible level	Test method
Fecal Coliform organisms number per 100ml	Undetectable	ES ISO9308^{-1} or ES ISO9308^{-2}
E.coli, number per 100ml	Undetectable	ES ISO9308^{-1} or ES ISO9308^{-2}
Total viable organisms, colonies per 100ml	Undetectable	ES ISO789
Faecal streptococci per 100ml	Undetectable	ES ISO789908^{-1} or ES ISO7899^{-2}

2.7. Water collection from the source water supply

In most developing countries, women are responsible for the collection of water (Sobsey, 2002).The work involved in fetching the water may differ in each region, it may vary according to the specific season, it depends on the time spent queuing at the source, the distance of house from the source and the number of house hold members for which the water must be collected (WHO, 1996b; WHO, 1996c). Water for domestic use is collected either by dipping the container inside the water supply, collecting rain water from a roof catchment system or by using different types of pumps connected to the water supply system(Sobsey, 2002).The transportation of the water from the water source supply could be either by Wheelbarrow , a donkey cart, a motor vehicle , using a rolling system or by carrying the container by hand or on the head.(CDC, 2001).A common practice often seen in a rural areas was the use of leaves or branches with leaves to stop water slopping out during transit in wide –neck storage and transport containers(Sutton and Mubiana, 1989).These study has shown that these leaves can be an additional source of coli form bacteria to the drinking water.

2.8. Water contamination between source and point-of-use

Source water contamination is likely to have a wide effect on the community because it can introduce new pathogens in the home environment(Sobsey,2002).However, several studies have reported that the microbiological quality of the water deteriorate after collection, during transport and during storage at the point of use due to secondary contamination factors(Rajasekaran et al., 1997;El Attar et al., 1982;Han et al., 1989;Lindskog , 1989;Sandiford et al., 1989;Blum et al ., 1990 ;Henry and Rahim, 1990;Mertens et al., 1990;Pinfold, 1990;Verweij et al., 1991;Simango et al , 1992;Swerdlow et al .,1992;Shears,et al, 1995;Kalten haler and Drasar, 1996;Genthe et al, 1997;Jensen et al., 2002;Wright et al, 2004).Due to the distances and un availability of piped water supplies on the dwelling or inside the households in many developing regions of the world, people are forced to store their drinking water(Sobsey, 2002).Transmission of microorganisms inside the house hold can occur through several routes(Brisscoe, 1984;Roberts et al, 2001). The most important transmission routes include water, food, person-to-person contacts, and unhygienic behavior (eg. Intra-house hold transmission of faeces), the storage conditions of the water storage containers at the point-of-use and the abstraction condition of water from the storage containers(Briscoe, 1984;Roberts et al., 2001).In addition a number of studies suggested that inadequate storage conditions increased the risk of contamination, which can lead to infectious diseases.

Table 4: Summary of studies indicating microbiological contamination of stored water

Summary of studies indicating increased microbiological contamination of stored water and the associated infectious disease risk due to inadequate storage conditions (Sobsey, 2002).

Study area	Storage Container	Storage time	Impact on microbial quality	Diseases Impact	References
Bangladesh	Water jars	1-2 days	Increased Vibrio cholera presence	Increased cholera rates	Spira et al 1980
Bahrain	Capped plastic vessels ,jars, pitchers	Not reported	Vibrio cholera present in stored and not in source water	Uncertain	Gunn et al .,1981
Sudan	Clay jars	Two days-one Months	Increased faecal indicator bacteria over time, in summer and during dust events	Not measured	Hammad and Dirar,1982
Egypt	Clay jars	<1-3 days	Algae growth and accumulated sediments	Not detected	Miller,1984
India	Wide mouth and narrow neck	Not Reported	Not measured	Cholera infections fourfold higher in wide mouth storage vessels	Deb et al.,1986
Burma	Buckets	Up to 2 days	Higher levels of faecal faecal coliform bacteria than sources	Not measured	Han et al.,1989
Liberia	Large containers, open or closed	Long time	High level of enterobacteria in stored samples compared to sources	Not measured	Molbak et al.,1989
South Africa	Other Plastic container	4 hours	Higher Coliform Levels over time	Measured; no effect	Verweij et al.,1991

Africa	Traditional and metal jars	24 hours and more	High total and faecal coliform level	Not measured	Empereur-Bisonette et al.,1992
Malaysia	Various containers	Not reported	Higher levels of faecal coliforms in unboiled than boiled water	Higher diarrhea risks from water unboiled or stored in wide neck than narrow neck containers	Knigh etal.,1992
Zimbabwe	Covered and un covered containers	12 hours or more	Higher E.coli and Aeromonas levels with storage and use	Not measured	Simango et al.,1992
Peru	Wide mouth container	Not reported	Higher faecal coliform levels and antibiotic resistance	Increased cholera risks	Swerdlow et al.,1992
Bangladesh	Traditional pots	Not reported	Increased faecal coliform levels and anti biotic resistance	Increased faecal coliforms and multiple antibiotic resistant flora	Shears et al.,1995
Trinidad	Open drum,barrel,bucket Vs tank or none	Not reported	Increased faecal bacteria levels in open storage vessels than tank	Not measured	Welch et al., 2000

The material of the container is also important because the chemical material of the storage container could be conductive to bacterial growth and survival of potentially pathogenic microorganisms if contamination of the water occurs.Vibrio cholera 01 survived longer in corroded iron drums than in new iron drums (Patel and Isaacson, 1989).The studies in table 3 showed that water can be stored between 4hours and one months at the point -of -use .There is a research that indicated that the time of storage was important, with the highest increase in faecal contamination occurring if the storage time was longer than 10 hours(Faeschem et al.,1983).Similar observation were reported by other studies , specially, if the storage periods were longer than 12 hours(Han et al. ,1989;Mertens et al., 1990;Verweij et al.,1991;Simango et al., 1992;Ahmed and Mamud, 1998;Momba and Kaleni, 2002).These studies have showed that the microbiological quality of water deteriorates during long storage times and increased the risk of the transmission of water borne diseases. Other factors, which could contribute to the contamination of the water during the storage at the point of use, included unsanitary

and inadequately protected (Open, uncovered, poorly covered) containers(Dunker, 2001).Many of the studies listed in table 4 had either uncovered containers, containers with wide openings or wide openings or buckets, which were used as storage containers. Storage containers need to be covered at all times to prevent flies, animals and small children from touching the water(Sobsey, 2002).Containers with openings of less than 10cm were less contaminated with coli form bacteria than those with wider openings. Water was poured from these containers, while water was dipped out with hands and utensils where containers with wider openings were used.

2.9 Systems for household storage of collected water to protect microbiological contamination

A review of the existing literature on collection and storage of household water revealed that such water often comes from fecally contaminated sources and therefore poses infectious disease risks to consumers. Furthermore, regardless of whether or not collected household water is initially of acceptable microbiological quality, it often becomes contaminated with pathogens of fecal origin during transport and storage due to unhygienic storage and handling practices. Studies show that the use of containers with narrow openings for filling, and dispensing devices such as spouts or taps/spigots, protect the collected water during storage and household use. Many container designs also have handles, are lightweight, are made from durable, UV-resistant plastic and are affixed with a label containing informational/educational on their cleaning and use. Other appropriate containers for safe storage are those in which water can be directly treated by the physical method of solar radiation and then directly stored and dispensed for household use. These improved containers protect stored household water from the introduction of microbial contaminants via contact with hands, dippers, other fecally contaminated vehicles or the intrusion of vectors (WHO, 2002).

2.10. Household water storage

As shown in table 5, the application of HACCP to water storage in household vessels is likely to address three hazards and their critical control points: (1)vessel type (appropriate versus inappropriate), (1) vessel integrity (intact, damaged, parts missing, etc.), and (3) vessel sanitation (cleaned, not cleaned and a system to monitor and document cleaning frequency). For each type of storage vessel a set of specific hazards, critical control points and other criteria for a HACCP plan can be established. For example, for household storage of water according to the CDC Safe

water system, a preferred vessel design and alternative vessel designs that are considered suitable are provided, as are vessel designs and types considered unsafe for sanitation reasons (no cover, wide opening allowing introduction of hands and dippers, etc.) (CDC Safe water, 2001). For the solar disinfection system using sunlight for heating and UV-irradiating water (SODIS and SOLAIR), recommended or preferred vessels are identified (including vessel size and type of plastic), criteria for the integrity of the vessel are specified (e.g., absence of scratches and surface damage that would reduce light penetration), and the maximum time period of water storage is specified (to avoid degradation of the microbial quality of water and biofilm accumulation due to bacterial regrowth). These and other hazards and their critical control points can be specified for each type of water storage vessel and system.

