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QUALITY ASSESSMENT OF RURAL DRINKING WATER SUPPLY SCHEMES FROM SOURCE TO -POINT OF- USE. (A CASE STUDY OF ADA’A WOREDA, IN OROMIA REGIONAL STATE OF ETHIOPIA).

A Report

Submitted to the School of Graduate Studies of Addis Ababa University In partial fulfillment of the Requirements for the Degree of Master of Engineering in Civil and Environmental Engineering.

(Major in Water Supply and Environmental Engineering).

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ABSTRACT

The poor quality of drinking water leads to water related diseases. The study was carried out to determine drinking water quality supply schemes of rural Ada'a Woreda at the source and point of use by assessing current water service that provided to the household. Total 36 water samples were collected from different sources and household (point -of -use). The PH, Turbidity, Total Dissolved Solids (TDS), Electrical Conductivity (EC), Fluoride, Nitrate, Total Hardness, Calcium and Magnesium Hardness, Phosphate and Microbiological (Total Coliform and C.coliform/CFU) of the samples were determined using laboratory analysis. The result was then compared with the WHO and Ethiopian water quality standards.

Results:- show that improved water supply schemes of woreda did not contain total coliform or E.coli at source level except one sample (SW-7 which contained total coliform of 8 cfu/100ml*)* which might be due to poorly maintained and crack damaged of the apron. However, water at point -of-use (household) from both shallow well and deep wells-indicates a decline in bacteriological level (0-57cfu/100ml T.C and 0-50cfu/100ml E.C) as compared to water at the source level. High record of calcium in two sources (S7 & S9 in Katella Kebele) which were 81.8 mg/l and 96.5 mg/l respectively observed which is greater than the recommended value of WHO and National Standard (75mg/l). In addition, high fluoride content was relatively observed in Dirre shoki kebele.

In conclusion, significant effect of technologies (shallow well and deep well) on water quality at the sources was not observed. In addition, high bacteriological level was investigated at the point of use as compared at the source; this might be attributed to water handling problems. Thus, chemical treatment at point-of-use is suggested as an appropriate solution to eliminate any post-source contaminations. In addition, it is also recommended that the future work has to be done to modify existing water development strategies by considering water quality at point-of-use. Moreover, awareness must be created about water; hygiene and sanitation (WASH) for rural communities to reduce water related disease.

Key words:-***Water Quality Assessment at source and Household, Physicochemical and Microbial parameters, WHO Standard, Water-Related Disease &Ada'a Woreda, Ethiopia.***

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DEDICATION

This research is dedicated to in remembrance of my late father, Mr. Desissa Gudeta and my mother for her unending prayers. Her prayers made a way for me and helped achieve this success.

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ABBREVIATIONS

AFD	African Development Fund
ES ISO	Ethiopia Standard International Standard Organization
ES	Ethiopia Standard
FDRE	Federal Democratic Republic of Ethiopia
GIS	Geographical Information System
GEMS	Global Environmental Monitoring System
GPS	Global Position System
SDG	Sustainable Development Goal
LCD	Liquid Crystal-Display
MCL	Maximum Contaminated Level
MS EXCEL	Microsoft Excel
MDL	Maximum Permissible Level
MoWRD	Ministry of Water Resource Development
NTU	Ne photometric Turbidity Unit
UNEP	United Nation Environmental Program
UNICEF	United Nation International Children's Emergency Fund
WHO	World Health Organization
CCME	Canadian Council Ministry of the Environment.
DWAF	Department of Water Affairs and Forestry
CFU	Colony Forming Unity
TNTC	Too Numerous To Count.
CLTS	Community Led-Total Sanitation
SPSS	Stastical Package For social science
APHA	American Public Health Association
RADWQ	Rapid Assessment of Drinking Water Quality
JMP	Joint Monitoring Program
WASH	Water, Sanitation and Hygiene.

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CHAPTER- **ONE**

1. INTRODUCTION

1.1 Background

Water is most vital liquid for maintaining life on the earth. About 97% of water on earth exists in an ocean that is not suitable for drinking and only 3% is fresh water wherein 2.97% is comprised by glaciers and ice caps. The remaining little portion which is only 0.3% is available as a surface and ground water for human use (Miller, 1997). Safe drinking water is a basic need for good health and it is also a basic right of humans. Fresh water is already a limiting resource in many parts of the world. In the next century, it will become even more limiting due to increased population, urbanization and climate change (Jackson et al., 2001). Unfortunately, in developing countries like Ethiopia, the drinking quality of water is continuously being contaminated and hazardous for human use due to high growth of population, expansion in industries, throwing away of waste-water and chemical effluents into canals and other water sources. According to recent estimates, the quantity of available water in developing regions of Africa, Middle East and South Asia is decreasing sharply while quality of water is deteriorating rapidly due to fast urbanization, deforestation, land degradation etc. (Annachhatre, 2006).

Worldwide, more people are dying from poor quality of water per year than from all forms of violence including war and it is estimated that about 26% of all deaths are outcome from contagious diseases caused by pathogenic bacteria (WHO, 2002; UNEP GEMS/ Water Programme, 2008).

Water mainly used for drinking, cooking and preparation of food, bathing, cleaning, washing and personal hygiene, watering in gardens, and water for livestock, sanitation. Various health problems may occur due to inadequacy and poor quality of water supply. Infant mortality rate is high due to unsafe water supply. High incidence of childhood diarrhea, helminthiasis, trachoma and the overall high mortality rates are associated with poor environmental sanitation (Mengesha et al., 2004). The World Health Organization estimated that up to 80% of all sicknesses and diseases in the world are caused by inadequate sanitation, polluted water or unavailability of water. In Ethiopia over 60% of the communicable diseases are due to poor environmental health conditions arising from unsafe and inadequate water supply and poor hygienic and sanitation

Practices (WHO, 2004). Several studies have confirmed that water-related diseases not only remain a leading cause of morbidity and mortality worldwide but that the spectrum of diseases is expanding and the incidence of many water- related microbial disease is increasing (WHO, 200 3). Diarrhea remains a major killer in children and it is estimated that 80% of all illness in developing countries is related to water and sanitation; and that 15% of all child deaths under the age of 5 years in developing countries results from diarrheal diseases (WHO, 2003). In rural areas and villages of Ethiopia, water for human consumption, drinking, washing (bathing, laundry), for preparation of food etc., is obtained from rivers, streams, shallow wells, springs, lakes, ponds, and rainfall. Unless water is made safe or treated for human consumption, it may be hazardous to health and transmit diseases. The main contaminants of these water sources are human excreta, animal waste and effluent because of open field defecation practices. Thus, the majority of rural communities use water from contaminated or doubtful sources, which exposes the people to various water- borne diseases (FDRE, MoWR, 2004)

Therefore, drinking water quality should be completely free from pathogenic microorganisms, physico-chemical element in concentration that causes health impact. It should be clear and aesthetically attractive, low turbidity and color recommended by WHO guide lines and should not be saline, contain any compounds that cause offensive and taste, should not cause corrosion scale formation, discoloring or staining and should not have a temperature unsuitable for consumption.

Water quality and the risk to waterborne diseases are critical public health concerns in many developing countries. Today, close to a billion people most living in the developing world do not have access to safe and adequate water (UNICEF/WHO, 2012). The World Health Organization (WHO) estimated that around 94% of the global diarrheal burden and 10% of the total disease burden are due to unsafe drinking water, inadequate sanitation, and poor hygienic practices (Fewtrell et al., 2007; Prüss-Üstün and Corvalán, 2006).

Thus, the provision of safe and adequate water contributes to better health and increased individual productivity. It is also recognized that there is significant relation between water supply and sanitation improvements and the potential for health and economic benefits (El-Fadel et al., 2003; Fewtrell et al., 2005; Peter, 2010; WHO/UNICEF, 2000). Accordingly, rural water supply schemes should deliver the expected service to users for a reasonable period of time in terms of quality, quantity, accessibility, coverage, affordability and continuity simply called sustainability (Harvey and Reed, 2004).

One of the most important factors that affect service delivery and the continued use of rural water supply schemes is the quality of water the schemes deliver to users (Brikke, 2002; Schouten and Moriarty, 2003). If water supply schemes fail to meet acceptable drinking water quality standards (that is, physical, chemical and/or bacteriological) people may stop using the scheme and resort to unsafe sources; and will be further exposed to acute and chronic illnesses (Karn and Harada, 2002). This will bring challenge in meeting the (SDGs) Sustainable Development Goals of target-Goal-6 (*Ensure availability and sustainable management of water and sanitation for all*) and of ensuring environmental sustainability, improving health and eradicating extreme poverty of the rural majority living in the developing world (United Nations, 2005).

The water supply coverage in Ethiopia has been one of the lowest in Sub-Saharan Africa (African Development Fund (ADF), 2005). The country's water supply sub-sector has been characterized by poor performance with a number of problems including unsustainability and unreliability of water supply services (MoWRD, 2006).

The main objective of this study is to assess the current quality of water from the improved sources to- point of-use of drinking water in Ada'a District.

1.2 Statement of the Problem

Water quality and the risk to water related diseases are serious public health concerns in many developing countries like Ethiopia. The community of Ada'a woreda is mainly suffering from water-washed disease and water -borne disease, especially diarrhea, helminthes, giardia and contamination due to open defecation near the schemes; logging problem water schemes, crack damage of apron, poor protection of the schemes and inadequacy of drinking water quality.

According to officials of the word health office, the major health problems are acute respiratory infection (including Pneumonia), infection of the skin and eyes, helminthes and Diarrhea. These are the most common water-washed disease and water born disease linked with inadequate use of water for domestic and personal hygiene. The prevalence of these water-washed diseases of these is an indication of poor status of drinking water supply and personal hygiene. It is important to develop the accessibility of water and reliability or continuity of the water supply which may reduce the influence the risk of diseases.

The woreda coverage of water supply is 52% of the woreda both urban area and rural indicate poor sewerage/sanitation system, rapid increase in population and cultivation with the application of chemical fertilizer of industry which discharges to shallow well and surface water may reduce the quality of drinking water in the woreda (source; Woreda Water Office). Major Water born and water-washed diseases recorded for the past two years (2006 to 2007 E.C) were collected from the Ada'a woreda health office shown in Table 1-1. Table shows except Diarrhea and trachoma, other water related disease were increased.

Table 1-1 Disease Reported Because of Water-washed and water-borne Disease in 2006/07 E.C

Types of disease	2006 Cause reported	2007 Cause reported
(ARI) Acute Respiratory Infections	4557	4815
Infection of the skin	1801	2263
Helminthes	1764	2080
Diarrhea (non-bloody)	2026	2020
Trauma /trachoma	1768	1554

Source: - Ada'a Woreda Health Office, Bishoftu

1.3 General Objectives

The general objective of this research is to determine quality of drinking water supply schemes at the Source and point of use by assessing current water services that provide to household.

To resolve this, the following specific objectives were:

- To assess the difference in water quality between different source technologies in woreda (Shallow well /Hand pumps and Deep well),
- To Evaluate the Bacteriological quality of drinking water supply schemes being supplied to community at source and potability of water at point of use by using total Coliform and E. Coliform.
- To identify the cause of water quality degradation at point of consumption (point-of-use) for both improved water source observed,
- To generate base line data for further studies and intervention.

1.4 Thesis Organization

Chapter 1:- The back ground of the importance drinking water quality definition and health significance of water-related diseases, statements of the problem, general objective and specific objectives.

Chapter 2:- It includes literature review and conceptual frame of drinking water quality assessment, main importance of drinking water quality parameters regards to physic-chemicals, and bacteriological tests analysis within maximum permissible limits regards to WHO guidelines, Ethiopia guidelines, and significance on the human health.

Chapter 3:- Methods and materials used description of the study area is in detailed; sample size determination and sample location of points of study area were explained.

Chapter 4:-It includes the result and discussion of the research in detailed.

Chapter 5:-It includes conclusion and Recommendation of the research in detailed

CHAPTER-TWO

2. LITERATURE REVIEW`

2.1 Water

Water is a liquid at ambient conditions, but it often co-exists on Earth with its solid state being ice, and gaseous state being water vapour or steam (Ameyibor and Wiredu, 1991). Human bodies are approximately 60% water, blood is at least 50% water and the human brain made of 77% water (Stanistski *et al*., 2000).

2.1.1 Sources of Water

Water can be grouped into Surface water comprising of oceans, rivers, lakes, reservoirs, lagoons, streams and many others, Ground water which is considered mostly as purer than the surface water and lastly the rain water which falls as a result of condensation and precipitation of the clouds (Stanistski *et al*., 2000).

Surface water frequently contains substances that must be removed before it can be used as drinking water while ground water is that pumped from wells and boreholes that have been drilled from underground aquifers and is usually free from harmful contaminants.

2.2 Wells

A well is an excavation or a structure created in the ground by digging, driving, boring or drilling to access groundwater in underground aquifers (Roger, 1982).The well water may be drawn by an electric submersible pump, a vertical turbine pump, a hand pump or a mechanical pump (e.g. from a water-pumping windmill). It can also be drawn up using containers, such as buckets that are raised mechanically or by hand (Obiri Danso *et al*., 2009).Wells can vary greatly in depth, water volume and water quality. Well water typically contains more minerals in solution than surface water and may require treatment to soften the water.

