DETERMINANT FACTORS AND QUALITY OF POTABLE WATER SUPPLY AND SANITATION CONDITION IN RURAL AREAS OF ALETA CHUKO WOREDA, SIDAMA ZONE, SNNPR.

MASTER OF SCIENCE THESIS

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Dedication

I dedicate this thesis to my entire family of my wife, father, mother, brothers and sister and all friends. It also goes to all the people of the developing world who at this moment lack access to potable water.

Statement of the author

I Feleke Lelamo, here by declare that this thesis: "**determinant factors *and Quality of Potable Water Supply and Sanitation condition in Rural Areas of Aleta Chuko Woreda, Sidama zone , Southern Ethiopia***" is my own work and has not been submitted for any degree in any other university. It is being submitted for the degree of Master of Science in Water Resources Engineering and Management at Hawassa University, and all sources of material used for this thesis have been dully acknowledged.

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LIST OF ABBREVIATIONS AND ACRONYMS

ACWWMEO	Aleta Chuko Wereda Water, Mine and Energy Office.
APHA	American Public Health Association
BOH	Bureau of Health
BOWI	Bureau of Water and Irrigation
CFU	Colony Forming Unit
CSA	Central Statistical Agency
EC	Electrical Conductivity
EPA	Environmental Protection Agency
ES	Ethiopian Standards
FS	Functional Schemes
FDRE	Federal Democratic Republic of Ethiopia
GIS	Geographic Information System
GPS	Global Positioning System
HDW	Hand Dug Well
JMP	Joint Monitoring Programme
MDGs	Millennium Development Goals
MOH	Ministry Of Health
MoWR	Ministry of Water Resource
NFS	Non Functional schemes
NGOs	Non-Governmental Organizations
NTU	Nephelometric Turbidity Unity
SNNPR	Southern Nation, Nationalities, and Peoples Region
SPSS	Statistical Program for Social Science
SS	Spring Spot
SW	Shallow Well
SZHO	Sidama Zone Health Organization
OSS	On Spot Spring

TDS	Total Dissolved Solids
TC	Total Coliform
UAP	Universal Access Plan
UN	United Nations
UNDP	United Nation Development Programmes
UNEP	United Nations Environment Programme
UNICEF	United Nations International Children‘s and Emergency Fund
VIF	Variance Inflation Factors
WHO	World Health Organization
WSS	Water Supply and Sanitation

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Abstract

Potable water supply and sanitation services are basic requirements for a society. Limited access associated with poor water supply, sanitation and hygiene make the community to depend on unsafe and poor water consumption and these calling for the expansion and improvement of basic water supply and sanitation services. This study was conducted in Aleta Chuko Woreda, Southern Ethiopia to examine determinant factors and quality of potable water supply and sanitation condition. For this study, four Kebele administrations were selected by purposive sampling technique and 130 households were randomly selected for primary data sources A total of 33 water samples were taken and examined for physico-chemical and bacteriological parameters. The data from the respondents were analyzed using descriptive and inferential statistical technique. Accordingly, multiple linear regression models were applied to identify factors influencing the HH water coverage, one way ANOVA was employed to see the statistical difference of the variables at 5% significant level and correlation was also used to observe associations of variables. The findings revealed that the major problems regarding drinking water were: low coverage (47%), low quantity(average 6.58litres) consumption per capita and almost all residents take less than 20 litres of potable water and long fetching time (average 52.75 minutes). It was observed that, HH water coverage is influenced by family size (p=0.00), functionality of the schemes (p=0.014), time required to fetch water (p=0.00) and distance to the schemes (p=0.01) was found to be statistically significant. The result of water quality test revealed that for all selected physico-chemical parameters such as pH(except hand dug well at Makala kebele), EC, Turbidity(except hand dug well at Rufo Chancho kebele) and Iron(except hand dug well at Gure kebele), TDS, TH, Nitrate,Iron, Fluoride, Magnesium and Chloride at source, storage and point of use were found within the acceptable limit of ES and WHO. However, the mean value of Temperature and Phosphate were beyond the recommended ES and WHO standards. The laboratory result of bacteriological water quality for all sampled sites exceeded to the ES and WHO standards. The value of temperature decrease significantly from water source to HH storage (p=0.002). However, other parameters showed no significant change from source to storage. The concentration of total coliform increases significantly from supply source to point of use(p=0.024).

Key words: *water supply,water quality,dry season, wet season, sanitation,Aleta Chuko*

1. INTRODUCTION

1.1 BACKGROUND

Water is a central theme, which can be used to achieve millennium development goals (MDGs) (SchusterWallace et al., 2008). Water is a natural resource of fundamental importance. It supports all forms of life and creates jobs and wealth in the water sector, tourism, and recreation. As global slogan, “Water is Life” implies that water is one of the critical life need for a human being. Without water, life as it exists on our planet is impossible (Asthana and Asthana, 2001).

Water supply and sanitation are two of the most important sectors of development. Development of community water supply and sanitation results in improved social and economic conditions and improved health (Davis et al., 1993). The improvement of water supply and sanitation are many benefits which are prevention of disease, improved basic health care, better nutrition, increased access to institutions such as health centers and schools, improved water quality, increased quantity of and access to water, reduction in time and effort required for water collection, promotion of economic activity, strengthening of community organization, improvements in housing and ultimately improved quality of life (Okun, 1988).

Even though coverage of safe drinking water supply has gradually increased at the national level, the rate is still very low. Inadequate quality of drinking water also remains a major cause of health problems and poor sanitation in rural areas of Ethiopia. The unavailability of safe drinking water in most rural locations is one of the main causes of diarrhea among children under the age of five (CSA 2006). The negative health impact of contaminated water is exacerbated because more than 90 percent of households consume this water untreated. Previous empirical studies elsewhere (Jalan and Ravallion 2003; Esrey 1996) also show that access to improved water is an important contributor to improved child health and mortality reduction.

In Africa, 602 million people had access to improved drinking water sources in2006. This shows coverage increased from 56% in 1990 to 64%. The rate at which Africans gained access to improved drinking water sources, 245 million people since1990, falls short of that required to meet the 2015 MDG drinking water target (Haysom, 2006).

Even though, Ethiopia is a country with high water potential that has twelve major river basins, which makes the country the "Water Tower" of East Africa. Yet, access to safe drinking water supplies and sanitation services in many parts of the country is among the lowest in Sub-Saharan Africa. While governmental and non-governmental organizations have been implementing water supply and sanitation projects in recent years, many lack sustainability due to improper management. This fact attributed to the service delivery modalities adopted by financers and implementing agencies (Yewondwossen, 2012).

The woreda is characterized by potential surface water source having a number of rivers, springs, and wetland. There are different rivers originating/crossing the woreda like kolla, malawo, gidawo and jigesa, are some of the river in the area. There are ground water and surface water potential in the Woreda. Despite the ground water supply potential of the Woreda, it is not possible to construct enough water schemes in all Kebeles. Even in Kebeles where there are improved water schemes, the water supply is not adequate and the functioning schemes themselves are not providing reliable and adequate services for different reasons to respective communities (ACWWMEIO, 2017).