Table 5: HACCP for Household Water Storage Vessels

Hazard	Vessel type	Vessel integrity	Vessel sanitation
Critical Control Point(s)	Appropriate or not appropriate, based on design	Intact or not intact, based on visible damage (e.g., cracks, scratches), broken or missing parts (e.g., cap)and leaks	Sanitary or nor sanitary, based on frequency of cleaning and cleaning method

2.11. The CDC safe drinking water storage Container

In the initial Safe Water System programs, CDC designed 20-liter modified jerry cans and provided them to users. This jerry can is now produced in Uganda, Afghanistan, Kenya, and the United States. Each jerry can costs approximately $5, excluding transport. (safewater@cdc.gov).

Figure 1:The CDC safe drinking water storage Container (CDC)

2.12. Purposes and benefits of household water treatment and storage

The purposes of household water treatment and storage are those intended to improve and maintain the microbial quality of the water for drinking and other potable purposes, such as food preparation and essential hygiene in child care and treatment of illness (breast feeding and preparation of infant foods and oral rehydration solutions) and thereby reduce disease transmission. The main benefit of microbiologically safe water for these purposes should be obvious: reducing the risks of diarrheal and other waterborne infectious diseases. The alternative, unsafe water is a major source of pathogen exposure and increased risk of waterborne infection, illness and death. Hence, the provision of microbiologically safe household water has the potential to reduce the infectious burden of the developing world's population. Recent estimates put this burden at 4 billion cases of diarrhea and 2.2 million deaths annually, mostly in children under five years of age. A compelling reason to accept and promote treatment and safe storage of collected household water to improve microbial quality is the ability of the health-related intervention to reduce the infectious disease burden of the user population. Notably, it is now well documented that the provision of safe water alone will reduce diarrheal and other enteric diseases by 6 to 50%, even in the absence of improved sanitation or other hygiene measures. Reducing household diarrheal disease by more than 5% is an important achievement, because this is the minimum achievable target reduction in ((Esrey et al., 1985; 1991).

2.13. Behavior Change Communications for safe water system

Behavior change communications focused on these topics are crucial to ensuring the sustainability of the SWS:

- Regular hand washing, improved sanitation, and improved hygiene
- Safe food and water handling practices, which help prevent contamination of treated, safely stored drinking water and reduce the risk of waterborne, food borne, and person-to-person transmission of diarrheal and other diseases.

CHAPTER THREE: OBJECTIVES & HYPOTHESIS

3.1. General objective

To assess the extent and causes of microbiological contamination of household drinking water in Hidi Hora , Serbo, and Turfe sami urban towns , Oromia region, Ethiopia.

3.2. Specific objectives

- To know level of bacteriological contamination of drinking water at the household level.
- To determine the key factors contributing to the bacteriological contamination of drinking water after collection and at the house hold level.
- To know the level of bacteriological contamination of the drinking water at the source.

3.3. Research questions

- What is the bacteriological quality of household water from households having an access to protected sources?
- What are the determinant factors that cause bacteriological contamination of water at the house hold level?

CHAPTER FOUR: RESEARCH METHOD AND MATERIALS

4.1. Study area

Three Semi urban villages in the Oromia region were included in a cross sectional study of the determinant factors of bacteriological contamination of drinking water collected from the source and stored in the households. The study was conducted in Hidi Hora , Serbo and Turfe villages. Serbo is found in Jimma zone, Kersa district; the village is located 325 km southwest of capital city Addis Ababa and 19 km from Jimma town. Hidi Hora village, Ada'a Merga district; East Shoa zone;Ada'a Merga district and Hidi Hora is 69km from Addis Ababa, and Turfe village is West Arsi zone; Shashamane district and it is 256km from Addis Ababa. The three villages are semi urban villages found in the Oromia region, Ethiopia.

4.2. Source populations

To minimize the expense of the study, the researcher purposively selected Oromia region from all regional states found in Ethiopia. The three zones were selected randomly from the 17 zones in Oromia regional state. The names of these three zones are Jimma zone, East Shoa zone and West Arsi zone. Each district was selected randomly from each zone participated in this study. Ada'a Merga was selected from East Shoa zone, Kersa was selected from Jimma zone and Shashamane was selected from West Arsi zone. Serbo village was selected from Kersa district, Hidi Hora village was selected from Ada'a Merga district and Turfe were selected from shashamane district. The data sources for the study were from the primary source. These primary Source populations were all households living in Serbo, Hidi Hora, and Turfe Semi urban villages.

4.3. Study population

The three villages were selected randomly from villages in Oromia regional state, Ethiopia as a place where to conduct this research. The researcher took these three villages randomly to make the research more representatives for all semi urban towns having simillar socio demographic factors in the country. All 78 households were selected randomly from Serbo, Hidi Hora and Turfe Semi urban towns. As the research was laboratory based cross-sectional study that needs

more time, expenses and reagents for analysis of bacteria in the water sample the researcher took purposively this number of households for this study.

4.4. Study design and period

A laboratory based cross-sectional study was conducted on the assessment of determinant factors of bacteriological contamination of water at the house hold level from July to September 2013 in Serbo, Hidi Hora, and Turfe sami urban villages, Oromia region, Ethiopia.

4.4.1 Study setting and population

The study population resided in Serbo, Hidi Hora and Turfe semi urban villages.

4.4.2 Criteria for inclusion

Households those with access to the protected water sources were included for this study.

4.4.3 Criteria for Exclusion

Households those without access to the protected water sources were excluded for this study.

4.4.4 Household selection

The communities were visited Monday through Friday between 12Am and 3PM, when residents were less busy. Households were included if residents were present on any 1 of 3 visits. Out of 130 households, 52 households were excluded because all inhabitants worked outside the community and only returned late at night or on weekend.

4.4.5 Sample size and sampling technique

The study selected purposively 30 households from the Serbo village, 30 households from Hidi Hora village and 18 households from Turfe village, Oromia region, Ethiopia. Totally 78

households were included in the study. The households were selected randomly from the Semi urban villages by systematic random sampling technique.

4.5. Variables

4.5.1 Dependent variable

Bacteriological contamination of drinking water at the household level or number of faecal coliforms and *Escherichia coli* bacteria in the house hold drinking water.

4.5.2 Independent variables

Factors that can affect the bacteriological quality of the drinking water at the house hold level are the independent variables for this study. These are:

- Socio demographic factors like
  - Age
  - Culture
  - Education
  - Family size
- Toilet facilities – open field/open drain/individual sanitary latrine/community sanitary latrine and sanitation of the environment of the house hold.
- Types of storage containers used by the house hold:
  - metal
  - Jerry can
  - Clay
  - others
- Whether drinking water was stored separately
  - in a covered/uncovered vessel
  - whether the vessel was wide/narrow mouthed
  - whether a separate utensil was stored for drawing water from the storage vessel
- Hand washing practices after using sanitary latrine.
- Income and occupation of family members and total household income.

- Time required and distance individuals must travel to access water sources for the households.
- Time they take to wait to fetch water for themselves from the source.
- Community perception on water quality.
- Lack of knowledge on the contamination of water at the house hold level.
- The time since water was collected (for what hours or days the drinking water stays in the house hold until the next water collection).
- Personal hygiene practice of the households.
- Type of vehicles used for water transportation.
- Water treatment practice at the house hold level.
- Type of the flour of the house of the house hold.
- The method of extracting water from the storage containers. While the households are collecting water from the tap, there may be contact of the hands to water
- Whether water collected from the source is transported to your house with covered containers or not.
- In the house, whether water for drinking is stored in a separate container from water intended for other purposes or not.
- Whether the drinking water that the households take from the storage containers has no contact with their hands or not.
- Total volume of drinking water collected at a time by the house hold.

4.6. Data collection procedure

The questionnaires were collected from the selected study areas to analyse the determinant factors of bacteriological water contamination at the housse hold level. Water samples were collected from the three villages selected for the study to identify bacteriological contamination of drinking water at the house hold level. Water samples were also collected from the source of the drinking water for bacteriological analysis and for comparison of the degree of contamination after the collection up to point of use. The water samples were collected from both the source of the water and from the house hold to see difference in number of indicator bacteria in 100ml of water sample.

4.6.1 Drinking water sampling methods

100ml water sample was collected from each house hold of the residents in a plastic (Zip-loc) bag for drinking water bacteriological analysis. 100ml water sample from six other water sources were collected in plastic (Zip-loc) bag for analysis of the bacteriological contamination of drinking water at the source. First, samples from each of the different stages described above were collected: (1) water from the principal storage container as normally collected by residents; (2) drinking water taken directly from the treated drinking water reservoir;(3) from Open body;(4) protected well;(5) Piped to house;(6) Public tap;(7) Vender.

4.6.2 Quality of the drinking water sample

Drinking water sample at the household level was collected from the main drinking water vessel in each household. As many households have multiple water storage vessels, care was taken to ensure that the water sample came directly from the vessel used to dispense water for immediate consumption.