In Ethiopia, groundwater (Shallow/hand pump or Deep Well) is an important source of water and dominant source for domestic supply in many areas, especially in the dry areas where surface waters are scarce and seasonal (e.g. Afar north and Somali region in the east). Few data exist for the general state of groundwater quality across Ethiopia. From those available, the quality is shown to be highly variable, ranging from fresh waters in many of the springs issuing from the crystalline basement rocks to more saline waters in parts of the Rift and the sedimentary formations of the plains (Aberra, 1990).

2.3 Well contamination

Shallow pumping wells can often supply drinking water at a very low cost, but because impurities from the surface easily reach shallow sources, a greater risk of contamination occurs for these wells when they are compared to deeper wells. Contamination of the wells increases during the rainy seasons where the aquifer is “topped up” more rapidly and both vertical and horizontal migrations of water are accelerated (Morgan, 1990).

Well is generally less susceptible to contamination and pollution when compared to surface water bodies (Zaman, 2002). Also the natural impurities in rainwater, which replenishes groundwater systems, get removed while infiltrating through soil strata (Veslind, 1993). Importantly, groundwater can also be contaminated by naturally occurring sources. Soil and geologic formation containing high levels of heavy metals can leach those metals into groundwater. This can be aggravated by over-pumping wells, particularly for agriculture (Gay and Proop, 1993). Pollution caused by fertilizers and pesticides used in Agriculture, often dispersed over large areas, is a great threat to fresh groundwater ecosystems. Pollution of groundwater due to industrial effluents and municipal waste in water bodies is another major concern in many cities and industrial clusters in Ethiopia. Observed increased salinity in many ground waters from sediments in the south, southeast and north-eastern parts of the country arises from the dissolution of evaporite minerals (the products of evaporation) in certain horizons of the sediments (Alemayehu, 2004).

The quality of the well water can be significantly increased by lining the well, sealing the well head, fitting a self-priming hand pump, constructing an apron, ensuring the area is kept clean and free from stagnant water and animals. Most of the bacteria, viruses, parasites, and fungi that contaminate well water come from faecal material from humans and other animals (Philip Victor Mintah, July 2011).

2.4 Contamination of Drinking water between source and point- of- use in rural area

In rural areas of most developing countries, women and children collect water from a communal source, often located several hundred meters from the home. The sources themselves may be unimproved (hand dug wells, unprotected springs, rivers), with low and seasonal flow rates, or improved (public taps, boreholes or pumps, protected wells, protected springs or harvested rainwater). A systematic review of 57 studies published before 2002 by Wright *et al.* (2004) showed that water contamination occurs between source and point-of-use. This pattern has been confirmed by subsequent studies of water contamination in rural Sierra Leone (Clasen and Bastable, 2003) and rural Honduras (Trevett, Carter and Tyrrell, 2005).

The purpose of study was to determine water contamination at source and point-of-use. To do this the quality of water at point source, from 'intrinsic' source (flamed) and the drinking cup used by community was measured.

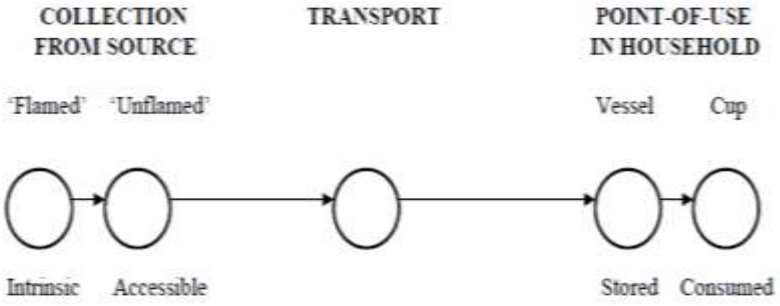

Figure2.1 Supply Chain of drinking water for household.

2.5 Drinking water quality

Drinking water quality is defined as water that is free from disease producing microorganisms and chemical substances deleterious to health (Tebutt, 1983). Even fully protected sources and well-managed systems do not guarantee that safe water is delivered to households. The majority of the world's people do not have reliable household water connections and many of these must still physically carry water and store it in their homes. Studies show that even water collected from safe sources is likely to become faecally contaminated during transportation, container and storage. Assessing of drinking water quality from source to point of use in rural of Mali (Mathew

D.seib, 2011) and Microbiological contamination between source and point of use (Jim Wright, January, 2004) prescribed that covered water container will reduce 50% of water born and water related diseases. Safe sources are important, but it is only with improved hygiene, better water storage and handling, improved sanitation and in some cases, household water treatment, that the quality of water consumed by people can be assured (Mathew D, Seib et al, 2011). An increasing body of evidence is showing that water quality interventions have a greater impact on diarrhea incidence than previously thought, especially when interventions are applied at the household level (or point-of-use) and combined with improved water handling and storage (Fewtrell et al, 2005; Clasen et al, 2007).

The provision of potable water to the rural and urban population is necessary to prevent health hazards. Before water can be described as potable, it has to comply with certain physical, chemical and microbiological standards, which are designed to ensure that the water is palatable and safe for drinking (Tebutt et al, 1983).

2.6 Water Quality Analysis

Water quality describes the physical, chemical, and biological characteristics and conditions of Water and aquatic ecosystems, which influence the ability of water to support the uses designated for it (CCME, 2006). Water quality involves the physical, chemical, microbiological, radiological and biological properties of water. It can mainly be altered by human activities which may affect/ change any of these properties to the extent of affecting aquatic and terrestrial organisms depending on it (DWAF, 1996). According to (WHO,2006) health priority potential of chemicals were Arsenic and Fluoride which can occur naturally, Nitrate which is applied to large areas of agricultural land as fertilizers ,Microbiological and also Turbidity.

2.7 Water Quality Parameters

2.7.1 Physico-chemical parameters

2.7.1.1 PH of pure water

PH is a measure of the Potential hydrogen ion (H+) available in water. The acidity of groundwater is due to the presence of organic acids in the soil as well as those of atmospheric origin infiltrated to the water (Chapman and Kimstach, 1996). According to the WHO guidelines, “No health-based guideline value is proposed for pH, although eye irritation and exacerbation of skin disorders have been associated with pH values greater than 11. Although pH usually has no direct impact on consumers, it is one of the most important operational water quality parameters”. Whenever water treatment or storage is taking place (arsenic removal, clarification, disinfection, rainwater harvesting), careful attention to the level of pH is necessary and the optimum pH required is generally within the range 6.5–8.5 (as per WHO, 2006,ES,2011) according to the parameter.

2.7.1.2 Total Dissolved Solids (TDS*)*

Water has the ability to dissolve a wide range of inorganic and some organic minerals or salts such as potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulfates etc. These minerals produced un-wanted taste and diluted color in appearance of water. There is no agreement have been developed on negative or positive effects of water that exceeds the WHO standard limit of 1,000 ppm. Total dissolved solids (TDS) in drinking water is originates many ways from sewage to urban industrial wastewater etc. Therefore, TDS test is considered a sign to determine the general quality of the water (Muhammad et al., 2013).

2.7.1.3 Electrical Conductivity (EC)

Electrical conductivity (EC) is a measure of water capacity to convey electric current. It signifies the amount of total dissolved salts (Dahiya and Kaur, 1999) and is a useful tool to evaluate the purity of water (Acharya et al., 2008). Conductivity shows significant correlation with ten parameters such as temperature, pH value, alkalinity, total hardness, calcium, total solids, total dissolved solids, chemical oxygen demand and chloride and iron concentration of water.

2.7.1.4 Turbidity

For water to be aesthetically accepted, its clarity must be ensured. Turbidity is defined as the light scattering and absorbing property that prevents light from being transmitted in a straight lines through the sample. Turbidity may be due to organic and / or inorganic constituents. Organic particulates may harbor microorganisms. Thus, turbid conditions may increase the possibility for waterborne diseases. Nonetheless, inorganic constituents have no notable health effects. If turbidity is largely due to organic particles, dissolved oxygen depletion may occur in the water body. The excess nutrients may results in algal growth.

Although it does not adversely affect human health, turbidity is an important parameter in that it can protect microorganisms from disinfection effects, can stimulate bacteria growth and indicates problems with treatment processes (WHO, 2004). For effective disinfection, median turbidity should be below 1 NTU although turbidity of less than 5NTU is usually acceptable to consumers (WHO, 2004).

2.7.2.1 Aesthetic parameters of drinking water quality

2.7.2.1.1 Colour

Colour in drinking-water may be due to the presence of coloured organic matter, e.g. humic substances, metals such as iron and manganese, or highly coloured industrial wastes. Drinking-water should be colourless. For the purposes of surveillance of community water supplies, it is useful simply to note the presence or absence of observable colour at the time of sampling. Changes in the colour of water and the appearance of new colours serve as indicators that further investigation is needed (WH0, Geneva, 1997).

2.7.2.2.2 Odour and Tastes

Odours in water are caused mainly by the presence of organic substances. Some odours are indicative of increased biological activity; others may result from industrial pollution. Sanitary inspections should always include the investigation of possible or existing sources of odour, and attempts should always be made to correct an odour problem. Taste problems (which are sometimes grouped with odour problems) usually account for the largest single category of consumer complaints. Generally, the taste buds in the oral cavity detect the inorganic compounds of metals such as magnesium, calcium, sodium, copper, iron, and zinc. As water should be free of objectionable taste and odour, it should not be offensive to the majority of the consumers (Gaur, 2008).

2.7.3 Chemical Aspects of Drinking water quality Parameters

2.7.3.1 Total Hardness

Hardness is caused basically by calcium and magnesium salts and is expressed in terms of equivalent quantities of calcium carbonate. Depending on other factor such as pH and alkalinity of water with hardness above approximately 200 mg/lit may cause scale deposits in the distribution system and results in excessive soap consumption. Again soft water with hardness less than 100 mg may cause corrosion. Hardness may range from zero to several hundreds of mg (ppm). Although acceptability levels vary according to consumers' acclimation to hardness, a generally accepted scale is based on taste and household use consideration and with this basis of reference, the WHO recommends a guideline value of hardness. Actually there are no health effects or drinking water standards for hardness but hard water can cause numerous aesthetic problems, especially when water is heated. Because hardness reduces corrosion of household plumbing, a level of 90 to 100 mg/L is often considered optimum to reduce corrosion while also preventing unwanted aesthetic effects. Total hardness is usually reported in one of four categories as follows:

Table 2-1: Classification of Water Based On Hardness

Sr.No	Hardness mg/l as $CaCO_3$	Water Class
1	0-75	Soft Water
2	75-150	Moderately Hard Water
3	150-300	Hard Water
4	Above 300	Very Hard Water

(Source:-Sawyer and McCarty, 1987)

2.7.3.2 Nitrate (**NO_3**)

Nitrate is the most widespread agriculture contaminant and is a human health concern since it can cause methemoglobinemia or "Blue-Baby Syndrome" in infants. Some nitrate in ground water is due to naturally occurring sources, but levels of nitrate (NO_3) above 3 ppm (parts per million) typically indicate that pollution is seeping in from latrines, septic tanks, animal wastes, fertilizers, municipal landfills etc. In shallow groundwater, the concentrations of nitrate from agriculture pollutants, from domestic and agricultural sources may be high and nitrate concentrations frequently fail WHO guideline values.

High levels of nitrate can develop in ground waters as a result of:

- Run-off from agricultural land using nitrate fertilizers
- Contamination with urine and faeces
- Industrial pollution (Water Aid, water quality standard and testing policy)

2.7.2.3 Magnesium

Magnesium is the most abundant element on earth crust and natural constituent of water. It is an essential for proper functioning of living organisms and found in minerals like dolomite, magnetite etc. Human body contains about 25g of magnesium (60% in bones and 40% in muscles and tissues). According to WHO standards the permissible range of magnesium in water should be 150 mg/l (Faryal; 2013).

2.7.2.4 Calcium

Calcium is the greatest significant and abundant in the human body and sufficient consumption is essential for normal growth and health. Around 95 percent of calcium in human 13 body stockpiled in bones and teeth. The high deficiency of calcium in humans may cause of; rickets, poor blood clotting, bones fracture etc. The maximum daily requirement of the order of 1- 2 grams and come from mostly dairy products. There is certain evidence to indication that the incidence of heart disease is reduced in areas served by a public water supply with a high degree of hardness, the primary constituent of which is calcium, so that the presence of the element in a drinking water supply is advantageous to health (Environmental Protection Agency, 2001). According to WHO (1996), its permissible range in drinking water is up to 75 mg/l.

2.7.2.5 Phosphate

Phosphates in surface waters mostly originated from sewage effluents, which contains phosphate, based synthetic detergents, from industrial effluents, or from land runoff where inorganic fertilizers have been used in farming. Ground water usually contains insignificant concentrations of phosphates, unless they have become polluted. Phosphorous one of the crucial nutrients for algal growth and can contribute significantly to eutrophication of lakes and reservoirs (Alan et al., 2000).

