THE BACTERIOLOGICAL AND PARASITOLOGICAL QUALITY OF DRINKING WATER AND PEOPLE'S WATER HANDLING PRACTICES IN AND AROUND ADAMA TOWN, OROMIA REGION, EASTERN ETHIOPIA

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The Bacteriological and Parasitological Quality of Drinking Water and People's Water Handling Practices in and around Adama Town, Oromia Region, Eastern Ethiopia

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BIOGRAPHICAL SKETCH

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ACRONYMS AND ABBREVIATIONS

AMB	Aerobic Mesophilic Bacteria
APHA	American Public Health Association
CFU	Colony Forming Unit
CSA	Central Statistical Authority
FC	Faecal Coliforms
FS	Faecal Streptococci
GPS	Global Positioning System
GV	Guideline Value
ISO	International Organization for Standardization
MDG	Millennium Development Goal
MOFED	Ministry of Finance and Economic Development
MOH	Ministry of Health
MOWE	Ministry of Water and Energy
MOWR	Ministry of Water Resources
MPN	Most Probable Number
NGO	Non-Governmental Organization
SPSS	Statistical Package for Social Sciences
TC	Total Coliforms
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations Children's Fund
USEPA	US Environmental Protection Agency
WHO	World Health Organization

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THE BACTERIOLOGICAL AND PARASITOLOGICAL QUALITY OF DRINKING WATER AND PEOPLE'S WATER HANDLING PRACTICES IN AND AROUND ADAMA TOWN, OROMIA REGION, EASTERN ETHIOPIA

ABSTRACT

Reduction of water-borne diseases and development of safe water resources is a major public health goal in developing countries.. Thus, the major purpose of this study was to assess the microbiological and parasitological quality of drinking water sources and the people's water handling practices in and around Adama Town, eastern Ethiopia. More specifically, the study gave emphasis to assess the bacteriological quality of drinking- water using indicator bacteria; the parasitological quality of drinking water and to assess people's water- handling practices and knowledge about water-borne diseases in the study area. A total of 447 water samples were collected from drinking- water sources in three rounds (432 from tap water, nine from well water, and six from river water sources) and tested addition, data regarding people's water handling practices and knowledge about water-borne diseases were collected through questionnaire and observation check-list from households. All the collected data were processed using and compared against standards set by WHO and the Federal Democratic Republic of Ethiopia, Ministry of Water Resources. The results indicated that Aerobic Mesophilic Bacteria (AMB), Total Coliforms (TC), Faecal Coliforms (FC), Faecal Streptococci (FS), Cryptosporidium oocyst and Giardia lamblia cyst were detected in almost all the samples of the different water sources. AMB were detected 100% in well and river, 88.89% of tap water samples. The mean AMB counts (±SE) for tap water, well water and river water samples were $5.94X10^{2}$*±33.6,* $1.70X10^{6}$*±*$1.89X10^{5}$*,* $2.17X10^{6}$*±*$2.56X10^{5}$*, respectively. TC bacteria were detected in 43.35% tap water samples and 100% of Well and River water samples. When the occurrence of TC was compared with standards, only 56.25, 27.55, 10.88, and 5.32% of the tap water samples were safe, of reasonable quality, polluted, and dangerous, respectively. The mean TC counts (±SE) were 24.58±2.9, 84.33±13.47, and 122.17±24.92 for tap, well and river water samples, respectively. FCs were also found in 39.35% of tap water samples and in all (100%) well and river water samples. However, out of samples tested from tap water sources, only 60.65% and 31.25% were safe and with reasonable quality, respectively. Mean counts of FCs (±SE) were 17.94±2.95, 37.33±7.83 and 51.33±13.41 for tap, well and river water samples, respectively. FS were detected in 4.17 and 100% of tap water and well & river water samples, respectively. With respect to the occurrence of FS, when compared with the standards, 95.83 and 4.17% of the tap water samples were safe and with reasonable quality, respectively. The mean counts of FS(±SE) were 3.5±0.27, 12.44±2.61, and 46.17±12.16 for tap, well and river water samples, respectively. Cryptosporidium* spp. *were detected in 23.61, 44.44, and 66.67% ,while Giardia lamblia was detected in 8.1, 33.33, and 50% of the tap water, well water and river water samples, respectively. Regarding water handling practices, Jerry can (81.76%) was the most commonly preferred type of water collection container in the study area. The findings also confirmed that only 13.36% of the households always cleaned the materials used for collecting drinking water. Moreover, more than half of the households (53.62%) were not covering drinking water collection containers during collection and transportation. The majority of the households (80.13%) were also storing drinking water for more than two days. The results of this study further showed a large number of the households (75.57%) were not using any form of treatment on the drinking-water they use. The study also showed that majority of the households (89.58%) had never been given the chance to participate in any training and awareness creation programs so far. As a result, their understanding about quality of drinking water and water-borne diseases was largely unsatisfactory. Finally, based on the findings of the study, making continuous follow- up on drinking water sources, developing appropriate control measures, conducting awareness creation activities, integrating sector office activities, arranging annual forum, and conducting further research are recommended*

Key Words: *Adama, Awareness, Bacteriological Quality; Parasitological Quality; Water Handling Practices*

1. INTRODUCTION

Water is a critical resource for development and essential for all activities of living things. It is a very precious resource of this planet as it is an established source of life. It is the most abundant substance in nature and vital for life activities. It is one of the most important compounds that constitute the largest part of life. Thus, the quality of water is central to all of the roles that water plays in our lives (Palaniappan *et al*., 2010). In this regard, as stated by organizations like United Nations Children's Fund UNICEF (2010), WAE (2010), World Health Organization WHO (2011), Ministry of Health MOH (2011), and Ministry of Water and Energy MOWE (2013), water intended for domestic uses should be free from toxic substances and microorganisms that are of health significance. So, clean, safe, and adequate freshwater is vital to the survival of all living organisms and the smooth functioning of ecosystems, communities, and economies.

However, the quality of the world's water is increasingly threatened as human populations grow, industrial and agricultural activities expand, and as climate change threatens to cause major alterations of the hydrologic cycle. Poor water quality threatens the health of people and reduces the availability of safe water for drinking and other uses (Palaniappan *et al*., 2010).

Research findings identified that every year, more people die from the consequences of unsafe water than from all forms of violence, including war. According to WHO (2011), worldwide, more than 80% of the human diseases are caused by unsafe water supply and inadequate sanitation practices. In a situation where there is no clean water and proper sanitation; millions of people would suffer from devastating diseases and millions of children would die due to water borne diseases.

Drinking water contaminated with human or animal excreta is the main cause of water-related diseases. The first such diseases identified were typhoid and cholera, and both remain a serious problem in many regions of the world. In addition, water-related diseases include most of the enteric and diarrheal diseases caused by bacteria, parasites and viruses, such as giardiasis, typhoid and rotavirus infections. Among these, the most common causes of severe diarrheal disease include rotavirus, pathogenic *E. coli*, *Campylobacter jejuni*, and protozoan parasites (WHO, 2011 and UNICEF, 2008).

Consequently, millions of people die from diarrhea every year. As stated by UNICEF (2008) and MOH (2011), the most predominant waterborne disease, diarrhea, has an estimated annual

incidence of 4 billion episodes and causes 2.2 million deaths every year. Of these, 90% of the deaths are in children under the age of five, mostly in developing countries. This is equivalent to one child dying every 15 seconds. These deaths represent approximately 4% of all deaths, and 18% of under-five child deaths in developing countries. Moreover, as described by WHO (2011), approximately 3.7% of deaths and disability-adjusted-life-years worldwide are attributable to unsafe water, poor sanitation and hygiene.

In Ethiopia, nearly about 40% of the population depends on different types of unprotected water sources (MOH, 2011). Besides, a recently published document (MoFED, 2012) also stated that potable water supply coverage in the country during 2009/10 was 65.80%. Consequently, communicable diseases account for about 60-80% of health problems in the country. Most of the time, the occurrence of communicable diseases is related to the quality of water supply conditions. Ethiopian child usually suffers five to twelve diarrheal episodes a year basically resulting from unsafe water and poor environmental sanitation; and between 50, 000 to 112,000 under five children die annually due to the same causes (MOH, 2011).

Unless water is made safe for consumption, it may be hazardous to the health of human and other animals. Potential pollution sources that pose threats to drinking water are open field defecation, animal wastes, economic activities (agricultural, industrial and other income generating businesses) and even wastes from residential areas as well as effluent from sewage system. Another way by which pollution reaches and enters a water supply is through inundation or infiltration by flood waters (MOH, 2011). If people do not sufficiently access potable water, they may be forced to use water from impure sources, which exposes them to various water-borne diseases.

Different types of pathogens can contaminate water in various ways. Therefore, detection and measurement of the magnitude of contamination by indicator microorganisms would help predict the presence of pathogens and estimate human health risks. In short, these indicators can be used to assess the water quality of a given area. The first priority in assessing drinking-water quality is to check the microbiological quality and safety for consumption. This can be done by measuring, at a minimum, the “essential parameters” of drinking-water quality including the determination of total coliform and faecal coliform (or *E. coli*) counts along with the assessment of the effectiveness of water treatment through the determination of residual chlorine content, pH and turbidity of water (WHO, 2008 and Aly*et al.*, 2013). In this regard, the World Health

Organization Microbiological Guidelines (WHO, 2011) and the Federal Democratic Republic of Ethiopia, Ministry of Water Resources (MOWR, 2002) recommended for drinking water zero total coliform and feacal coliform/100 ml of water.

Based on these indicators, studies carried out in different parts of the country showed that water sources and distribution systems of towns and rural areas had serious water quality problems. For example, an assessment of bacteriological and physico-chemical qualities of urban source water and tap water distribution systems in Ziway (Kassahun, 2008), and Bahir Dar towns identified contaminations of the water with heavy loads of indicator bacteria such as total coliforms, faecal coliforms and faecal streptococci (Getnet,2008) .

Similarly, underground water sources from rural areas in Menge District, Benishangul Gumuz region (Mebratu, 2007), and protected springs and hand pumped wells in Werebabo District, South Wello (Atnafu, 2006) indicated that 60-100% of the water samples were positive for total coliforms and faecal coliforms. Moreover, a recent study conducted in Bishoftu (Desta, 2009), Dire Dawa (Desalegn *et al*., 2013), and Simada District, Gonder (Meseret, 2012) also revealed that improper sanitary services and failure in the protection of water sources together with poor community sanitary practices around the source and in the catchment areas contributed to the contamination of drinking water with faecal matter.

On the whole, all the above reports confirmed that water quality problems are rampant both with small scale and large-scale water delivery systems in the country. These would pose high health risks to users unless prompt intervention is undertaken.

However, according to the report of MOH (2011), in Ethiopia water quality monitoring and surveillance activities are not conducted on scheduled and continuous basis by sector organizations. Drinking water quality assessment is not regularly practiced on scheduled basis in the country. The latest assessment of drinking water quality was conducted from December 2004 to April 2005. Since 2005, water quality monitoring and surveillance has not been done so far in the country (MOH, 2011).Nevertheless, the analysis of water quality parameters alone cannot provide a complete picture of the water quality status of a community and its water sources. As stated by UNICEF (2008), the concept of water quality assessment has been broadened to include not just the water supply systems and their immediate surroundings, but also analysis of routes through which contamination may occur, and the practices in communities and households. Water is often contaminated during transportation to the home and in the home

itself. Moreover, such contamination is linked to hygiene awareness and practices of water bearers and family members.So, assessing the water handling and storage practices of households can yield valuable findings about the causes of poor water quality and to forward likely interventions for the improvement of water quality status in the study area.

In Adama, like in other towns of the region and the country at large, there is chronic shortage of adequate potable water and sanitation services. Potable water coverage in the town was found to have remained at 68.86% (ACA, 2014). The sanitation coverage of the town was only 51%; particularly in low income areas its coverage is very poor (ACA, 2014). However, no study has been done on the quality of drinking water sources and water handling practices in the study area so far.

These situations and the above-mentioned problems call for researchers to carry out studies on issues related to bacteriological and parasitological qualities of drinking water sources and water handling practices in Adama town and its surrounding areas. Thus, this study was conducted to investigate the quality of drinking water with the following objectives.

General Objective:

The general obiective of the study was to assess the microbiological and parasitological quality of drinking water sources and the people's water handling practices in and around Adama Town, Oromia Regional State, Eastern Ethiopia.

Specific Objectives:

The specific objectives the of current study were:

a) To assess the bacteriological quality of drinking water in the study area using standard indicator bacteria.
b) To assess the parasitological quality of drinking water (tap water, well water, and river water) in the study area.
c) To assess the people's water handling practices and the level of knowledge about water-borne diseases in the study area.

2. LITERATURE REVIEW

2.1. The Quality of Drinking Water

Drinking water quality, 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, 2008). It 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.

Drinking water quality has a strong impact on people's health because water is a vehicle of transmission for many pathogenic microorganisms that causes diseases (Howard and Bartram, 2005). According to Howard and Bartram (2005), the basis of good water quality is important to human health. It has a strong impact on people's health because water is a means of transmission for many pathogenic microorganisms that cause diseases.

Different water sources are highly subjected to contamination, due to various reasons. In many developing countries, water supplies are of poor quality often is unsafe for human consumption. Consequently, diseases will continue to spread among the poor until adequate wastewater disposal accompanies the provision of safe drinking water (Davison *et al*., 2005; UNICEF, 2008; WAE, 2010; and WHO, 2011). As a result, water quality is a growing concern throughout the developing world. Drinking water sources are under increasing threat from contamination, with far-reaching consequences for the health of children and for the economic and social development of communities and nations.

Nowadays, the matter of drinking water quality is becoming an issue of global human health concern, principally due to water contamination with pathogens and potentially toxic chemicals. The provision of an adequate supply of safe water was one of the components of primary health care identified by the International Conference on Primary Health Care. Water quality standards have been developed to minimize the known chemical and microbial risks of human health (UNICEF, 2008).

In spite of concentrated efforts to improve access to safe drinking water (notably the International Drinking Water and Sanitation Decade, from 1981 to 1990); an estimated 1.1 billion people lack access to an improved water source. Over three million people, mostly children, die annually from water-related diseases. Almost two million of these deaths are the

result of diarrheal diseases, which are caused by the ingestion of water contaminated by faecal matter, as well as by inadequate sanitation and hygiene (UNICEF, 2008; WAE, 2010).

It is generally agreed that the principal risk to human health associated with the consumption of polluted water are microbiological. Waterborne disease outbreaks, usually involves source contamination and the breakdown of the treatment systems, contamination of the distribution lines and the use of untreated water. The uses of polluted water from these sources are incriminated with most of the water borne diseases (WHO, 2008).Contaminated water resources can also contribute to the spread of diseases caused by skin contact or by vectors. In addition to causing direct health impacts, unsafe drinking water has a number of subtle or indirect adverse health effects.

The consequences of poor water quality go beyond health. Chronic bouts of water-related diseases impose significant social and economic burdens both on victims themselves and society as a whole. Poverty alleviation and other Millennium Development Goals will be difficult to achieve without improvements in water quality. While microbiological contamination is the largest public health threat, chemical contamination can be a major health concern in some cases (WHO, 2008; Aly *et al*., 2013; and UNICEF, 2008).Moreover, poor water quality has many economic costs associated with it, including health-related costs; increased water treatment costs; and reduced property values. As described by Palaniappan *et al* (2010), the estimated costs of poor-quality water in countries in the Middle East and North Africa range between 0.5 and 2.5 percent of GDP per year.

In general, water from contaminated sources may cause numerous diseases and premature deaths. The fact that, man needs water and cannot live without it, forces him to use it even for drinking purposes, whether clean or contaminated. As a result, people suffer from water-borne diseases especially in Ethiopia. In rural villages and urban areas of Ethiopia, the main contaminants for water are human excreta, animal waste, liquid waste from factories, garages, pesticides from different sources. Water sources contaminated with these wastes is not fit for human use, unless it is made safe or treated (Desalegn, 2013; and MOH, 2007).

Improvements in microbiological water quality as well as the prevention of use of unhygienic water sources are best interventions to prevent water-borne diseases (Brown, 2003). Many studies have clearly shown that supply of microbiologically safe water can reduce directly or indirectly, the morbidity of waterborne diseases (WHO, 2011). Thus, the importance of doing

away with microbiological contamination is the major benefit of ensuring good water quality for drinking and reducing of water-borne diseases transmitted by the faecal-oral route. So, in order to reduce diseases outbreaks emanated from polluted water, it is important to emphasize on the quality of drinking water sources (Howard and Bartram, 2005).

2.2. Diseases Transmitted Through Drinking Water

Drinking-water is an important source of infectious agents, particularly ones that cause enteric infections. Many of the great epidemics of history have been caused by faecal contamination of drinking-water. While person-to-person contact is equally important it is common for the population to indicate water as a source of disease. The significance of any particular organism varies with the disease caused under local water supply conditions (MOH-NZ, 2013).

Many bacteria, viruses, protozoa and parasites can cause disease when ingested. The majority of these pathogens derive from human or animal faeces and they are transmitted through the faecal-oral route (WHO, 2011 and UNICEF, 2008). In this regards, the data in Table1, pathogens for which there is some evidence of health significance related to their occurrence in drinking-water supplies are listed in four categories as identified by WHO (2011).