This study was conducted in Aleta Ghuko woreda, Sidama zone, SNNP Regional State, the water supply and sanitation challenges which still are untouched and unsolved problems. The investigator considered from his observation and experience that the problem of water in Aleta Chuko is growing from time to time. Improving the water supply coverage and evaluating seasonal variation of water quality has a number of advantages for the society of the woreda as well as for the government socially and economically.

1.2 Statement of the Problem

Ethiopia ranks among the lowest countries in the world in levels of safe water and sanitation coverage 66% of Ethiopia's 83 million citizens do not have access to an improved water supply and 79% lack access to basic sanitation. The majority of Ethiopia's citizens live in rural areas where rates of coverage are even worse. Among rural Ethiopians, only 34% have access to an improved water supply.

Aleta Chuko is one of the rural woreda in Ethiopia, where the community does not have access to potable water and basic sanitation. Thus, the communities are forced to use water from unprotected water sources, which they may share with their animals. Access and coverage of potable water supply and sanitation services are supposedly very sounding problem in study area. It was observed that there are several factors in the community that were likely resulting in water contamination at sources or during collection, storage and point of-use in household level. These factors called for question the basic assumption that water will remain safe from the time it leaves the tap to when it is consumed. If this assumption is shown to be faulty, it would have implications for future development strategies focused on water quality.

The other major problems related to water, sanitation and hygiene in the study area are lack of awareness of people and microbiological pollution. Diarrhea, gastroenteritis, malaria, typhoid, and hepatitis are the most prevalent water associated communicable diseases in the study area that varies from season to season.

This research work were specifically investigated the determinant factors for water supply coverage, water quality with their timely and seasonal variation, sanitation situation and the gap associated with water scarcity to initiate intervention measures in order to address the mentioned problems in Aleta Chuko woreda.

1.3 Objectives

1.3.1 General objective

- To assess determinant factors and quality of potable water supply and sanitation in the study area.

1.3.2 Specific objectives

- To assess the determinant factors for the provision of safe water supply services in the Woreda.
- To evaluate water quality variation in dry and wet season to each improved water source observed by using selected physico-chemical and bacteriological parameters at the source, storage and point of-use
- To assess the sanitation situation of the Woreda.

1.4 Research questions

In order to address the above issues, the study will be attempts to answer the following five research questions:

- What are the main challenges in the provision of safe water and sanitation services in Aleta Chuko Woreda?
- Does the water quality in the study area fulfill the established standards?
- What actions should be taken to improve the water supply and sanitation services in Aleta Chuko Woreda?

1.5 Significance of the study

The result of this study is expected to find out of determinant factors for household water coverage, drinking water quality variation from source to point of use and sanitation condition in Aleta Chuko Woreda. It increases the knowledge and up to date information for individuals who are interested to study further on the coverage and is significant determinants‟, quality of drinking water and sanitation status in the study area. It also serves as a working document to policy makers in the water sector and the non-governmental organizations. Furthermore, it helps to draw possible suggestions and recommendations in order to improve status of water supply, quality of drinking water and sanitation in the study area.

1.6 Scope of the Study

The focus of this study is on water supply and sanitation constructed in the rural part of Aleta Chuko Woreda. This study specifically emphases on evaluation of rural water supply and sanitation. The study area is limited to rural Kebeles in woreda. The study could covers selected Kebeles of water supply and sanitation where data were generated from selected household beneficiaries.

2. LITERATURE REVIEW

2.1 Global Issue in Water Supply and Sanitation

Since 1970"s, there was a consensus that governments and donors should alleviate poverty in rural areas through providing basic needs such as drinking water, which was largely free at least in capital costs. This approach is now labeled as supply driven (Kleemieer, 1995).

The survival and well being of a nation depends upon sustainable development and for this, water supply and sanitation which are ingredients of a healthy and productive life are essential requirements. For the poor people residing in urban slums and rural areas, to achieve a better economic growth rate and higher productivity, priority has to be given to the health of these people, for which provision of public utilities like water supply and sanitation is necessary (Pathak et al, 2002).

Water has always been a very important issue on the United Nations (UN) agenda. The aim of the UN is to reduce by half the proportion of people without sustainable access to safe drinking water by 2015 (UNESCO, 2003). The UN says guaranteeing a proper water supply is vital to eradicating poverty. It says the absolute daily minimum amount of water a person needs is 50 liters which include: 5 liters for drinking, 20 for sanitation and hygiene, 15 for bathing and 10 for preparing food. Achieving these goals requires sustainable economic and social development in developing countries. However, UNESCO (2003) also notes that most of the constraints to development are increasingly tied to water.

Inaccessibility of safe water and adequate sanitation facility strengthens the cycle of disease, poverty and weakness; therefore, water and sanitation programs are instrumental in efforts to rescue people from poverty. In other word, provision of water and sanitation should be indispensable parts of the Poverty Reduction Strategies applied by developing countries. In the developing world today, poor access to safe water and adequate sanitation continues to be a threat to human health. Expanding access to basic water supply and sanitation, integrated with hygiene education can reduce the burden of water-related diseases significantly by improving the lives of a large part of the world’s population. Since provision of sanitation breaks the vicious cycle of poverty and initiates a virtuous cycle of economic well-being, it should be a vital ingredient in the poverty alleviation programs (Pathak et al, 2002).

Africa has the lowest total water supply coverage of any region, with only 62 percent of the population having access to improved water supply. The situation is worst in rural areas, where coverage is only 47 percent. According to the JMP (2010), around 2.6 billion people do not have access to basic sanitation; and because of poor access to basic sanitation 1.5 million peoples die each year. Many of these people live in south East Asia and sub-Saharan Africa. Sanitation coverage in Africa also is poor, only 60 percent of the total population in Africa has sanitation coverage, with coverage varying from 84 percent in urban areas to 45 percent in rural areas (JMP, 2010).

2.2 Water Supply

2.2.1 Water supply in Ethiopia

Provision of safe and sufficient water supply and adequate sanitation services are indispensable components in the sustainable development of Ethiopia's urban and rural socio economic wellbeing. At present, most of the population does not have adequate and safe access to water supply and sanitation (WSS) facilities. As a result, over 70% of the contagious diseases in the country are water borne/based diseases. Source of most of these diseases could be traced back to inadequate WSS facilities (MoWR, 2001).

Ethiopia has been trying to supply potable water to its population, without great success, for more than a century. water resource management for domestic supply has been relatively neglected, especially before the post imperial period. Even today, rural water supply programs, which affect the majority of the country's population, have not been given sufficient attention (Rahmato, 1999).

The water distribution systems in the country are generally inadequate. The problem is associated partly with unfavorable topography, seasonal fluctuation of the water reservoirs, low capital investment, and lack of efficient water governance among concerned authorities (Getachew, 2002; Tesfaye, 1985). Quite frequently Ethiopian planners emphasize the agronomic, engineering, or technical aspects of water projects, while giving less attention to governance and participation of stakeholders. Rahmato (1999) observed that among the main reasons given for the slow progress in water supply services in the 1980s (but still relevant today) are the lack of comprehensive water legislation, inadequate investment resources, and the lack of a national water tariff policy.

However the Ministry of Water Resources (MoWR) estimates that 33% of water supply Schemes in Ethiopia are non-functional at any time, with negative impacts on coverage and universal access due to lack of funds for operation and maintenance, inadequate community mobilization and commitment and a lack of spare parts (Moriarty et al., 2009).