2.7.3.6 Fluoride

Fluoride minerals are abundant in certain rock types. Immunoglobulin heavy locals (IGH) concentrations of fluoride can be released into ground waters through dissolution of these fluoride minerals, especially after prolonged contact periods within aquifers. According to WHO and Ethiopian standards the permissible range of Fluoride in drinking water should be 1.5mg/l.

2.7.4 Bacteriological Aspects of Drinking Water Quality

The microbial quality of water is determined by the presence of bacteria indicative of faecal (sewage) contamination, namely, total coliforms and faecal coliforms such as *Escherichia coli*. Coliforms occur naturally in soil and in the gut of humans and animals. Thus, their presence in water may indicate contamination. *E. coli* and certain species of *Enterobacter aerogenes* are present only in the gut of humans and animals. Their presence therefore indicates definite faecal pollution. The presence of coliform bacteria in well water may be as a result of surface water infiltration or seepage from a septic system (Obiri-Danso *et al* 2008).

Total coliforms are a group of bacteria commonly found in the environment, for example in soil or vegetation, as well as the intestines of mammals, including humans.

E. coli is the only member of the total coliform group of bacteria that is found only in the intestines of mammals, including humans. The presence of *E. coli* in water indicates recent faecal contamination and may indicate the possible presence of disease-causing Pathogens, such as bacteria, viruses, and parasites. Although most strains of *E. coli* bacteria are harmless, certain strains, such as *E. coli O157:H7* may cause illness, such as hemorrhagic diarrhea and hemolytic uremic syndrome (HUS) which causes kidney failure, especially in young children and elderly persons (Karch *et al*, 2005). Total coliforms and *E. coli* are used as indicators to measure the degree of pollution and sanitary quality of well water, because testing for all known pathogens is a complicated and expensive process.

The main source of pathogens in drinking water is through recent contamination from human and animal wastes, from

- Improperly treated septic sewage discharges
- Leaching of animal manure
- Storm water run-off
- Domestic animals or wildlife

2.7.5. Concept of Sanitary Survey

The analysis of water quality parameters alone cannot provide a complete picture of the water quality status of a community and its water supply systems. Periodic quality testing is only a snapshot: it provides limited information on the source of contamination and it can miss important seasonal quality fluctuations. Remediation of actual and potential water quality problems is only possible if information is available on the sources and pathways of contaminants, and this information can only be provided by sanitary survey (UNICEF, 2008).

A sanitary Survey is an on-site appraisal by trained people of actual and potential contamination hazards and pathways in and around water supply systems. Hazards are contamination sources that may be a risk to water systems, such as latrines too close to shallow point sources or stagnant surface water. Pathways are routes through which contamination may occur, such as leaking pipes or cracked well aprons. Hazards and pathways can be indirect or intermittent, such as a broken gate that allows animals into well enclosures or erosion that uncovers buried pipelines. Sanitary survey focuses on microbiological contamination sources. However, in some cases survey can identify chemical hazards from local industries or agricultural activity such as intensive fertilization near a surface water source intake or effluents from a tannery near a point source (UNICEF, 2008).

2.7.6. Common Behaviors, Beliefs, and Understanding

Most behaviors related to water collection, transportation and storage of community were the following common practices that have been observed elsewhere in the worldwide (Trevett, et al. 2004; Clasen and Bastable 2003; Jensen, et al. 2002):

- Water collected in open top buckets or jerry cans
- Buckets cleaned before use by swirling water and rubbing with a hand

- Hand-water contact is common in transit between source and household storage
- Water stored in clay pots with loose lids
- Water scooped out of clay pots with communal cup
- Hand washing not observed
- Storage containers are kept in an area that may be shared with animals

While most behaviors related to water are universal, the basis for these behaviors may be derived from different nuances in culture, beliefs and understanding.

2.8 Regulation of Drinking water quality limitations

Drinking water well defined as having adequate quality in relations to its physical, chemical, bacteriological parameters so that it can be safely used for drinking and cooking (Addisie, 2012). WHO describes drinking water to be safe if and only no any significant health risks during its lifespan of the schemes and when it is consumed. This research thesis is emphasis on water quality for drinking purpose only.

2.8.1 Institutional Assessment and Analysis about water supply schemes

Institutional assessment of water supply schemes will help to identify poor operation and maintenance situation of relevant functions like defective design, ineffective supervision, and inappropriate latrine design, insufficient training, lack of inter-sector co-ordination resulting in capacity gaps and absence of clarify of roles, which consequently the water supply components fail to operate at optimum efficiency (WHO,2006).

2.8.2 Bacteriological limits of Drinking water Quality

Totally coliform group could be primary indicator bacteria for the presence of disease causing organisms in drinking water. It is a primary indicator of suitability of water for consumption. If large number of coliforms could be found in water, there is high probability that other pathogenic bacteria or organisms exist. The WHO and Ethiopian drinking water guidelines require Zero presence of total coliform in public drinking water supplies. The disease caused by water related micro-organisms is divided into four main classes;

- Water-borne diseases: it is caused by water that contaminated by human, animal or chemical wastes. Examples include cholera, typhoid, meningitis, dysentery, hepatitis and diarrhea. A host of bacterial, viral, causes diarrhea and parasitic organisms most of which can be spread by contaminated water (WHO, 2006). Poor nutrition resulting from frequent attacks of diarrhea is the primary cause for stunted growth for millions of children in the developing world (Addisie, 2012)
- Water-related vector diseases: diseases that transmitted by vectors, such as mosquitoes that breed or live near water. Examples include malaria, yellow fever, dengue fever and filarial. Malaria causes over 1 million deaths a year alone (WHO, 2006). Stagnant and poorly managed waters provide the breeding grounds for malaria-carrying mosquitoes.
- Water-based diseases: Parasitic aquatic organisms referred to helminthes cause that and to be transmitted via skin penetration or contact. Examples include Guinea worm disease, filarial, paragonimia, clonorchiasis and schistosomiasis.
- Water-Washed diseases: These diseases flourish in conditions where freshwater is scarce and sanitation is poor. Examples include trachoma and tuberculosis.

2.8.3 Physicochemical Quality of Drinking Water

Amount of chemical contaminants have been to cause adverse health effects in humans because of prolonged exposure through drinking water. These include, both organic and inorganic chemicals including some pesticides. Some of them are toxic to humans or affect the aesthetic quality of water. In this regard, the WHO has put forward guideline values that set limits for many of the contaminants in drinking water. Ethiopia has also ready its own drinking water quality specification in line with the international norms and values. The Quality and Standards Authority of Ethiopia have stipulated legally binding drinking water quality specifications (i.e. ES 261:2001) in 2001. The Ethiopian standard ES 261:2001 set limits for not only the physiochemical parameters but also for Microbiological and radiological parameters (Girma, et al., 2011).

2.8.3.1 Physical Requirements

The drinking water shall be fairly clear (i.e., of low turbidity and color) and contain no compounds that cause offensive taste and odour and free of substances and organisms that causes corrosion or encrustation of water supply system Ministry Water Resource (MOWR,2002) as presented in table 2-2.

Table 2-2: Physical Characteristics of Drinking Water Quality

Characteristics	Maximum Permissible level(MPL)	Test Method
Odor	Unobjectionable	ES605
Taste	Unobjectionable	
Turbidity (NTU)	5	ES ISO 7027
Color (TCU)	15	ES ISO 7887

2.8.3.2 Chemical Requirements

Several of the inorganic elements for which maximum permissible levels has been settled are recognized to be essentials elements in human nutrition. No attempt has been made here to define a minimum desirable concentration of such substance in the drinking water as prescribed in the Table 2-3 below.

Table 2-3:- Characteristics that affect the Deliciousness of Drinking Water

Substances or characteristics	Maximum permissible level	Test method
Total hardness (as $caco_3$) mg/l	300	ES 607
Total dissolved solids mg/l	1000	ES 609
Total iron (as Fe) mg/l	0.3	ES ISO 6332
Manganese (as Mn) mg/l	0.5	ES ISO 6333
Ammonia (NH_3+NH_4^+) mg/l	1.5	ES ISO 7150-2
Residual free chlorine mg/l	0.5	ES ISO 7393
Anionic surfactants mg/l	1	ES ISO 7875-1
Magnesium (as Mg) mg/l	50	ES ISO 7980
Calcium (as Ca) mg/l	75	ES ISO 7980
Copper (as Cu) mg/l	2	ES ISO 8288
Sulfate (as So_4) mg/l	250	ES ISO 9280
Chloride (as Cl) mg/l	250	ES ISO 9297
Total alkalinity (as $Caco_3$)	200	ES ISO 9963-1
Sodium (as $Caco_3$) mg/l	200	ES ISO 9964-1
Potassium (as K) ,mg/l	1.5	ES ISO 9964-2
PH value ,units	6.5 to 8.5	ES ISO 10523

Sources: National Drinking Water Quality monitoring and surveillance strategies, 2011, Addis Ababa

2.8.4 Bacteriological Analysis of Drinking Water Quality

Drinking water practitioners are concerned with water supply and water purification through a treatment process. In treating water, the primary concern, of course, is producing potable water that is safe to drink (free of pathogens) and has no accompanying unpleasant characteristics, such as a foul taste or odor. To achieve this, the drinking water practitioner must possess a wide range of knowledge. In short, to correctly examine raw water for pathogenic microorganisms and to determine the type of intervention necessary to ensure that the quality of the product potable water meets regulatory standards.

The most serious public health risk associated with drinking water supplies is microbial contamination. Pathogens, bacteria, virus and parasites, then cause a wide range of health problems when consumed in drinking water, but the primary concern is infectious diarrhea diseases transmitted by faecal-oral route. It is unpractical to analyze water every individual pathogen, some of which can cause disease at very low doses. As an alternative, since most diarrheas causing pathogens are aerobic and facultative anaerobic non spore forming bacteria that ferment lactose at 35 to 37$^{\mathbf{0}}$C with the production of acid and gas within 24-48 hours (WHO, 1985; Hurst *et al.*, 2002).

Coliforms that come from faecal matter can tolerate higher temperature than most environmental coliforms, so those that ferment lactose and produce gas as 44^{o}C are called thermo tolerant coliforms. The most specific indicator of faecal contamination is Escherichia coli (E.coli), which unlike some faecal coliforms never multiplies in the aquatic environment (UNICEF, 2008).

When evaluating faecal contamination, it is suggested to measure turbidity along with E.Coli (or faecal coliforms), since pathogens can adsorb onto suspended particles, and to some extent be shielded from disinfection. When water has been disinfected, it is also important to measure chlorine residual and PH. These four parameters (E.coli/faecal coliforms, turbidity, disinfectant residual chlorine and PH) are considered the minimum set of “essential parameters” required to assess microbiological quality of drinking water (WHO, 2004). Therefore, bacteriological analysis mainly includes estimation of faecal coliforms and total coliforms.

2.8.4.1 Total Coliforms

The coliform organism was better referred to as total coliforms to avoid confusion with others in the group, is not an index of faecal pollution or of health risk, but can provide basic information on source water quality. Total coliforms have been long utilized as a microbial measure of drinking water quality, largely because they are easy to detect and enumerate in water.

Traditionally they have been defined by reference to the method used for the group's enumeration and hence there have been many variations dependent on the method of culture. In general, definitions have been based around the following characteristics; gram-negative, on-spore forming, road shaped bacteria capable of growing the presence of bile salts or other surface active agents with similar growth inhibiting properties ,oxidize-negative, fermenting lactose at 35-37^{o}C with the production of acid, gas, and aldehyde with 24-48 hours according to Assessing Microbial Safety of Drinking Water (WHO,2002).

2.8.4.2 Faecal Coliforms

Thermo-tolerant 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 (Garcia-Armisen and Servais, 2006; Howarth, 1996). The genus Escherichia comprise to a lesser extent, species of klebsiella, Entero-bacter, and citrobacter. Of these organisms, only E.coli was considered to be specifically of faecal origin, being always present in the faeces of humans, other mammals, and birds in large numbers and rarely, if ever, found in water or soil in temperature climates that not been subject to faecal pollution (Fujioka et al.,1999). The danger of coliforms presence can rest on the health or sensitivity of the user. The risk of E.Coli presence, rather than WHO Guideline is zero count per 100ml that may be of only low or intermediate risk. The drinking water shall be free from any diseases causing pathogenic organisms and concentration of toxic chemical compounds that have adverse effect on human health. According to (Michael H, 2006) the risk classification of coliforms or E.coli as prescribed in Table 2-4)

Table 2-4:- Water Quality Counts 100mL and associated risks for rural supplies schemes (Sources: Michael H.2006).

No	Water quality counts per 100ml and the associated risk counts per 100ml	Risk category
1	0	In conformity with WHO Guidelines
2	1-10	Low
3	11-100	Intermediate
4	101-1000	High risk
5	> 1000	Very high risk

Table 2-5:- Maximum Permissible Bacteriological Level.