Table 1 **: Pathogens transmitted through drinking water** WHO (2011)

Pathogenic microbes	Health significance[b]	Persistence in water supplies[c]	Resistance to chlorine[d]	Relative infectivity[e]	Important animal source
I. Bacteria					
Burkholderia pseudomallei	High	May multiply	Low	Low	No
Campylobacter jejuni, *C.coli*	High	Moderate	Low	Moderate	Yes
Escherichia coli-Pathogenic[f]	High	Moderate	Low	Low	Yes
E. coli-Enterohaemorrhagic	High	Moderate	Low	High	Yes
Francisella tularensis	High	Long	Moderate	High	Yes
Legionella spp.	High	May multiply	Low	Moderate	No
Leptospira	High	Long	Low	High	Yes
Mycobacteria (non-tuberculous)	Low	May multiply	High	Low	No
Salmonella Typhi	High	Moderate	Low	Low	No
Other salmonellae	High	May multiply	Low	Low	Yes
Shigella spp.	High	Short	Low	High	No
Vibrio cholerae	High	Short to long[g]	Low	Low	No
II. Viruses					
Adenoviruses	Moderate	Long	Moderate	High	No
Astroviruses	Moderate	Long	Moderate	High	No
Enteroviruses	High	Long	Moderate	High	No
Hepatitis A virus	High	Long	Moderate	High	No
Hepatitis E virus	High	Long	Moderate	High	Potentially
Noroviruses	High	Long	Moderate	High	Potentially
Rotaviruses	High	Long	Moderate	High	No
Sapoviruses	High	Long	Moderate	High	Potentially
III. Protozoa					
Acanthamoeba spp.	High	May multiply	High	High	No
Cryptosporidium hominis/parvum	High	Long	High	High	Yes
Cyclospora cayetanensis	High	Long	High	High	No
Entamoeba histolytica	High	Moderate	High	High	No
Giardia intestinalis	High	Moderate	High	High	Yes
IV. Helminths					
Dracunculus medinensis	High	Moderate	Moderate	High	No
Schistosoma spp.	High	Short	Moderate	High	Yes

a-This table contains pathogens for which there is some evidence of health significance related to their occurrence in drinking-water supplies.
b-Health significance relates to the incidence and severity of disease, including association with outbreaks.
c-Detection period for infective stage in water at 20 °C: short, up to 1 week; moderate, 1 week to 1 month; long, over 1 month.
d-When the infective stage is freely suspended in water treated at conventional doses and contact times and pH between 7 and 8. Low means 99% inactivation at 20 °C generally in < 1 min, moderate 1–30 min and high > 30 min. It should be noted that organisms that survive and grow in biofilms, such as *Legionella* and *mycobacteria*, will be protected from chlorination.
e-From experiments with human volunteers, from epidemiological evidence and from experimental animal studies. High means infective doses can be $1–10^2$ organisms or particles, moderate $10^2–10^4$ and low > 10^4.
f-Includes enteropathogenic, enterotoxigenic, enteroinvasive, diffusely adherent and enteroaggregative.
g-*Vibrio cholerae* may persist for long periods in association with copepods and other aquatic organisms.

2.2.1. Bacterial Pathogens

The human bacterial pathogens that can be transmitted orally by drinking-water and which present a serious risk of disease include *Salmonella spp, Shigella spp, Enteropathogenic*

Escherichia coli, Vibrio cholerae, Yersinia enterocolitica, Campylobacter jejuni, and *Campylobacter coli.* While typical waterborne pathogens are able to persist in drinking-water, most do not grow or proliferate in water. The most common waterborne pathogens are those that are highly infectious or highly resistant to decay outside the body (WHO, 2011). If present in drinking-water, faecal contamination and hence the related waterborne bacterial pathogens are likely to be dispersed widely and rapidly. Outbreaks of waterborne disease are therefore frequently characterized by an infection across a whole community (Aly *et al*., 2013).

Although bacterial contamination normally can be thought of as a short-term event, there are examples of long-term after effects. A seven-year follow-up study report of Walkerton residents (MOH-NZ, 2013), for example, showed that many continued to experience long-term adverse health effects. One of the most severe complications of *E. coli* O157 infection is HUS (haemolytic uremic syndrome) and survivors of HUS may have permanent kidney damage, potentially requiring a kidney transplant later in life. Therefore there has been a particular focus on children who suffered HUS during the outbreak. Also, it was found that among those who had experienced severe gastroenteritis during the outbreak, 36 percent had developed Irritable Bowel Syndrome, compared to 28 percent of those who had moderate gastroenteritis and 10 percent of those who had not been ill (APHA, 2005; UNICEF, 2008; and MOH-NZ, 2013).

Most water-borne bacterial infect the gastrointestinal tract and cause diarrheal disease. In most cases, the specific bacteria responsible for infection is not identified and case identification and treatment is fairly generic. Two very serious forms of diarrheal disease, cholera and shigellosis, should be considered separately because of their severity and tendency to create epidemics (UNICEF, 2008).

2.2.2. Protozoan Parasites

The majority of protozoa are free-living aquatic organisms of no significance to public health. Protozoa generally feed on other micro-organisms such as bacteria, algae, cyano bacteria, or other protozoa. They likely to be found in drinking-waters and of public health significance can be grouped into those of enteric or environmental origin:

a) Enteric protozoa occur widely as parasites in the intestine of humans and other mammals and involve at least two stages (trophozoite and (oo)cyst) in their life cycle

b) Some free-living protozoa (FLP) are opportunistic pathogens in humans and are responsible for some serious diseases of the nervous system and the eye.

The most prevalent enteric protozoal parasites associated with waterborne disease include *Giardia, Cryptosporidium hominis and C. parvum. Toxoplasma gondii, Entamoeba histolytica,* and *Balantidium coli* have also been associated with waterborne outbreaks. *Cryptosporidium*, a coccidian protozoal parasite, was only identified as a human pathogen in 1976. It can cause diarrhoeal illness in the immune competent but with dire consequences in immune compromised individuals. The disease is endemic throughout the world. The incidence of infection is also high, illustrated by the finding that in the USA 20 percent of young adults has evidence of infection by *Cryptosporidium* (WHO, 2008; and MOH-NZ, 2013).

Other emerging protozoal parasites of concern include *Cyclospora cayetanensis* and *Isospora belli*. Microsporidia are also emerging pathogens of public health importance and, although recently classified as fungi, their fate and behavior in water can be similar to that of the parasitic protozoa.

The transmissive/infective stages of these parasites are cysts (*Giardia, Balantidium, Entamoeba),* oocysts *(Cryptosporidium, Cyclospora, Isospora, Toxoplasma)* or spores (Microsporidia). These forms are excreted in faeces of infected hosts as fully infectious agents (*Giardia, Cryptosporidium*, Micropsporidia, Balantidium) or as immature stages (*Cyclospora, Isospora, Toxoplasma*) requiring a short period of development in the environment to reach the mature stage. They can get into drinking-water supplies by contamination with human or animal faeces. All are widely dispersed and have been associated with outbreaks of infection resulting from drinking contaminated water (WHO, 2008).

Giardia and *Cryptosporidium* are the most widely reported causes of waterborne parasitic disease in developed countries. These organisms can causes varying degrees of enteric condition that can be manifested from violent diarrhea symptoms to being asymptomatic. Immunocompetent people typically recover without intervention. Dehydration is the most frequent symptom requiring attention in severely affected individuals.

2.3. Microbiological Indicators of Water Quality

The presence of certain microorganisms in water is used as an indicator of possible

contamination and an index of water quality (Hurst *et al*., 2002). Indicator organisms are selected to demonstrate the presence of human and animal wastes and hence the potential presence of pathogens in drinking water (Brian, 2002; Mombal *et al*., 2006; and Plummer and Long, 2007).

In order to identify indicator organisms for water quality analyses, the indicator organisms should fulfill the following criteria; an indicator organism should always be present when pathogens are present, indicators and pathogens should have similar persistence and growth characteristics, indicators and pathogens should occur in a constant ratio so that counts of the indicators give a good estimate of the numbers of pathogens present, indicator concentrations should by far exceed the pathogen concentration at the source of pollution, the indicator should not be pathogenic and should be easy to quantify, tests for the indicator should be applicable to all types of water and the test should detect only the indicator organisms thus not giving false-positive reactions (Slaats *et al*.,2002, Hurst *et al*., 2002; and WHO, 2008).

Using such indicators and to assess water quality problem, WHO prepared a standard for microbiological water quality evaluation checklist: *zero=safe, 1-10=reasonable quality, 11-100= polluted water, 101-1000= dangerous and >1000 very dangerous CFU/100 ml* (WHO, 2011).

2.3.1. Bacteriological Water Quality Indicators

International organizations and most countries use *Escherichia coli* (*E. coli*) as the bacterial indicator, with a maximum acceptable value (MAV) of less than 1 per 100 ml. *Faecal coliforms* (thermotolerant or presumptive coliforms) and total coliforms (TC) can be monitored instead of *E. coli*, but with the proviso that a positive result for either should be treated as a positive *E. coli* result. Given that, one can obtain either faecal coliforms or total coliforms in the absence of *E. coli*, this option is generally more demanding (APHA, 2005; and WHO, 2011).

Escherichia coli comes from the family of bacteria known as Enterobacteriaceae and is the most common bacterial species of this group. It is characterized by possession of the enzymes β-galactosidase and β-glucuronidase. *E. coli* is nearly always present in the gut of humans and animals and usually in high numbers, and it is found in fresh faecal material at densities of more than 10^9 organisms per gram. It can survive for considerable periods in water, which is generally similar to some of the waterborne faecal pathogens. A few strains of *E. coli* may be pathogenic in the gut. Both pathogenic and non-pathogenic strains of *E. coli* are equally important as

indicators of faecal contamination, as are animal and human sources (WHO, 2011; and UNICEF, 2008). Thus, as illustrated in Table 2, it is practical to classify water quality results in terms of an overall grading for water safety linked to priority for action. Water quality have relation with the number of population served that water sores(WHO, 2011).

Table 2: Categorization of Quality of Drinking-Water Systems and the Population Size WHO (2011:91)

Quality of drinking-water system[a]	Proportion (%) of samples negative for *E. coli*		
	< 5000 population	5000–100 000 population	> 100 000 population
A	90	95	99
B	80	90	95
C	70	85	90
D	60	80	85

[a] Quality decreases from A to D.

However, the absence of *E. coli* does not necessarily guarantee the absence of faecal contamination. Absence of evidence does not logically denote evidence of absence. Although their presence is a definite indication of pollution, their absence suggests that pathogenic bacteria and viruses are probably absent also (WHO, 2011; MOH-NZ, 2011; and UNICEF, 2008).

Since most pathogens in drinking water derive from faecal contamination, the WHO Guidelines for Drinking-Water Quality gives guideline values for microbiological indicator species illustrated in Table 3 (WHO, 2011).

Table 3: Guideline Values for Verification of Bacteriological Quality WHO (2011)

Organisms	Guideline value
All water directly intended for drinking	
E. coli or thermotolerant coliform bacteria[b,c]	Must not be detectable in any 100 ml sample
Treated water entering the distribution system	
E. coli or thermotolerant coliform bacteria[b]	Must not be detectable in any 100 ml sample
Treated water in the distribution system	
E. coli or thermotolerant coliform bacteria[b]	Must not be detectable in any 100 ml sample

[a] Immediate investigative action must be taken if *E. coli* are detected.
[b] Although *E. coli* is the more precise indicator of faecal pollution, the count of thermotolerant coliform bacteria is an acceptable alternative. If necessary, proper confirmatory tests must be carried out. Total coliform bacteria are not acceptable as an indicator of the sanitary quality of water supplies, particularly in tropical areas, where many bacteria of no sanitary significance occur in almost all untreated supplies.
[c] It is recognized that in the great majority of rural water supplies, especially in developing countries, faecal contamination is widespread. Especially under these conditions, medium-term targets for the progressive improvement of water supplies should be set.

Moreover, assessment of priority of remedial action for household drinking-water systems is based on a grading system of microbial quality as shown in Table 4 (WHO, 2011).

Table 4: Escherichia coli classification (as decimal concentration/100ml) and associated risk

Count per 100 ml	Risk Category
	Inconformity with the Guideline
1-10	Low risk: No action required
11-100	Intermediate risk: Low action priority
101-1000	High risk: Higher action priority
>1000	Very high risk: Urgent action required

Source: WHO (2011)

In general, the presence of indicator organisms in water indicates contamination of water by faecal matter, which could probably contain pathogens. In other words, the presence of indicators of faecal pollution means that thlikelihood of faecal pathogens occurring in that water is high (MOH-NZ, 2011). According to USEPA regulations the main groups of bacteria that served as indicators to monitor water quality are: Aerobic Mesophilic Bacteria (AMB), total coliforms (TC), faecal coliforms (FC), and *Enterococcus* (USEPA, 2005 and Aly *et al*., 2013).

A. Aerobic Mesophilic Bacteria (AMB)

Aerobic Mesophilic Bacteria grow in heterotrophic plate count (HPC) method and are almost always present in drinking-water and used as an indicator of overall cleanliness of the water supply system. The heterotrophic plate count (HPC) method uses a standard culture technique to grow a wide range of aerobic mesophilic bacteria on a non-selective agar medium. The bacteria that grow in these conditions are almost always present in drinking-water and are therefore an indicator of overall cleanliness of the water supply system.

Elevated HPC levels occur especially in stagnant parts of piped distribution systems, in domestic plumbing, in bottled water and in plumbed-in devices, such as softeners, carbon filters and vending machines. The principal determinants of re-growth are temperature, availability of nutrients and lack of residual disinfectant. Nutrients may derive from the water body and/or materials in contact with the water. HPC measurements are used: to indicate the effectiveness of water treatment processes, thus as an indirect indication of pathogen removal; as a measure of numbers of re-growth organisms that may or may not have sanitary significance; and as a measure of possible interference with coliform measurements in lactose-based culture methods. This application is of declining value, as lactose-based culture media are being replaced by alternative methods that are lactose-free(USEPA, 2005).

Piped water systems of large buildings may incur greater growth than encountered elsewhere (because of storage tanks, extensive internal distribution networks and temperature-related growth). The principal health concerns in these networks are cross connections and growth of *Legionella* bacteria, which are not detected by the HPC test procedures.

Colony counts (heterotrophic plate counts) can be a useful indicator to monitor operational performance. They represent bacteria that have entered the water supply or that have survived the treatment processes and are able to grow and produce viable colonies on the growth medium used for the tests, under specified conditions (eg, incubation time, temperature). Not all bacteria in water will, however, grow under these test conditions. It is usually not the absolute concentration of HPC but a change in HPC concentration that is useful to the water industry.

Colony counts are usually determined after incubation at 20–22°C or at 35–37°C. Plate counts of bacteria able to grow at 20–22°C or at 35–37°C in a standard nutrient medium may be relevant to the nutrient status of the water but not the faecal pollution. The count at 22°C will favor many environmental organisms. It has little sanitary value but is useful in assessing the efficiency of

water treatment, specifically the processes of coagulation, filtration and disinfection, each of which reduces bacterial numbers. It may be used to assess the cleanliness and integrity of the distribution system and the suitability of water for manufacturing food and drink where a high count may lead to spoilage.

The count at 35°C will include some environmental organisms and also some from faeces. A significant increase above normal in this count may be an early sign of contamination. For this reason, in many cases, the only heterotrophic plate count performed is that at 35°C. Colony counts should only be used as an adjunct to routine monitoring for *E. coli*. When a large number of organisms are detected, some form of remedial action is recommended, such as cleaning of storage tanks or inspection and repair or disinfection of the reticulation system. It may be useful to identify the dominant organisms present, particularly where there is persistent bacterial growth in a reticulation system.

These counts are a useful measure of the general quality of a water supply and to some extent of the standard of treatment or the microbial condition of the distribution system. The numbers should fall substantially during treatment processes. Generally, well-maintained water supplies should have little difficulty in obtaining samples with colony counts as follows (using the pourplate technique with standard plate count agar at 35°C for 48 hours).

B. Total Coliforms (TC)

Total Coliforms are the ones that are commonly measured as indicator bacteria for drinking water quality (Brian, 2002; and Hurst *et al.,* 2002). They are defined as aerobic and facultatively anaerobic non spore-forming bacteria that have rod shap and gram -negative that ferment lactose at 35 to 37^0C with the production of acid and gas within 24-48 hours (Hurst *et al.,* 2002).

Coliform bacteria belong to the family *Enterobacteriace* and include *Escherichia coli* as well as various members of the genera *Nitrobacteria*, *Klebsiella* and *Citrobacter* (Hurst *et al.,* 2002). These bacteria originate in the intestinal tract of warm-blooded animals and can be found in their wastes. They can also be found in soil and on vegetation (Brian, 2002).