However the paradox is Ethiopia has 12 major river basins, the total annual runoff from these basins is estimated at about 122 billion cubic meters (MoWR, 2000). Although a comprehensive national ground water resources study has not been conducted, some surveys suggest that the ground water potential in many parts of the country is high (UNDP, 2005). The results of lack of safe water supply are not sickness and death, but also economic crises. Therefore, safe drinking water is an essential component of primary health care and is vital for poverty alleviation. Introducing improved water supply sources at the household level enhance personal and community knowledge as well as awareness of the importance of other factors, such as hygiene and sanitation (sobsey, 2002).

2.2.2 Water supply in SNNPRS

Access to water supply in SNNPR has been steadily improving over the past two decades. In the SNNPR region there are about 12,079 water supply schemes operating throughout the region including 903 spring with distribution, 5,710 spring on spot, 4,854 shallow wells (including hand dug wells fitted with pump), 604 deep bore hole with distribution and 8 surface water based pumped water supply systems constructed by the regional government and NGOs in recent years. The predominant water supply technology used in SNNPR is spot spring approximately 31.7% of the population with access to safe water supplies in rural area is served by spot spring followed by shallow wells which is 31.2% (BoWI,2014).

The functionality rate for improved water supply in SNNPR is reported to be 72.95% in rural water supply schemes. However, it has been noted that about 27% of the water supply schemes are non-functional at any given time. The causes for non-functionality are; technical break down (45%), low yield (21%), management/financial problem (20%) and others like water quality (14%) (BoWI, 2011).

However, lack of sustainability of project aggravated the existing poor coverage of water and sanitation implying negative impacts on coverage and on the attainment of the plan. At the end of 2009, access to water supply for rural part was 50.66% and 75.33% in urban areas of the region. The average access to water supply was 52.50%.(BoWI, 2017).

2.2.3 Water supply in Sidama Zone

Sidama zone is located in the north east part of the SNNPR. Access to per capita water supply coverage rate for rural areas was 45.3 % with per consumption rate of 15 liter/capita/day with in 1.5 km and access to urban water supply coverage was 77.3 % within per consumption rate of 20 liter per capita per day with in 0.5km. The average access to safe water supply coverage rate are 61.3%. The non-functionality rate in rural area is 22.2% . The non functionality is due to lack of good management, technical break down, low yield of water supply schemes and lack of spar parts(SZWMEIO, 2017). These supply systems are constructed by different organizations such as governmental and non-governmental organizations at different times. Totally available water supply schemes in Sidama Zone are:-

Table 2-1 Existing water supply schemes in Sidama Zone (Source; SZWMEIO, 2017).

Water supply schemes	**Hand dug well (No)**	**Rope pump (No)**	**Shallow well (No)**	**On spot spring (No)**	**Borehole (No)**	**Spring with distribution (No)**
Functional schemes	253	121	465	2631	97	94
Non- Functional schemes	101	34	204	258	16	9
Total	354	155	669	2889	113	103

2.2.4 Water supply in Aleta Chuko Woreda

There is a huge ground and surface water potential in the Woreda. Despite the ground water supply potential of the Woreda, it is not possible to construct enough water schemes in all Kebeles. Even in Kebeles where there are improved water schemes, the water supply is not adequate for all, and the functioning schemes themselves are not providing reliable and adequate services for different reasons to respective communities. The water coverage of the Woreda is about 47%. Only 104,619 beneficiaries are getting access to safe water and the rest of the population use unsafe water from unprotected water source like spring, and rivers (ACWWMEIO, 2017). It was observed that no coordination, collaboration, and partnerships amongst non-state actors and government WaSH Sectors in water access. Due to this reason; 22.7% of water schemes are non-functional, 62% of schemes cannot cover operation and maintenance costs, 54 of the scheme catchments are poorly managed and water scheme committees are not well equipped to effectively manage water schemes (ACWWMEIO, 2017).

These supply systems are constructed by different organizations such as governmental and non-governmental organizations at different times. Totally available water supply schemes in the Woreda are

Table 2-2 Existing water supply schemes in Aleta Chuko Woreda (Source;ACWWMEIO, 2017).

Water supply schemes	**Hand dug well (No)**	**Rope pump (No)**	**Shallow well (No)**	**On spot spring (No)**	**Borehole (No)**	**Spring with distribution (No)**
Functional schemes	6	3	98	58	11	1
Non-Functional schemes	7	-	39	2	4	-
Total	13	3	137	60	15	1

2.3 Water quality deterioration at different level of utilities

While it is important to increase access to improved water sources, the assumption that improved sources of water are of higher microbial quality does not necessarily hold true after the water has been transported and stored in the home. For example, there are opportunities between the water source and the household for the water to become re-contaminated through contact with unwashed hands, further perpetuating the cycle of poor quality drinking water. Household storage containers often allow for recontamination when water is removed using a cup through the opening at the top of the storage container, be it a traditional clay pot or a plastic bucket (Melinda, 2007). Drinking water has to be wholesome and clean when it becomes available for the consumers. However, from the time water leaves the water works, an array of processes may affect its quality during transport and storage (WHO, 2010).

A number of processes may alter water quality during transport in the distribution system to the consumer. This may be due to inherent properties of the water which may lead to microbial after growth or corrosion, or to the choice of materials in contact with drinking water which may allow migration of organic materials that can sustain microbial growth or may release heavy metals such as copper, lead or nickel. Finally, leaks or fractures may permit the entry of pollutants such as organic micro pollutants (for example gasoline compounds) or pathogens from surface or wastewaters (Jonas, 2009).

Most behaviors related to water collection, storage and use in Aleta Chuko are not unique to that community. The following common practices have been observed elsewhere 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.

2.4 Determinants of water supply

Evaluation of the amount of water available and the amount of water demanded by the public are primary tasks in designing any water supply system. Demand of water is the amount of water required to meet all the needs of the people, which the system serves. It is expressed as per capita per day (l/c/d). Water resource planning requires reliable forecasts of population and water demand. Increasing populations translate into increased water demand for municipal, residential and commercial uses. Community growth, the growth of local commerce and industry and the development of new industries all increase demand for water. In planning the water supply is necessary to find out not only the total yearly water requirement but also to access the required average rate of flow and the variation in these rates (Kaika, 2003).

Population growth

The design of the water supply projects is done on the basis of projected population since it is the main factor which affects the water supply project. Future population growth can be influenced by affecting birth, death, or migration rates due to social, economic, political, technological, and scientific developments (Lee and Tuljapurkar, 1994; O'Neill et al., 2001).The two approaches commonly used for characterizing uncertainty in demographic forecasting are scenario and probabilistic. Scenario uses to describe its projections in consistent story in which fertility, mortality, and migration assumptions are embedded to provide a comprehensive picture of what the future might be. Probability distribution explicitly accounts for uncertainty in projected trends of fertility, mortality, and migration; and derives the resulting probability distributions for projected population size and age structure (Khatri and Vairavamoorthy, 2007). The knowledge of population forecasting is very important for the design of any water supply scheme. The design is done on the basis of projected population at the end of the design period. Otherwise a present scheme will be inadequate in the near future (Chatterjee, 2005).