Organism	Maximum permissible level	Test method
Total viable organisms, colonies per ml	Must not detectable	ES ISO 4833
Fecal streptococci per 100ml	Must not detectable	ES ISO7899-1 ES ISO7899-2
Coliform organisms, number per 100ml	Must not detectable	ES ISO 9308-1
E.coli ,number per 100ml	Must not detectable	ES ISO 9308-1 ES ISO 9308-2

Sources: National Drinking Water Quality monitoring and surveillance strategies may, 2011 Addis Ababa

Note: Table 2-5 shows that, any treated water shall not contain faecal and coliform organisms when tested with the corresponding test methods and any treated water shall not contain any faecal streptococci when tested according to ES ISO-7899-1 or ES ISO-7899-2.

2.9 Quality Control

Procedures in microbiological sampling in the field data collection will ensure that the data generated are reliable:

- Proper cleaning, pumping for 3-5minutes and burning the outlet of shallow and Deep well
- Supervision, Equipment review, proper handling and transportation,
- Field blank sample analysis (reference) to check contamination

CHAPTER-THREE

3. MATERIALS AND METHODS

3.1 Description of The study area

Ada'a woreda lies between longitudes 38º51' to 39º04' East and latitudes 8º46' to 8º59' North covering a land area of 1750 km^2 and far from 47km on east of Addis Ababa (Figure 3-1). Most of the land (90%) is plain highland ranging between 1600 to 2000 meters above sea level. The woreda is characterized by sub-tropical climate and receives 860 mm rainfall/annul.

In general, the main rainy season occurs between mid-June and September, followed by a dry season that might be intercepted by the short rainy season in February and March. Mean annual temperature ranges from about 8–28ºC. Black clay Vertisol is the dominant soil type, with good soil fertility but with water logging problems in those areas where the land slope is below 8%.

Ada'a is one of the woredas found in the East Shewa Zone of Oromia Region and has 22 in the district (18 rural) and 4 were Urban kebele. It is part of the former Ada'a-Chukala woreda that was divided between Ada'a and Liben woredas. Part of the East Shewa Zone located in the Great Rift Valley and upper part of Awash River Basin; and it is bordered on the south by Dugda Bora, on the west By the West Shewa Zone, on the northwest by Akaki, on the northeast by Gimbichu, and on the East by Lome. Demographically, the 2007 national census reported a total population of the woreda was 130,321, of whom 67,869 were men and 62,452 were women. (102,874-Rural area and 27,447-Urban area of the woreda).

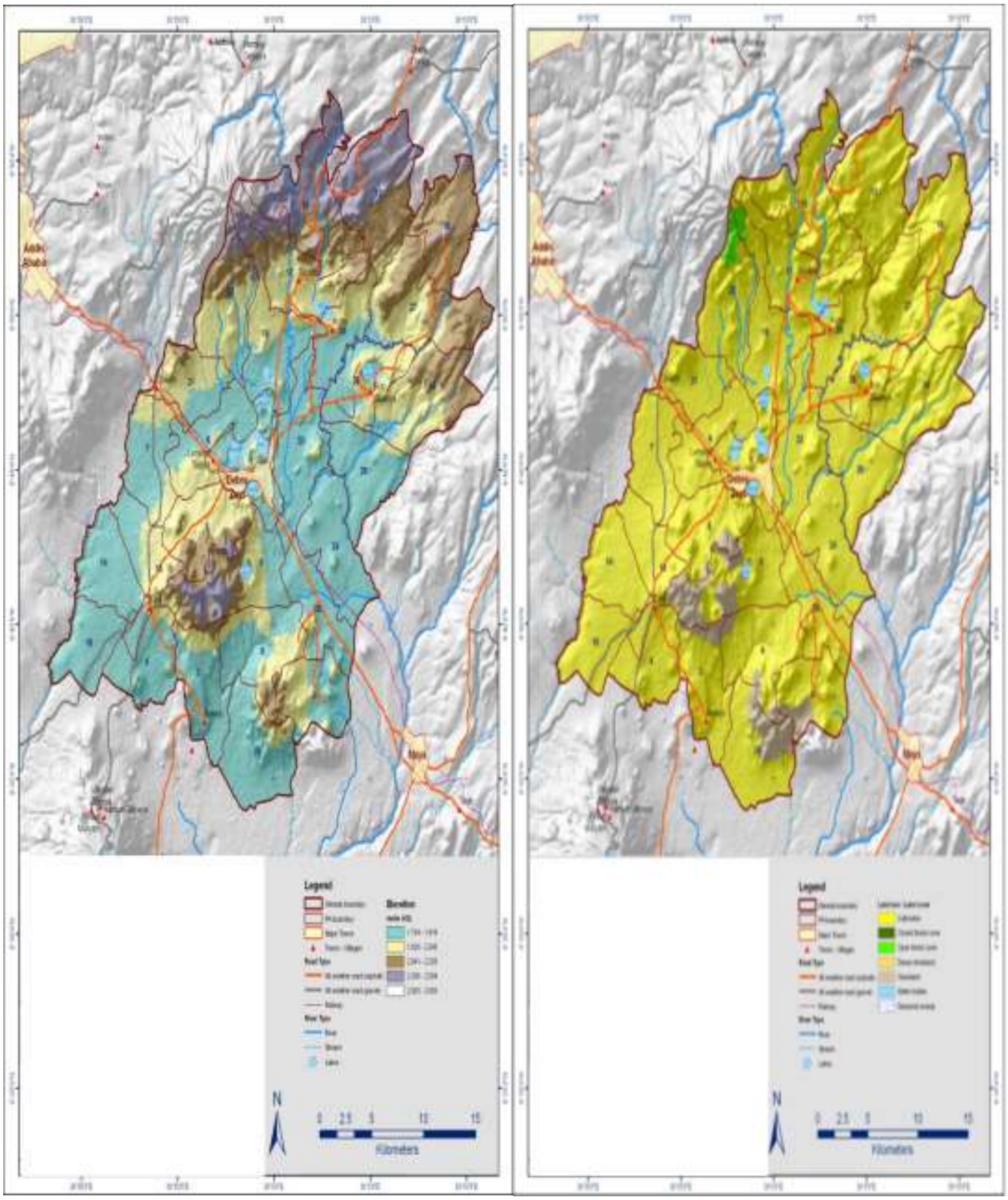

Figure 3.1 Topographical and Land cover Map of Ada’a Woreda Respectively.

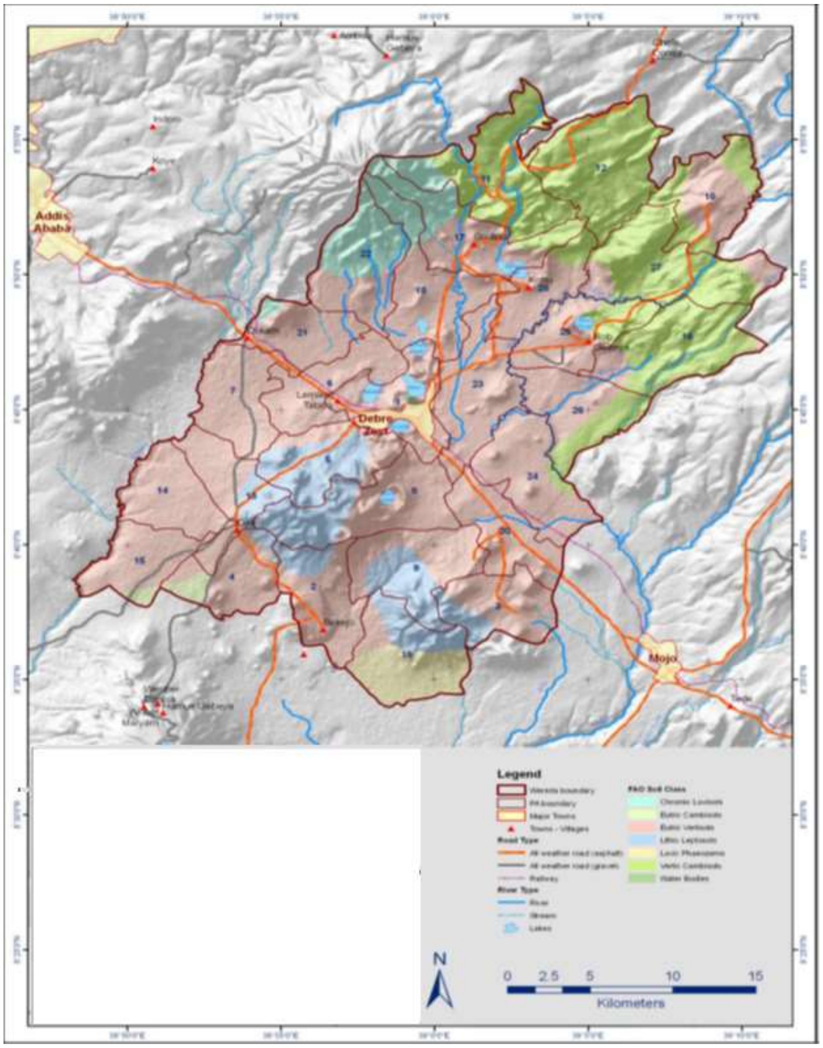

Figure 3.2 Soil Map of Ada'a Woreda.

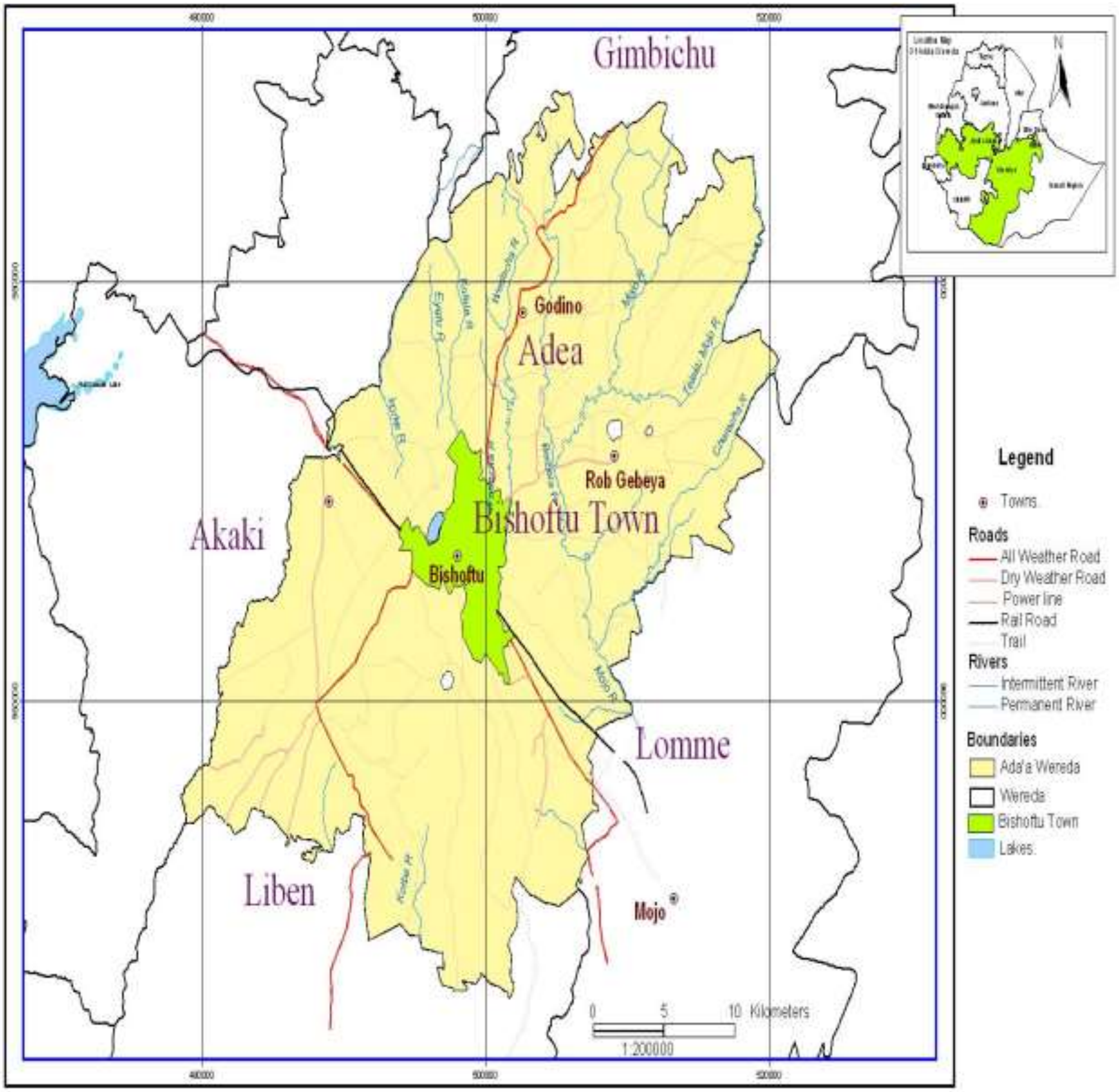

Figure 3- 3 Location of Ada'a Woreda and Other Woreda Boundaries.