4.6.3 Water Sample collection

The method of sample collection at each source, and at each house hold was according to the WHO Guidelines (WHO,1994, 1995) for drinking water quality assessment and laboratory manual (Monica, 2000). Water samples were collected in sterile plastic bag and transported to the laboratory in a cold box containing ice freezer packs. From each source, and each house hold 100 ml of water samples for microbiological analysis were treated with sodium thiosulphate to stop the death of bacteria in the sample at the moment of taking the sample (i.e. 100 mg sodium thiosulphate).Water samples were collected in three villages: one with a simple piped water system that transports treated underground water, one that rely on unimproved surface water from fast-flowing rivers, and one that relies on protected well water from a small stream. In addition to their primary water source, some villagers also use simple wells and/or collect rainwater as source waters for drinking. Samples were collected from waters identified as drinking water sources by household members and from storage containers within the house. A number of samples were collected from each type of source (both directly from the source and

from storage containers in the household); sample collection and processing took place from July 2012 to September 2013.

To collect water sample the investigator has been following the following procedure. First the researcher removed WhirlPak Sampling bag from sealed larger bag, then WhirlPak Bag was labeled with date, time, and sample identification number in permanent ink to avoid confusion. The researcher washed his hands with hand alcohol and Opened WhirlPak bag without touching the lip of the bag. The investigator filled WhirlPak bag with sample without touching anything to the lip of the bag, then Whirled the bag three times quickly, and cinched sides closed. Finally, the investigator Placed WhirlPak bag upright in a cooler with ice and the researcher completed analysis of sample within 8 hours.

4.6.4 Indicator bacteria used

In this study the analysis used two of the following three indicator bacteria: (1) total coli forms which are Gram-negative bacteria that ferment lactose at 35–37^{0}C within 24–48h;(2) faecal thermo-tolerant coliforms which are a subset of total coliform bacteria that ferment lactose at 44–45 ^{0}C and (3) *E. coli* which are exclusively faecal in origin, are a sub-group of the faecal coli forms that produce the enzyme B-galactosidase and not urease. World health organization guidelines state that none of these bacteria should be detectable in a 100-ml of water sample (WHO, 1997). Of these bacteria, E. coli are regarded as the most reliable indicator of faecal contamination and total coliforms as the least reliable indicator.

4.6.5 Household information

Interviews were conducted by trained local assistants from the head of household (female) about the sources of the drinking water, walking time to usual water source, toilet facilities, and physical possessions of the household and household social and demographic characteristics. Water sources included pipes or taps, boreholes, wells, surface water, bottled water, water in sachets, tankers or rainwater. Boreholes are 10 to 20 feet deep, covered at ground level, and fitted with hand pumps. Wells are stone or clay round pits that are wide in diameter at the surface and not covered. Typically a carrying vessel is dipped into the well to retrieve water. Surface water could be from a pond, lake, rain water or river water. Tankers are trucks with large water tanks which dispense water. Rainwater is collected from house roofs in barrels. An index of

material possessions was created based on whether the household owned the following items: working radio or cassette player, television, video recorder, telephone or mobile phone, stove, refrigerator or freezer, clock, sofa or chair with cushions, bed with mattress, bicycle, motorcycle, car or motor vehicle and other kind of properties the house hold possess from their houses. This index serves as our indicator of household wealth.

4.6.6 Survey instruments

A well structured, pretested questionnaire was administered to collect information on socio-demographic variables, availability of water storage practices. The questionnaire comprised of the following sections – water storage practices, environmental and personal sentation and socio-economic survey, history of diarrheal illness and toilet facilities. The variable on which data was collected includes:

- Incidence of diarrhea among children for two week recall period. Diarrhea was defined as the passage of loose, liquid or watery stools more than three times a day.
- Family size, occupation of family members and total household income
- toilet facilities – presence of well established sanitary latrine
- Sources of water supply – municipal piped supply/shallow hand pumps/tube wells, protected well
- Whether municipal water supply was intermittent/continuous.
- Whether supply was at individual household level/through public stand posts.
- Whether drinking water was stored separately, in a covered/uncovered vessel.
- Whether the vessel was wide/narrow mouthed and also whether a separate utensil was stored for drawing water from the storage vessel.
- Home chlorination of drinking water.
- Hand washing practices and etc.

4.7. Data analysis procedure

The data was analyzed from the house hold drinking water samples and questionnaire interview collected from the households. Crude odd ratio and multiple regression or adjusted odd ratio with 95% confidence interval were used as statistical analysis to measure the association and the

strength of the association between the independent variables and dependent variables or number of *E.coli* and F.coliform per 100ml of house hold drinking water.

4.7.1 Water sample Analyses

Samples were analyzed using standardized bacteriological analysis method to determine the degree of bacteriological contamination**.** All Samples were analyzed for the presence of indicator bacteria;faecal coliforms and *Escherichia coli*. Water samples were collected in WhirlPak bags and stored in ice packs found in the cold box, and analyzed within 8 hours of collection. A sterile, disposable sample cup and filter were placed on top of a filtration stand, and the appropriate dilution of sample water and buffered dilution water was poured or pipetted into the cup. Measured 100ml sample water was filtered manually through a 0.45µm filter through the stand with a syringe. The cup was removed, and using flamed forceps, the filter was placed in a petridish over a pad impregnated with a specific growth media and incubated at a 44^{o}C temperature for 24 hours. Colonies grew in specific blue and red colors in the 24 hours, and are manually counted. In all cases, analysis was performed by the Membrane Filtration Method. To keep the validity of the analysis, distilled water was included as control at the same time during the analysis. After-incubation, all colonies were counted, using a colony counting lens. Typical colonies were counted with binocular wide-field microscope at a low power (20 x magnifications) but were not verified by additional tests (APHA, 1989 and WHO, 1984b).

4.7.2 Enumeration of E.coli and F.coliform

The isolation and enumeration of both E.coli and Thermo tolerant coliforms were carried out using membrane filtration techniques; MF techniques in which plastic bags were aseptically opened and a 100ml of sample was filtered through the membrane filter (Millipore 45µm nitro-cellulose filter). Membrane Lauryl Sulfate-Based medium (mLSB Oxoid, UNIPATH Ltd., Basingstoke, England) was prepared with 20-25 mℓ de-ionised water. The prepared mLSB measured in autoclaved measuring flask 2 mℓ of the solution was applied to filter pad which was placed on 50mm Petri dish. The filter was placed on to the membrane pad containing mLSB and incubated at an ambient temperature of 44C for 24h to permit bacterial growth. After-incubation, all blue and red colonies were counted, using a colony counting lens. Typical colonies were

counted with binocular wide-field microscope at a low power (20 x magnifications) but were not verified by additional tests.Blue colonies were counted as *E.coli* and the red colonies were counted as F.coliform (ISO, 1997; WHO, 2000).

4.7.3 Statistical analysis

Frequencies and variation was obtained for each variable. Logistic regression was used to estimate the odds of unsafe household water quality, i.e.>zero E. coli /100 ml of water and greater than zero F.coliform per 100 ml of drinking water. The crude odds ratio and adjusted odds ratio with 95% confidence interval were employed to describe the strength of association between the selected study variables and the number of Fecal coliform and E.coli per 100ml of water sample by controlling inferences about the potential confounding of some of the relationships.

4.7.4 Quality assurance/quality control

The importance of quality assurance/quality control procedures in microbiological sampling in the field cannot be overestimated. In addition to normal variability in concentrations of microbiological indicators between samples from the same location, there exists the possibility of contamination in every step of a microbiological sampling procedure. The following techniques were under taken to ensure that the data generated are reliable:

- One blank sample (using boiled dilution water) was completed for every 10-20samples. If the blank samples have shown no bacteria which indicates how contamination has not occurred during the procedure, and data must not be discarded. Dilution water can be: (1) commercially purchased and imported; or (2) made locally by boiling low-turbidity water and adding (if necessary for the media used)buffer solution available from commercial companies in plastic sachets.
- If the positive controls do not show bacterial growth, then either the media is ineffective or the incubation temperature is incorrect and inconsistent, and all data run must be discarded. To avoid this kind of error the researcher run Positive controls (using unclean water at hand) each time the possibility that all results would show bacterial growth.

- There is normal variability in the microbiological concentration between one 100 ml sample and the next from the same source. In addition, duplicates provide additional quality assurance and allows for averaging of two samples for more accurate results. Because of this reason the researcher duplicated 20 percent of all samples.
- From each source, and each house hold 100 ml of water samples for microbiological analysis were treated with sodium thiosulphate to stop the death of bacteria in the sample at the moment of taking the sample (i.e. 100 mg sodium thiosulphate).
- Pretest of questionnaire was carried out on similar households having similar socio-demographic characteristics.

4.8. Ethical consideration

Ethical clearance to conduct this study was obtained from the research and ethical committees of Jimma University. Permission from municipality of the towns for public water source samples and consent from private water source owners were obtained before water sample collection. Regard to data collected at the household, study objectives were clearly explained to the households' parents. Each household was assured that the information provided would be confidential and used only for the purpose of research. In each study household, the wife of the household was asked to sign a written informed-consent document.