Socio-economic changes

There is a strong correlation between water consumption and socio-economic changes. Examples are changing life style, changing housing type and household size, acceptability, and market penetration of water efficient appliances alternative sources of water, economic development, employment opportunities, education level, and water pricing (Bradley, 2004; Clarke et al., 1997; Scheider 1991).

Climate change

Climate variability and change affect the availability of demand and quality of water, and runoff or temperature extremes. Different sources of uncertainties stemming from the climate change; such as future temperature, precipitation, sunshine duration, wind speed, relative humidity, evaporation rate, transpiration rate, soil moisture content will have significant impact on future water consumption. The extreme events (drought or frequent flood) will have also considerable impact on future demand. Therefore, how these climatic parameters changes in future will govern to water demand forecasting (IPCC, 2007)

Accessibility of Water

According to WHO (2008), access to safe water is the share of the population with reasonable access to an adequate amount of safe water. Safe water includes treated surface water and untreated but uncontaminated water such as from springs, medium/shallow wells and boreholes. In rural areas the water source a shallow well, hand dug and protected on-spot spring not more than 1.5km away from households. An adequate amount of water is that which is needed to satisfy metabolic, hygienic and domestic requirements usually about 15 liters of safe water per person per day. This minimum quantity, however, vary depending on whether it is an urban location or rural and whether warm or hot climate. Perhaps this is why the WHO (2008) described basic human water need to be 20 to 50 liters of uncontaminated water daily.

2.5 Water Quality

Water quality is a measure of the condition of water relative to the requirements of one or more biotic species and to any human need or purpose and it is most frequently used by reference to a set of standards against which compliance can be assessed (Diersing- Nancy, 2009). Water quality parameters include the physical, chemical, and biological characteristics of water. Monitoring the quality of water facilitates evaluation of nature and extent of pollution, effectiveness of pollutant control measures, water quality trends and prioritization of pollution control efforts (Abed et al., 2005).

Apart from quantities consumed, water quality compromised by various factors that require measurement. Some factors such as physical, chemical and bacteriological processes because the quality of surface water to vary during the years (Rainer, 1990). The available sources for a potable water supply are groundwater and surface water. Therefore, it should be protected, used, and maintained in an appropriate way. There are several parameters used to determine the suitability of water and the health contaminants such as microbiological, physical, chemical, and microscopic examinations, which may be found both in untreated and treated water (Chinn, 2003).

To provide safe water, there is a need to ensure that the quality of drinking water is assessed and monitored (UNEP, 2008). Quality is defined by certain physical, chemical and biological characteristics. Even a personal preference such as taste is a simple evaluation of acceptability. Drinking water qualities assessed by comparisons of water samples to drinking water quality guidelines or standards. These guidelines and standards provide for the protection of human health by ensuring that clean and safe water is available for human consumption (WHO, 2008).

2.5.1 Physico-Chemical Water Quality Aspects

Physico-chemical parameters are the physical and chemical parameters associated with water which have an influence on its quality and also affect the biological constituents of the water (Oluyemi et al, 2010).

Turbidity is a measure of the cloudiness of water and used to indicate water quality and filtration effectiveness. Turbidity of natural water is caused by the presence of compounds such as clay, mud, organic matter, bacteria, and algae (WHO, 2003). Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria (APHA, 1998). These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches. Drinking water should have low turbidity since suspended particulates matter provides suitable sites for the growth of bacteria and other microorganism, which have health, risk (Cairncross, 1990; Hutton 1996).

Total dissolved solids (TDS) in waters constitute mainly carbonates, bicarbonates, chlorides, sulfates, calcium, magnesium, potassium, dissolved metals, dissolved organics and other substance account for a small portion of the dissolved residues in water. Dissolved solids and residues in drinking water tend to change the waters physical and chemical nature of drinking water (Zenaw, 1997). The WHO recommended limit of TDS concentration of drinking water should be 1000mg/l (Hutton, 1996).

PH is one important water quality parameter, the pH of water, affects the biochemical processing water (Chapman, 1996). Most drinking water have a pH from 4 to 9 and the majority are slightly alkaline due to carbonates and bicarbonates of calcium and magnesium dissolved in water with variable pH are most likely contaminated and indicating the introduction of industrial wastes (Hutton, 1996).

Electrical Conductivity (EC): is the electrical conductivity (EC) of a water a measure of its ability to carry an electric current; the more dissolved ions solutes in a water, the greater its electric conductivity (SAWQD, 1996). Conductivity can be regarded as a crude indicator of water quality for many purposes, since it is related to the sum of all ionized solutes or total dissolved solid (TDS) content (Keith, 2004). Pure water is a poor conductor of electricity. Water shows significant conductivity when dissolved salts are presented (Keith, 2004). The health Effect of EC will be the function of TDS in the drinking water. SAWQD (1996) states that, Health effect related to TDS are minimal at concentration below 2,000-3,000 mg/l TDS. In contrast, high concentration of salts imparts an unpleasant taste to water and may also adversely affect the kidneys.

Temperature in analysis of the Physico- chemical quality of pipe water samples, temperature is considered as a critical parameter. It has an impact on many reactions including the rate of disinfectant decay and by-product formation (Volk et al., 2002).

According to Collicott et al.(2003) cited in Solomon (2011), as the water temperature increases, the disinfectant demand and by-product formation, nitrification, microbial activity, algal growth, taste and odour episodes, and lead and copper solubility increases. Moreover, sand calcium carbonate (CaCO) precipitation also increases.

An aesthetic objective is set for maximum water temperature to aid in selection of the best water source or the best placement for a water intake. It is desirable that the temperature of drinking water should not exceed $15C^o$ because the palatability of water is enhanced by its coolness. In addition to cool water tasting better than warm water, temperatures above 15 degree Celsius can speed up the growth of nuisance organisms such as algae, which can intensify, taste, odor and color problems. Temperature also affects water treatment (TID, 2000). If nutrients are available, the microbial activity (as measured by hetero plate count) increases significantly at water temperatures above 15ºC in the absence of a disinfectant residual.

Therefore, water supplies generally tend to keep the temperature as low as possible in order to minimize the bacterial growth. Keeping the temperature low reduces the risk for pathogenic proliferation and survival since the optimal temperature for most pathogens is close to the human body temperature (Boe-Hansen, 2002).

Hardness is measure of concentration of calcium and magnesium salt in water, is important variable for drinking water quality. They are generally present as carbonate and bicarbonate salts. Scaling problem in pipes and utensil makes hard water objected by consumers in addition to its health and taste discomfort. Magnesium is the major contributor to hardness and like calcium, concentration of magnesium above 150mg/l especially if present with sulfate can cause gastrointestinal irritation and diarrhea; some salts of magnesium in water are toxic by ingestion or inhalation, concentration of magnesium greater than 125mg/l also can have a cathartic and diuretic effect (Clesceri et al., 1998).

Fluoride is found naturally in much water, it is also added in many water systems to reduce tooth decay. Excessive fluoride concentration can cause stained or mottled teeth (Sandra,1996). This is true where the natural fluoride content is above 2.4mg/l the concentration of fluoride in drinking water is critical when considering the strength of growing teeth and bones. Exposure to high levels of fluoride, which occurs naturally, can lead to mottling of teeth and, in severe cases, crippling skeletal fluorosis (WHO, 2008).