3.2 Data Collection Methods and Household Selection

Various methods of data collection are used during the survey period from Mid-February to 1st-April, 2016. Samples were collected from the woreda three times with one week intervals from 8:00 to 12:00AM. The selection of the area was grouped into two major classes or regions of rural and urban areas. A stratified random sampling technique was adopted to select the sample needed for the study. As a first stage 9 water points were selected out of 36 (24-Shallow well and

12-Deep well) total improved water supply from 4**rural area (**Udde,Dirre-shoki,Wajitu and Katella) and **1-urban area (**Godino**)**.These 9 water points include**,** six shallow well and two deep well from rural area ,and one deep well from urban area. The selection of water points were limited to nine points due to sparsely population of the kebeles, lack of infrastructure (Logistic), finance, time and enough laboratory technician problems.

Five kebeles were selected for study depending on high number population benefiting from the sources, and Woreda recommendation.

In the second stage, households were selected for Microbiological test for each water schemes points. The sampling methodology determined by (CochranWG, 1977) was used to select households for each source. The sample size determined the expected rate of occurrence as not less than 90% at 95% confidence level.

$$\mathbf{n(i)} = \frac{\mathbf{N*Z^2*p*Q}}{\mathbf{w^{2(N-1)}+Z^2*P*Q}}$$

$$n = \frac{5246*(3.8416)*0.5*0.5}{0.0025(5245)+3.8416*0.5*0.5} = \mathbf{360}$$

Where,

n= $sample\ size$ of Households

N= $Total\ number\ of\ households\ Heads$

Z= $Confidence\ level\ (\ at 95\%\ level\ Z = 1.96\ )$

P= $proportion$ 50% (0.5, $this\ maximizes\ the\ sample\ size$)

W= $error\ limits\ of$ 5% (0.05)

Q= 1-P

Note that from the above calculation I was expected to take about 40 households for each water point. However, because of financial problems, lack of infrastructure (logistic), time, sparsely population, and enough laboratory technicians who assist me during the data collection. In addition, most of the households have the same life status. For example, similarity of their Water Container (Jericans), duration water stays in house, they do not treat water at household, and they use similar cups to drink water. The only difference between the households might be water handling, personal hygiene and Sanitation. Therefore, because of the above reasons and the recommendation of previous studies mentioned below, in this study I decided to use 3 households at 13 household's interval.

- One sample should be taken from the source of water and then samples taken from 3-5 households randomly selected within the community, but not too close to the source. Make sure to confirm that the water in the household is collected from the source you have just tested (WHO, and UNICEF, October, 2012) for assessment of Drinking Water-Quality.
- Mengestayhu Birhanu (2007) assessed the Physico-chemical and microbiological quality of drinking water at sources and house hold in selected communities of Akaki-kaliti Sub city, Addis Ababa City Administration. From total of 10,053 Household customers, 35 Household Containers were selected as a sample size for Biological test.
- Rural Assessing Drinking water Quality at source and point-of-use: A case study of Koila Bamana, Mali (House hold selection for Microbiological test, household's getting water from each of those sources randomly five (5) Households selected for each water points),Michigan University (Mathew. D.seib, 2011)
- Center for Affordable Water and Sanitation Technology (CAWST) for water Drinking Quality test recommended 5%-10% of sample size if the sample size is greater than 100 Households (October,2013)

Remark: - I decided to use (WHO and UNICEF, October, 2012 Manual) listed above, for rural drinking water quality of Microbiological household test select Minimum range of 3HHs with an interval of 13HHs sample size in each kebele randomly selected from each water point. These were also used for Physiochemical test. Table 3-1 deployed the sample size determination of selected household.

Table 3-1: Sample Size Determination of Selected Households Biological water quality test.

Kebeles	Rural & Urban Ada'a Word-Sample size determination			
	Type of water points	No of Households Heads in each kebele	No of Sample size households in each kebele	Sample Households selected for Bacteriological test from each water points.
Udde	3-Shallow-Well	719	120	9
Dirre Shoki	1-Deep-Well	847	40	3
Wajitu	1-Deep-Well	1511	40	3
Katella	3-Shallow-Well	1108	120	9
Godino	1-Deep Well	1061	40	3
5-kebele	**9-water points**	**5246**	**360**	**27 HHs**

3.5 Water Quality parameters and instruments

3.5.1 Physico-chemical test Methods

PH, Turbidity, Temperature, Total Dissolved Solids and Electrical Conductivity Measurements, were properly washed and rinsed appropriate sampling bottles. The pH meter wagWT-3020 and Temperature, Electrical Conductivity meter wagWT-3020 and TDS having electrodes were used immediately on spot to measure pH, Temperature, Electrical Conductivity (EC), and Total Dissolved Solids (TDS), respectively and also Turbidity. These electrodes were immersed in the samples and then the measured parameters were displayed on the LCD screen of the instruments.

The physiochemical tests were performed using DR/2800 spectrophotometer. A powder reagent chemical was dissolved in 10ml of water sample in a cylindrical sample cell and allowed to react. Color develops with intensity proportional to the amount of the target element was measured. Each element has a unique maximum absorption wavelength at which the spectrophotometer was adjusted. Light was allowed to pass through the sample cell so that light is absorbed at the required wavelength. The results were displayed on the LCD screen in mg/l in proportion to the amount of light absorbed at that particular wavelength.

3.5.2. Bacteriological **test Methods**

The bacteriological testes were undertaken within 6 hours after collection to avoid the growth or death of microorganisms in the sample (WHO, 2006). Water samples were collected in pre-sterilized plastic bags and were filtered on the spot using membrane filters with a spore size of 45µm. The filters were incubated in an ELE Paqualab 25 field incubator, in sterilized aluminum Petridis with a bacterial medium of m-Coli Blue24 on absorbent pad, at 37^{o}C and 44^{o}C for total coli forms and E-coli/fecal coli forms, respectively. No variation difference of microorganisms in all water points, because samples were collected once in dry season. The filters were examined for 24 hours to assess bacterial growth. The results were compared with WHO guidelines maximum permissible limit value.

3.6 Sanitary Inspection Methods

At each site a sanitary inspection was made during the sampling period. The sanitary inspections involved the use of unstructured questionnaire based on the individual state of the wells. Sanitary inspections are a form of risk assessment and are designed to evaluate the water supply to see whether there is likelihood of contamination occurring. Sanitary inspection data often allows conclusions to drawn about the ongoing status of the supply and the potential risks of contamination in the long-term. Sanitary inspection data will also identifies what interventions are required. It is a tool that can be used by community to be able to monitor their water supply.

In sanitary inspection, young girls and women's are structurally the respondent of inspection at household survey, to identify that may lead to contamination of water supply. It also provides a system that allows risk to be quantified, which is useful when limited resources mean that priorities must be set for, remedial and preventions. Sanitary Inspection at source and Household Water Quality form inspection presented Appendix-D-A and D-B, respectively (Howard, A.G, 2002).

3.7 Interviews

At each well, unstructured questionnaire fifteen to twenty regular young girls and boys users of the well waters were interviewed. Interviewees were asked about the uses they put the water fetched from the wells to. They were asked about their perception on the quality of the water, as well as whether they had experienced any illness they could link to the use of the water in their various activities and most of the users response is no.

3.8 Method of data analysis

The result of the experimental data was used to analyzing by using application of software such as MS EXCEL Version2010 and SPSS. Finally the analysis results were compared with WHO guideline values and Ethiopia Guidelines.

3.9 Location of Sampling Points.

A total of 9 wells were selected for sampling in five kebele of the study. Three shallow wells were selected from Udde kebele (i.e. SW1, SW2 and SW3), three Deep wells from (Godino, Wajitu and Dire shoki (i.e., DW4, DW5 and DW6 Respectively) and three shallow wells from Katella kebele (i.e.SW7, SW8 and SW9). These points should include the samples representative conditions of woreda water Quality may possible point contamination at source and point of use (Household). The location of sample points selected in this study area is shown in Figure 3-4.

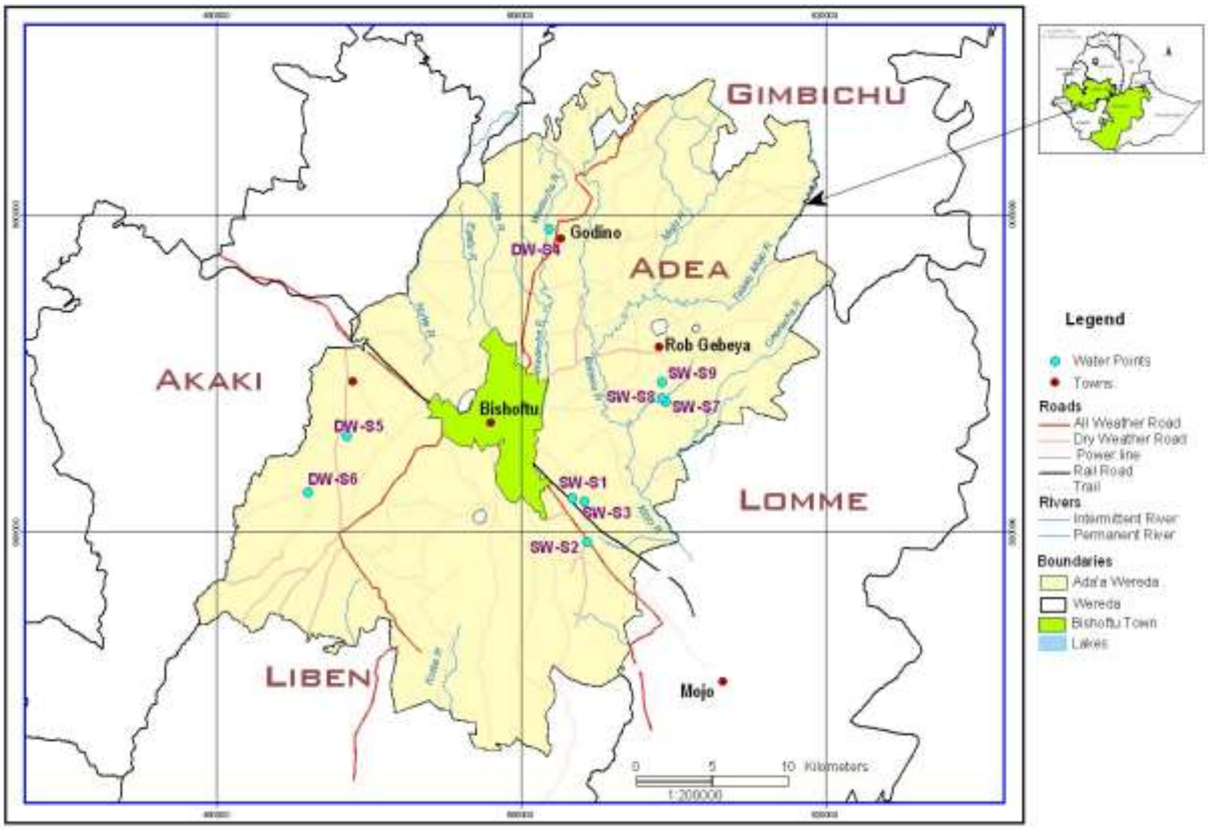

Figure 3-4:- Location of Sampling Points

CHAPTER-FOUR

4. RESULTS AND DISCUSSION

4.1 Water Quality Analysis

4.1.1. Physicochemical analysis

The physico-chemical parameters directly related to the safety of the drinking water to human consumption. The physico-chemical water quality parameters provide important information about the health of a water body. These parameters are used to find out the quality of water for drinking purpose. During field survey the following physico-chemical parameters were also investigated using laboratorial experiment.

The physical and chemical water quality parameters analyzed in the laboratory were PH, Turbidity , Temperature (degree),Electrical Conductivity (EC),Total Dissolved solids (TDS) , Total hardness (TH)) Calcium(Ca^{+2}),Magnesium (Mg^{+2}), Nitrate (No3), phosphate and fluoride (WHO,2004).

4.1.1.1 Turbidity

Turbidity is the unity of measurement for the qualifying the degree to which light traveling through a water column is scattered by the suspended organic (including algae) and inorganic particles. The scattering of light increase as the presence of suspended load increases and turbidity is commonly measured in Nephelometric Turbidity Units (TNU) and determined onsite by using Wag –International WT3020 turbid meter.