4.9. Operational definitions

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

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

Storage: putting water in the container for future use

Survey instrument: Questionnaire used for this study

4.10. Reporting Results and Information Dissemination

Following the analysis of the data, a report will be presented to the college of public health and Medical Sciences, Jimma University. The result of the study will also be presented to the

municipality offices of the three sami urban towns and other concerned bodies through the reports and possible publications in journal.

4.11. Limitations of the study

Similar to any other lab based cross-sectional study, this study has some limitations.

- As the study involved sensitive issues including the income of the house hold and other important information about their house hold, there may be information bias.
- When the researcher couldn't get house wife from the household, purposively he took information from girl found in the house at a time. The information from this girl may not represent study population.
- This lab based cross sectional study was self sponsored research. Because of the lack of money it was very difficult to take large number of sample size for the analysis and to see the effect of any independent variables on the bacteriological contamination of the drinking water.

4.12. Strength of the study

- The study included both qualitative and quantitative parts for analysis.
- Another strong point of the study was its being community based study.

CHAPTER FIVE: RESULTS

5.1. Socio-demographic characteristics of the house hold

78 households were asked to access the determinant factors of water contamination at the house hold level. Looking at the distribution of the respondents across age groups, 30(38.5%) of the respondents are in the age of 15-30 years age group, 34(43.6%) of the respondents are in the age of 31-50 years age group, and 14(17.9%) of the age group are in the age of greater than 50 years age group. Across the marital status, 58(74.4%) of the respondents are married, 2(2.6%) of the respondents are unmarried, 14(17.9%) of the households are widowed, 3(3.8%) of the house hold are divorced and 1(1.3%) of the house hold are out of the above groups. Educational status of the woman in the households;40(51.3%),7(9.0%), 15(19.20%), 7(9.0%), 15(19.2%),7(9.0%),5(6.4%) and 4(5.1%) of the households are illiterate, read and write, grade one to six, grade seven to eight, grade nine to ten, grade eleven to twelve, and above grade twelve respectively. Occupation of the women in the households;30(38.5%), 2(2.6%),5(6.4%),25(32.1%), 9(11.5%),6(7.7%), and 1(1.3%) of the woman in the households are farmers, skilled daily laborer, unskilled daily laborer, merchant, teachers and other official works, jobless ,and other works respectively. According to this study, there is no significant association between socio-demographic characteristics and bacteriological recontamination of water at the house hold level. Household size is negatively associated, and the household possessions index is marginally negatively associated, with E. coli and F.coliform levels.

Table 6: Socio demographic characteristic of the house hold

		Frequency	Present
Language	Afan oromo	20	25.6
	Amahric	58	74.4
Sex	Male	9	11.5
	Female	69	88.5
Age	age 15 to 30	30	38.5
	age 31 to 50	34	43.6
	age greater than or equal to 51	14	17.9
Marital status of the house respondent	Married	58	74.4
	Un married	2	2.6
	Widowed	14	17.9
	Divorced	3	3.8
	Others	1	1.3
Educational status of the woman in the house hold	Illiterate	40	51.3
	read and write	7	9.0
	grade one to six	15	19.2
	grade seven to eight	7	9.0
	grade nine to ten	5	6.4
	above grade twelve	4	5.1
Occupation of the woman in the house hold	Farmer	30	38.5
	skilled daily laborer	2	2.6
	un skilled daily laborer	5	6.4
	Merchant	25	32.1
	Teacher	9	11.5
	job less	6	7.7
	Others	1	1.3
Education of husband in the house hold	Illiterate	14	17.9
	read and right	12	15.4
	grade one to six	10	12.8
	grade seven to eight	14	17.9
	grade nine to ten	9	11.5
	grade eleven to twelve	13	16.7
	Above grade twelve	6	7.7
Occupation of husband in the house hold	Farmer	30	38.5
	skilled daily laborer	2	2.6
	un skilled daily laborer	5	6.4
	Merchant	25	32.1

	Teacher	9	11.5
	job less	6	7.7
	Others	1	1.3
	un skilled daily laborer	5	6.4
	Merchant	25	32.1
	Teacher	9	11.5
	job less	6	7.7
	Others	1	1.3
Number of females greater than 18 years in the house hold	0 females	2	2.6
	1 females	44	56.4
	2 females	20	25.6
	3 females	12	15.4
Number of males greater than 18 years in the house hold	0 male	7	9.0
	1 male	43	55.5
	2 males	15	19.2
	3 males	10	12.8
	4 males	2	2.6
	5 males	1	1.5
Number of children in age 5 to 17 in the house holds	0 children	2	2.6
	1 children	44	56.4
	2 children	20	25.6
	3 children	12	15.4
	4 children	4	5.1
	5 children	2	2.6
	6 children	2	2.6
Number of children less than 5 years	0	19	24.4
	1 child	15	19.2
	2 children	24	30.8
	3 children	12	15.4

5.2. Environmental and personal hygiene of the households

Drinking water from households that use a water closet type of toilet has significantly higher *E. coli* and F.coliform compared with those who do use high grade of toilet facility. Households using a pit latrine type toilet also have significantly higher *E. coli* and F.coliform in drinking water. These associations remained significant after further adjustment for sanitary, total volume of water collected at a time, distance of the source of water from the household, type of storage container and time since water was collected. According to this study, there is no association between personal hygiene and bacteriological contamination of water at the house hold level.

Table 7 : Environmental and personal hygiene of the house hold

		Frequency	Percent
How do the adults in the house hold take bath?	Greater than one per week	45	57.7
	Once per a week	22	28.2
	1 to 3 per a month	9	11.5
	Less than one per a month	2	2.6
How do the children of less than five years take bath?	Greater than one per week	47	53.8
	Once per a week	7	9.0
	1 to 3 per a month	2	2.6
	Less than one per a month	1	1.3
	none of the above	26	33.3
How the clothes are washed in the house hold	Greater than one per week	33	42.3
	Once per a week	33	42.3
	1 to 3 per a month	6	7.7
	less than one per a month	5	6.4
Presence of standardized sanitary latrine for the house hold	Non standardized sanitary latrine	70	89.7
	standardized sanitary latrine	8	10.3
Type of the flour of the house of the house hold	Earth	76	97.4
	Cement	2	2.6
Presence of hand washing practice after using latrine	No hand washing practice	72	92.3
	There is hand washing practice	6	7.7

5.3. Source of water and the water sample used for analysis

The average walking time to a water source is around 27.19minutes and average walking distance is 815.49m; approximately 50.4% needed more than 30 minutes and around 27% of the house hold took 1000m to get to a water source. According to this study, the households use different sources of water at different time. The type of the sources of water the households were using are listed below in the table 6.The study indicated the existence of significant association between the distance of the source of water from the house hold and contamination of water at the house hold level.

Table 8: data on the type of source of water sample and water handling practices

		Frequency	Percent
Type of source of water the house hold uses as first option	Open body	1	1.28
	protected well	1	1.28
	Piped to house	8	10.3
	Public tap	53	71.9
	Vender	12	15.4
Time required category to reach to the first water source in minutes	less than 15 minutes	41	52.6
	15minutes to 30 minutes	21	26.9
	greater than 30 minutes	16	20.5
distance category of the first water source from the house in meter	less than 500m from the house	49	62.8
	500m to 1000m from the house	16	20.5
	greater than 1000m from the house hold	13	16.7
time required to wait for queue category to fetch water in minutes	less than 15 minutes	46	59.0
	15 minutes to 30 minutes	19	24.4
	greater than 30 minutes	13	16.7
the time since the water was collected for drinking	Today	37	47.4
	Yesterday	35	44.9

	Before yesterday	5	6.4
Whether the water is treated at the house level or not	Not treated at the house level	77	1.3
	treated at the house level	1	98.7
Type of water container	Clay	3	3.8
	jar can	73	93.6
	Metal	1	1.3
	Other	1	1,3
Type of the mouth of the container	Wide	3	3.8
	Narrow	73	96.2
Method of water extraction from the container	Directly from the container	76	97.4
	By dipping cup in the container	2	2.6
Whether the house hold is using this source of water for drinking or preparing food or not	Is Not using	5	6.4
	is using	73	93.6
When does the house hold use this water source	rainy season	0	0
	dry season	5	6.4
	both season	73	93.6
Does the house hold use animal, bicycle or cart for water transportation	doesn't use	51	63.4
	does use	27	34.6

5.4. Result of the bacteriological test

The percentage of samples testing positive for indicator bacteria may decrease after collection from highly contaminated sources because of die-off as bacteria compete for limited oxygen and nutrients in the water (Momba & Notshe, 2003). Conversely, the percentage of positive samples may increase after water is collected and stored from safe sources because of the contamination through hands, unwashed containers and other key factors. The geometric mean indicator bacteria count and percentage of samples positive for such bacteria were therefore used to measure the bacteriological contamination of drinking water at the house hold level.