Chlorine as the chloride ion is the major constituent in water and wastewater with a wide range of concentration from few mg/l in clean rain to 10 mg/l in supersaturated, hot saline ground water. Chloride may be increased in surface water since it is concentrated in human and animal urine reaching watercourses. Human urine may contain 1-1.5% of NaCl. A related health problem of chlorine contamination in drinking water includes Eye/nose irritation; Anemia; Infants and young children: nervous system effects (Sandra, 1996).

Nitrates are the most oxidized forms of nitrogen and the end product of the aerobic decomposition of organic nitrogenous matter. The significant sources of nitrates are chemical fertilizers from cultivated lands, drainage from livestock feeds, as well as domestic and industrial sources. Natural waters in their unpolluted state contain only minute quantities of nitrates. High nitrate levels in water can cause methemoglobinemia or blue baby syndrome, a condition found especially in infants less than six months. The stomach acid of an infant is not as strong as in older children and adults. This causes an increase in bacteria that can readily convert nitrate to nitrite (NO2 -). The WHO standard for nitrate in drinking water is 50 mg/L for short time exposure. The health effects of nitrate in drinking water are shortness of breath and blue-baby syndrome and other disorders (WHO, 2004).

Iron is one of the most abundant metals in the earth's crust. Iron contamination is a particular problem for anaerobic groundwater supplies, but iron can get into drinking-water from the use of iron coagulants or from corrosion of galvanized iron, steel and cast-iron pipes in the distribution system. Iron also promotes the growth of iron bacteria, which oxidize ferrous iron to ferric iron, and in the process corrode the piping and deposit a slimy coating on its surface (Howard et al., 2003; WHO, 2004). Some surface waters also have iron problems, particularly related to colloidal iron.

Total chlorine or residual chlorine in areas where there is little risk of a water borne outbreak, residual free chlorine of 0.2 to 0.5 mg/l at all points in the supply is recommended. General system failures, inefficiency in disinfection, poor maintenance are some of factors that affect the quality of water in Ethiopia (Dagnew et al., 2007). Therefore, when water leaves the treatment plant residual free chlorine of about 1 mg/l is needed for health reasons and it is recommended that such level is maintained at points of consumption (Momba et al.,2006).

2.5.2 Bacteriological Water Quality Aspects

The most common bacteriological water quality indicators include TC, FC, FS and E.coli (USEPA, 1997). An indicator organism may not necessarily pose a health risk but it can be easily isolated and enumerated, is present in large n umbers, is more resistant to disinfection than pathogens, and does not multiply in water and distribution systems. Indicator bacteria are used to evaluate the pot ability of drinking water because it would be impossible to accurately enumerate all pathogenic organisms that are transmitted by water (Paccker et al., 1995). Coli forms are a group of bacteria with common characteristics used to indicate unacceptable water quality. The presence of any coli form organism in drinking water is used as an indicator of faecal contamination since they are the most sensitive indicator bacteria for demonstrating excretal contamination (Paccker et al., 1995). With in the total coliforms group, E.Coli bacteria are specifically used to indicate faecal contamination (Erah et al., 2002).

Escherichia coli (E.coli), a thermo tolerant coli form, is found to be the most numerous in animal or human faeces of the total coli form group, rarely grows in the environment and is considered the most specific indicator of faecal contamination in drinking water. The presence of E.coli provides strong evidence of recent faecal contamination (Stevens et al., 2003).

2.5.3 Water Quality Standards and Guidelines

The World Health Organization (WHO) drinking water quality guidelines provide international norms on water quality and human health that are used as the basis for regulation and standard setting, in developing and developed countries worldwide. These guidelines are adopted by many countries as national guidelines to follow. These countries including Ethiopia set drinking water quality guidelines based on the WHO guidelines but may modify these based on what is achievable in the country.

Table 2-3 Maximum allowable concentrations of selected water quality variables for drinking uses (WHO, 2008; ES, 2002).

Parameters		**Unit**	**WHO guideline**	**Ethiopian Standard**
Physical parameters	Turbidity	NTU	5	7
Chemical parameters	PH	PH	6.5-8.5	6.5-8.5
	TDS(mg/l)	mg/l	1000	1000
	Nitrate	mg/l	50	50
	Chloride	mg/l	250	250
	Fluoride	mg/l	1.5	3
	Total Hardness ($CaCO_3$)	mg/l	300	300
	Iron	mg/l	0.3	0.4
	Manganese	mg/l	0.1	0.8
	Chlorine	mg/l	5	5
Bacteriological parameters	E.Coli/thermo tolerant coli form bacteria		0/100ml	0/100ml

2.5.4 Water Quality Associated Disease

Water-borne diseases are diseases caused by the ingestion of water contaminated by human or animal faeces or urine containing pathogens. Water-washed diseases are diseases caused by inadequate use of water for domestic and personal hygiene. Water-based diseases are infections cased by parasitic pathogens found in aquatic host organisms. Water-related diseases are caused by insect vectors, which either breed in water or bite near water (WHO, 2006). Many bacteria, viruses, protozoa and parasites can cause disease when ingested. The majorities of these pathogens derive from human or animal faeces, and are transmitted through the faecal-oral route (UNICEF, 2008).

Although both animal and human faeces are threats to human health, human faeces are generally the most dangerous. Faecal pathogens can be classified as causing both water-borne and water-washed diseases (UNICEF, 2008). Chronic diarrheal disease can also exacerbate malnutrition. Both early childhood malnutrition and anemia can cause permanent effects in brain development: malnourished and anemic children grow up to be less intelligent and do less well in school (Pollitt, 1995). Research indicates that diarrheal disease may also directly affect cognitive development (Dillingham and Guerrant, 2004). Brazilian children aged six to ten who had suffered serious and ongoing episodes of diarrhea during the first two years of life performed less well than other children on standard intelligence tests, even after controlling for socio-economic status and early childhood malnutrition or helminthes infections (Niehaus *et al*., 2002). Similarly, Berkman *et al.* (2002) showed that Peruvian children who experienced multiple infections with Giardia scored lower on intelligence tests.

2.6 Sanitation

2.6.1 Sanitation in Ethiopia

According to MOH (2008) sanitation refers to the hygienic principles and practices relating to the safe collection, removal or disposal of human excreta, refuse and waste water, as they impact upon users and the environment. Several studies have documented the significant positive effect of sanitation on reducing child diarrhea (Esrey et al., 1991; Fewtrell et al., 2005; and Waddington et al., 2009). Moreover, improved sanitation has been shown to lower the health risks related to bilharzias, trachoma, intestinal helminthes and other sanitation related diseases. In addition, improved sanitation is likely to reduce the burden of disease related to other major health issues by reducing the average stress level for the immune system, and thus strengthening the resistant to response to new infections.

Ethiopia's environmental health organization was reported that the percentage of households with access to sanitation was 28.6 per cent but that 30-80 per cent of the available pit latrines may be non-functional (Gebreselassie, 2007).