According to the WHO (2012) standard for turbidity, maximum allowable permissible limit value must always be low, preferably lower than 1NTU. It is recommended that for water to be disinfected, the turbidity should be reliably less than 5NTU and preferably have a median value of less than 1NTU. Figure 4-1 shows that the turbidity of study area is range from 0.47-2.54NTU, which fit the WHO Maximum Permissible limit and three samples are unfit for minimum preferable less than 1NTU (which are 1NTU, 1.25NTU &2.54 NTU, udde, Katella &Dirre shoki or SW-S3,SW-S9 &DW-S6) respectively. Similarly study conducted in Bona district,simada Zone, southern Ethiopia, out of 6 improved well 1well reported 11NTU,and others resulted <5NTU (Berhanu and Hailu,2015). (Although the findings of this particular study showed that the turbidity levels of all source water samples were compliant with both WHO and National Guide Line of less than 5NTU (WHO, 1997; NGL, 2002,Desta et,al,2009),

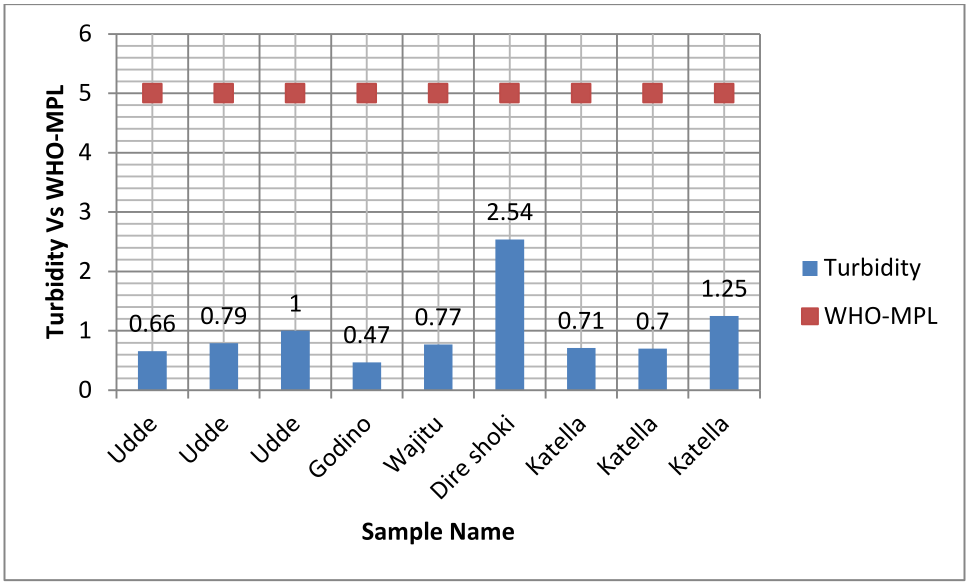

Figure 4-1 Turbidity of study area Compare with WHO Maximum Permissible Limit.

4.1.1.2 Temperature (°C)

Temperature measurements are very useful in understanding the trend of physical, chemical and biological activities which are enhanced/ retarded by the variation of temperature. In the present study the water temperature range of Ada'a Woreda water scheme was recorded between 22.9 (Godino kebele) and 28.7°C (Wajitu kebele). It is beyond recommended unit of WHO <15^{0}C (2004c), this due to the climatic of Rift valley area making the temperature to be high and It may enhance the growth of bacteria and increase water test . Nationally it has no guideline value (since it is not health-based problem, non-Objectionable, ES, 2001).

4.1.1.3 Electrical Conductivity (EC=µS/Cm)

Pure water is not a good conductor of electric current rather a good insulator. Increase in ions concentration enhances the electrical conductivity of water. Generally, the amount of dissolved solids in water determines the electrical conductivity. Electrical conductivity (EC) is actually measures the ionic process of a solution that enables it to transmit current.

According to WHO standards EC value should not exceeded 400-1,200 µS/cm. In study areas, EC value in Udde kebele was 672-712 µS/cm, 620 µS/cm, 426 µS/cm and 524 µS/cm in Godino, Wajitu and Dirre shoki respectively and Katella 585 µS/cm-600 µS/cm. These results clearly indicate that water in study areas was considerably ionized and has the higher level of ionic concentration activity due to excessive dissolve solids. Thus, it is a fine conductor of electric current.

4.1.1.4 Total Dissolved solids (TDS= ppm)

In drinking water, total dissolved solids are primarily made up of inorganic salts with small concentrations of organic matter. Contributory ions are mainly carbonate, bicarbonate, chloride, sulphate, nitrate, potassium, calcium and magnesium. Major contribution to total dissolved solids in water is due to natural contact with rocks and soil. Minor contributions to TDS are from pollution including urban runoff. In some cases, however, considerable impact occurs from snow and ice control on roads in winter. A total dissolved solid of the sample study area was between 215-357 ppm. The health risks are not significant as the value of TDS is much less than 1,000PPM, which is the WHO standard maximum permissible limit (Mohammed, 2013).

4.1.1.5 PH of potable water

PH is an index of the amount of hydrogen in (H^+) that are in a substance. The PH scale measured with respect to neutral substances as reference. Substances with a PH higher than 7.0 (7.1-14.0) are considered alkaline or basic. Substance with a PH less than 7.0(0-6.9) are considered as acidic. According to the WHO, the minimum and maximum allowable PH ranges from 6.5 to 8.5 for potable water. There is no health risks related to consuming slightly acidic or basic water. After all, we can eat lemons, drink soft drinks, and eat eggs. Figure 4-2 shows the PH values of water in the study area. The PH values study area ranges from 7.40 to 8.45 which is unfit for the minimum allowable PH Value of WHO and fit for maximum Value of WHO 6.5-8.5, high range of PH Value recoded in Dirre Shoki kebele and Minimum in the udde Kebele. Similar study conducted in wondogenet district, southern Ethiopia, the PH value reported 6.6 to 7.8 (Haylamicheal and Moges ,et al,2012) .In general, the result shows that the water supply scheme of Ada'a woreda is slightly basic and better taste.

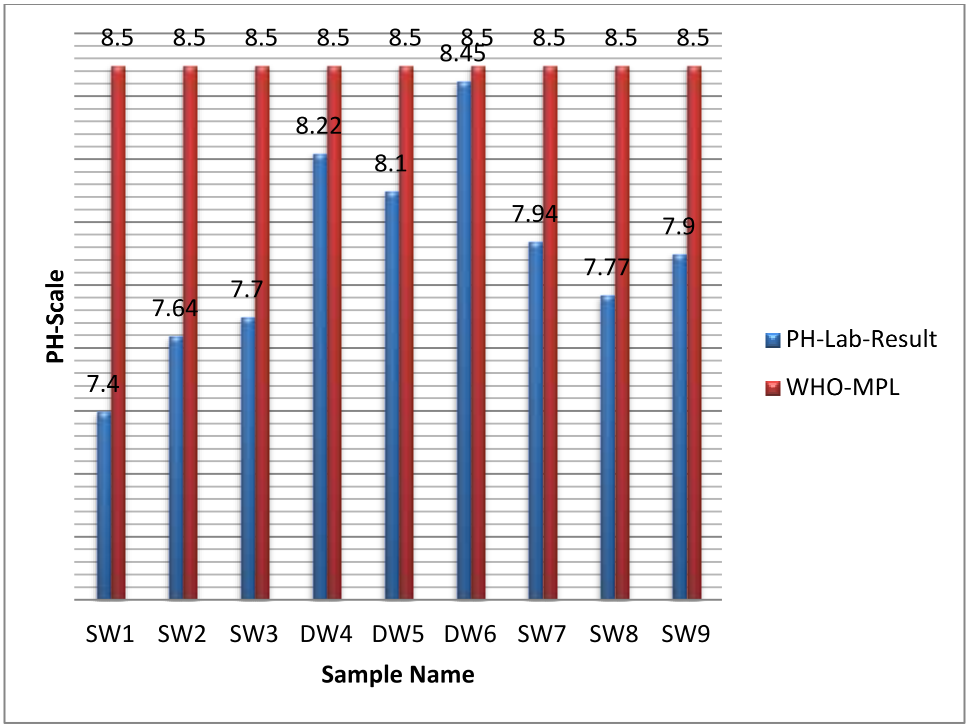

Figure 4-2 PH Values compare with the WHO Maximum Permissible Limit.

4.1.1.6 Total Hardness

Hard water is characterized with high mineral contents that are usually not harmful for humans. It is often measured as calcium carbonate (CaCO3) because it consist mainly calcium and carbonates the most dissolved ions in hard water. According to World Health Organization (WHO) hardness of water should be 500 mg/l. Hardness of study area is range from 8.36-20.5 mg/l which is categorized as soft water according to discussed in literature review and similar study was conducted in Temeke district of Dar es salaam, total hardness reported from 30mg/L to 710mg/L (Z.A.Napacho and S.V.Manyele,2010) .Therefore, according to the literature of study area improved water supply of Ada'a district is not harmful for consumer according to the WHO standard. Appendix-c shows result hardness.

4.1.1.7. Nitrate (NO3-)

Nitrate one of the most important diseases causing parameters of water quality particularly blue baby syndrome in infants. The sources of nitrate are nitrogen cycle, industrial waste, nitrogenous fertilizers etc. Groundwater contains nitrate due to leaching of nitrate with the percolating water and can also be contaminated by sewage and other wastes rich in nitrates. The nitrate content in the study area varied in the range 0.6 mg/L to 1.3 mg/L and found within the prescribed limit of WHO Maximum permissible limit of nitrate in drinking water is 5 mg/l (Murhekar Golpalkrushna H., June, 2011) Similar study reported in wondogenet district of nitrate range from 0.9 to 12.7 mg/l (Haylamicheal and moges,2012).Figure 4-3:- Shows that the Nitrate range of study area was 0.06-1.3mg/which Indicates pollution free, good water quality wise and suitable for drinking purpose.

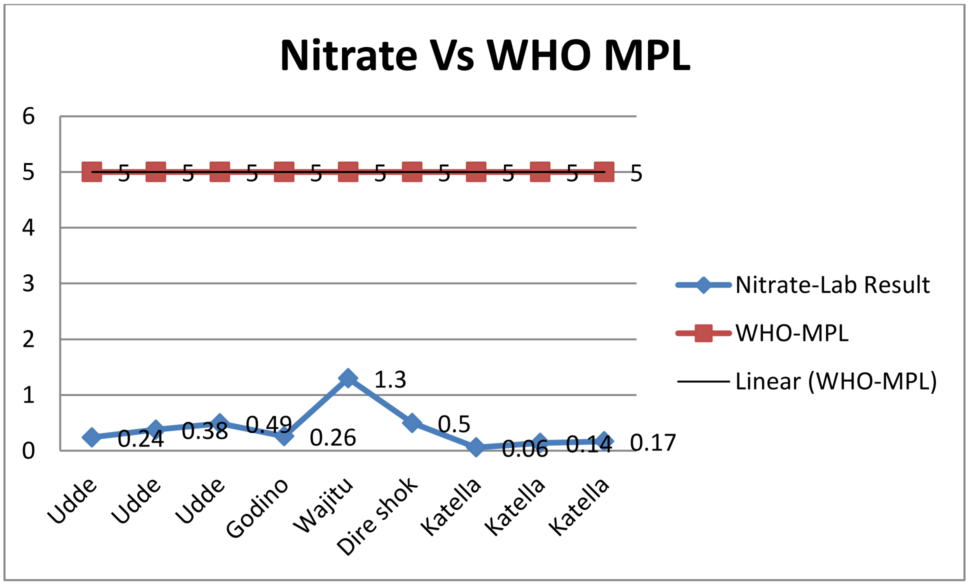

Figure 4-3 Nitrate Lab-Result Compare With WHO Maximum Permissible Limit.

4.1.1.8 Fluoride

Ingestion of excess fluoride is associated with dental and skeletal fluorosis that may cause severe deformation and disability in susceptible individuals, a situation that occurs in many countries world-wide, particularly in parts of India, China, Central Africa and South America, but high concentrations can be encountered locally in most parts of the world. If no data on the presence of fluoride in water are available it should always be suspected if people have mottled teeth or skeletal deformities. However, a lack of fluoride is also associated with dental caries and therefore in some countries fluoride is added to drinking-water to improve dental health. Further information can be found in Farwell *et al*. (2006). Although fluoride may be released by industrial pollution, the majority of fluoride found in drinking-water supplies at levels of health concern is derived from natural sources (e.g. fluoride-containing minerals). Fluoride should always be analyzed during source development, in particular for groundwater sources.

Fluoride can be determined by using a spectrophotometer or colour comparator; it can be determined by these methods in the laboratory or by use of ion-specific electrodes. For fluoride, WHO has set a health-based guideline value of 1.5 mg/l (WHO, 2011a), There are significant health effects of long-term exposure to fluoride in water. Higher amounts of fluoride between 1.5 – 4.0 mg/L can cause dental fluorosis. Very high amounts of fluoride greater than 10.0 mg/L can lead to skeletal fluorosis. This is why the WHO suggests that drinking water should not have more than 1.5 mg/L of fluoride.

In study areas, results show that the concentration of fluoride ranges from 0.95-1.13 mg/l in udde kebele (S1-S3), 0.84 mg/l, 0.79 mg/l and 1.40 mg/l Godino, Wajitu and Dirre Shoki respectively and 0.831-1.14mg/l in Katella kebele (S7-S9). Figure 4-4 shows Fluoride quantities in all kebeles were no health problem according the WHO Guide value. The Rift Valley region of Ethiopia is characterized by higher level of groundwater fluoride. For instance, Tekle-Haimanot et al. (2006) reported that out of 668 wells (deep and shallow) analyzed for fluoride level in the Rift Valley region of Ethiopia, 44.5% of the wells had values above 1.5 mg/l.