Table 9: Mean Number of F.coliform and E.coli per 100ml source water

Number	Source of the water Sample	Mean E.coli count per 100ml of water	Mean F.coliform count per 100ml
1	Open body	68	34
2	protected well	16	25
3	Piped to house	6	8
4	Public tap	9	7
5	Vender	5	6
6	Reservoir	4	5

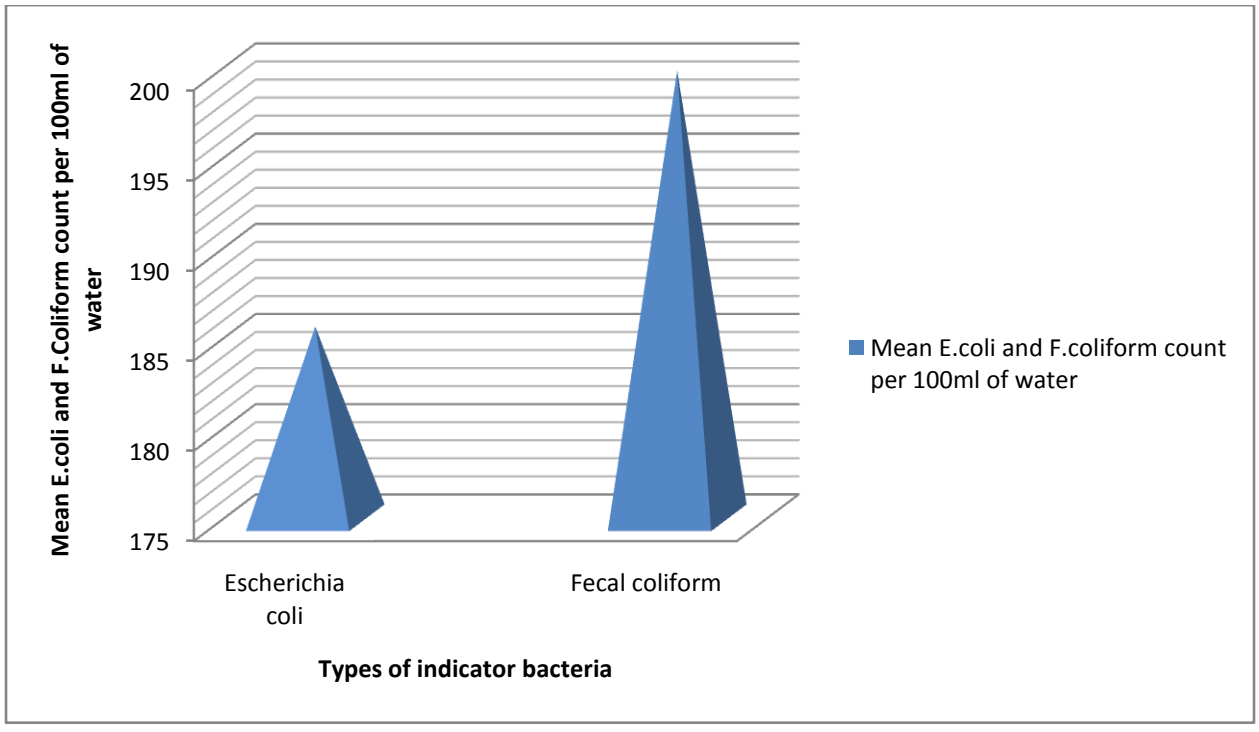
Household water quality was characterized by relatively high levels of E. coli/100 ml and F.coliform/100ml of drinking water. According to bacteriological analysis water from households has significantly more E.coli than water from the source. The mean was 185.6E.coli/100ml of water and a range from 0 to 1500 E. coli/100 ml H_2O and mean of 199.76F.coliform/100ml of water and ranges from 0 to 2640F.coliform/100ml of drinking water. Almost three quarters of the households, 74.4%, had water with greater than zero E. coli /100 ml of water and 89.74%, had water with greater than zero F.coliform/100ml of house hold drinking water.

Table 10: Result of bacteriological test of the house hold drinking water

Type of bacteria		frequency	percent	Mean
Escherichia coli	less than 100 E.coli per 100ml of water	44	56.4	185.6
	100 to 1000 E.coli per 100ml of water	32	43.5	
	greater than 1000 E.coli per 100ml of water	2	2.56	
Fecal coliform	less than 100 F.coliform per 100ml of water	37	47.43	199.8
	100 to 1000 F.coliform per 100ml of water	39	50.01	
	greater than 1000 F.coliform per 100ml of water sample	2	2.56	

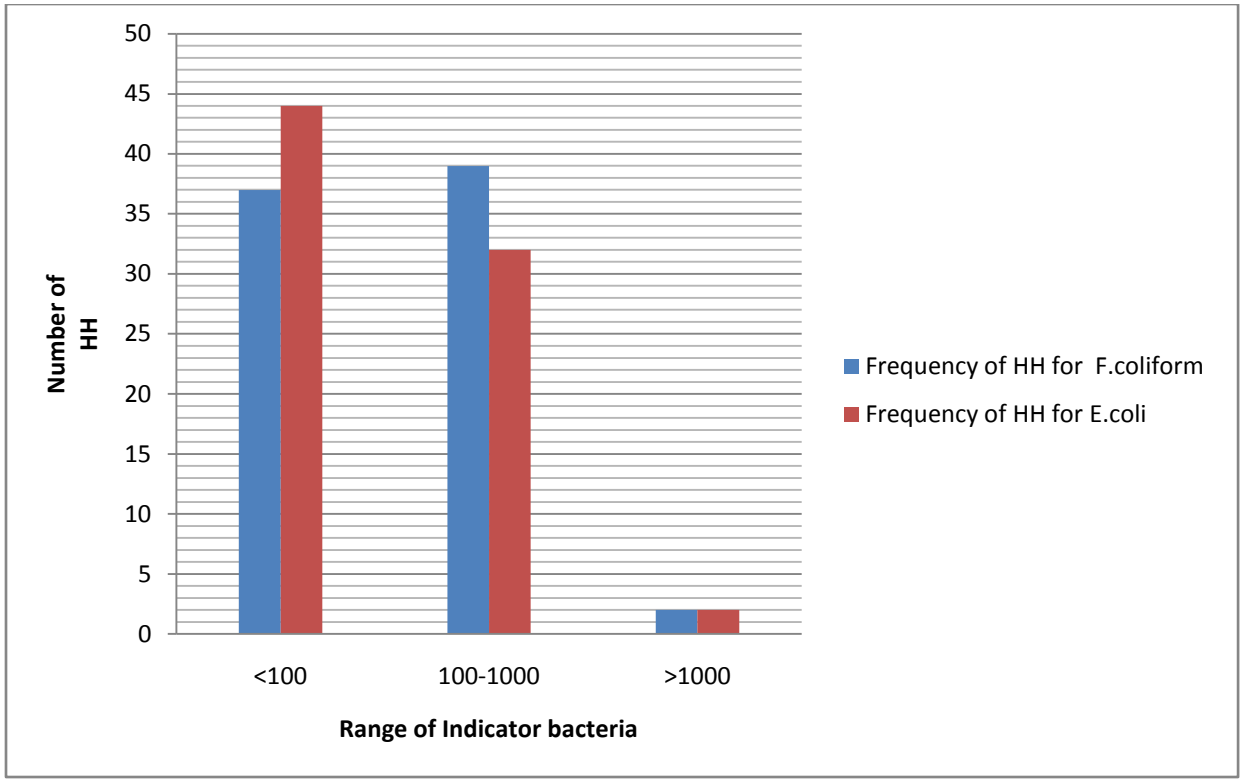
According to the results in table 8 and figure 2 mean E.coli per 100ml of drinking water that is 185.6E.coli per 100ml H_2O is less than that of mean F.coliform per 100ml drinking water that is 199.8F.coliform.The drinking water was more contaminated with F.coliform than with E.coli.

Figure 2: Comparison of Mean E.coli and F.coliform count per 100ml of water in the three towns