Although coliform bacteria are not pathogens, their presence indicates the possibility of finding pathogens in drinking water (Nold, 2008). Consequently, they are used to assess possible faecal contamination or water pollution from sewage. According to Hurst *et al*. (2002), the persistence of total coliform bacteria in aquatic systems is comparable to that of some of the waterborne bacterial pathogens. Furthermore, coliform bacteria are relatively simple to identify and are

present in much larger numbers than more dangerous pathogens (Brian, 2002; and Hurst *et al.,* 2002). For this reason the degree of faecal pollution and the presumed existence of pathogens can be estimated by monitoring coliform bacteria (Volk *et al*., 2002). The coli forms group consists of several genera of bacteria belonging to the family Entrobacteriaceae including Citrobacter, Entrobacter, Escherichia and Klebsiella.

C. Faecal Coliforms or Thermotolerant Bacteria (FC)

Thermotolerant bacteria are the ones that are commonly measured as indicator bacteria for drinking water quality (Brian, 2002; and Hurst *et al.,* 2002). They are defined as aerobic and facultatively anaerobic non spore-forming bacteria that have rod shap and gram -negative that ferment lactose at 44.5^0C with the production of acid and gas within 24-48 hours (Hurst *et al.,* 2002).

Thermotolerant bacteria are found in the subgroup of coliform bacteria that grow at 44°C (Aliev *et al*., 2006). Faecal coliforms live in the intestines' of warm blooded animals. As a result, they show excellent positive correlation with faecal contamination of water from warm blooded animals (Hurst *et al*., 2002).

Apart from the fact that the faecal coliform (*E.coli*) are considered as one group of indicators of faecal contamination of water (Stephen, 2004), some strains such as enter hemorrhagic and entroinvasive *E. coli* have become serious causative agents of emerging waterborne diarrheal diseases (Nold, 2008).

The reason for testing for fecal coliforms is that they are more restricted in their source to the gastro intestinal tract of warm-blooded animals. In addition, they have an excellent positive correlation with fecal contamination from warm-blooded animals (Toranzos *et al*., 2002). The presence of coliform bacteria in potable water indicates unsuitable sanitation practices (Hawarth, 1996; and Aliev *et al*., 2006).

Many countries have adopted the use of FC as indicators in their water quality standards and they have been recommended as the indicator of choice for evaluating the microbiological quality of recreational waters (Toranzos *et al*., 2002).

D. Faecal Streptococci (FS)

Faecal streptococci are species of gram-positive cocci belonging to two genera, *Enterococcus* and *Streptococcus*. The relevant species are linked by common biochemical and antigenic properties and are found in the faeces of humans and other animals. Many will grow in 6.5 percent sodium chloride solutions and at 45°C. They are Gram-positive, catalase-negative cocci that grow at 45°C on selective media such as bile aesculin agar. The two genera, *Enterococcus* and *Streptococcus,* possess the Lancefield group D antigen.

Enterococci include all faecal streptococci that grow at pH 9.6, 10°C and 45°C and in media supplemented with 6.5% NaCl. They are a subset of faecal streptococci that grow under the conditions outlined above. Alternatively, enterococci can be identified directly as microorganisms capable of aerobic growth at 44±0.5°C and hydrolyzing 4-methylumbelliferyl-β-D-glucoside (MUG, used for detecting β-glucosidase activity by blue florescence at 366 nm), in the presence of thallium acetate, nalidixic acid and 2,3,5-triphenyltetrazolium chloride (TTC, which is reduced to the red formazan) in the specified medium (ISO/FDIS 7899-1 1998). The presence of faecal streptococci and enterococci in water is an indicator of faecal pollution of water and the possible presence of enteric pathogens in water (WHO, 2008).

Enterococcus and *Streptococcus* occur regularly in faeces but not in such numbers, or so invariably, as *E. coli*. Certain species of *Enterococcus* can be found free-living in soil and thus their presence in water may be from a non-faecal source (Leclerc *et al*., 2001). Thus, while the specificity of this indicator is acceptable, it is less sensitive than *E. coli*. Its persistence in water is less than that of *E. coli*, and it is generally a poorer indicator of the presence of certain pathogens that die off slowly (WHO, 2011).

2.3.2. Parasitological Water Quality Indicators

Giardia and *Cryptosporidium* are the two protozoan pathogens that have been implicated in a number of outbreak and sporadic disease patterns in most countries; and are widespread in many water sources; they are endemic in livestock, domestic and feral animals. Therefore, surface waters, including shallow groundwater, must be considered to be potentially contaminated (WHO, 2011; APHA, 2005; and MOH-NZ, 2013).

The level of treatment required for surface waters and non-secure bore water is determined from the concentration of *Cryptosporidium* in the source water. The premise is that *Cryptosporidium*

is known to be very resistant to treatment processes, and is smaller than *Giardia*, so is used as an indicator for all pathogenic protozoa. Thus, the level of treatment selected to remove *Cryptosporidium* should also provide a level of protection from other less resistant pathogenic protozoa, including *Giardia.*

In general, methods for the detection of *Giardia* and *Cryptosporidium* in water have advanced considerably in the last few years. Detecting these protozoa involves the filtration of large volumes of water as the oocysts are usually present in very low numbers. Methods have been developed using filtration and immuno-based techniques with monoclonal antibodies for separation (immunomagnetic separation, IMS) and detection (immunofluorescence assay, IFA) to determine concentrations of oocysts with confirmation through vital dye staining (DAPI) and differential interference contrast (DIC) microscopy (MOH-NZ, 2013). However, the recovery success of this process can be variable; monoclonals may vary in their avidity and specificity to oocysts or cross-react with other animal species, and the methods are costly.

2.4. People's Awareness and Water Handling Practices

Improved local awareness and people's knowledge about the effect of poor water quality and water handling practices leads ultimately to safer water supplies. Thus, the analysis of water quality parameters alone cannot provide a complete picture of the water quality status of a community and its water sources. As stated by UNICEF (2008) recently, the concept of water quality assessment has been broadened to include not just system and their immediate surroundings, but an analysis of routes through which contamination may occur, and the practices in communities and households. It often contaminated during transportation to the home and in the home itself. Moreover, such contamination is linked to hygiene awareness and practices of water bearers and family members UNICEF (2008).

Even if the source of drinking water is safe; it become faecally contaminated during collection, transportation, storage and drawing in the home (Thomas and Cairncross, 2004). Water may become unsafe at any point between collection and use. Unrestricted and unhygienic water collection activities, soiled hands and unclean water collection vessels were potential contributors for the contamination of drinking water sources (UNICEF, 2008; and WHO, 2011). Key factors in the provision of safe household water includes; the conditions and practices of water collection, storage and the choice of water collection and storage containers/vessels.

So, along with building or improving water points, therefore, providing hygiene education for all user groups is necessity. Promoters in the sector should inform community members about the correct use and storage of water, the need for safe sanitation facilities, personal and environmental hygiene, aiming at sustainable behavior change (WHO, 2008).However, water quality is often a much lower national priority than water coverage, especially in countries where coverage levels are low. People usually do not demand improved quality, they demand increased coverage - and governments respond accordingly. This situation is largely a reflection of public's low level of awareness about water quality issues (UNICEF, 2008).

With regard to this, as stated by Federal Ministry of Health, in Ethiopia, there is no significant involvement of the community in water quality monitoring and surveillances. As there is scarcity of potable water in the country, communities give priority to quantity than quality. There is also little awareness creation work done regarding water quality issues in the country (MOH, 2011). Similarly, a Civil Society Organizations' Joint Report on Water, Sanitation and Hygiene practices for the Year 2009/10 in the country also stated that, there are noticeable downsides in the water sector with regard to water quality management and awareness raising activities in the area of drinking water quality that target the community are weak (Dagnew, *et al*. 2010; and WAE, 2010).

In relation to this, it is argued that, when families and communities are aware of the problem, the solution and the responsibilities they and others have to keep water safe, they can more effectively take action on water quality problem in the community (UNICEF, 2008). Thus, awareness-raising programs on issues related to water quality are used as a starting point for community-based water quality surveillances and to promote service upgrades.

Moreover, as recommended by WHO (2011) a holistic approach to the risk assessment and risk management of a drinking water supply increases confidence in the safety of the drinking-water. This approach entails systematic assessment of risks throughout a drinking-water supply (from the catchment and its source water through to the consumer) and identification of the ways in which these risks can be managed, including methods to ensure that control measures are working effectively. It incorporates strategies to deal with day-to-day management of water quality, including upsets and failures (WHO, 2011).

However, failure to ensure drinking-water safety may expose the community to the risk of outbreaks of intestinal and other infectious diseases. So, outbreaks of waterborne disease are

particularly to be avoided because of their capacity to result in the simultaneous infection of a large number of persons and potentially a high proportion of the community (Palaniappan *et al*., 2010; WHO, 2011 and MOH-NZ, 2013).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The study area was Adama town located in Eastern Showa Zone of Oromia Regional State. Adama was founded in 1915 and authorized as municipal town in 1944. It is located at about 100 km South East of the capital Addis Ababa in the Great Rift Valley of East Africa. Geographically, the town is located at 39° 27' E longitude and 8° 54' N latitude and at an altitude of 1,600 - 1,700 meters above sea level. Adama has a temperate type weather condition with average daily temperature of 21^0C and 760 mm average annual rainfall (ACA, 2014).

Adama city has a total area of 13,366.5 hectares (133.6 km^2), which has been subdivided into 18 (14 urban and 4 rural) *Kebele* administrations. The town has more than 350,000 populations(ACA, 2014). Adama is one of the largest and most populated towns in Oromia, and the third largest urban center in the country (ACA, 2014).

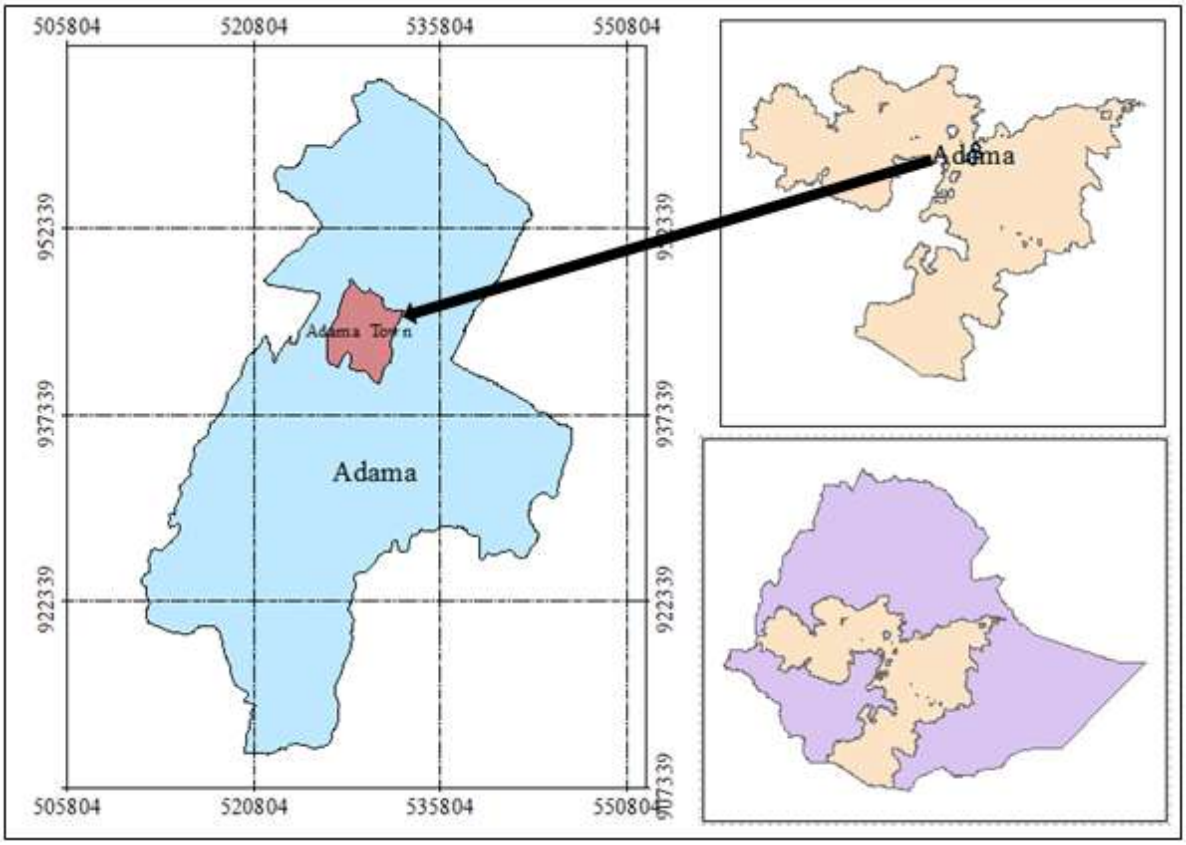

Figure 1: Map of Adama City Administration and its Surroundings

In Adama city, there are 142 hotels, 187 cafeterias, 213 restaurants, 174 pensions, 154 butcheries, 125 groceries and 15 nightclubs (ACA, 2014). Bedrooms found in the town had the capacity to accommodate 7,000 persons per day. Besides, the halls found in the town had a potential to serve 17,000 individuals daily (ACA, 2014). As a result Adama is considered as a conference city serving local, regional, national, and international conferences and meetings (ACA, 2014).

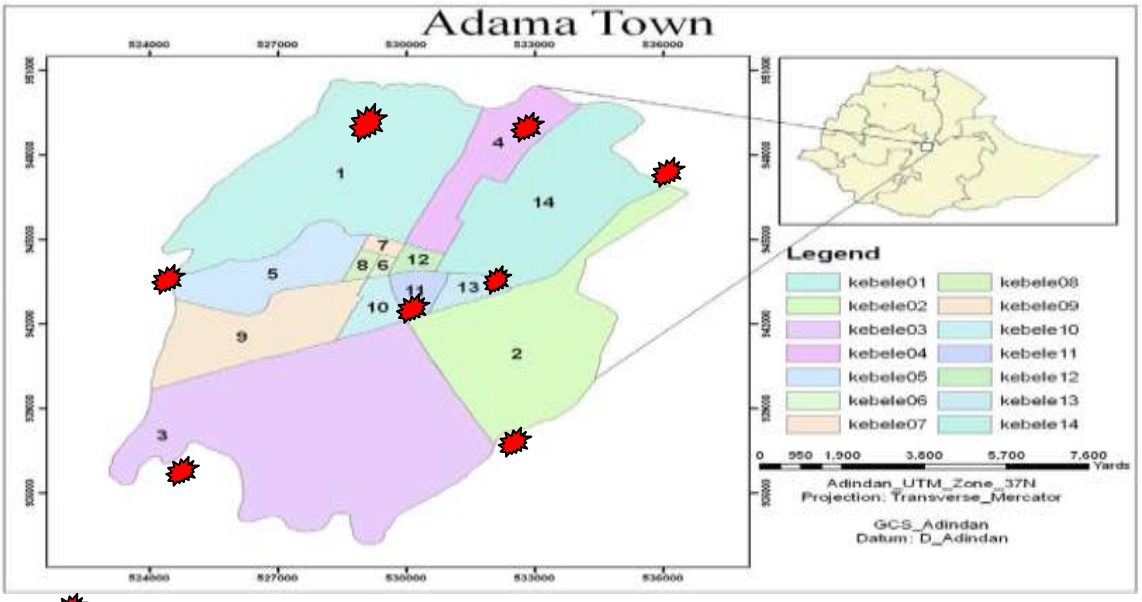

Figure 2: *Kebeles* of Adama City Administration included in the Study

In Adama city, the drinking water treatment plant provides treated water to the residents of Adama town. The treatment plant is found at 17 km in the southern part of the town near Awash River (raw water source) and was established in July 2003. The plant uses calcium hypochlorite for disinfection and Aluminium Sulphate and polyelectrolyte (organic compound) for coagulation and clarification purpose. The treatment plant is supplying 19.28 m^3 potable water daily(ACA, 2014). However, the demand for pure water in the city is 28,000 m^3 per day(ACA, 2014). Potable water coverage level in the town was found at 68.86%.

Nevertheless, two projects for potable water supply of the town are ongoing; namely, expansion of potable water supply from Awash River, which is expected to increase the current daily supply of pure water from 19.28 m^3 to 45,000 m^3; and potable water supply from three deep holes and one moderate level underground water source (ACA, 2014). These projects were assumed to start providing the services at the beginning of 2016.

3.2. Study Design

In this study, a cross-sectional survey was conducted to determine the bacteriological and parasitological quality of drinking water sources in and around Adama Town. The design included laboratory investigation which was carried out by collecting water samples from different sources at the beginning of the year 2016 (in the month of February). Moreover, questionnaire survey was conducted to collect data related to respondents' socio-demographic characteristics and water handling practices of households in the study area. The questionnaire was validated and pretested for its reliability using some selected respondents before it was used as data collection instrument for this study.

3.3. Sources of Data and Study Population

The primary sources of data in this study were drinking water samples and households. The water samples were obtained from three sources: tap water, well water, and river water. On the other hand, households were selected from eight *kebeles* found in and around Adama Town in four major directions surrounding the town.

3.4. Sample Collection, Sample Size Determination and Sampling Points

3.4.1. Water Sample Collection

According to World Health Organization (WHO, 2011) and American Public Health Association (APHA, 1998) guide lines, for drinking water quality assessment it is recommended to be 2-4 times as many sites as the minimum number required, and that these are rotated on a regular. Moreover, as stated in Ethiopian Drinking Water Quality Guideline (MOWR, 2002), the minimum frequency of sampling and analysis of on-spot distribution water schemes is once initially, thereafter as situation demands.