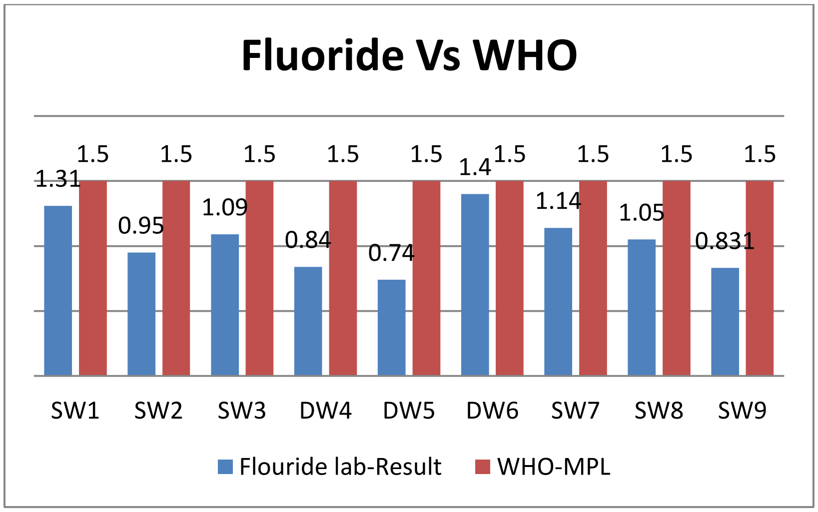

Figure 4-4 Fluoride Lab-Result compare with WHO Maximum Permissible Limit.

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4.1.1.9 Calcium (Ca+2)

Calcium is the most abundant element on the earth crust and is very important for human cell physiology and bones. About 95% calcium in human body stored in bones and teeth. The high deficiency of calcium in humans may cause rickets, poor blood clotting, bones fracture etc. and the exceeding limit of calcium produced cardiovascular diseases. According to WHO (1996) and ES ISO-7980 standards its permissible range in drinking water is 75 mg/l.

In study areas, results show that the concentration of calcium ranges from 58.10-69 mg/l in udde kebele,50.8mg/l,64.9 mg/l and 60.9 mg/l Godino, Wajitu and Dirre Shoki respectively and 64.6-96.5mg/l in kattela kebele (Figure 4-5) and other study conducted in Kumasi district of republic of Ghana, water assessment on shall well calcium reported range from 0.09 to 24.80mg/L (Nkansah, et al, 2010). Calcium quantity in kattela kebele exceeded the limit by WHO and may be harmful for local residents.

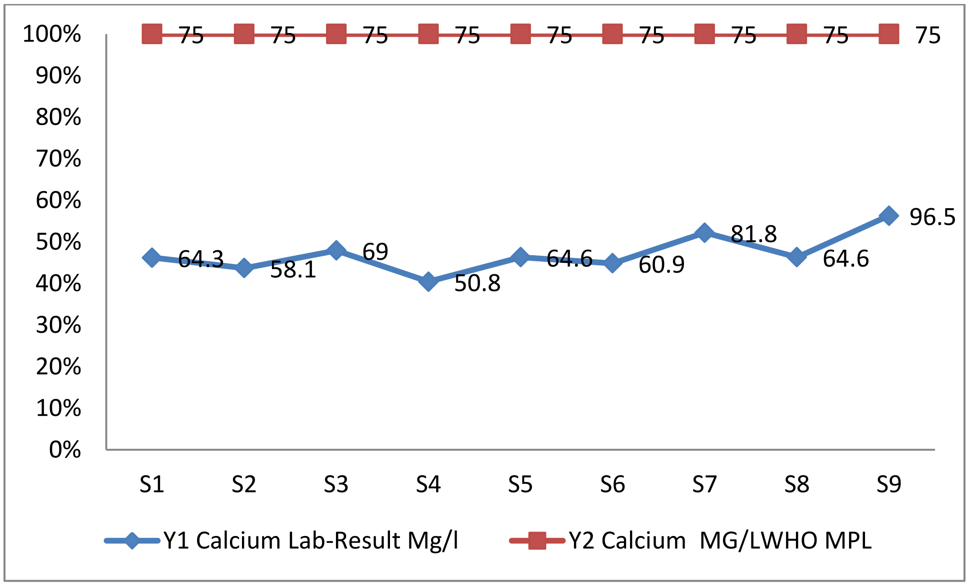

Figure 4-5 Calcium Lab-Result Compare With WHO-Maximum Permissible Limit.

4.1.1.10 Magnesium (mg+2)

Magnesium is the most abundant element on earth crust and natural constituent of water. It is an essential for proper functioning of living organisms and found in minerals like dolomite, magnetite etc. Human body contains about 25g of magnesium (60% in bones and 40% in muscles and tissues). According to ES ISO 7980 standards the maximum permissible level range of magnesium in drinking water should be 50 mg/l.

In study areas, results show that the concentration of magnesium ranges from 16.4-28.3 mg/l in udde kebele, 5.35 mg/l, 31.5 mg/l and 18.5 mg/l Godino, Wajitu and Dirre Shoki respectively and 9.23-19mg/l in kattela kebele and found within prescribed limit. Similar research in Kumasi district of Ghana magnesium reported range from 0.01 to 11.80mg/L (Nkansah .et.al, 2010)

4.1.1.11 phosphate (p043-)

Phosphorous in water occurs mainly in orthophosphate, condensed phosphate and organically bound phosphate. The microbial detraction of organic matter releases the phosphorous in phosphate form. The significance of phosphorous lies in its ability to cause eutrophication water in presence of other nutrients, especially nitrogen. The quality criteria of phosphorous in waters in only to check the unwanted algal growth, in the study area range phosphate is 0.14-2.61mg/l and other similar study conducted in water quality assessment shall well in Kumasi district of Ghana phosphate reported range from 0.33 mg/L to 9.30mg/L (Nkansah.et.at,2010)

Table 4-1:- Stastical Summary Results of Chemical Parameters.

		Fluoride	Nitrate	Magnesium	Calcium	Hardness	Phosphate
WHO Guideline Value		1.5 mg/l	5mg/l	50 mg/l	75 mg/l	100-200mg/l	
N	Valid	9	9	9	9	9	9
	Missing	0	0	0	0	0	0
Mean		1.0244	.3933	18.5533	67.8444	14.5733	1.2567
Std. Deviation		.19456	.37239	8.43786	13.62233	3.56916	.86297
Minimum		.79	.06	5.35	50.80	8.36	.41
Maximum		1.40	1.30	31.90	96.50	20.50	2.65

4.1.2 Bacteriological test analysis

An examination of the data provides a general description of patterns and trends within categories. It should be noted that all microbial results are reported as counts per plate from l00 mL water samples. All concentrations are reported as CFU/mL, as the standard CFU/100 mL concentration.

4.1.2.1 Bacterial Testing Results at Sources

Bacteriological guidelines WHO (2004) and Federal Democratic Republic of Ethiopia, Ministry of Water Resources (2002) for drinking water recommend zero total coliforms and faecal Coli Cfu /100 ml of water at source and point of use.

Testing for the presence of bacteria in source water shows no difference between shallow well and deep well at source level. But one shallow well (S-7) contained 8CFU/100ml of total coliform and 0 CFU E.Coliform/100ml,as prescribed in table 4-2

Table 4-2:- Shows Water Source Contained Total Coliform and E.Coliforms of Bacterial Result.

Name of Kebele	Sample Name	E.Coliform 100ml/CFU	Total Coliform 100ml/CFU	Michael H.,2006) Risk Category
Udde	Shallow Well-1	0 CFU	0 CFU	In conformity with WHO
	Shallow Well-2	0 CFU	0 CFU	In conformity with WHO
	Shallow Well-3	0 CFU	0 CFU	In conformity with WHO
Katella	Shallow Well-7	0 CFU	8 CFU	Low/Good (DWAF,1996)
	Shallow Well-8	0 CFU	0 CFU	In conformity with WHO
	Shallow Well-9	0 CFU	0 CFU	In conformity with WHO
Godino	Deep Well-4	0 CFU	0 CFU	In conformity with WHO
Wajitu	Deep Well-5	0 CFU	0 CFU	In conformity with WHO
Dirre-Shoki	Deep-Well-6	0 CFU	0 CFU	In conformity with WHO

Table 4-2 Result shows that no bacterial problem at source level except-source-SW-7, which have total coliform at source level because of poor construction well with a cracked apron and entry of drainage of water into the shallow well. Figure 4-6 shows the difference between well-constructed and poor constructed of same type of source (Shallow-Well). The figure proved that there is no difference in terms of technology they used whether deep well or shallow well, but it

depends their construction of the well (which proves the specific objective 1 of the thesis) and the source was found to compliant to (WHO and MOWE,2002) Microbiological water quality guideline (0Total Coliform/100ml and 0Ecoli/100ml). Similarly, underground water sources (hand dug wells) 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.

In general, my review explained that no problem of microbial contamination at source level for improved water supply in study area and fit for human consumption.

Figure 4-6:- A Poorly Constructed Shallow Well with a Cracked Apron versus Well Constructed Shallow Well

4.1.2.2 Bacterial Testing Results at Point-of use

Testing at point-of-use (household) was done to characterize the quality of water coming out of the “cup” compared to the “tap” (at the water source). Analysis at point-of-use was set up to determine: (1) water quality degradation at point of consumption (point-of-use) for both each improved water source observed, (2) To Evaluate the Bacteriological quality of drinking water supply schemes being supplied to community at source and potability of water at point of use by using total Coliform and E. Coliform.

Table 4-3 and 4-4 shows that microbial for point use of faecal coliform for shallow and deep well (16.7%, 22.2%, 38.9% &22.2%), WHO Guideline Value, Low, Intermediate and high risk respectively for shallow well and deep well (66.7%,11.1%,11.1%, &11.1%), WHO Guideline Value , Low, Intermediate and high risk respectively. This table proved that the percentage of point-of-use of samples contaminated with faecal coliforms was also lower where households generally covered their water container, separate from animal contamination and sanitation and hygiene awareness. Bacterial testing at point-of-use (households) was done to characterize water coming out of the "cup" compared to the "tap" (water source). In the study area from all assessed Households (n=27) only 3HHs and 9HHs are free from Total Coliform and Faecal Coliform respectively, the rest were Contaminated from low risk to high risk. Because of different factors such as poor washing of their container, hygiene problem, and hand contact with water, no household water treatment practices; they have not awareness of bacterial disease through water, they use similar container Jeri cans and utensil to drink water at home. This observation is supported by intervention studies, which have found that covered vessels reduce faecal and total coliform counts in stored water by 50% (Chidavaenzi et al. 1998; Mazengia et al. 2002).

Table 4-3:- (% of Samples) for total Coliform and E.Coliform in Shallow Well Water Samples at Source and Household.

Total Coliform (CFU/mL	Shallow Well (n=6) at source	Household (n=18)	**E. Coliform (CFU/mL)**	Shallow Well (n=6) at source	Household (n=18)	Michael H,2006
0	83.3% (5)	0%	0	100%	16.7% (3)	WHO G Value
1-10	16.7% (1)	27.8% (5)	1-10	-	22.2% (4)	low
11-100	-	55.5% (10)	11-100	-	38.9%(7)	Intermediate
101-1000	-	16.7% (3)	101-1000	-	22.2% (4)	High risk

Table 4-4:- (% Samples) for total Coliform and E.Coliform in Deep Well Water samples at Source and Household.

Total Coliform (CFU/mL	Deep Well (n=3) at source	Household (n=9)	**E. Coliform (CFU/mL)**	Deep Well (n=3) at source	Household (n=9)	Michael,2006
0	100% (3)	33.3% (3)	0	100% (3)	66.7% (6)	WHO G Value
1-10	-	33.3% (3)	1-10	-	11.1% (1)	low
11-100	-	22.2% (2)	11-100	-	11.1%(1)	intermediate
101-1000	-	11.1% (1)	101-1000	-	11.1% (1)	High risk

4.1.3 Sanitary Inspection Analysis at source and Household.

4.1.3.1. Sanitary inspection analysis at source.

A sanitary inspection is an on-site inspection of a water supply facility to identify actual and potential source of contamination**.** The physical structure and operation of the system and external environmental factors (such as latrine location) are evaluated. This information can be used to select appropriate remedial action to improve or protect the water supply.

Sanitary inspections should be carried out for all new and exist sources of water used for drinking and regularly monitoring. Thereafter, inspections should be carried out by a suitably trained person using a simple, clear report form**.** These forms consist of a set of questions which have “yes” or “no” answers. The questions are structured so that the “yes” answers indicate that there is risk of contamination and “no” answers indicate that the particular risk is absent. Each “yes” answer scores one point and each “no” answer scores zero point. At the end of the inspection the points are added up, and the higher the total of identified risks, the greater the risk of contamination, as prescribed in table 4-5 and 4-6

Table-4-5:- Shows Sanitary Inspection Result at Source.