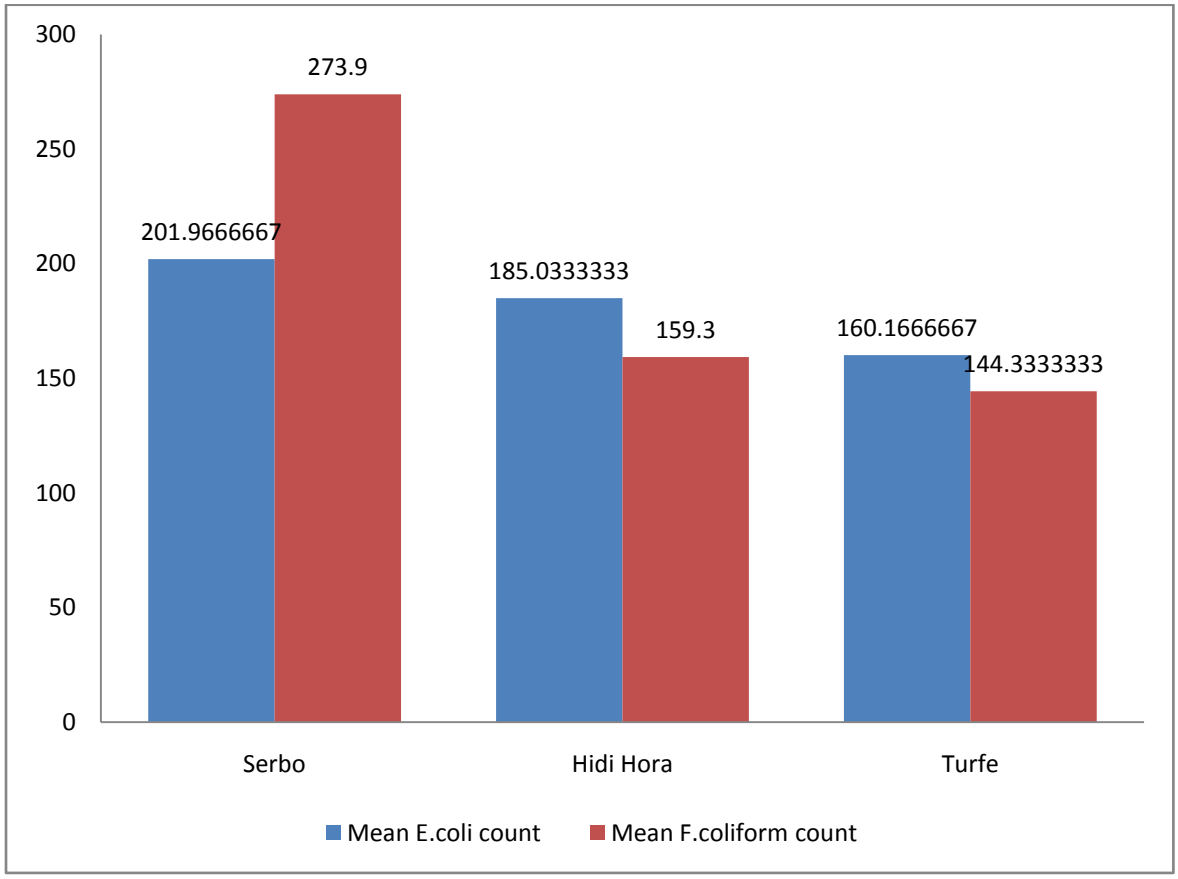
According to this finding, 56.4% of the households have from 0-100 *E.coli* per100ml H_2O, 43.5% of the households have 100-1000 *E.coli* per H_2O drinking water and 2.56% of the households have greater than 1000E.coli per 100ml of drinking water. Also the study indicated that 47.43% of the households have 0-100 F.coliform per 100ml 0f drinking water, 50.01% of the households have 100-1000 F.coliform per 100ml of water, and 2.56% of the households have greater than 1000 F.coliform per 100ml of water. According to USEPA, 2006 about risk classification for thermo tolerant coliforms or E. coli of drinking water, the ranges listed here have low to very high health risks.

Figure 3: Ranges of indicator bacteria



In this finding, the level of bacteriological contamination of drinking water varies from town to town. More bacteriological contamination of water was observed in Serbo village, and also that of Hidi Hora village was greater than that of Turfe village.

Figure 4: Variation in number of indicator bacteria among the three towns



- The level of bacteriological contamination of drinking water varied from village to village.
- More bacteriological contamination of water was observed in Serbo village, and also that of Hidi Hora village is greater than that of Turfe village.

5.5. Association between bacteriological water contamination and prevalence of diarrhea disease

According to this finding, there were children of less than five years or equal to five years who were caught by diarrhea disease within two weeks in the group under investigation. This was because the households were using bacteriological contaminated water at the house hold level. This contaminated water can cause diarrhea and other related disease to the children living in the households. But whether the bacteriological water contamination is positively associated to the prevalence of diarrhea disease was not analyzed statistically.

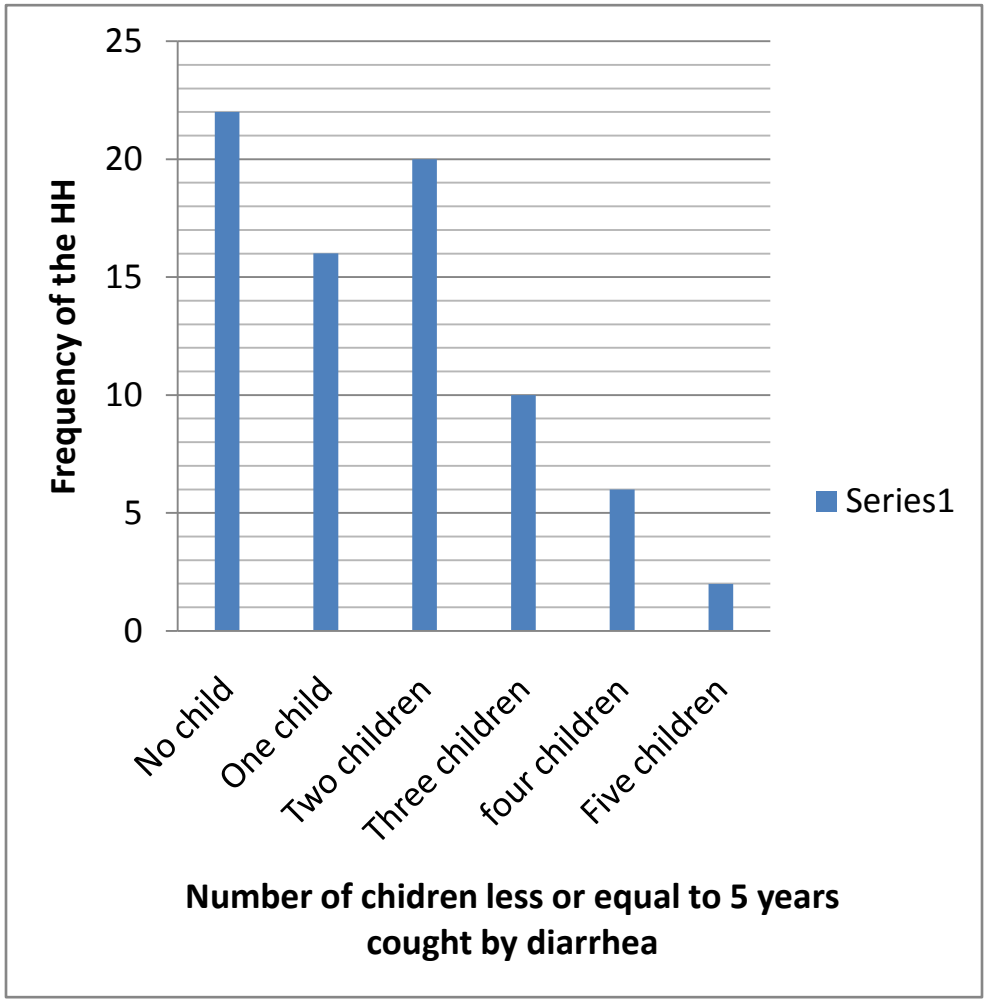
Table 11 : Number of childrenwho were caught by diarrhea within two weeks

		Frequency	Percent
Number of children less than or equal to five years who were caught by diarrhea within two weeks	No child	22	28.2
	One child	16	20.5
	Two children	20	25.6
	Three children	10	12.8
	Four children	6	7.7
	Five children	2	2.6

As it was listed in the table 9, diarrhea disease prevalence was observed among 71.8% of the households.12.8% of the households have three children each who were caught by disease within the near past two weeks; 25.6% of the households have two children each who were caught by disease within the near past two weeks; 20.5% of the households have one children each who were caught by disease within the two weeks; 2.6% of the households have five children each

who were caught by disease within the near past two weeks; 7.7% of the households have four children each who were caught by disease within the near past two weeks.

Figure 5: Association between household water contamination and prevalence of diarrhea



5.5. Crude and Adjusted odds ratio on bacteriological contamination and the key independent variables

Table 12: frequency and logistic regression between independent variables and *E. coli* Contamination ($p < 0.05$)

Variables		Access to contamination		Presence/absence	COR(CI) for E.coli Contamination	AOR(CI) for *E.coli* contamination
		Yes (N (%))	No (N (%))			
total volume of water fetched at a time	Volume less than 20L at a time	22(28.2%)	56(71.8%)		Referent	Referent
	Volume 20L to 40L	25(32.1%)	53(67.9%)		12.833	21.838
	Volume greater than 40L	31(39.7%)	47(60.1%)		25.375	6.832
type of container used for drinking water	Clay	23(29.5%)	55(70.5%)		Referent	Referent
	Jar can	29(37.2%)	49(62.8%)		6.650	1132719.020
	Metal	14(17.9%)	64(82.1%)		12.133	732868.436
	Other	12(15.4%)	66(84.6%)		0.150	0.046
storage time since water was collected	Today	18(23.1%)	60(76.9%)		Referent	Referent
	Yesterday	26(33.3%)	52(66.7%)		8.400	
	Before yesterday	34(43.6%)	44(66.4%)		32.000	45.734
Walking distance to water sources	Less than 500m	17(21.8%)	61(78.2%)		Referent	Referent
	500m to 1000m	19(24.4%)	59(75.6%)		27.625	
	Greater than 1000m	42(53.8%)	36(46.2%)		30.875	
Presence of toilet at the		26(33.3%)	52(66.7%)	No toilet	47.222	73.934
				Toilet	Referent	Referent

household level Hand washing practices after using latrine	26(33.3%)	52(66.7%)	No water for hand washing	47.222	0.022
			There is water\ for hand washing	Referent	Referent