Regarding the minimum number of samples required from piped drinking water in the distribution system, the guideline further states that 2 should be collected from piped drinking water sources that serve less than 5,000 population, 6-120 from those sources serving between 5,000 to 100, 000 population; and more than 120 water samples from those piped distribution water supply schemes serving more than 100, 000 population (that is, Sample = Population served divided by 10000, plus 120).

Accordingly, for this study, 149 triplicate water samples; a total of 447 water samples were collected from three types of drinking water sources: that is, 144 from piped water (tap water),

three from protected well and two from river sources as illustrated in Table 5. The water samples were collected in the month of February, 2016.

Table 5: Drinking Water Sources and Number of Water Samples

No	Water Sources	Estimated Number of Population Served	Calculated Number of Water Samples*	Total Number of the Samples	Remarks
1	Tap	241,010	144	432	
2	Well	2,950	3	9	
3	River	900	2	6	
	Total	244,860	149	447	

** The numbers of water samples are calculated based on the guidelines of MOWR (2002)*

Water samples from tap water were collected from locations that are representative of the water distribution system and private tap connections (Daniel, 1995). The 144 ,3 and 2 water samples (144x3=432 ,3x3=9 and 2x3=6 samples) were collected from tap,well and river water sources repectively . The water samples from tap water connections were selected systematically using simple random sampling technique using their hous number from 2330 households found in the eight *Kebeles* included in this study from four directions of the town.

Water samples from each site were collected by using sterile glass bottles that were sterilized by autoclaving. All sterilized glass bottles with water samples were labeled with basic information and codes.

With regards to chlorinated water samples, the guidelines of World Health Organization (WHO, 2011) state that where chlorine is used as a disinfectant for a water supply, it is important that the chlorine residual can be neutralized by the addition of sodium thiosulfate ($Na_2S_2O_3$) to the sample before it is sterilized. According to this guideline and others, for drinking-waters, 0.1ml of a three percent solution of sodium thiosulfate can neutralize up to 5 mg/l of free available chlorine (FAC) in a 120 ml of water sample (MOH-NZ, 2013; WHO, 2011 and APHA, 2005). Thus, for the chlorinated water samples, sodium thiosulfate was added to stop the chlorination process during storage and transportation of the water samples.

Furthermore, these water samples were kept in icebox (4°C) and transported to Oromia Public Health Research, Capacity Building and Quality Assurance Laboratory found nearby Adama Hospital (Adama) for bacteriological and parasitological water quality analysis. In order to get

reliable results, the water samples were subjected to microbiological analysis at the laboratory within 3 to 4 hrs after collection as suggested by WHO (2011).

3.4.2. Sampling and Data Collection on Water Handling Practices

Regarding water handling practices and knowledge about water-borne diseases among households, the required sample size determined using population proportion formula developed by Israela (2012).

$$\text{n} = \frac{Z^2 pN(1-p)}{d^2(N-1) + Z^2 p(1-p)}$$

Valid where:

- n = required sample size
- Z^2= the table value of chi-square for 1 degree of freedom usually at 95% confidence level (=1.96^2)
- *P*= is the population proportion (assumed to be 0.50 to provide the maximum sample size)
- *N*= Population size (=2330 households)
- *d* = is the degree of accuracy expressed as a proportion or margin of sample error (0.05)

According to the data obtained from Information and Communication Office of Adama town, there were a total of 2330 households in the eight *kebeles* included in this study. So, the sample size for the questionnaire survey was determined based on the 5% error term and the 95% confidential interval at 0.05 degree of accuracy expressed as a proportion or margin of sample error. Since there were no previous related studies conducted in the area, 50% was assumed for the proportion of the respondents (P).

$$\text{n} = \frac{1.96^2 * 0.5 * 2330 * (1-0.5)}{0.05^2(2330-1) + 1.96^2 * 0.5 * (1-0.5)} = 329.91$$

Accordingly, using the above formula out of 2330 householders 330 respondents (one from each household) were selected as respondents of the questionnaire. The selection of sample households from each of the eight *kebeles* was done using proportional random sampling technique. Furthermore, since women are believed to be the primary managers of water at household level in most developing countries (WHO, 2011; Palaniappan*et al*., 2010) including Ethiopia, attention was given for women when selecting sample respondents from households.

Moreover, through the selection of members of sample households as respondents of the questionnaire, the following eligibility criteria (Inclusive and Exclusive) were considered:

i) ***Inclusive criteria***: Members of the households who had lived in the study area for more than one year, whose ages were at least 18 years old and who were able to give informed consent were chosen.

ii) ***Exclusive criteria***: Household members who were unable to hear, seriously ill, or mentally disabled and unable to give informed consent were excluded. Besides, those considered as new dwellers (who had lived in the study area for less than one year) were not included in the sample as a respondent.

The questionnaire was prepared by the researcher on the basis of extensive literature review and it included both open-ended and closed-ended questions encompassing three parts: socio-demographic characteristics of the respondents, water handling practices of the households (related to water collection, storage and utilization) and knowledge about water-borne diseases. Administration of the questionnaire to the selected sample respondents was done at their respective residential places.

Initially, the questionnaire was developed in English language and then translated to Amharic local language - to allow respondents' understanding of the questions and respond correctly. Furthermore, the process of data collection through the questionnaire from households was carried out by the researcher with the assistant of four trained data collectors.

3.5. Determination of the Microbiological Quality of Water

3.5.1. Analysis of the Bacteriological Quality of Water

The bacteriological quality of water samples collected during dry season in the month of February, 2016 for this study were analyzed using the membrane filtration (MF) method, following the standard procedures described in WHO (2011) and APHA (1998). As stated by WHO (2011), in membrane filtration method a water sample (typically 100 ml) was filtered through a cellulose membrane(supplier) with a pore size of 0.45 microns for screening out all bacteria. The membrane was then placed in a growth medium and incubated at a particular temperature. Bacterial colonies that grew on the medium were counted after 24 to 48 hours. Results were reported as colony-forming units (CFU) per 100 ml.

Accordingly, all water samples collected for this study were analyzed for aerobic mesophilic bacterial (AMB), total coliform (TC), faecal coliform (FC) and faecal Streptococci (FS) counts.

For TC and FC, membrane lauryl sulfate (MLS) medium was used and incubated at 37 and 44.5°C, respectively, for 18-24 hrs. Yellow colonies appearing on the surface of the membrane filter after incubation at 37 and 44.5°C were counted as TC and FC, respectively (APHA, 1998). On the other hand, FS were detected and counted using M *Enterococcus* agar, which was prepared according to APHA (1998) standards and the medium was test with growth supporet, growth inhibitary and sterility taste quality control after the medium was removed from autoclave. After incubating at 44^{o}C for 24-48 hrs, all black colonies appearing on M *Enterococcus* agar surface of the medium were counted as FS.

In addition, aerobic mesophilic bacterial (AMB) was grow using Standard Plate Agar at 30^{o}C. and medium was incubated at 30 ^{0}C for 12-24 hrs for sterility taste after the mdia was removed from autoclave. The bacteria that grow under these conditions are almost always present in drinking-water and are therefore indicators of overall cleanliness of the water supply system.

3.5.2. Analysis of the Parasitological Quality of Water

In order to detect the presence of protozoan parasites, specifically *Giardia lamblia* and *Cryptosporidium* spp., water samples were concentrated according to the guideline of World Health Organization (WHO, 1991). Samples were transferred into 15 ml centrifuge tubes and sedimented at 5000rpm using a centrifuge(model origin) at 4^{0}C for 15 minutes. The sediments were preserved at 4^{0}C for 1 hr. The parasitological quality of water (in terms of the occurrence of *Cryptosporidium* oocysts and *Giardia lamblia* cysts) were analyzed following the procedures of US Environmental Protection Agency guideline (USEPA, 2005). *Giardia lamblia* cysts and *Cryptosporidium* oocysts were detected using the direct wet smear method and the modified Ziehl Nelson method, respectively, as described below.

i). Direct wet smear method

Using an applicator (wire loop), a small portion of (2-3cm diameter) of the preserved sediment was taken and mixed with iodine solution on clean slide. Then, the mixed solution was spread over an area of approximately 2cm×1cm and the mixture of sediment and iodine solutions were covered with a cover slip. Finally, the cysts and oocysts were examined under the microscope using 10×40 objectives and their identifications were done following the procedures of WHO parasitological laboratory examination (WHO, 1995).

ii). Modified Ziehl Nelson method:

A drop of sediment was emulsified on clean slide and spread over an area of 2cm ×1cm and allowed to dry. After fixing the smear with absolute methanol for 10 minutes, the slide was flooded with carbol fuchsine for 20 minutes and rinsed in tap water for 20 minutes. It was then decolorized in 5% H_2SO_4 for 30 minutes, rinsed with tap water for additional 20 minutes and finally flooded with 0.3%methylene blue. The presence of oocysts was examined under oil immersion objective (Desalegn *et al*., 2015, and WHO, 1995).

3.6. Quality Control and Data Assurance

Appropriate quality assurance and analytical quality control procedures were implemented for all activities linked with collection and processing of data required for this study. This was based upon standards set by WHO (2011), the Federal Democratic Republic of Ethiopia, Ministry of Water Resources (MOWR, 2002) and a practical guide of the International Organization for Standardization (ISO). These ensure that the data are fit for purpose, that is, the results produced had adequate accuracy.

Moreover, in order to assure quality of data required from the assessment of water handling practices of the households, the questionnaire was validated and pre-tested at pilot level for its reliability before distributed for sample respondents and used as data collection instrument. Primarily, the validity of the instrument was tested by the research advisors to judge the items on their appropriateness and clarity of its contents. Then, the reliability of the questionnaire was tested on 32 randomly selected respondents from the study area but not included as a sample in this study. In addition, the questionnaire was checked during data collection, encoding and data processing for completeness, clarity and consistency of the data and findings (For more information, see Appendix F, that describes about quality controls made during laboratory examination of the water samples collected from the three sources).

3.7. Data Analysis

Quantitative data collected for this study were organized, processed and analyzed using Microsoft Excel version 2007 and Statistical Package for the Social Sciences (SPSS), Version 20 Software. Descriptive statistics like frequency, percentage, mean, SD, and range were employed to analyze the numerical summaries of the study findings. For visual presentation, the quantitative data were presented using graphs and tables.

Finally, the results obtained from the bacteriological and parasitological quality studies were processed and analyzed using SPSS and TC, FC, and FS counts obtained from tap water were compared against standards set for treated waters by WHO (2011) and the Federal Democratic Republic of Ethiopia, Ministry of Water Resource (MOWR, 2002).

4. RESULTS AND DISCUSSION

In this chapter, the results and discussions are presented in three parts on the basis of the objectives of the study. The first part presents results and discussions on bacteriological quality of drinking water in the study area. In the second part, laboratory results related to parasitological quality of drinking water are presented and discussed. Finally, the third part presents results and discussions on Households' Water Handling Practices and the extent of their Knowledge on water-borne diseases.

4.1. Bacteriological Quality of Drinking Water

4.1.1. Aerobic Mesophilic Bacteria (AMB)

The Aerobic Mesophilic Bacteria were enumerated by the heterotrophic plate count (HPC) method and are almost always present in drinking-water and used as an indicator of overall cleanliness of the water supply system.

Table 6: Analysis of the Occurrence and Loads of AMB from Three Drinking Water Sources Located in and around Adama Town

Percentage occurrence and mean bacterial counts	Water Sources			
	Tap (N=432)	Well (N=9)	River (N=6)	All Sources (N=447)
Occurrences of AMB (%)	384 (88.89%)	9 (100%)	6 (100%)	399 (89.26%)
Mean count ±SE CFU/0.1ml	$5.94x10^2 \pm 3.36x10^1$	$1.70x10^6 \pm 1.89x10^5$	$2.17x10^6 \pm 2.56x10^5$	$7.19x10^6 \pm 4.56x10^5$
Minimum count CFU/0.1ml	$3.0x10^2$	$1.10x10^6$	$1.15x10^6$	$3.0x10^5$
Maximum count CFU/0.1ml	$2.20x10^3$	$2.98x10^6$	$2.89x10^6$	$2.98x10^6$

The results shown in Table 6 reveal the presence of AMB in water samples of all three sources. AMB were present in 100% of the water samples collected from well as well as the river while they were detected in 384(88.89%) of the tap water samples.

The average AMB count was obtained from the river water samples ($2.17x10^6$ CFU/0.1ml). As shown from Table 6, AMB count also increased or decreased by $2.56x10^5$ CFU/0.1ml. In Well water source, the average amount of AMB count was $1.70x10^6$ with a possibility of increasing or decreasing by $1.89x10^5$ CFU/0.1ml. The minimum amount of AMB was counted in samples of Tap water source ($3.0x10^2$ CFU/0.1ml).

On the other hands,other related study conducted by Shamsuddeen *et al*, (2010)

in Nigeria also showed similar concentration of AMB CFU/0.1ml This indicates the occurrences of different bacteria that grow at 30^0c in addition to Coliform bacteria. The bacteria that grow in these conditions present in drinking-water are therefore an indicator of overall cleanliness of the water supply system. Total Coliforms (TC)

Table 7: Analysis of the Occurrence and Loads of TC from Three Drinking Water Sources Located in and around Adama Town

Percentage occurrence, mean bacterial counts, and conformity with standards		Water Sources			
		Tap (N = 432)	Well (N=9)	River (N=6)	All Sources (N=447)
Occurrences of TC (%)		189 (43.75%)	9 (100%)	6 (100%)	204 (45.64%)
Mean TC count ±SE (CFU/100 ml)		24.58 ±2.90	84.33 ±13.47	122.17 ±24.92	30.08 ±3.16
Conformity with Standards*	0	243 (56.25%)	NA	NA	NA
	1 to 10	119 (27.55%)	NA	NA	NA
	11 to 100	47 (10.88%)	NA	NA	NA
	>100	23 (5.32%)	NA	NA	NA

* = WHO (2011): According to WHO (2011) and FDRE MOWR (2002); Zero (0) CFU/100ml=Safe; 1 to 10 CFU/100ml=Reasonable Quality; 11-100CFU/100ml=Polluted; and >100CFU/100ml = Dangerous; N=Number of water samples; NA = Not applicable.

With regard to the occurrences of TC; out of 432 Tap water sample tested TC was detected in 189 (43.75%) while in all water sample taken from well and river (100%) TC was detected in this study (Tabel 7).

The occurrence of TC was high in river water sources (with the maximum number 147.09 CFU/100 ml). Next to this the occurrence of TC in well was found on average at 84.33 CFU/100 ml. The lowest number of TC was detected in tap water sources (with the minimum 21.68 and the maximum 27.48 CFU/100 ml).

According to WHO (2011) and FDRE MOWR (2002) standards, in terms of TC, out of 432 water sample taken from tap water source; only 56.25% and 27.55% were safe and found at reasonable quality, respectively. However, the remaining 16.20% are polluted and dangerous. So it is not suitable to use for drinking purpose at all.

In this regards, the results of studies conducted in various areas also showed similar results with the findings of the current study. For example, using the data collected in May to July 2008, an assessment of Physico-Chemical and Bacteriological Quality of Drinking Water at Sources and

Household made in Adama Town by Temesgen and Hameed (2015) showed that, only 73.1% of water sample collected from pipe water sources are safe and found at reasonable quality for drinking purpose.

Moreover, almost similar result was identified in study carried-out by Aly, *et al*. (2013) in Saudi Arabia. According to the results of their study, TC were detected in eleven out of thirty six (31%) of drinking water samples included in the study from tap water sources. The results further showed that, 12% of water sample tested from piped water sources were exceeded the standards set by WHO guideline (>10 CFU/100 ml).

In relation to river water sources, the results of a study made on Microbial Quality of Jimma Water Supply by Sofonias and Tsegaye (2006) identified similar results with findings of the current study. All water samples (100%) collected from River water sources contained TC. Yet, the result showed that, on average 198.3 CFU/100 ml TC detect in water samples collected from river source found in Jimma town. Besides, based on WHO (2011) and FDRE MOWR (2002) standards, the results showed that, 91.7% of water sample collected from River source was polluted and dangerous to use for drinking purposes; which was almost corroborate with the findings of the current study.

In Debrezeit, as reported by Desta (2009) all tap water samples (100%) were found to contain TC ranging from 1CFU/100 ml up to 108CFU/100 ml. Moreover, from the bacterial water quality tests 83% of the tap water samples did not meet the TC standard (1-10 CFU/100ml) set by WHO (2011) and FDRE MOWR (2002).

In a similar study on hand-dug pump well water from South Wello, Atnaf (2006) also reported similar results with the current study findings. According to the auther, 50% of the well water sources contained TC counts (CFU/100 ml).