2.6.2 Sanitation in SNNPR

The scope of education on Sanitation and hygiene was at that time limited, due to lack of appropriate strategies for community education and mobilization. Messages on Sanitation and hygiene were communicated, when community members came to health institutions to obtain health services. The approach to Sanitation and hygiene was supply driven, with health authorities raising the expectations of households that incentives to improve the practices would be provided by government. The Bureau of health recorded that, therefore, HH demand for Sanitation and hygiene services had been low (Shiferaw Teklemariam, 2003).

Sanitation coverage is quoted to be 33%. In the rural areas long queues around safe drinking water points are not uncommon. Some 60% rural households have access to latrine facilities compared to 80% in urban areas (national figure 63%). Local environmental conditions, such as loose soils, high groundwater tables, floods, termites attacking construction timber, and lack of timber threaten. However, to make the lifetime of latrines short; i.e. questions do arise as to the sustainability of this wave of latrine construction (e.g. need for technical innovative improvements) if HHs are not to drop off the sanitation ladder and stop using latrine (BoH,2017).

Field observation suggest a high rate of latrine use, but reveal still poor hand washing and water storage/handling practices (despite respondents to the survey declaring much higher rates). If the BoH approach is not to be reduced to just 'latrine counting,' the behavioral aspects need more effective attention amongst otherwise strong communication campaign. This echoes one weakness in the way messages were communicated, whereby the focus given to coverage responding to the ambitious quotas for latrine construction – diverted attention from latrine utilization and personal hygiene, those being behavioral issues harder to change than hardware(Tefera, 2008).

Government and non-government organization (NGOs) have dedicated considerable resources to improve sanitation and hygiene in Southern Region. For example, the MoH in 2003 launched a new health care plan to provide quality preventive health services in an accessible and equitable manner to all segments of rural population through a comprehensive Health Extension Program (HEP) (Alula, 2008). One of the focal point of this program is hygiene and environmental sanitation and Health extension workers are working at the kebele level in order to promote proper and safe excreta disposal system in household throughout the region.

Regarding latrine availability, the data from the four welfare monitoring survey reports (2004) shows that the waste disposal facilities of most households 60.57% of the country and 54.12% of SNNPR region was to use wastes as manure whereas 32.06% versus 39.63% respectively practice throwing away to the environment.

Despite such figures, latrines are virtually non-existent in rural communities with defecation taking place in fields, bushes or along drainage ditches. The non-functionality of the available latrines was estimated to be greater than 80% in the country (Gebreselassie, 2007) which is likely the same in the region. If this trend of non-functionality of sanitation facilities continues, the risk of fecal-oral transmission and the mortality rate of children due to poor sanitation increase.

2.6.3 Sanitation in Sidama Zone

Improving access to safe water and sanitation facilities leads to improved health in families and communities. However, when people are also motivated to practice good hygiene practices, health benefits are significantly increased. Hand washing with soap can result in major health improvements. One review of studies in Sidama zone documented a 35- percent reduction in diarrheal morbidity from improved hand-washing (SZHO, 2016). Hygiene is especially important for the survival and development of young children. Good hygiene practices among mothers and other caregivers (especially hand washing with soap after defecating and before preparing food and the safe disposal of children's feaces) prevent diarrhea. Children's feaces are often not disposed of safely even though they are more likely to contain diarrheal pathogens than adult feaces. In Sidama zone, more than half of households surveyed in rural areas the faces of children less than three years old were not disposed of safely. There is a need to educate the people to dispose off the waste in proper places. Improved sanitation coverage in Sidama Zone is 13.1% (Source; SZHO, 2017).

2.6.4 Sanitation in Aleta Chuko Woreda

The quality of water that is well recognized as major transmission route for infectious diarrhea, typhoid and other water borne disease. According to the information obtained from the Woreda health office, the sanitation coverage of the Woreda is 75%, which in turn indicates that most of the population is at risk of communicable disease. Most of this could be preventable by introduction of safe water supply, hygiene and sanitation. Moreover, pesticides used in agricultural fields impose additional burden in the study area (ACWMEIO, 2017). Diarrhea, gastroenteritis, malaria, typhoid, and hepatitis are the most prevalent water associated communicable diseases in the study area that varies from season to season. From the above quantitative WASH baseline data, the practices of sanitation though exist in the Woreda, the implementation is poor as to the data of sanitation and community hygiene (ACWHO, 2017). Hand washing practice with water and soap is weak. Hand washing facilities are poorly designed and dirty water is often used, with hand washing facilities' not located near the latrine all of which results in dirty hands with high risks of transmission of faecal-oral diseases. Lack of public latrines at gathering places forces people to use open defecation which may undermine their adapted behavior of latrine use at home (ACWHO, 2017).

3.MATERIALS AND METHODS

3.1. Bio-physical set up of the study area

3.1.1. Description of the Study Area

Aleta Chuko is located between 6°46'00" - 6°72'00"N of latitude and 38°2'00" -38°56'00"E of longitude in Sidama Zone, Southern Nations, Nationalities and Peoples Regional State (SNNPRS), Ethiopia. The capital town of Aleta Chuko woreda is Chuko, which is located at 62 km south of Hawassa, regional capital city. The Woreda has 26 rural kebeles. The woreda is bounded economical and political with North Dale Woreda, South Dara Woreda, East Aleta Wondo Woreda and West Loka Abaya Woreda.