Table 13: frequency and logistic regression between independent variables and F.coliform contamination(p<0.05)

Variables		Access to contamination			COR(CI) for F.coliform Contamination	AOR(CI) for F.coliform Contamination
		Yes (N (%))	No (N (%))			
total volume of water fetched at a time	Volume less than 20L at a time	22(28.2%)	56(71.8%)		Referent	Referent
	Volume 20L to 40L	25(32.1%)	53(67.9%)		2.857	7.475
	Volume greater than 40L	31(39.7%)	47(60.1%)		7.500	1.531
type of container used for drinking water	Clay	23(29.5%)	55(70.5%)		Referent	Referent
	Jarry can	29(37.2%)	49(62.8%)		4.75	997031.394
	Metal	14(17.9%)	64(82.1%)		8.667	3445815.790
	Others	12(15.4%)	66(84.6%)		2.5	0.134
storage time since water was collected	Today	18(23.1%)	60(76.9%)		Referent	Referent
	Yesterday	26(33.3%)	52(66.7%)		4.200	4.63242
	Before yesterday	34(43.6%)	44(66.4%)		10.333	856.352
Walking distance to water sources	Less than 500m	17(21.8%)	61(78.2%)		Referent	Referent
	500m to 1000m	19(24.4%)	59(75.6%)		22.800	0.130
	Greater Than 1000m	42(53.8%)	36(46.2%)		43.200	2.161
Presence of toilet at the house hold level		26(33.3%)	52(66.7%)	No toilet	12.000	
				Toilet	Referent	
Hand washing practices after using latrine		26(33.3%)	52(66.7%)	No water for hand washing	12.000	23.453
				There is water for hand washing	Referent	

CHAPTER SIX: DISCUSSION

Water contamination between source and point-of-use

Despite clean, adequately chlorinated source water and the widespread practice of using water from the treated source, we found that contaminated water is consumed with remarkable frequency in these Sámi-urban communities. According to this study change in the microbiological quality of water at source and point-of-use indicate a decline after collection, although there is significant variation between the households. The results in table 9 and table 10 suggested that approximately most of the included samples were significantly contaminated after collection. There were fewer instances where microbiological water quality improved significantly after collection. The decline in water quality between source and point-of-use measured in terms of faecal coliform and E.coli proportionately greater where source water is largely contaminated. These are often improved water sources, such as protected well, piped to house, public tap, vender, reservoir. For such sources, safer household water storage (Chidavaenzi et al. 1998) may be an appropriate additional intervention to prevent contamination of domestic water. If water testing is performed only at sources in such settings, then results of monitoring may not reflect the quality of water actually consumed in the home. Escherichia coli and fecal coli form contamination increased as we followed the water from its source to drinking water storage containers and then into the glasses used to serve the water.

In comparisons of health impacts due to source water and household-level interventions, such post source contamination has been shown to increase diarrhea risk (Clasen, 2006). Our data detected no relationship between water quality at the house hold stage and the household's educational status, family size, culture, occupation , domestic and personal hygiene, time the house hold took to wait to fetch the water from the source because the p-value for these independent variables are greater than 0.05. Our data suggested strongly that the major sources of contamination resulted from poor water storage, distance of the source of water from the house hold, absence of well established toilet for the house hold, time since the water was collected, the total volume of water collected at a time, and absence of water for hand washing after using latrine. Households gathered water with low but adequate amounts of free chlorine and less E.coli and fecal contamination. Introduction of E.coli and fecal contamination during transport was maximal in this community. Instead of carrying water in buckets or other

containers, some study households used long hoses to route water directly from a standpipe or neighbor's spigot to household storage containers. This practice likely developed as a much easier way to collect water in the steep, rocky conditions of this community. The combination of poor water quality and low level of infrastructure for safe water and sanitation suggest substantial risk from water-borne infectious diseases in this region. Given that 23% of childhood communicable diseases can be attributed to unsafe water and sanitation (WHO, 2002), urgent attention is needed to extend safe water systems, provide direct investments for sanitary facilities and conduct household level health education campaigns about water and sanitation (Soares et al. , 2002).

Toilet type at the household level

Households with no toilet or who use a pit latrine have significantly ($P < 0.001$) higher E. coli levels relative to those who have toilet. Our findings on the associations of toilet type with water quality replicates high-established results from many other studies about sanitary habits and local environmental hygiene infrastructure (Duse et al., 2003; Howard et al., 2003; Cronin et al., 2006). In this study, drinking water from the house hold without well-established toilet is highly contaminated with *E.coli* when compared with the house hold that have well –established toilet at their house hold level.Water contamination by Escherichia coli at the house hold level has strong positive association with absence of well-established toilet at the house hold level. Households with a pit toilet or no toilet facilities have 47 times higher odds of contaminated water with *E.coli* relative to those with a water seal toilet ($P < 0.001$, COR =47.222). Even after adjustment for other key factors considered in the study ($p <0.01$, AOR =73.934). Association between feacal coliform drinking water contamination and absence of toilet is significant at individual factor level ($p < 0.05$, COR =12.000) and F.coliform water contamination became insignificant after adjusted with others key factors ($P >0.05$). Lower water quality is associated with households using a pit toilet or without a toilet. If the toilets around the house holds are not established properly the microbial can contaminate the drinking water at the households. This is because the microbial easily go to the house of the house holds with out any protection and contaminate the drinking water stored in the houses. This is similar to many researches done in other areas in developing nations (Stephen T et al, 2008). This suggests the critical importance of

reducing these pathways to contamination of household water through a variety of investments from health education to investment in sustainable waste water and disposal systems (Clasen et al., 2007; Stephen et al., 2008).

Hand washing practices after using latrine

Analysis of the data has shown that hand washing practices after using latrine has significantly associated with the contamination of water by E.coli and they have strong positive association ($p < 0.02$, COR = 47.222), but after adjustment for other key factors like total volume of water fetched at a time, type of storage container, absence of well-established toilet, time since the water was collected and distance of the source of water from the house hold, it is negatively associated with the contamination of drinking water by *E.coli* ($P < 0.05$,AOR =0.022) that is it is protective for drinking water contamination by *E.coli*. Association between hand washing practices after using latrine and contamination of drinking water by F.coliform is positive association that is 12 times that of the house hold those practiced hand washing after using latrine($p < 0.05$, COR =12.000).This was not disappeared when analyzed with other factors ($p < 0.05$, AOR = 23.453).When the house holds wash the glass used for drinking water with out washing their hand after using latrine the water can easily feacally contaminated.This result agrees with the research done in other countries (William et al., 2007).

Walking distance to water sources or walking time

The transportation of the water from the water source supply could be either by Wheelbarrow, a donkey cart, a motor vehicle, using a rolling system or by carrying the container by hand or on the head.(CDC, 2001).A common practice often seen in a rural areas was the use of leaves or branches with leaves to stop water slopping out during transit in wide –neck storage and transport containers(Sutton and Mubiana, 1989).

Increased walking time to water source was associated with higher number of E.coli in drinking water ($p < 0.01$) but this effect was attenuated to non-significance with the addition of other key factors. From the value of COR, the water sample taken from walking distance between 500m and 1000m is 28 times contaminated with *E.coli* than walking distance of less than 500m($p < 0.05$, COR = 27.625).The water sample from the walking distance greater than 1000m from the

house hold is 31 times contaminated with *E.coli*/100ml of H_2O than the walking distance less than 500m($p < 0.05$, COR =30.875).This result was attenuated when adjusted with other determinant factors in this study($p > 0.05$). Also in that sample, there was a positive significant association between walking distance to the water source and F. coliform level. The water that obtained from sources of walking distance between 500m and 1000m is significantly contaminated with F.coliform, which is 23 times than that of water source of walking distance of less than 500m($p < 0.002$, COR=22.800). The water that taken from sources of walking distance greater than 1000m is more significantly contaminated with F.coliform, which is 43 times than that of water source obtained from walking distance of less than 500m ($p<0.01$, COR=43.200).When this association was analyzed with multivariate, water obtained from walking distance between 500m and 1000m became negatively associated to number of F.coliform per 100ml of water in the drinking water ($p< 0.05$, AOR =0.130). But, when this association was analyzed with multivariate water obtained from walking distance greater than 1000m became also a positively associated to number of F.coliform per 100ml of water in the drinking water. This is 2 times that of water from walking distance of less than 500m ($p<0.05$, AOR =2.161). Regardless of whether or not collected household water is initially of acceptable microbiological quality, it often becomes contaminated with pathogens of fecal origin during transport and storage due to unhygienic storage and handling practices (WHO, 2002). This suggests that distance from the water source to the house of the household might be significantly associated with higher water contamination regardless of source – perhaps through contamination during transport, or in association with some household sanitary behaviors' linked in currently unknown ways to the distance from the source (Jagals et al., 1999). This is similar to many other areas in developing nations and to other research done in the regions in Ghana (Stephen et al, 2008; WHO, 1996b; WHO, 1996c).