4.1.2. Faecal Coliforms (FC)

Table 8: Analysis of the Occurrence and Loads of FC from Three Drinking Water Sources Located in and around Adama Town

Percentage occurrence, mean bacterial counts, and conformity with standards		Water Sources			
		Tap (N=432)	Well (N=9)	River (N=6)	All Sources (N=447)
Occurrences of FC (%)		170 (39.35%)	9 (100%)	6 (100%)	185 (41.39%)
Mean FC count ±SE (CFU/ml)		17.94 ±2.95	37.33 ±7.83	51.33 ±13.41	19.96 ±2.81
Conformity with Standards*	0	262 (60.65%)	NA	NA	NA
	1 to 10	135 (31.25%)	NA	NA	NA
	11 to 100	17 (3.94%)	NA	NA	NA
	>100	18 (4.17%)	NA	NA	NA

* = WHO (2011): According to WHO (2011) and FDRE MOWR (2002); Zero (0) CFU/100ml=Safe; 1 to 10 CFU/100ml = Reasonable Quality; 11-100CFU/100ml = Polluted; and >100CFU/100ml=Dangerous; N=Number of water samples; NA = Not applicable

Concerning the occurrence of FC, the data in Table 8 showed that out of 432 tap water samples tested in this study, FC found in 170 (39.35%). On the other hand, in well and river water samples FC encountered in all (100%) samples of both sources.

The occurrence of FC in tap water sources on average was 17.94CFU/100ml. It was relatively higher in river sources (on average 51.33CFU/100ml); which was about three times greater than tap water sources. In well water sources on average 37.33 CFU/100 ml was identified in the study area.

As can be seen from the data illustrated in Table 8, FC in tap water sources in terms of WHO (2011) and FDRE MOWR (2002) standards, 60.65% and 31.25% of them are safe and with reasonable quality, respectively. The remaining 8.11% are polluted and dangerous. According to WHO (2011) and FDRE MOWR (2002) FC must be zero in drinking water of any sources.

In this regards, the results of Rapid Assessment of Drinking Water Quality in Ethiopia, which was made in 2004-2005 by World Health Organization and UNICEF (Dagnew *et al.,* 2010) showed that of the 1602 samples tested for thermo-tolerant coliforms in Ethiopia, 72.0% met both the national standard and the WHO guideline value of <1CFU/100 ml. Among the four technology categories investigated, compliance was significantly higher for utility piped

supplies: 87.6% of water samples collected from utility piped supplies met both the WHO guideline value and national standards (Dagnew *et al.,* 2010).

The results of a survey of bacteriological quality of drinking water in North Gondar also showed that unprotected wells demonstrated that 75% of the samples taken were contaminated by fecal coliforms, especially *E. coli*. Fifty percent of the samples had a coliform count of 180 CFU and above per 100 ml. No sample had a coliform count of less than 10 CFU/100 ml. None of the water line samples had zero coliform count per 100 ml (Mengesha, *et al*., 2004). The presence of indicator organisms showed that the water supply needs surveillance and analysis for its quality to be used for human consumption.

Further, concerning water samples collected from River sources the results of a study made on Microbial Quality of Jimma Water Supply, also identified similar results with the findings of the current study. FC was identified in all water samples (100%) collected from River water sources. Yet, the result showed that on average more than 200 CFU/100 ml FC was identified from river samples collected (Sofonias and Tsegaye, 2006).

On the other hands, other related studies conducted in different town of the country reported higher concentration of FC in tap water sources than the findings of the current study. For example, in the Akaki-Kalit tap water system, Mengstayehu (2007) detected FC bacteria from 83% of the tap water samples; and a study result from Bahr Dar town revealed that tap water samples displayed the occurrence of FC indicators to the tune of 43% (Getnet, 2008). Moreover, among piped water samples investigated in Debrezeyit town, 86% (1-58CFU/100 ml) of the samples were found to contain FC. Only 14% did not show any FC in their tap water samples. In addition it showed that from the bacterial water quality tested 86% of tap water samples failed to meet “safe water quality” standard of WHO (2011) and country’s MOWR (2002).

In general, the data showed faecal contamination from both human and animals which is a reflection of intense human and animal activities in and around Adam town. All taken together, the overall picture showed that the underground water sources are not free from bacterial contamination, in general, and that of the hitherto monitored sources in most area of this country, in particular.

4.1.3. Faecal Streptococci (FS)

As can be seen from the results illustrated in Table 9, FS was notdetected as that of TC and FC in all water samples obtained from the three sources. Particularly, FS detected in tap water source was veary small (4.17%). The highest percentage of FS occurrence was encountered in water samples obtained from well and river sources (100%)

Table 9**: Analysis of the Occurrence and Loads of FS from Three Drinking Water Sources Located in and around Adama Town**

Percentage occurrence, mean bacterial counts, and conformity with standards		Water Sources			
		Tap (N = 432)	Well (N=9)	River (N=6)	All Sources (N=447)
Occurrences of FS (%)		18 (4.17%)	9 (100%)	6 (100%)	33 (7.38%)
Mean FS count ±SE (CFU/ml)		3.50 ±0.27	12.44 ±2.61	46.17 ±12.16	13.70 ±3.53
Conformity with Standards*	0	414 (95.83%)	NA	NA	NA
	1 to 10	18 (4.17%)	NA	NA	NA
	11 to 100	0 (0.00%)	NA	NA	NA
	>100	0 (0.00%)	NA	NA	NA

* = WHO (2011): According to WHO (2011) and FDRE MOWR (2002); Zero (0) CFU/100ml = Safe; 1 to 10 CFU/100ml = Reasonable Quality; 11-100CFU/100ml = Polluted; and >100CFU/100ml=Dangerous; N=Number of water samples; NA = Not applicable

Moreover, the average number of FS count was detected in river water source (46.17 CFU/100 ml). The number of FS in tap and well water sources were found at lower level 3.50 CFU/100 ml and 12.44 CFU/100 ml respectively. The data in Table 9 further showed that in terms of FS, from the total amount of tap water samples taken, 95.83% of them were safe and 4.17% are found at reasonable quality. This indicates that tap water sample was not significantly contaminated with FS.

In this regards, the results of Rapid Assessment of Drinking Water Quality conducted at national level of Ethiopia (Dagnew *et al*., 2010), showed that out of the samples analyzed for FS, 66.4% were in compliance with both the national standard and the WHO guideline value (WHO, 2011). Water samples from utility piped supply showed the highest compliance (68.2% with < 1CFU/100 ml), followed by those water sample investigated from dug wells sources (44.4%),

which was lower than the findings of the current study. The variation may be associated with study area and size of the sample included both urban and rural area of the country.

Furthermore, the results of the study conducted in Debrezeit town showed that FS counts in tap water samples were within the lowest count of 1CFU/100 ml and the highest count of 41 CFU/100 ml. FS counts were detected from 20% of Well water samples. The FS counts were within the range of 1-17 CFU/100 ml. Among piped water samples, 76% (1-41CFU/100 ml) of the samples were found to contain FS. Only 24% did not show any FS in tap water samples (Desta, 2009). Similarly, in the Akaki-Kalit tap water system, FS bacteria were detected from 69% of the tap water samples (Mengstayehu, 2007).

However, an assessment made by Temesgen and Hameed (2015) on Physico-Chemical and Bacteriological Quality of Drinking Water in Adama Town, using the data collected in May to July 2008, showed similar results with the findings of current study, in that with respects to FS, 92.3% of water sample collected from Tap sources are safe and found at reasonable quality for drinking purpose in compliance with both the national standard (MOWR, 2002) and the WHO guideline value (WHO, 2011).

4.2. Parasitological Quality of Drinking Water

This section shows the results of the laboratory test made for determining the Parasitological Quality of Drinking Water from three sources (Table 10).

Table 10: Parasitological quality of drinking water samples collected in and around Adama Town

Sources	Results	*Cryptosporidium Oocyst*		*Giardia lamblia Cyst*	
		Frequency	%	Frequency	%
Tap	Positive	102	23.61	35	8.10
	Negative	330	76.39	397	91.90
	TOTAL	432	100.00	432	100.00
Well	Positive	4	44.44	3	33.33
	Negative	5	55.56	6	66.67
	TOTAL	9	100.00	9	100.00
River	Positive	4	66.67	3	50.00
	Negative	2	33.33	3	50.00
	TOTAL	6	100.00	6	100.00
All Sources	Positive	110	24.61	41	9.17
	Negative	337	75.39	406	90.83
	TOTAL	447	100.00	447	100.00

The data in Table 10 illustrated that all water sources were contaminated with *Cryptosporidium oocyst* and *Giardia lamblia* cyst.

4.2.1. Cryptosporidium spp.

As can be seen from Table 10, out of 432 tap water samples, 23.61% were positive for *Cryptosporidium* spp. In contrast, of the total 9 and 6 water samples collected from well and river, *Cryptosporidium* oocysts were detected in 4(44.44%) and 4(66.67%) of the samples, respectively.

Overall, when the three water sources are compared, the occurrence of *Cryptosporidium* oocyst in river water was much higher than in well and tap water samples. Particularly, in tap water samples, the occurrence of oocysts was minimal when compared with those of the River and Well water sources. This may be due to the fact that tap water was frequently treated at the level

of reservoirs and distributors through confined pipelines with disinfectants compared to either well water or river water.

In relation to this, assessment of drinking water quality carried-out by Aly *et al*. (2013) indicated that 16.7% of the drinking water samples collected from piped water contained *Cryptosporidium* oocysts. Their results were, however, a little lower than the results of the current study. Such variations may be associated with location of the sample sources, adequacy of treatment made at reservoir and the status of pipe lines currently used in the distribution system of the study area.

As reported by different previous researchers, in contrast to other waterborne pathogens, the occurrence of cryptosporidiosis is unknown in many parts of the world; however, the mean prevalence rate of *Cryptosporidium* infection is between 1 and 3% in Europe and North America; about 5% in Asia, and greater than 10% in sub-Sahara countries in (Current, 1999). However, a study carried-out by Robertson *et al*. (2001) found that 16% of water samples in Norway were positive for *Cryptosporidium*. In addition, a study of water conducted in western Japan indicated that 47% of the samples tested were positive for *Cryptosporidium* (Ono and Tsuji, 2001).

Moreover, various study findings also reported that *Cryptosporidium* oocysts were detected in 92% of drinking water samples in Argentina (Abramovich *et al*., 2001). In Russia, from different water samples collected during 2006, *Cryptosporidium* spp. was found in 18.1% of the samples using immune-fluorescence test (Karanis *et al*., 2006). This difference of prevalence may be attributed to different methods used for detection of *Cryptosporidium parvum* in the study area.

4.2.2. Giardia lamblia

The results of the laboratory test for the occurrence of *Giardia lamblia* cyst in drinking water source are shown in Table 10. According to these data, *Giardia* cyst was only detected in 8.1% of the 432 tap water samples. However, in Well and River water samples, the occurrence of *Giardia lamblia* cyst was relatively higher than Tap water samples. As can be seen from Table 10, *Giardia lamblia* cyst was detected in 33.33% of the well water samples and 50% of water samples collected from the river.These implied that, though *Giardia lamblia* cyst was detected from all water sources, its occurrence in river and well water was higher than in tap water. So, using such water for drinking purposes without treatment could easily expose people to water-borne diseases in the study area.

According to WHO (2011) and FDRE MOWR (2002), *Giardia lamblia* cyst must not be detectable in 100 ml water sample from any water source directly intended for drinking purpose. In view of this guideline, therefore, even the tap water may not be safe for consumption.. This calls for immediate attention of all concerned bodies who are engaged in drinking water quality management and human health in the study area.

In relation to this, a study conducted by Aly *et al.* (2013), in Nigeria, also reported that Giardia cyst was found in 25% (9/36) of water samples collected from Tap water sources, which was higher than the findings of the current study. The difference in the findings of these studies were associated with the sample taken and the study area in that the study carried out in Nigeria focused on sub-urban areas of the community; while the current study took place in and around Adama City Administration.

Furthermore, in relation to well water sources, the results of parasitological evaluation of domestic water sources conducted by Chollom (2013) in a rural community in Nigeria also showed that out of total water samples collected from well, 35% were contaminated by parasites like *Giardia lamblia* cyst. This finding was almost similar with the results of the current study (33.33%) regarding water samples collected from wall water.

Moreover, empirical evidence also showed that *Giardia* was detected in 31% of drinking water samples in Argentina (Abramovich *et al*., 2001). In 2002, monitoring water for one year in Japan using coagulation-flocculation, sedimentation and rapid filtration, investigators found *Giardia* in 92% of raw water samples and in 12% of filtered samples (Hashimoto *et al.,* 2002). Lower rate of *Giardia* cyst detection in water samples was reported in Russia from different water samples collected during 2006. *Giardia* was found only in 9.6% of these samples using immuno-fluorescence test (Karanis *et al*., 2006). This reflects the efficient methods adapted by the water treatment facilities in these countries for controlling the quality of drinking water. Many countries are routinely monitoring water every year and establishing techniques to identify these parasites.

4.3. Household Water Handling Practices and Knowledge about Water-borne Diseases

Table 11 shows respondents' background information, which includes gender, age, educational background, and number of family members.

With regards to sex, among households who participated in this study, 232 (75.57%) were females, while the remaining 75 (24.43%) are males. This implies the participation of female respondents in this study was three times greater than their counterparts

Table 11: Characteristics of the Respondents

		Frequency	%
sex	Male	75	24.43
	Female	232	75.57
	Total	307	100
Age	Up to 30 Years	77	25.08
	31-40 years	99	32.25
	Above 40 year	131	42.67
	Total	307	100
Educational Background	Read and write	42	13.68
	Primary	36	11.73
	Secondary	130	42.35
	Diploma	47	15.31
	First Degree & Above	52	16.94
	Total	307	100
Number of Family Members	**1-3 persons**	**30**	**9.77**
	4-6 persons	187	60.91
	7-9 persons	81	26.38
	10 and more persons	9	2.93
	Total	307	100.00

This large percentage of female respondents may be associated with the fact that women usually suffer from the burden of fetching water. Because of this, large number of women participants in this study might help to understand extent of the problems and to propose possible recommendations that would help to alleviate the identified problems related to water quality and water handling practices among households in the study area.

Regarding age,less than half of respondents (42.67%) were found to be above 40 years old. Next to this, 32.25% of the respondents were found between the ages 31-40 years. Moreover, the respondents up to 30 years old account for 25.08% of the total households in this study. Overall,

the data shown in the Table 11 show that three-fourth of the households in this study were adults above 30 years old.

Concerning educational status of the respondents, the data showed that 42.35% of the respondents had attended secondary school education. The remaining respondents were degree holders (16.94%), diploma holders (15.31%), capable of reading and writing (13.68%), and with background of primary school education (11.73%). Alareg number of of the respondents (74.59%) were relatively educated since most had completed secondary school education.

Regarding number of family members, the data in Table 11 show that 60.91% of the households had 4-6 family members. Moreover, about one fourth (26.38%) of the households had 7-9 family members. Furthermore, the data also show 9.77% of the households had 1-3 family members. Overall, the data revealed that on average each household in the study area had about five family members. In this regard the data obtained from 2007 population census also confirmed that the average family size in Adama City was 5.3 (CSA, 2008).

Table 12 shows the responses regarding water handling practices of the households during water collection.Atotal of, 190(61.89%) of the households had spent less than 15 minutes; while 66(21.50%) of them took 15-30 minutes to collect drinking water for their households. Moreover, there were 12.38% households who spent 30-45 minutes to bring drinking water from sources to their home. Yet, few numbers of households spent about an hour (4.23%) to collect drinking water from sources to their house.

In relation to this the results of observation cheek list made by the researcher (Appendix-B) also showed two meter as a minimum and 500 m as a maximum distance traveled by the households to collect drinking water from sources to their home. According to this observation results, 28.99% and 28.66% of the households were traveled for about 51-100 m and above 100 m respectively . When the time required for traveling such distance were added with waiting time to get the water from the sources, it may took 30 and more minutes.

Young male children (41.69%) and the female once (24.43%) were the main responsible household members to collect drinking water from sources to the house. In addition, 17.26% and 10.42% of the respondents also indicated as adult female and male member of the households usually fetche water for the family respectively.

Table 12: Water Handling Practices of respondents during Collection

	Items	Female		Male		All	
		Frequency	%	Frequency	%	Frequency	%
1	Average time spent to collect drinking water from sources to house						
	Less than 15 minutes	156	67.24	34	45.33	190	61.89
	15-30 min	44	18.97	22	29.33	66	21.50
	30-45 min	24	10.34	14	18.67	38	12.38
	45 mints to 1hr	8	3.45	5	6.67	13	4.23
	Total	232	100.00	75	100.00	307	100.00
2	The person who usually fetches water for the household						
	Adult female	49	21.12	4	5.33	53	17.26
	Adult male	22	9.48	10	13.33	32	10.42
	Young female child	61	26.29	14	18.67	75	24.43
	Young male child	89	38.36	39	52.00	128	41.69
	Others (Please specify)	11	4.74	8	10.67	19	6.19
	Total	232	100.00	75	100.00	307	100.00
3	Materials regularly used for collection of drinking water						
	Tanker	4	1.72	0	0.00	4	1.30
	Jar or Clay pot	6	2.59	3	4.00	9	2.93
	Bucket	84	36.21	25	33.33	109	35.50
	Jerry can	182	78.45	69	92.00	251	81.76
	Pitcher	74	31.90	23	30.67	97	31.60
	Barrel	5	2.16	4	5.33	9	2.93
	Kettle	32	13.79	13	17.33	45	14.66
4	The practice of washing/cleaning the containers used for collecting water during the collection						
	Always	119	51.29	24	32.00	41	13.36
	Most of the time	73	31.47	28	37.33	122	39.74
	Sometimes	26	11.21	8	10.67	70	22.80
	Rarely	10	4.31	15	20.00	62	20.20
	Not at all	4	1.72	0	0.00	12	3.91
	Total	232	100.00	75	100.00	307	100.00
5	The practice of covering the containers used for collecting water during the collection						
	Always	30	12.93	11	14.67	143	46.58
	Most of the time	98	42.24	24	32.00	101	32.90
	Sometimes	53	22.84	17	22.67	34	11.07
	Rarely	41	17.67	21	28.00	25	8.14
	Not at all	10	4.31	2	2.67	4	1.30
	Total	232	100.00	75	100.00	307	100.00

Jerry can (81.76%) was the most commonly preferred type of water collection container in the study area.followed by Bucket (35.50%), and Pitcher (31.60%) Furthermore, 14.66% of households were agreed as they used Kettle for collection of drinking water from the pipe, well or river for their family. Barrel (2.93%) and Jar or Clay Pot (2.93) were also used among few households for drinking water collection in the study area.