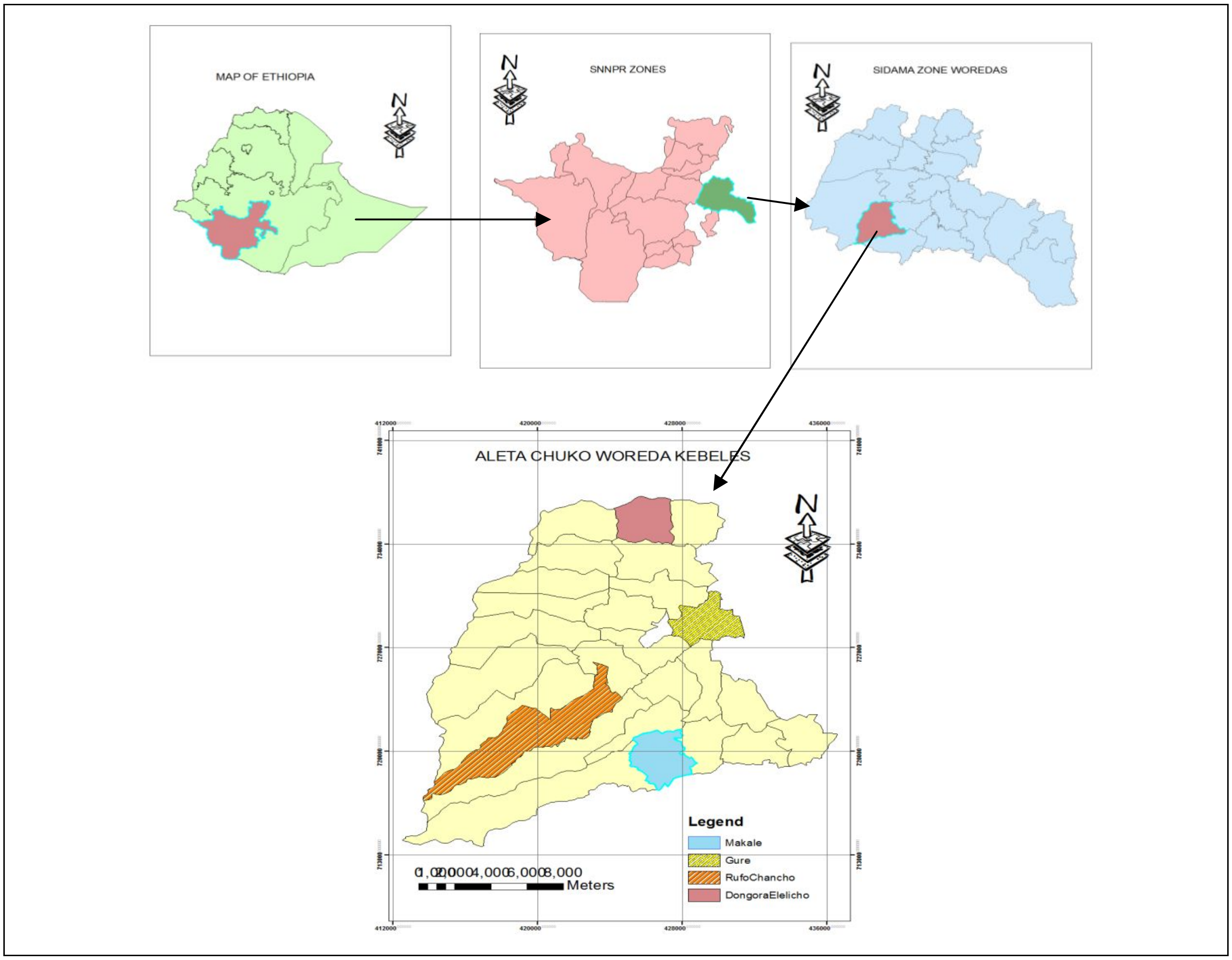

Figure 3-1 Map of the Study area.(Source SZANRO, 2017)

3.1.2. Climate and Vegetation

The Woreda is generally categorized into Woina Dega and Kola agro climatic Zones. The annual average rainfall is estimated to vary from 1100 to 1400 mm and the annual average temperature vary from 10^0C to 26^0C. Wet and dry season of the Woreda are June to September and November to February respectively. The Woreda is covered by green vegetations consisting of inset, coffee and different type of mature indigenous trees, shade trees for coffee plant and increasingly expanding eucalyptus trees. According to Aleta Chuko Rural Agricaltural Sector (ACRAS, 2017), the average elevation is 1850 m.a.s.l. The vegetation coverage in the woreda from the 32,248 hectares ; natural forest contains 1,112.7 hectares, plantation forest contains 2,397 hectares and bushes and shrubs are 971 hectares.

3.1.3. Population

According to the data from Aleta Chuko Woreda Finance and Economic Development Office (ACFEDO), the total population of the Woreda is estimated to be 222,595 Out of which 114,413 are male and 108,182 are female. Aleta Chuko is one of the highest population density areas among the Sidama Zone which are 641 Persons per square kilometers. The annual growth rate is 2.9% and the composition of age 0 to 14 is 46.5% , 15 to 64 is 51% and above 65 is 2.5 % .The average household size is five (ACFEDO, 2017).

3.1.4 Economy

According to Aleta Chuko Rural Agricultural Sector the major source of income in the Woreda is crop production, live stock rearing, trade, labor. The major crops grown are Inset, coffee, chat, maize and pineapple. Pineapple and chat are major cash crops. The live stocks raised in the area are cattle, sheep, goat, donkey, and poultry and has significant contribution for income. Inset followed by maize and potato constitute the staple food production in the area (ACRAS, 2017).

3.2 Schematics of the research

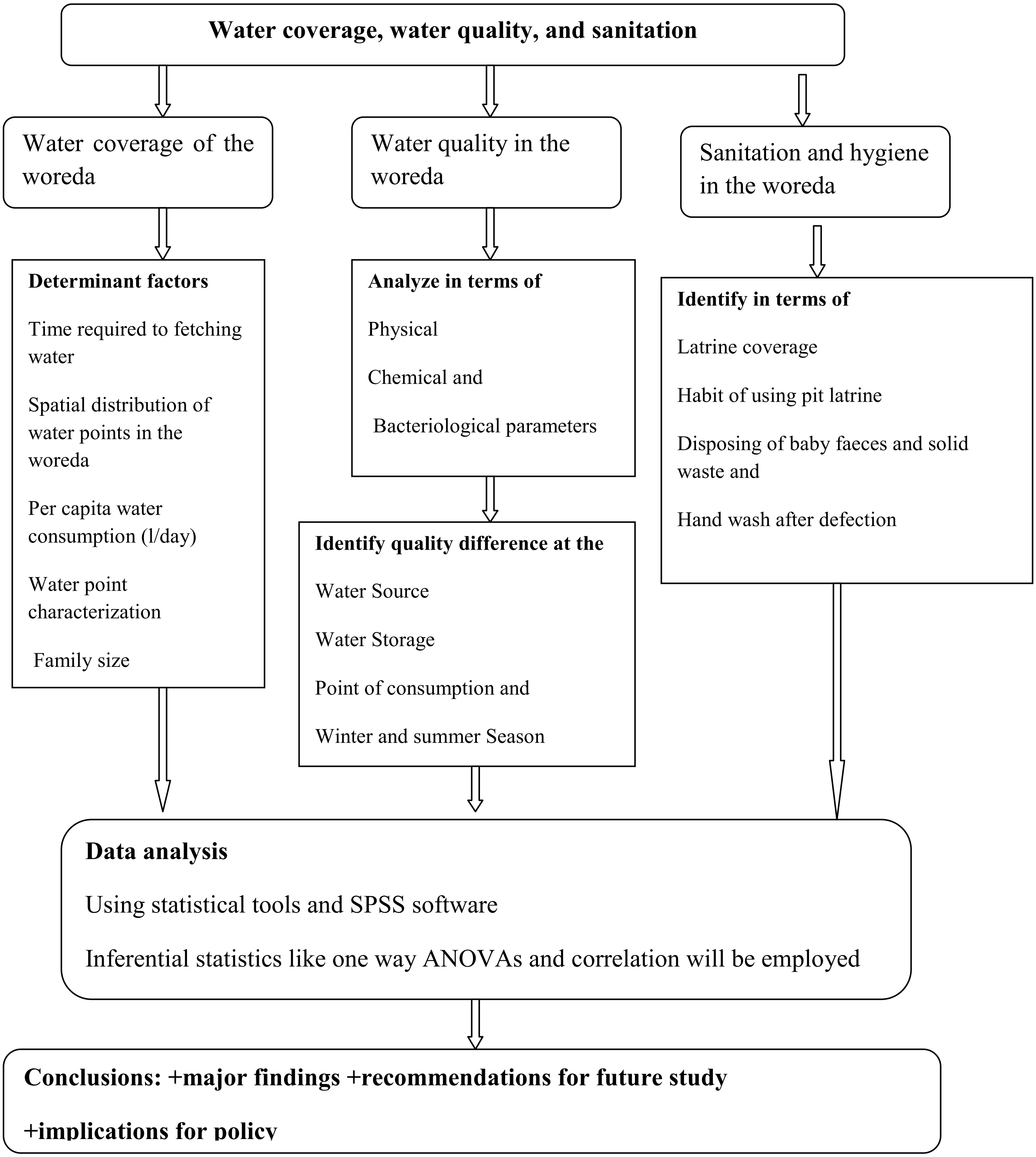

Figure 3-2 schematic representation of the research

3.3 Data sources and collection instruments

Multiple data gathering instruments are employed to collect data for this study. The questionnaires were both close and open-ended questions. The close ended questions are meant to capture direct answers from the respondents, while the open ended questions are to arrive at relevant information that could not be obtained by the close ended questions. The questionnaires are supported by personal in depth interview and transect walk. Structured and unstructured interview, personal observation and document analysis are the principal means of gathering the data used in the study. The researcher supervised and managed the interview of the key informant. Interviewers are recruited and given short-term training, so that they would collect the primary data using structured questionnaires. The water source/points of the Woreda, the spatial distribution of water source/point of the whole Woreda and the study area location were carried out using GPS and Arc GIS software.