Types of storage containers used for the house hold drinking water

Types of storage container affect the keeping quality of household drinking water (Jensen P.K, 2002).From the total households of this study 23(29.5%),29(37.29%),14(17.9%) and 12(15.49%) use clay , Jerry can, metal and other kind of containers for drinking water storage, respectively. Washing intervals of water storage container also affect the quality of water. The daily or

alternate day washing interval prevents the biofilm formation and contamination of drinking water. Addition of fresh water in container containing residual water or residual water of dipper or jar or glass in storage container enhances the chance of bacteriological contamination of the drinking water. Households those used Jerry can containers for drinking water storage was associated with lower water quality that is contaminated with *E.coli* per 100ml of water. It was contaminated with *E.coli* 7 times that of the house hold that used clay as drinking storage container($p<0.001$, COR = 6.650).When it was analyzed with the multivariate level of contamination of drinking water with E.coli became 1132719 times that of the drinking water stored in the clay container($p <0.05$, AOR = 1132719.020).The water stored in metal container was contaminated with *E.coli* 12 times than water stored in clay container ($p<0.001$, COR =12.133).When data was seen with multivariate regression, it became 732868 times contaminated with *E.coli* than water stored in clay container($p<0.05$, COR = 732868).The water stored in the metal container is significantly more contaminated with *E.coli* when compared with water stored in the Jerry can container. Also water stored in Jerry can container was significantly contaminated with F.coliform when compared to clay container ($p< 0.01$).

It was 5 times contaminated with F.coli form than water stored in the clay container (COR = 4.75). It was also not attenuated when adjusted with the other determinant factors ($p<0.05$, AOR =977031.394). Water stored in metal container was significantly contaminated with F.coliform than water stored in the clay container. This one was 9 times contaminated with F.coli form than water stored in the clay container ($p< 0.01$, COR =8.667). This was also not attenuated when adjusted with the other determinant factors ($p<0.02$, AOR =3445815.790).Increased E.coli and F.coliform counts in house hold stored water container are high even when the source water is of good quality, suggesting that contamination is widespread during storage and drawing of water (Wright et al, 2004).Water must be stored and drawn in a safe manner otherwise the water can be recontaminated. The latter often happens when there is a communal drinking cup or dipper on top of the covered storage vessel. When wanting a drink, adults and children in the family dip this dipper in to the water and may then touch the water with soiled hands, eg. from anal cleansing. In this way, bacteriological quality of drinking water significantly decline after collection and water quality deterioration occurred between the supply and consumption (Clansen et al, 2004).

Total volume of drinking water collected at a time for the house hold

According to this study, the bacteriological quality of drinking water highly depends on the total volume of water collected at a time. There was significant association between bacteriological quality of water and total volume of water fetched per one day. The total volume of water between 20L and 40L collected in one day was 13 times contaminated with *E.coli* than total volume of water less than 20L collected in one day($p<0.02$, COR =12.833).When analyzed with multivariate regression, the difference became more significant($p<0.04$, AOR =21.832). The total volume of water greater than 40L collected in one day was 25 times contaminated with *E.coli* than total volume of water less than 20L collected per a day($p<0.001$, COR =25.375).When analyzed with multivariate regression analysis, this also became more significant($p<0.004$, AOR =6.832).In this study also the association between F.coliform and total volume of water fetched per a day was positive association($p < 0.05$).Total volume of water between 20L and 40L fetched per a day was 3 times contaminated with F.coliform than total volume of less than 20L fetched per a day($P < 0.04$, COD = 2.857).This was not disappeared when compared with other key factors ($p < 0.05$, AOR =7.475).Total volume of water greater than 40L fetched per a day was 8 times contaminated with F.coliform than total volume of less than 20L water collected per a day($P < 0.02$, COR = 7.500).This was less significant when adjusted with the other factors($p<0.05$, AOR =1.531).This result agrees with research done in other country that studied on the effect of large container on the contamination of water at the household level(Molbak, et al.,1989) and also agrees with the research done on the effect of the number of house hold members for which the water must be collected which indirectly related to the total volume of water collected at a time(WHO, 1996b; WHO, 1996c).

Time since the water was collected for the house hold (storage period of water)

Characteristics such as a spigot or narrow mouth reduce the rate at which chlorine volatilizes from water. Not surprisingly, we detected lower free chlorine levels in water stored for a longer time. In addition, longer storage time implies more opportunity for contamination, because hands and the handle or outer surface of collecting utensils frequently carry fecal pathogens.

The logistic regression models estimated that water which was collected by yesterday was 9 times more likely to be contaminated, i.e.> zero E. *coli*/100 ml H_2O, compared with water collected today($p<0.01$,COR=8.400). Water which was collected yesterday appeared to be more contaminated with *E.coli*, but this effect disappeared with further adjustment for environmental sanitary, types of storage container, and other factors ($p>0.05$). Household water collected before yesterday is also associated with 32 times elevated odds of contamination ($p<0.001$, COR=32.000). Water collected before yesterday appeared to be more Contaminated and this effect also appeared to be more significantly contaminated with *E.coli* with further adjustment for sanitary and other key factors of the study ($P< 0.03$, AOR = 45.734) .Drinking water which was collected yesterday was 4.6 times contaminated with F.coliform when compared with the water collected today(($p < 0.001$, COR = 4.632). This was not disappeared after adjustment with other key factors ($p<0.02$, COR =4.632). The water collected before yesterday became 10.333 contaminated by F.coliform than water collected today ($p<0.02$, COR =10.333). The result was not disappeared when analyzed with other determinant factors ($p<0.01$, AOR=856.352).Water which was collected before yesterday appears to be more contaminated with E.coli and F.coliform, also this effect appeared with further adjustment for environmental sanitary ,types of storage container, and other determinant factors. This result agrees with research done in other countries on the contamination of drinking water at the house hold level (William et al, 2007).

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CHAPTER SEVEN: CONCLUSIONS AND RECOMANDATIONS

7.1. Conclusions

- Water from the households has significantly more *E. coli* and F. coliform than water from the source.
- The mean of *E. coli* for all samples from households was 185.6 *E. coli* per 100 ml water and 199.8 F.coliform per 100ml of water.
- Number of *E. coli* and F.coliform has strong association with distance to water sources, total volume of drinking water collected, hand washing practices after using toilet, time since the water was collected, toilet type and types of storage containers.

7.2. Recommendations

As protection of the water source does not guarantee safe consumption, communities should get awareness of the possibility contamination of water at household level through:

- Extension workers.
- Wareda health offices and other concerned bodies.

The Ministry of Water and Energy, Ministry of Health and other stakeholders working on WASH should use this scientific fact to teach the community:

- How best to introduce household water treatment and storage technology.
- How to ensure correct use of technology/hardware within the community.
- How to ensure sustainability of behavioral change on the contamination of water.

7.3. Future research

It is clear that the microbiological processes occurring within the transport and storage vessels are complex, given the interaction of the biota in the collected water with biofilms in the containers and/or recontamination through dipping hands and cups into containers.

Future research is required:

- To understand these processes in more detail and also to assess how the storage period affects point-of-use water quality.

- The researcher also recommended that future studies record turbidity as this may indicate the presence of organic matter, a major influence on regrowth or die-off micro-organisms.
- The investigator also recommended that how strong research is required to see the association between bacteriological water contamination at the house hold level and prevalence of diarrhea disease statistically.

Annexes

Annex one: References

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Annex two: Questionnaire

Informed consent form for participants

Hello. My name is _____I am data collector for Mr Elias Ayana who is a graduate student at Jimma University. He is conducting a study on determinant factors of bacteriological water contamination at the house hold level in Hidi Hora, Serbo and Turfe semi-urban villages. The information I collect will help the federal Government of Ethiopia to better plan on recontamination of water by bacteria at the house hold level. You are randomly selected to participate in this study. The questions I plan to administer take about 30 to 40 minutes. All of the answers you give will be confidential and will not be shared with anyone other than members of our study team. I hope you will agree to answer the questions as much as possible since your views are important. Responding to these questions is believed to cause no harm to your health and wellbeing other than those encountered in normal day-to-day life. If I ask you any question that you don't want to answer, just let me know and I will go on to the next question or you can stop the interview at any time. In case you need more information about the survey, you may contact Mr Elias Ayana (the investigator) with Tel-0911758498.Do you have any question?

I have understood the above information, and have received answers to any question I asked. I consent to take part in the study.

Respondent's signature _____Date _____

Name and signature of the interviewer: _____Date_____

Name and signature of the Supervisor _____Date_____