Studies reveal that the level of water contamination is high at the point of consumption than the point of collection which may be attributed to the mode or drawing water from the containers (Tiku *et al.,* 2003).

Only 13.36% of the households always cleaned the materials used for collecting drinking water before collection. Nevertheless, 39.74% and 22.80% of households had attempted washing the materials for water collection 'most of the time' and 'sometimes' respectively. Yet, one-fifth of the households (20.20%) in the study area had argued as they '*rarely'* tried to clean the containers they used to collect drinking water for their respective family.

Only 46.58% of them were agreed as they always cove the container usually used to collect drinking water from sources to the home (Table12). Majority of them did not cover drinking water collection containers during collection and transportation. Though, among the remaining majority of the respondents, about one-third of them (32.90%) had agreed as they make effort to cover the container.the surrounding neatness of the collection water points were observed in such a way that 2.61% and 18.58% of the water sources including in this study had very clean and clean surroundings, respectively.

The neatness of the surroundings of drinking water sources could affect the quality of the water source directly or indirectly. According to WHO (2006), there was evidence that due to problem of the neatness of the surrounding scheme of hand dug well became nonfunctional at all. In addition to lack of proper neatness of the sources; poor drainage system also can causes water related disease, waste water enter back in to the source, bad smell caused by lack of removing mud, growing algae and grasses and livestock waste (Demeke, 2009).

Moreover, according to the findings of study conducted by Dagnew *et al. (*2010) at national level (Ethiopia), the major sanitary risk factors identified in relation to drinking water sources were cracks or breaks in the infrastructure; leaks; unsanitary conditions around the source; a latrine, sewer or other potential source of pollution nearer to the water supply than prescribed by technology standards; and a poor drainage system. The problem was even worse for the piped

distribution systems, where 53% of the inspection taps and 56% of the household pipes were found to lack sanitation.

The data illustrated in Table 13 emphasizes on households' water handling practices during storage and utilization. According to the data illustrated in (Table 13), most of the households surveyed practiced storing water for drinking using Barrel (53.09%), Jerry can (43.32%), and Tanker (40.07%). Moreover, about one-fourth (24.43%) of the respondents were indentified '*Bucket'* as drinking water storage material used among households in the study area.

Table 13: Water Handling Practices of respondents during Storage and Utilization

	Items	Female		Male		All	
		Frequency	%	Frequency	%	Frequency	%
1	Materials regularly used for drinking water storage						
	Tanker	90	38.79	33	44.00	123	40.07
	Jar or Clay pot	16	6.90	7	9.33	23	7.49
	Bucket	52	22.41	23	30.67	75	24.43
	Jerry can	106	45.69	27	36.00	133	43.32
	Pitcher	2	0.86	0	0.00	2	0.65
	Barrel	127	54.74	36	48.00	163	53.09
	Kettle	2	0.86	5	6.67	7	2.28
2	For how long/many days do you store the water in the container?						
	Less than One day	18	7.76	6	8.00	24	7.82
	1-2 days	25	10.78	12	16.00	37	12.05
	3-4 days	86	37.07	18	24.00	104	33.88
	5-6 days	37	15.95	11	14.67	48	15.64
	A week	40	17.24	21	28.00	61	19.87
	For more than a week	26	11.21	7	9.33	33	10.75
	Total	232	100.00	75	100.00	307	100.00
3	The Practices of covering water storage containers						
	Always	107	46.12	24	32.00	131	42.67
	Most of the time	79	34.05	31	41.33	110	35.83
	Sometimes	14	6.03	6	8.00	20	6.51
	Rarely	26	11.21	12	16.00	38	12.38
	Not at all	6	2.59	2	2.67	8	2.61
	Total	232	100.00	75	100.00	307	100.00
4	The Practices of washing/cleaning water storage containers						
	Always	34	14.66	16	21.33	50	16.29
	Most of the time	68	29.31	12	16.00	80	26.06
	Sometimes	52	22.41	11	14.67	63	20.52
	Rarely	54	23.28	32	42.67	86	28.01
	Not at all	24	10.34	4	5.33	28	9.12
	Total	232	100.00	75	100.00	307	100.00

Majority (80.13%) of the households in the study area had stored drinking water for more than two days. Only 7.82% and 12.05% of the households practiced storing drinking water for less than one day or for 1-2, days respectively. More than one-third of them (33.88%) were stored water used for drinking purpose

for about 3-4 days. This was more agreed by female respondents (37.07%) than male respondents (24%). Over 19.87% and 10.30% of the stored drinking water for a week or more days.

Only 42.67% of them agreed as they always cover the containers(Table 13). Such practice was relatively agreed by female respondents (46.12%) than male (32%). Most of the households did not cover the containers used to store drinking water for their families. However, some of the households (35.83%) tried to cover the storages 'Most of the time'. In similar manner 12.38% of the households agreed as they make effort to cover the container 'rarely'.

Only 16.29% of the households washed the containers used for storing drinking water.(Table 13) However, 28.01% of the households attempted washing the containers used for water storage 'rarely'. Yet, 26.06% of the households argued as they tried to clean the containers they used for drinking water storage most of the time (Table 13). Figure 3 depicts the respondents' responses regarding the practices of treatment methods used for drinking water at household level (for further information see Appendix A).

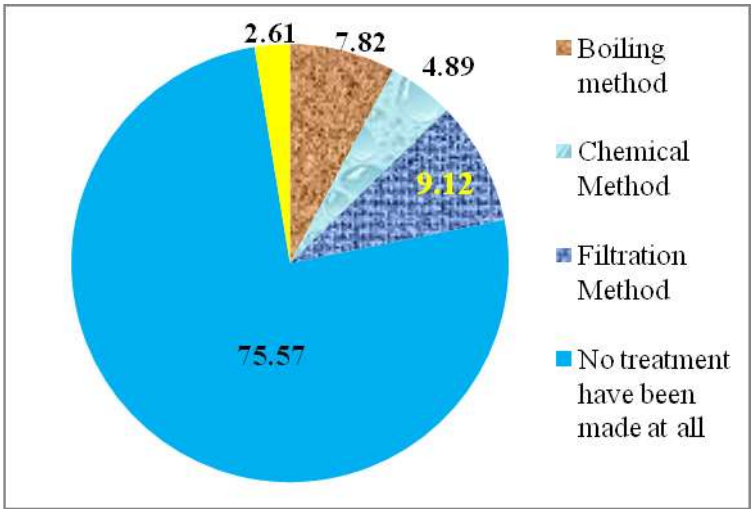

Figure 3: Treatment method used on drinking water at household level (Percentages)

Most of them (75.57%) said that they don't follow any treatment and drink the water as it is obtained from the sources (Figer 3). Only 24.43% households reported at least one treatment device installed on drinking water they currently obtained from sources, with the most common types: filtering, boiling, and using chemicals.

Water treatment method somewhat more practiced by households than others in the study area was filtering (9.12%) with cloth or some other materials which is not very effective in preventing microbial contaminations. Moreover, boiling and using chemicals as water treatment method

were practiced by 7.82% and 4.89% of the participants respectively. Besides, a small number of households (2.61%) also reported other methods not specified in the questionnaire.

In this regards, the results of an assessment made on drinking water quality and determinants of household potable water consumption in Simada District of North Gonder showed 85% of urban respondents did not use any treatment measures. From the total number of respondents only 10% of the urban households had treated the water using boiling techniques.

The results of another study Dagnew *et al*.,(2010), showed that out of the samples household container inspected 87.4% of were kept at ground level; 44.7% of them had no cover in place; 49.1% of the storage containers were cracked; 76.1% of the areas around the storage containers was unsanitary; and 66% of the utensil used to draw water from the container was unsanitary. Of the 554 household samples analyzed in this study, 73.6% complied with the WHO guideline value and the national standard for thermotolerant coliforms. Compliance was significantly higher for household piped water (85.4%) than for water from household containers (43.6%). For the majority of sites inspected, there was no change in the thermotolerant coliform counts between source and household, but for more than one fifth of the sites the microbiological quality of the water deteriorated after collection from the source (Dagnew *et al*., 2010).

Table 14 presentes issues related to households' knowledge and understanding about water quality and water-borne diseases.

Some of the respondents (44.63%) believed that, the water they currently obtained from sources for drinking purpose is not safe at all. Particularly some of female respondents (46.55%) did not belief the quality of the water as it was safe than male respondents (38.67%). Those households who assumed the water as 'Somewhat safe' and 'Partially safe' account 32.25% and 15.96%, respectively. These implies that about 55% of the households to some extent assumed that the water they currently obtained from sources for drinking purpose was safe and continued using the water for their respective families. This may be resulted from lack of proper understanding about the status of water quality they currently obtained from sources.

The data in table 14 (item number 2) also showed that the prevalence of diarrhea, twelve months prior to the survey was 45.28% in the study area. Among 307 households participated in this study, 139 of them were reported the occurrence of diarrhea among their family during the recent past 12 months. However, the occurrence of worm infestation diseases in recent past 12 months

was reported only by 20.85% of the households participated in this study (Item number 3 of Table 14).

Table 14: Knowledge about Water-borne Diseases

	Items	Female		Male		All	
		Frequency	%	Frequency	%	Frequency	%
1	Respondents belief about the quality of water currently used for drinking						
	Highly Safe	4	1.72	0	0.00	4	1.30
	Safe	18	7.76	0	0.00	18	5.86
	Partially safe	32	13.79	17	22.67	49	15.96
	Somewhat safe	70	30.17	29	38.67	99	32.25
	Not safe at all	108	46.55	29	38.67	137	44.63
	Total	232	100.00	75	100.00	307	100.00
2	Occurrence of Diarrhea in resent past 12 months among the family						
	Yes	106	45.69	33	44.00	139	45.28
	No	126	54.31	42	56.00	168	54.72
	Total	232	100.00	75	100.00	307	100.00
3	Causes of Diarrhea occurrences for those encountered						
	Eating highly spiced foods	0	0.00	0	0.00	0	0.00
	Taking hot foods	2	1.89	2	6.06	4	2.88
	Eating dirty foods	8	7.55	0	0.00	8	5.76
	Eating expired foods	13	12.26	4	12.12	17	12.23
	Drinking unclear water	29	27.36	11	33.33	40	28.78
	Unknown	54	50.94	16	48.48	70	50.36
	Total	106	100.00	33	100.00	139	100.00
4	Occurrence of worm infestation diseases in resent past 12 months						
	Yes	46	19.83	18	24.00	64	20.85
	No	186	80.17	57	76.00	243	79.15
	Total	232	100.00	75	100.00	307	100.00
5	The practices of hand washing *with soap* among members of the households						
	Yes always	37	15.95	11	14.67	48	15.64
	Yes most of the time	64	27.59	9	12.00	73	23.78
	Yes sometimes	89	38.36	31	41.33	120	39.09
	Yes rarely	40	17.24	18	24.00	58	18.89
	Almost Never/Not at all	2	0.86	6	8.00	8	2.61
	Total	232	100.00	75	100.00	307	100.00
6	Getting training and awareness creation programs about drinking water quality and water-borne diseases so far.						
	Yes	30	12.93	2	2.67	32	10.42
	No	202	87.07	73	97.33	275	89.58
	Total	232	100.00	75	100.00	307	100

There were many beliefs and assumptions about the causes of diarrhea and worm infestation among the community. When asked about the causes; more than half of the households (50.36%) did not able to indicate the cause of diarrhea occurrce among their family. Only 28.78% of the

respondents in the study area were aware of the real cause of the disease; in that they indicated drinking unclean water as the cause for the occurrences of diarrhea among their family. Moreover, 12.23% and 5.76% of them believed that diarrhea occurs by consuming expired and dirty foods, respectively.

Various studies have shown that chronic diarrhea and worm infestation were a consequence of poor hygiene and environmental contamination. Most of the households in study area were unaware of the actual cause of worm infestation and diarrhea. This indicates that people were not aware of the close linkage between unsafe drinking water and diseases, thus showing an urgent need of health education in that area.

In this regards, similar results identified in study conducted in India (Bhattacharya, *et al.,* 2011). According to the responses of mothers' of children below five years of age about the causes of diarrhea; only 20% mothers were aware of the real cause of diarrhea disease. The rest were unaware of the causes.

It was argued that, lack of access to safe water supply and inadequate sanitation facilities together with unhygienic conditions can contributed to high morbidity. A simple measure like hand washing with soap can prevents transmission of organisms that cause diarrhea and thus millions of diarrheal deaths can be prevented globally (Bhattacharya, *et al*., 2011).

However, the data illustrated under item number five of Table 14 showed that, hand washing with soap was frequently practiced only by 15.64% of the households participated in this study. Moreover, 39.09% of them had attempted to wash their hands with soap 'Sometimes'. This indicated the need for interventions to change behavior of the community regarding hand washing practices with soap.

The respondents were further asked to respond whether they obtain training or awareness creation program about drinking water quality and water born disease in the recent past two years. The result illustrated in the Table 14 showed that 89.58% of the respondents replied as they did not obtained any training and awareness creation program on the issue. This means, nine out of ten households had not offered any awareness creation program concerning water quality and water-borne diseases in the study area. However, the responses of male respondents (97.33%) showed more absence of awareness program than female respondents (87.07%).

This may negatively affect households on water handling practices and the utilization of drinking water for their families. They may not properly collect, store and utilize drinking water for their respective families. This calls an immediate action of all concerned bodies related to water quality and water-borne disease.

5. SUMMARY AND CONCLUSIONS

5.1. Summary of Major Findings of the Study

This study was designed and carried-out to assess the microbiological and parasitological quality of drinking water sources and the people's water handling practices in and around Adama Town, Oromia Regional State; Eastern Ethiopia. In order to achieve objectives of the study, a total of 447 water samples were collected and tested from drinking water sources. The output of the data processed through SPSS were compared against standards set by WHO (2011) and the Federal Democratic Republic of Ethiopia, Ministry of Water Resource (MOWR, 2002). Moreover, data regarding people's water handling practices and knowledge about water-borne diseases were collected through questionnaire and observation check-list from 307 households. Thus, based on the analysis made in accordance with the study objectives, major findings of the study were summarized and presented hereunder.

The results of this study showed that AMB was fully identified in well and river water. Moreover, among 432 samples AMB was identified in 88.89% of water samples taken from tap water samples source. The maximum number of AMB count was found in river ($2.17x10^6$ CFU/100 ml). The minimum amount was counted in tap water source ($5.94x10^2$ CFU/100 ml).

Concerning TC, out of tap water sample tested it was identified in 43.35% of them; while 100% in Well and River water samples. When the occurrence of TC was compared with WHO (2011) and FDRE MOWR (2002) standards, only 56.25% and 27.55% of water samples taken from tap water source are safe and found at reasonable quality, respectively.

With regards to the occurrence of FC, out of tap water samples tested, it was found in 39.35% of them. On the other hand in well and river water samples FC was identified in all samples tested in this study. In relation to stated standards, out of samples tested from tap water sources, only 60.65% and 31.25% of them are safe and with reasonable quality, respectively.

Regarding FS, what was identified in tap water source was insignificant (4.17%); and from those water samples, 95.83% of them were considered as safe and 4.17% are found at reasonable quality. However, FS was identified in all water samples obtained from well and river sources.

With regards to *Cryptosporidium oocyst,* it was identified in 23.61% tap water samples. Moreover, 44.44% of water samples obtained from well water source were contaminated with Cryptosporidium *oocyst*. Similarly, Two-third (66.67%) of water samples collected from river sources were contaminated with *Cryptosporidium oocyst*.

Giardia cyst was not significantly identified in tap water sources. it was only identified in 8.10% of the samples collected from tap water source. However, it was identified in 33.33% and 50% of water samples collected from well and river water sources, respectively.

Regarding water handling practices and knowledge about water-borne disease among households; the result showed that, 61.89% of the households spent less than 15 minutes; and 21.50% of them took 15-30 minutes to collect drinking water for their households. Young male children (41.69%) and the female ones (24.43%) were the main responsible household members to collect drinking water from sources to the house. Jerry can (81.76%) was the most commonly preferred type of water collection container in the area. Next to this, bucket (35.50%) and pitcher (31.60%) were also preferred by households for collecting drinking water.