Source-Facility Shallow Well or Deep Well (n=9)	Risk score
Is there a latrine within 10m Shallow Well?	0= Low (0-3)
Is there a latrine uphill of the shallow Well?	0= Low (0-3)
Are there any other sources of pollution with 10m Shallow Well? (E.g. animal breeding. Cultivation, roads, industry, etc.)	High risk = (3-5), cultivation of agriculture
Is there drainage faulty allowing ponding within 2m of Shallow Well?	0= low (0-3)
Is there drainage channel cracked, broken or need cleaning?	0= low (0-3)

Is there the fence missing or faulty?	0= low (0-3)
Is the apron less than 1m in radius?	0= low (0-3)
Does split water collect in the apron area?	1= low (0-3)
Is the apron cracked of damaged?	1= low (0-3)
Is the hand pump loose at point of attachment to apron	O= low (0-3)

Risk score: 9-10=very high; 6-8=High; 3-5= Medium; 0-3=low

4.1.3.2 Sanitary inspection analysis of household water container

As the table 4-6, indicates the causes for contamination were poor clean outside drinking water container and kept lack of above floor level and away from contamination (70.4% and 59.25% respectively).

Table 4-6:- Result of Sanitary Inspection of household Water Containers in Ada'a Woreda

Household (n=27)	Risk Category (Y/N)
Is drinking water kept in a separate container?	44.4% (n=12)
Is drinking water container kept above floor level and away from contamination	59.25% (n=16)
Do water containers have a narrow mouth/opening?	100%
Do containers have a lid/cover?	100%
Is the utensil used to draw water from the container clean?	25.9% (n=7)
Is the utensil used to draw water the container kept away from surfaces and stored in hygienic manner?	22.2% (n=6)
Is the inside of the drinking water container clean?	59.25% (n=16)
Is the outside of drinking water container clean?	70.4% (n=19)

Notes:-The percentage indicates the percent for yes.

Table 4-7:- Frequency of cleaning Storage Water Containers with Study area of Ada'a Woreda.

Types of answer by peoples	Frequency	Percent
Every day	9	33.33
Every week	4	14.81
Every month	2	7.41
Rarely	12	44.44
Total	27	100.0

The storage container washing frequency among the households has been assessed and it was found that only 9 (33.33 %) households wash every day. Others every week, every month and rarely are 14.81%, 7.41% and 44.44% respectively. Similar study reported in Akaki-Kality sub-city 17 HHS out of 35HHs selected sample frequency of every day (48.6%) by (Birhanu, 2007).

CHAPTER- **FIVE**

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

To summarize, the general objective of this research was to determine quality of drinking water supply schemes at the Source and point of use by assessing current water services that they provide to household. The characterization and analysis of drinking water quality parameters were done using a total of 36 water sample selected from source and representative household of rural woreda. Comparison of the water quality parameters with the permissible limit of the WHO guidelines (2012) and with that of the Ethiopian recommended values (Girma et al,2011) were made regarding with safe and acceptable level of drinking water for users.

The main physico-chemical parameters considered for investigation include temperature, turbidity, pH, electrical conductivity, total dissolved solids, total hardness, calcium, Magnesium, fluoride, nitrate and phosphate. Bacteriological tests such as faecal coliforms and total coliforms were analyzed in relation to the health prevalence of water-associated diseases.

The laboratory results have shown that except for calcium, among the physico-chemical parameters tested , the remaining all parameters were found within the permissible limit of WHO guidelines and Ethiopian recommended values concerning the safety and acceptability level (Girma et al,2011) for the users. Each result of all tested physiochemical parameters were, Temp (22.90-28.70 degree Celsius), PH (7.40-8.45), Turbidity (0.47-2.54 NTU), EC (426-712mg/l), TDS (215-357mg/l), Fluoride (0.79-1.40 mg/l), Nitrate (0.06-1.30mg/l) calcium (50.80-96.50mg/l) magnesium (5.35-31.90mg/l) and Total hardness (9.36-20.50mg/l) at source level .The result deploys concerning the physico-chemical parameters ,the water seems to be safe at source level and no significant effect of on health of users. And water source some area was relatively shows base because of its PH (ranging from 7.40-8.45), mean above PH neutral (7.0)

The results of bacteriological analyses have shown that most of the sample source points of all 9-water schemes are at Zero risk except sample point-7 of shallow well shows 8 CFU/100ml total coliform at source level. But household water sample result of bacteriological ranges from 0 CFU/100ml-“Too Numerous to Count” (TNTC), mainly due to the poor handling of water at household, no chemical treatment application and lack sanitation and Hygiene awareness in all community. (Household result of Bacteriology sited at appendix-c-2).

5.2 Recommendations

Bacteriological testing method and physicochemical testing on time at source and household could be a good option to reduce water born disease. In developed communities the preferred technology is a piped distribution system with indoor household taps, but this is also the most expensive. Until such a solution can be made a reality for everyone more cost effective solutions need to be employed; water access in the form of communal taps are likely intermediate solutions. The myriad different waterborne pathogens, and removal requirements associated with each, suggests that an effective system for communities that can only afford to have communal water collection points would be to adopt a two-tiered approach. Part one would be to provide an improved source, such as a shallow well with hand pump, to preserve source water quality and minimize contamination. Part two would be chemical disinfection at point-of-use, to eliminate many common waterborne pathogens introduced from collection, transport, storage, and use. Sustainable access to safe drinking water needs to include increased availability of consistent water supplies and a means of ensuring that water is safe up to the time it is consumed (Nath, et al. 2006).

Generally;

- Disinfection of water at the household level can be an added advantage
- The present work is limited to few physico-chemical parameters and sampling frequency. Therefore, year round sampling and analysis of additional water quality parameters such as fluoride and heavy metals should be undertaken,
- A Proper WASH (Water, Sanitation and Hygiene) program at community-Led Total sanitation (CLTS) to tech how to handle water at home.
- Maintenance of Water supply schemes ,Integrated and programmed sectorial activities are necessary to reduce over-crowdedness , also reduce water-related disease problem and Microbial monitoring at source level and point-of-use

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LIST OF APPENDIXES

APPENDIX- A

Some Images of Sources Used for Testing

APPENDIX-A-1 SHALLOW WELL

APPENDIX-A-2-SHALLOW WELL-GPS-Reading at source

APPENDIX-A-3 SHALLOW WELL

APPENDIX-A-4 SHALLOW WELL

APPENDIX-A-5 DEEP-WELL

APPENDIX-A-6, When *DEEP WELL*water sample collection at source.

APPENDIX-B

Some Images of Households Used for testing

APPENDIX-B-1 HOUSEHOLD WATER SAMPLE

APPENDIX-B-2 HOUSEHOLD WATER SAMPLE

APPENDIX-B-3 HOUSEHOLD WATER SAMPLE

APPENDIX-B-4 HOUSEHOLD WATER SAMPLE.

APPENDIX-B-5, Unstructured Sanitary Inspection at source of Points.

APPENDIX-C

APPENDIX-C-1 Physico-Chemical Parameters of drinking water at studied source location of Ada'a Word.

(Note: All parameters are in mg/l except PH, EC in *μS/Cm, and TDS in PPM and Turbidity in NTU).*

Kebele	Source	Colour	Odour	PH	Temp	Turbid	E.C/ *μS/Cm*	TDS	Fluoride	Nitrate	Ma^{+2}	Ca^{+2}	Total Hardness(**CaCo3)**	Phosphate
Udde	SW1	colourless	odourless	7.4	25.4	0.66	672	332	1.13	0.24	16.4	64.3	12.8	2.61
	SW2	colourless	odourless	7.64	24.7	0.79	712	357	0.95	0.38	23	58.1	20.5	0.41
	SW3	colourless	odourless	7.7	24.9	1	706	357	1.09	0.49	28.3	69	16.2	0.82
Godino	DW4	colourless	odourless	8.22	22.9	0.47	620	310	0.84	0.26	5.35	50.8	8.36	0.55
Wajitu	DW5	colourless	odourless	8.1	28.7	0.77	426	215	0.79	1.3	31.9	64.6	16.4	0.81
Dirre shoki	DW6	colourless	odourless	8.45	25.8	2.54	524	265	1.4	0.5	18.5	60.9	12.8	2.65
Katella	SW7	colourless	odourless	7.94	25.2	0.71	585	291	1.14	0.06	9.23	81.8	13.6	1.05
	SW8	colourless	odourless	7.77	23.4	0.7	600	303	1.05	0.14	15.3	64.6	12.6	0.69
	SW9	colourless	odourless	7.9	24.9	1.25	563	281	0.83	0.17	19	96.5	17.9	1.72
WHO Guideline Value		**15 tcu**		**6.5-8.5**	**N.G.V**	**<5**	**400-1,200 mg/l**	**1000 mg/l**	**1.5 mg/l**	**5mg/l**	**50mg/l**	**75mg/l**	**100-200 mg/l**	

n.g.v- No guideline Value, tcu-true Colour unit, Appendix-C-2 Bacteriological Laboratory Analysis Result of Source and Household, According to the Risk Category.

Sample	E-coli/100ml of faecal coliform	Total coliform/100ml	Remark
Udde-SW-S1	**NILL**	**NILL**	**No Risk**
HH1	TNTC	TNTC	High Risk
HH2	TNTC	TNTC	High Risk
HH3	26 CFU	30 CFU	Intermediate
Udde-SW-S2	**NILL**	**NILL**	**No Risk**
HH1	12 CFU	26 CFU	Intermediate
HH2	5CFU	19 CFU	Intermediate
HH3	NIL	10 CFU	Low
Udde-SW-S3	**NILL**	**NILL**	**No risk**
HH1	NILL	5 CFU	Low
HH2	15 CFU	26 CFU	Intermediate
HH3	50 CFU	57 CFU	Intermediate
Godino-DW-S4	**NILL**	**NILL**	**No Risk**
HH1	3CFU	9CFU	low
HH2	NILL	NIL	No Risk
HH3	NILL	5CFU	Low
Wajitu-DW-s5	**NILL**	**NILL**	**No risk**
HH1	NILL	NILL	No Risk
HH2	NILL	20 CFU	Intermediate
HH3	27 CFU	40 CFU	Intermediate
Dirre-Shoki-DW-s6	**NILL**	**NILL**	**No risk**
HH-1	NILL	NILL	No Risk
HH-2	TNTC	TNTC	High risk
HH-3	NILL	1 CFU	Low
Katela-SW-S7	**NILL**	**8 CFU**	**Low**
HH1	TNTC	TNTC	High Risk
HH2	16 CFU	38 CFU	Intermediate
HH3	15 CFU	40 CFU	Intermediate
Katela-SW-S8	**NILL**	**NILL**	**No Risk**
HH1	25 CFU	43 CFU	Intermediate
HH2	10 CFU	24 CFU	Intermediate
HH3	5 CFU	5 CFU	Low
Katela-SW-S9	**NILL**	**NILL**	**No Risk**
HH1	3CFU	10 CFU	Low
HH2	NILL	5CFU	Low
HH3	TNTC	TNTC	High Risk

APPENDIX-D

APPENDIX-D-1. Sanitary Inspection Forms at source

Sr.No	Source-Facility Shallow Well or Deep Well (n=9)	Y/N
1	Is there a latrine within 10m Shallow Well?	
2	Is there a latrine uphill of the shallow Well?	
3	Are there any other sources of pollution with 10m Shallow Well? (E.g. animal breeding. Cultivation, roads, industry, etc.)	
4	Is there drainage faulty allowing ponding within 2m of Shallow Well?	
5	Is there drainage channel cracked, broken or need cleaning?	
6	Is there the fence missing or faulty?	
7	Is the apron less than 1m in radius?	
8	Does split water collect in the apron area?	
9	Is the apron cracked of damaged?	
10	Is the hand pump loose at point of attachment to apron	

Risk score: 9-10=very high; 6-8=High; 3-5= Medium; 0-3=low

APPENDIX-D-2. Household Water Quality Inspection

Sr. No	Household (n=27)	Risk frequency with %
1	Is drinking water kept in a separate container?	
2	Is drinking water container kept above floor level and away from contamination	
3	Do water containers have a narrow mouth/opening?	
4	Do containers have a lid/cover?	
5	How is water taken from the container? (Poured, cup ,other utensil)	
6	Is the utensil used to draw water from the container clean?	
7	Is the utensil used to draw water the container kept away from surfaces and stored in hygienic manner?	
8	How often the container is cleaned? Every day, Every week, Every Month, Rarely ,Never	
9	Is the inside of the drinking water container clean?	
10	Is the outside of drinking water container clean?	

APPENDIX-E

Coordination of Water Sampling Points**.**

Sr.N	Kebele	Water Point Type	Attributes of GPS Points.		
			X-Coordinate	Y-Coordinate	Z –Elevation(Ft.)
1	Udde	Shallow Well	503361	962146	6260
		Shallow Well	504309	959382	6268
		Shallow Well	501863	979098	6261
2	Godino	Deep Well	488543	966048	6550
3	Wajitu	Deep Well	486005	962517	6260
4	Dirre Shoki	Deep Well	504156	961931	6266
5	Katella	Shallow Well	509529	968225	6241
		Shallow Well	509283	968453	6221
		Shallow Well	509238	969441	6280