Regarding the practices of cleaning the containers used for collecting drinking water, the findings of this study confirmed poor practices of the households in the study area. Only 13.36% of them always cleaned the materials. Moreover, more than half of them (53.62%) did not cover drinking water collection containers during collection and transportation. A large number of the households stored water for drinking using barrel (53.09%), jerry can (43.32%), and tanker (40.07%). Majority of the households (80.13%) had stored drinking water for more than two days; even for a week and more days. Concerning covering drinking water storage containers only 42.67% of them were agreed as they always cover the containers. Most of the households did not cover the containers used to store drinking water for their families. There were also weak practices of washing containers used for storing drinking water. Only 16.29% of them washed 'always' the containers used for storing drinking water.

The results of this study further showed significant number of the households (75.57%) didn't follow any treatment on drinking water. They drink the water as it was obtained from the sources. However, 9.12% of the households used filtering method (with cloth or some other materials). Besides, some of the respondents (44.63%) believed that the water they obtained from sources for drinking purpose is not safe at all. Moreover, 139 (45.28%) of them were reported the occurrence of diarrhea among their family during the recent past twelve months. However, the occurrence of worm infestation diseases was reported only by 20.85% of the households participated in this study. But more than half of the households (50.36%) did not able to indicate the cause of its occurrences. Only 28.78% of the respondents indicated drinking unclean water as the cause. This indicates that people were not aware of the close linkage between unsafe drinking water and diseases, thus showing an urgent need of health education in

that area. Furthermore, the findings of this study showed that hand washing with soap was not regularly practiced. Only 15.64% of the households washed their hands with soap frequently. Besides, 89.58% of the respondents replied as they had not obtained any training and awareness creation program on the issue.

In general, poor water handling practices and lack of understanding among households may negatively affect households on collecting and the utilization of drinking water for their families. They didn't properly collect, store and utilize drinking water. This calls for an immediate action of all concerned bodies related to water quality and water-borne disease.

5.2. Conclusion

Based on summary of the findings, the following conclusions were drawn.

The results of this study showed the presence of AMB, TC, FC, and FS in water samples obtained from the three sources. Similarly, most of the samples from tap water source also contaminated with AMB, TC, FC, and FS. All water sources were contaminated with parasites.

Thus, from stated results of this study one can conclude that, people in the study area and are at risk of poor quality of drinking water sources and water-borne diseases.

Creating awareness among the community regarding drinking water quality and water-borne diseases is very important for better use of the existing water resources and to prevent the incidences of water related diseases. However, almost all households understanding about quality of drinking water and water-borne disease was unsatisfactory. They did not properly clean water contenders used for collecting and storing drinking water; they stored drinking water for longer time in such containers; they did not use any treatments method on drinking water; members of the households did not usually practiced washing their hands with soap. So, developing strategies for provision of safe drinking water should be given utmost priority besides educating people about quality of drinking water and water-borne disease in the area.

5.3. Recommendations

The findings of this study, particularly laboratory results were reported during laboratory analysis to Adama City Water Supply Office by Oromia Health Research, Capacity Building & Quality Assurance Laboratory for immediate actions of the office. Based upon the results of this study, the office had already made an action that helped to improve water quality of the City (for

further information see Appendix-G; a letter written from the laboratory to Haramaya University).

Based on major findings of the study, the following pertinent suggestions were forwarded to improve drinking water quality and households' water handling practices and their understanding about water-borne diseases in the study area:

- Making proper and sufficient disinfection of drinking water sources with chlorine and other treatment methods is a prime importance.
- Continuous follow up on drinking water sources will give a better chance to sustain the supply of safe water for drinking purpose. So, Adama City Water Supply Offices and Health Institutions should consider for a proper regular monitoring program to determine the primary sources of contamination and health threat. In addition, it is advisable if the City Administration (with all other concerned bodies) will develop appropriate control measures to avoid any public health risk aroused from such water sources.
- Further, strengthening institutional arrangements will increase continuous inspection of functionality of water schemes and health status of the households in the area. Besides, integrating sector offices activities are necessary to improve the current status of drinking water quality and water handling practices among households and people's understanding about water-borne diseases.
- A lot of awareness creation activities should be doneusing minimedia on water handling practices and water-borne related issues including hand washing practices through health extension workers in the study area.

Finally, the researcher recommended that it is advisable if bodies engaged in quality water supply conduct further in-depth investigation on issues related to drinking water quality of all sources and households' water handling practices and their understanding about water-borne diseases in the study area.

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APPENDICES

Appendix-A: Treatment method used on drinking water at household level

No	Methods	Number	%
1	Boiling method	24	7.82
2	Chemical Method	15	4.89
3	Filtration Method	28	9.12
4	No treatment have been made	232	75.57
5	Others	8	2.61
	Total	307	100.00

Appendix-B: Results of Observation Check-List Healed by the Researcher

Items		Count	%
CL2	Average distance from water source to the house (in meters)		
	Up to 10M	68	22.15
	11-50M	62	20.20
	51-100M	89	28.99
	Above 100M	88	28.66
	Above 200M	307	100.00
CL3	Cleanness status of drinking water source surroundings		
	Very Clean	8	2.61
	Clean	57	18.57
	Partially Clean	135	43.97
	Somewhat Clean	74	24.10
	Not Clean at all	33	10.75
CL4	The occurrence of taps/pipes leakage		
	Yes	114	37.13
	No	193	62.87
CL5	Existence of crack evidence on the water pipes		
	Yes	89	28.99
	No	218	71.01
CL6	Distance between drinking water sources and the latrine or sewage tanker		
	Up to 5M	141	45.93
	6-10M	82	26.71
	11-15M	12	3.91
	16-20M	25	8.14
	Above 20M	47	15.31
CL7	The presence of waste disposal near or around drinking water sources		
	Yes	72	23.45
	No	235	76.55
CL11	Sanitation status of the place where drinking water storage container is kept		
	Very Clean	12	3.91
	Clean	86	28.01
	Partially Clean	157	51.14
	Somewhat Clean	40	13.03
	Not Clean at all	12	3.91
Total		307	100

Cod Number _____

HARAMAYA UNIVERSITY
School of Graduate Studies
College of Natural Sciences
Department of Biology
A Questionnaire to be Filled by Member of the Households

Dear respondent;

The purpose of this questionnaire is to collect relevant data that will be used for the study conducted on "Bacteriological and Parasitological Quality of Drinking Water Sources in and Around Adama Town, Oromia Region, Eastern Ethiopia". I would like to assure you that this study is purely academic and hence would not affect anyone in any ways as all information will be kept confidential. The result of this study is expected to be valuable input for the improvement of Drinking Water Quality in and Around Adama Town.

Thus, your genuine and frank responses are of importance for the success of the study. Please, carefully read the questions and answer all of them honestly.

Sincerely!

General Directions

- Writing your name in any parts of the questionnaire is not required
- Respond to all closed-ended questions by putting "✓" marks and to the open-ended ones by writing your responses on the spaces provided.

Part One: Demographic Characteristics of the Respondent/ Household

1. Location/Address: Kebele _____ Village (Specific Name) _____
2. Sex: a) Male _____ b) Female _____
3. Age: a) Less than 18 years ___ b) 18-25 years ___ c) 25-32 years ___
   d) 33-40 years ___ e) Over 40 years ___
4. Educational status of the respondent:
   a) Read and write ___ b) Primary ___ c) Secondary ___
   d) College Diploma ___ e) Degree and above ___
5. Number of people living in the house: Male _____ Female _____ Total _____

Part Two: Items Related to Water Handling Practices of the Households

6. Major water source of your household:
   a) Piped water supply at home _____
   b) Public tap water supply _____
   c) Well ____
   d) River _____
   e) Other (Please specify) _____

7. How much time you spent to collect water from the source to house? (Average time spent to collect drinking water from sources to house):

   a) Less than 15 mints_____ c) 30-45 min _____ e) Above 1 hour _____

   b) 15-30 min _____ d) 45 mints to 1 hr_____

8. Who usually fetches water for your household?

   a) Adult female_____ d) Young male child _____

   b) Adult male_____ e) Others (Please specify) _____

   c) Young female child_____

9. What types of container do you Materials regularly used for water collection and storage?

No	Types of the containers	for Collection	for Storage
1	Tanker		
2	Jar or Clay pot		
3	Bucket		
4	Jerry can		
5	Pitcher		
6	Bowl		
7	Kettle		
	Others (Specify)		

10. How many times do you usually collect water for your household Per Day/Per Week?

Repetitions		Per Day	Per Week
a	Once		
b	Twice		
c	Three times		
d	Four times		
e	Five times		
f	More than five times		
	Other (Please specify)		

11. For how long/many days do you store the water in the container?

   a) Less than a day___ c) 3-4 days___ e) For a week ___

   b) 1-2 day___ d) 5-6 days___ f) For more than a week___

12. Covering and washing water containers while collecting and storing the water:

	Items	Always	Most of the time	Sometimes	Rarely	Not at all
1	Do you cover the containers used for collecting water while water collection?					
2	Do you cover water storage containers?					
3	Do you properly wash/clean the containers used for collecting water before water collection?					
4	Do you properly wash/clean water storage containers before transferring water from collection containers to them?					
If the storage container is a Tanker; within how many days do you clean the container? _____						

13. How do you describe ways of taking out water from storage container for use?

_____

_____

_____

14. Do you think that the water you currently collected from the source is safe for drinking?

a) Highly Safe _____
b) Safe _____
c) Partially safe _____
d) Somewhat safe _____
e) Not safe at all _____

15. Do you execute any treatment method on the water collected from the major source before using for drinking?

a) Yes, Boiling method _____
b) Yes, Chemical Method _____
c) Yes, Filtration Method _____
d) No treatment have been made _____
e) Other (please specify) _____

16. Do your encountered interruption incidences of water supply services (particularly Piped water and Public tap water supply) so far? a) Yes ____ b) No ____

If your answer is 'Yes' for the above question; please state frequency and durations of the interruptions:

_____

_____

_____

17. Do your family encored Diarrhea in resent past 12 months? Yes _____ No _____

If "Yes" What do you think are the causes for its occurrences?

a) Eating highly spiced foods_____
b) Taking hot foods_____
c) Eating dirty foods_____
d) Eating expired foods_____
e) Drinking unclear water_____
f) Unknown _____

18. Do all members of your household properly practiced hand washing ***with soap***?
    a) Yes always _____
    b) Yes most of the time _____
    c) Yes sometimes _____
    d) Yes rarely _____
    e) Almost Never/Not at all _____
19. Do your family encored Worm infestation diseases in resent past 12 months? Yes _____ No _____
    If "Yes" What do you think are the causes of its occurrences? _____
    _____
    _____
20. Have you ever participated in any training and awareness creation programs about drinking water quality and water-borne diseases in recent past two to three years? a) Yes ____ b) No ____
    If your answer is 'Yes', please mention topics and situations of the program.
    _____
    _____
21. Have you made a complaint related to drinking water quality supply during the past 12 months?
    a) Yes _____ b) No _____
    What are the major reasons for your complaint? _____
    _____
    What was the result of the complaint? _____
    _____
22. What is most important for your household regarding the supply of drinking water?
    a) Water with very low price _____
    b) Water easy to buy, near where I live ___
    c) Quality and clarity of the water _____
    d) Advice & training on water quality _____
    e) Other (Specify) _____
23. Which of the following aspects of water supply do you think needs improvement in the future?
    a) Access _____
    b) Price rate _____
    c) Quality _____
    d) Reliability _____
    e) Service quality _____
    f) Maintenance _____
    g) Others (Specify) _____
24. Any comment or suggestions you have; _____
    _____
    _____

Thank you!

መለያ ቁ____

ሐረመያ ዩንቨርሲቲ
የድህረ ምረቃ መረሀግብር
የተፈጥሮ ሳይንስ ኮሌጅ
የባዩሎጅ ድፓርትምንት
በቤተሰብ ኃላፊዎች የሚሞላ መጠይቅ

የተከበሩ መልስ ሰጪ!

የዚህ መጠይቅ ዋና ዓላማ ለማስተርስ ዲግሪ መመረቂያ "***በአዳማ ከተማና አከባቢው ባሉት የመጠጥ ውሃ አቅርቦት ውስጥ የባክተሪያና ጥገኛ ህዋሳት መገኘት ሁናታ እና የውሃ አያያዝና አጠቃቀም***" በሚል ርዕስ ለሚካሄደው ጥናትና ምርምር መረጃን ለማሰባሰብ ሲሆን የጥናቱ ውጤትም በዋናነት የሚያገለግለው ለትምህታዊ ጉዳይ ሲሆን በተጨማሪም ከመጠጥ ውሃ ጥራትና ውሃ ወለድ በሽታዎች ጋር በተያያዘ ያሉትን ችግሮች ለመቅረፍ ይረዳል።

ስለሆነም እርስዎም ይህንን መጠይቅ በመሙላት የበኩልዎን አስተዋፅኦ እንዲያበረክቱ ተመርጠዋል። የሚሰጡትም ምላሾችና መረጃዎችም ከጥናቱ ዓላማ ውጪ ለሌላ ለማናቸውም ወገን ተላልፈው የማይሰጡ በመሆኑ በየትኛዉም መልኩ የእርስዎን ስብዕና አይነካም። ስለዚህ በእርስዎ የምሰጡ ምላሾች ለጥናቱ መሳካት እጅግ ጠቃሚ መሆናቸውን በመገንዘብ ሁሉንም የመጠይቁ ጥያቄዎች በጥሞና በማንበብ እንዲመልሱ በአክብሮት እንጠይቃለን።

ስለ ትብብርዎ በቅድሚያ እናመሰግናለን!!

አጠቃላ ሁኔታ መግለጫ

- በማናቸውም የመጠይቁ ገጾች ላይ ስም መጻፍ አያስፈልግም፤
- አማራጭ ለተሰጣቸው ጥያቄዎች መልሱን የ"✓" ምልክት በማድረግ ይመልሱ፤
- አማራጭ ለሌላቸው ጥያቄዎች ምላሽዎን በተሰጠው ባዶ ቦታ ላይ ይጻፉ።

ክፍል አንድ፤ የመላሾች አጠቃላይ ሁኔታ መግለጫ

1. አድራሻ: ቀበሌ _____ መንደር/ሰፈር _____
2. ጾታ a) ወንድ _____ b) ሴት _____
3. ዕድሜ: a) ከ18 ዓመት በታች ___ b) ከ18-25 ዓመት ___ c) ከ25-32 ዓመት ___
   d) ከ33-40 ዓመት ___ e) ከ40 ዓመት በላይ___
4. የትምህርት ደረጃ:
   a) ማንበብና መጻፍ ___ b) አንደኛ ደረጃ ___ c) ሁለተኛ ደረጃ___
   d) ዲፕሎማ ___ e) የመጀመሪ ዲግሪና ከዚያ በላይ ___
5. የቤተሰብ አባላት ብዛት: ወንድ _____ ሴት _____ ድምር _____

ክፍል ሁለት: የመጠጥ ውሃ አያያዝንና አጠቃቀምን የተመለከቱ ጥያቄዎች

6. ቤተሰብዎ የመጠጥ ውሃ የሚያገኘው ከየት ነው?

a) ከቧንቧ (በመኖሪያ ቤት) _____
b) ከቦኖ _____
c) ከጉድጓድ ውሃ ____
d) ከወንዝ _____
e) ሌላ (ካለ ይግለጹ) _____

7. የመጠጥ ውሃን ለማግኘት ከመኖሪያ ቤትዎ ምን ያህል ይጓዛሉ? (የሚፈጀውንየጊዜ እርዝማኔ ይግለጹ):

a) ከ15 ደቂቃ በታች ____
b) 15-30 ደቂቃ _____
c) 30-45 ደቂቃ _____
d) ከ45 ደቂቃ እስከ አንድ ሰዓት _____
e) ከአንድ ሰዓት በላይ ___

8. በቤተሰብዎ ዉስጥ የመጠጥ ውሃን የሚቀዳው ማነው?

a) ጎልማሳ ሴቶች _____
b) ጎልምሳ ወንዶች_____
c) ወጣት ሴት ልጆች _____
d) ወጣት ወንድ ልጆች _____
e) ሌላ (ካለ ይግለጹ) _____

9. ለውሃ መቅጃና ማጠራቀሚያ ምን ዓይነት ዕቃዎችን ይጠቀማሉ?

ተ.ቁ	የዕቃዎች ዓይነት	ለመቅጃ	ለማጠራቀሚ
1	ታንከር		
2	እንስራ		
3	ባልዲ		
4	ጀሪካን		
5	ተለቅ ያለ ጆግ		
6	በርሜል		
7	ማንቆርቆሪያ		
8	ሌላ(ካለ ይግለጹ)		

10. ለቤተሰብዎ ውሃን ለምን ያህል ጊዜ በቀንና በሳምንት ደጋግመው ይቀዳሉ?

ድግግሞሽ		በቀን	በሳምንት
a	አንድ ጊዜ		
b	ሁለት ጊዜ		
c	ሦስት ጊዜ		
d	አራት ጊዜ		
e	አምስት ጊዜ		
f	ከአምስት ጊዜ በላይ		
	ሌላ (ካለ ይግለጹ)		

11. አንዴ የቀዱትን የመጠጥ ውሃ ለምን ያህል ጊዜ በማጠራቀምያ ውስጥ አቆይተው ይጠቀማሉ?

a) እስከ አንድ ቀን____ c) ከ3-4 ቀናት ____ e) ለሳምንት ____

b) ከ1-2 ቀናት ____ d) ከ5-6 ቀናት ____ f) ከሳምንት በላይ ____

12. የውሃ መቅጃንና ማጠራቀሚያን በየጊዜው ማጠብንና መክደኛ መጠቀምን በተመለከተ፤

	ጉዳዮች	ሁል ጊዜ	አብዛኛውን ጊዜ	የተወሰነ ጊዜ	አልፎ አልፎ	ምንም
1	የመጠጥ ውሃን ሲቀዱ ለመቅጃነት የተጠቀሙበትን እቃ የመክደን ልምድዎን እንዴት ይገልፃሉ?					
2	የመጠጥ ውሃን ለማጠራቀም የሚጠቀሙበትን ዕቃ የመክደን ልምድዎን እንዴት ይገልፃሉ?					
3	ለመጠጥ ውሃ መቅጃነት የሚጠቀሙበትን እቃ ውሃውን ከመቅዳትዎ በፊት የማጠብ ልምድዎን እንዴት ይገልፃሉ?					
4	የመጠጥ ውሃን ከመቅጃ ወደ ማጠራቀሚያ ከመገልበጥዎ በፊት ለውሃ ማጠራቀሚያነት የሚጠቀሙበትን ማጠራቀሚያ የማጠብ ልምድዎን እንዴት ይገልፃሉ?					
የመጠጥ ውሃን የሚያጠራቅሙት ***በታንከር*** ከሆነ በምን ያህል ጊዜ ታንከሩ እንደሚታጠብ ቢገልጹልን ___ _____						

13. ውሃን ከማጠራቀሚያ ውስጥ እንዴት እንደሚቀዱና በምንስ ቀድተው እንደሚጠቀሙ ቢገልጹልን?

_____

_____

14. በአሁን ወቅት የሚጠጡት ዉሃ በትክክል ለመጠጥነት የሚገባ ነው ብለው ያምናሉ?

a) በጣም በከፍተኛ ደረጃ አምናለሁ_____ d) በመጠኑ አምናለሁ _____

b) በከፍተኛ ደረጃ አምናለሁ_____ e) በጭራሽ አላምንም_____

c) በከፊል አምናለሁ_____

15. ለመጠጥነት የሚጠቀሙትን ውሃ ቀድተው ወደ ቤትዎ ካመጡ በኃላ እና ከመጠጣትዎ በፊት በመኖሪያ ቤትዎ ደረጃ በተለያዩ ዘዴዎች በመጠቀም ያጣራሉ ወይም ማጣራትን ያከናውናሉ?

a) አዎ, በማፍላት _____ d) ምንም የማጣራት ስራ አይከናወንም _____

b) አዎ, ኬሚካል በመጠቀም _____ e) ሌላ (ካለ ይግለጹ) _____

c) አዎ, ማጥለያን በመጠቀም _____

16. የመጠጥ ውሃ አቅርቦት መቋረጥ/እጥረት አጋጥምዎት ያውቃል? a) አዎ ___ b) አያውቅም ____

መንስኤው ምን እንደሆነ ቢገልፁልን፤ _____

_____

17. ባለፉት 12 ወራት ከቤተሰብዎ ውስጥ ተቅማጥ ያጋጠመው ሰው አለ? አዎ አለ _____ የለም _____

ካለ መንስኤው ከዚህ በታች ከተዘረዘሩት ውስጥ የትኛው እንደነበር ቢገልፁልን፤

a) ቅመም የበዛበት ምግብ በመመገቡ/ቧ_____ e) ንጹህ ያልሆነ ውሃ በመጠጣቱ/ቷ_____

b) ያልቀዘቀዘ ትኩስ ምግብ በመመገቡ/ቧ_____ f) ሌላ (ካለ ይግለጹ) _____

c) ንፅህናው የተጓደለ ምግብ በመመገቡ/ቧ_____ _____

d) ጊዜው ያለፈበት ምግብ በመመገቡ/ቧ _____

18. ከቤተሰብዎ ውስጥ በጥገኛ ህዋሳት አማካኝነት በሚከሰት በሽታ የተያዘ ሰው አለ? አዎ አለ___ የለም__
ካለ ለበሽታው መከሰት ምክንያቱ ምን እንደነበር ቢገልፁልን፤_____

_____

19. የቤተሰብዎ አባለት በሙሉ እጃቸውን በሳሙና ዉሃ ይታጠባሉ?
a) ሁል ጊዜ ይታጠባሉ_____ d) አልፎ አልፎ እንዳጋጣሚ ይታጠባሉ _____
b) አብዛኛውን ጊዜ ይታጠባሉ_____ e) በሳሙና አይታጠቡም _____
c) የተወሰነ ጊዜ ይታጠባሉ _____

20. ባለፉት ሁለትና ሶስት ዓመታት ስለ ንፁህ መጠጥ ውሃ እና ውሃ ወለድ በሽታን በተመለከተ የግናዛቤ ማዳበሪያ ስልጠና ወስደው ያውቃሉ? a) አዎ__ b) ወስጀ አላውቅም __
ወስደው ከሆነ ስለ ስልጠናው ርዕስና ሁኔታ ቢገልፁልን፤

_____

_____

21. ባለፉት 12 ወራት ውስጥ ንፁህ የመጠጥ ውሃ አቅርቦትን በተመለከተ ለሚመለከታቸው አካላት ቅሬታ አቅርበው ያውቃሉ? a) አዎ ___ b) ቅሬታን አቅርቤ አላውቅም ___
የቅሬታዎ መነሻና ምክንያትስ ምን ነበር?_____

_____

የቅሬታዎ ውጤትስ ምን ሆነ?_____

_____

22. ከመጠጥ ውሃ ጋር በተያያዘ ከዚህ በታች ከተጠቀሱት ውስጥ እርስዎና ቤተሰብዎ የተለየ ትኩረት የምትሰጡት እና የጎላ ጠቀሜታ አለው የምትሉት የትኛውን ነው?
f) በዝቅተኛ ዋጋ የመጠጥ ውሃ ማግኘት ____
a) የመጠጥ ውሃን በቅርበት በመኖሪያ ቤት አከባቢ ማግኘት ___
b) ጥራት ያለውና ንፁህናው የተጠበቀ የመጠጥ ውሃ ማግኘት ___
c) ስለ ንፁህ የመጠጥ ውሃ አያያዝና አጠቃቀም ምክርና ስልጠና ማግኘት ____
d) ሌላ (ካለ ይግለጹ) _____

23. የመጠጥ ውሃን በተመለከተ ከሚከተሉት ሁኔታዎች ውስጥ በቀጣይ የትኛው መሻሻል አለበት ይላሉ?
a) የመጠጥ ውሃ አቅርቦት__
b) የመጠጥ ውሃ የመሸጫ ዋጋ _____
c) የመጠጥ ውሃ ጥራት____
d) የውሃ አቅርቦት መቆራረጥ_____
e) የመ/ቤቱ የአገልግሎት አሰጣት ጥራት ___
f) የውሃ መስመሮች ጥገናና እድሳት ___
g) ሌላ (ካለ ይግለጹ) _____
_____

24. ተጨማሪ አስተያየት ካልዎት _____

_____

እናመሰግናለን!!

Appendix-D: Observation Check-List

HARAMAYA UNIVERSITY

Cod Number _____

School of Graduate Studies

College of Natural Sciences

Department of Biology

A Checklist to be Filled by Data Collector at Sample Household

Address/Location: Kebele _____ Village (Specific Name) _____

No	Factors/Checklist Items	Responses
1	Type of drinking water source used by the household	
2	Average distance from water source to the house (in meters)	
3	Cleanness status of drinking water source surroundings (respond using the scales; 5= Very Clean, 4=Clean, 3=Partially Clean, 2=Somewhat Clean, and 1=Not Clean at all)	
4	The occurrence of taps/pipes leakage *(Yes/No)*	
5	Presence of collected water on the ground nearby drinking water source *(Yes/No)*	
6	Distance between drinking water sources and the latrine or sewage tanker (in meter)	
7	The presence of waste disposal near or around drinking water sources *(Yes/No)*	
8	Within a radius of 10 meters, do animals have access to the area around the water source? *(Yes/No)*	
9	Place where water-storage container kept in the household *(State its exact place like; on the ground, above ground (in meter), etc)*	
10	Features and situation of water dipping utensils used to dip water from storage containers for use (*Explain*)	
11	Sanitation status of the place where drinking water storage container is kept *(respond using the scales; 5= Very Clean, 4=Clean, 3=Partially Clean, 2=Somewhat Clean, and 1=Not Clean at all)*	

Checked by: Name _____ Signature: _____ Date: ___/___/2016

Appendix-E: Degree of Bacteriological Contamination in Tap Water Source (Summary)

Water Sources	Standards	AMB (30 ^{O}C/24Hrs)		TCC (37 ^{O}C/24Hrs)		FCC (44 ^{O}C/24Hrs)		Feacal Step (44 ^{O}C/24hrs)		Remarks
		Count	%	Count	%	Count	%	Count	%	
Tap	0	NA		243	56.25	262	60.65	414	95.83	Safe
	1 to 10	NA		119	27.55	135	31.25	18	4.17	Reasonable Quality
	11 to 100	NA		47	10.88	17	3.94	0	0.00	Polluted Water
	>100	NA		23	5.324	18	4.17	0	0.00	Dangerous
	Total	NA		432	100	432	100	432	100	

*Keys: WHO (2011): According to WHO (2011) and FDRE MOWR (2002); 0 CFU/100ml=safe; 1-10 CFU/100ml =Reasonable Quality; 11-100CFU/100ml=Polluted; and >100CFU/100ml=Dangerous.
NA = Not applicable

Quality Control: Description Obtained from lab-technicians and experts During Laboratory Tests

1) Transport Quality control:
   - Sterilized distilled water with in the water sample collection bottle transported with water sample collecting bottles and returned to the laboratory and analyzed the same way as the water samples.
   - The results should be negative for AMBC, TCC, FCC, & FSC
2) Duplicate sample collection one in every 20^{th} water sample
   - To increase sensitivity in detecting the indicator bacteria, duplicate water sampling from the same source with different sampling bottles are collected and analyzed separately and the mean result is used as final result.
3) Sterility test quality control
   - After preparing membrane lauryl sulpate broth, PCA, and the media are sterilized.
   - But before usage PCA (Plate Count Agar) pour plated without any sample and incubated accordingly .
   - MLSA is added on the pad within the aluminum petridish and membrane is put on the moistened pad and incubated accordingly.
   - Inspect the media for any bacterial growth.
   - A known negative control is processed along with the water sample the same way as water sample.
4) Growth support quality control
   - Positive control for MLSA is *Escherichia coli* (ATCC E. coli)
   - MLSA is inoculated with this control organism.
5) Growth inhibition quality control
   - On MLSA there should be no *Staphylococcus aureus.*
   - We inoculate MLSA with ATCC *S. aureus*.
   - The result should be no growth.
6) Differential characteristics quality control
   - Positive control is *E.coli*
   - Negative control if *Salmonella typhimurium*
7) Incubator temperature monitoring
   - The fluctuation of the incubator inbuilt temperature reading should be plus or minus 0.1
   - The incubators adjusted at 44^{o}C, 37^{o}C, & 30^{o}C are monitored externally twice a day.

Appendix-G: Letter from the Oromia Health Research, Capacity Building & Quality Assurance Laboratory

GIDDUGALA QO'ANNOOF QORANNOO HAWASA
LJERSA ... TO' ANNOO QULQULINNA
LAABORATORII ... OROMIYYA /ADAMA

OROMIA HEALTH RESEARCH, CAPACITY
BUILDING & QUALITY ASSURANCE LABORATORY/ADAMA
የኦሮሚያ ክልል የህብረተሰብ ጤና ምርምር
የላቦራቶሪ አቅም ግንባታ እና ጥራት
ቁጥጥር ማዕከል (አዳማ)

ቁጥር RfRL-8034-05-xa.ba
ቀን 22/11/08.

ለሐረማያ ዩኒቨርሲቲ

ሐረማያ

ጉዳዩ፡ በወ/ሮ መሰረት ደምሴ አማካኝነት በአዳማ ከተማ የመጠጥ ውሃ ጥራት ላይ ስለተካሄደው ጥናትና ምርምር ምስጋና ማቅረብ ይሆናል፤

ከዩኒቨርሲቲያችሁ የባዮሎጅ ድፓርትመንት December 30, 2015 በተፃፈ የትብብር ደብዳቤ መነሻነት ወ/ሮ መሰረት ደምሴ ለማስተርስ ዲግሪ ማሟያ በአዳማ ከተማ እና አከባቢዋ የመጠጥ ውሃ ጥራት ላይ ያካሄዱት ጥናትና ምርምር የቤተ-ሙከራ (ላቦራቶሪ) ስራ በድርጅታችን የተከናወነ በመሆኑ በምርምሩ የተገኘው ውጤት ላይ በመመስረት አስቸኳይ የእርምት እርምጃ እንዲወሰድ ለማድረግ አስችሉናል፡፡

በዚሁም መሰረት በምርምሩ በመጠጥ ውሃ ውስጥ የተገኙት የባክቴሪያዎች እና ጥገኛ ህዋሳት መጠን ለሰው ልጆች ጤንነት አደገኛ ስለነበሩ ውጤቱን ለአዳማ ከተማ የውሃና ፍሳሽ አገልግሎት ጽ/ቤት ሪፖርት በማድረጋችን የእርምት እርምጃ እንዲወሰድ ተደርጓል፡፡

ስለዚህ በከተማው ህዝብ ላይ ይደርስ የነበረው አደጋ በዚህ ጥናትና ምርምር ግኝት መሰረት መቀረፍ በመቻሉ ለወ/ሮ መሰረት ደምሴም ሆነ ለሐረማያ ዩኒቨርሲቲ ላቅ ያለ ምስጋናችንን እናቀርባለን ፡፡

ከሠላምታ ጋር!

ግልባጭ

ለወ/ሮ መሰረት ደምሴ

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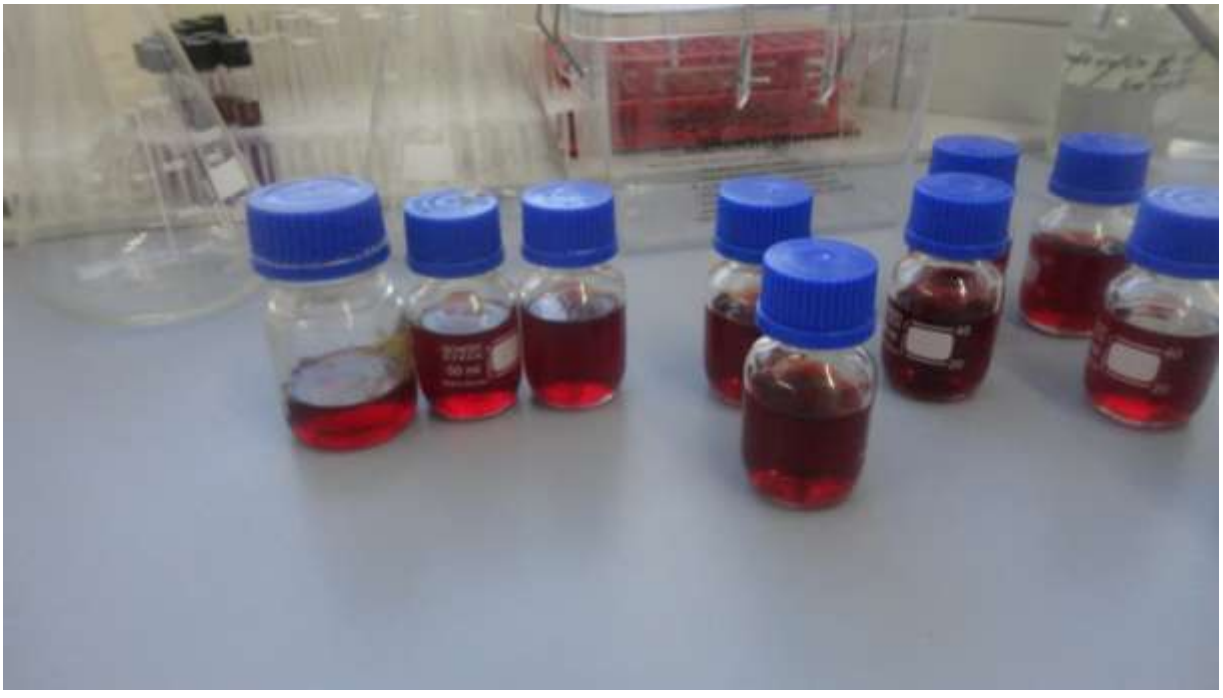
Appendix-H: Pictures at Laboratory Tests

Pictures at Laboratory Tests



Pictures at Laboratory Tests

Pictures at Laboratory Tests