3.3.1 Primary data collection

Primary data were collected from the respondents by using household survey, key informant interviews and personal observations (structured and unstructured interview) of water supply and sanitation conditions of the study area.

A. Household survey

For the evaluation of rural water supply systems, four indicators have been taken in to consideration according to the guidelines of WHO (2004). These indicators mainly focused on water quantity and quality supplied to users, the accessibility for continuity supply of the water supply system, convenience of the water sources. In addition to this, access to water supply, operation and maintenance, hygiene and sanitation and community participation were addressed through the questionnaires. The author with the help of assistants physically administered the questionnaires and pretesting was made before the data collection. Totally four research assistants were selected one for each kebele to interview. The research assistants selection are based on three criteria a) previous involvement in administering interview, b) Understanding of the local language and c) College/university graduates. The researcher briefed them on the purpose and process of the research, guided them throughout the research process.

B. Key informant interview

Key informants interviews were carried out to collect background information on institutional set up, operation and maintenance, causes of non-functionality of the schemes, coverage of water supply and sanitation situation of the Woreda. The interviews were held with selected individuals of Woreda and Zone water office experts who were believed to have good knowledge about the subject matter and experience.

C. Personal observation and site visits

It was employed to observe and record the status of water supply at water points. Photographs is a part of the assessment instruments to pick up the status of different water supply schemes. Field observations using structured checklists and unstructured interview administered. Observation can be used as a supportive or supplementary technique to collect data that may complement or set in perspective data obtained by other means. These are basically carried out at the water points and households of the locality. Data for the observation include mainly protection mechanism like presence of fence, guard, appropriate and fixed time of fetching, problems related with service structures, presence of latrine and its situation.

3.3.2 Secondary data collection

Secondary data is collected from different data sources such as publications, research documents and reports of various organizations. A detailed literature review of the related documents on water supply system, quality and sanitation made. The purpose of the literature study is to see what have been done before and what the gaps were hither to so that the researcher able to come up with theories, which used to make analytical generalizations of the empirical data to be collected.

3.3.3 Sampling techniques

For this study, from the 26 rural kebele administrations in Aleta Chuko Woreda 4 Kebeles of the Woreda were selected using purposive sampling techniques for household water use pattern and sanitation. Aleta Chuko Woreda has two agro-climatic zones from which 42% are kolla, and 58% are Woinadega (ACRAS, 2016).

Accordingly, four Kebeles were selected for this purpose Dongora Elelcho and Rufo Chancho from ‟Kolla‟ kebeles , Gure and Makala kebeles were selected from Woinadega agro climatic zone.by simple random sampling in order to have representative sample based on availability of water supplies and consideration on agro-climatic zonation.

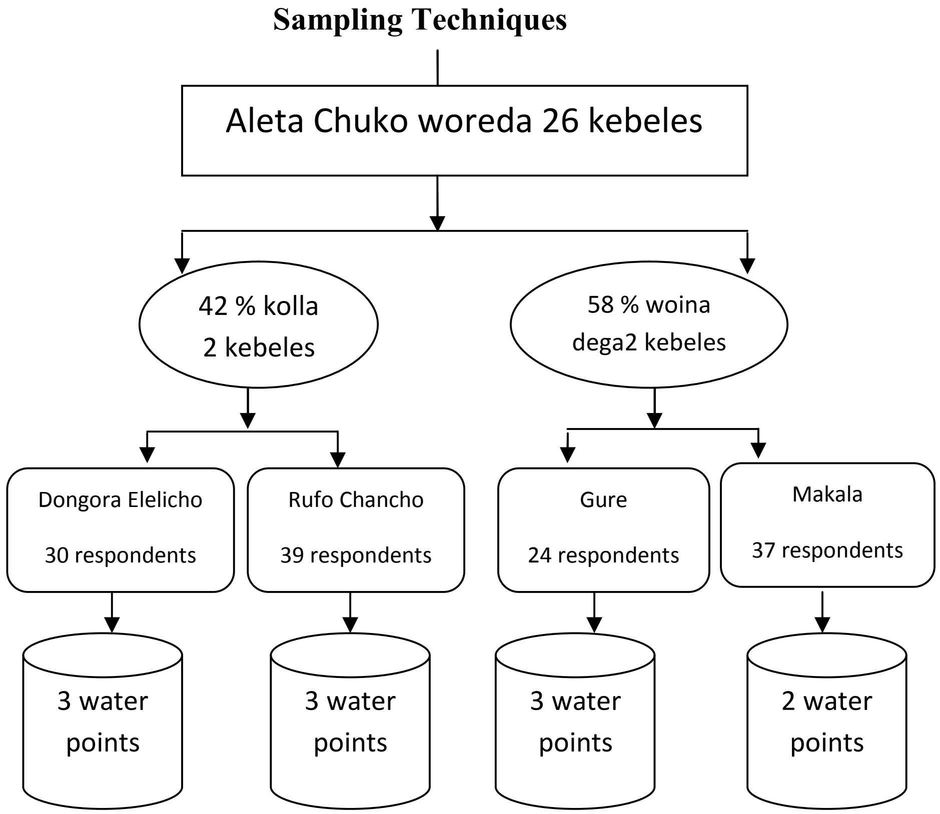

Figure 3-3: Schematic illustration of sampling techniques.

3.3.4 Sample size determination

Beneficiaries were the main primary data sources in this study. In order to ensure the generalization of the finding to larger population, the study considered adequate sample respondent for selection through appropriate techniques. The number of sample HHs for interview were determined by using the formula developed by Cochran (1977).

$$n' = \frac{z^2pq}{d^2} \text{ ………………… eq. (1)} \quad \text{and} \quad n = \frac{n'}{1+\frac{n'-1}{N}} \text{ ……………...... eq. (2)}$$

Where, n' = desired sample size when the population > 10,000

n= N° of samples size when the population < 10,000

Z= 95 % confidence level corresponding z-value is 1.96

P= 0.05 q = 1 - 0.05 i.e. (0.95)

N= total number of HHs (4301)

d= margin of error or degree of accuracy (0.05).

Since the populations (HHs) of the kebele involved in the study area are less than 10,000. Both equations (1 and 2) are used to determine the sample size required for this study as shown below:

$$n' = \frac{z^2pq}{d^2} = \frac{(1.96)^2 x\,(0.05)x(0.95)}{(0.05)^2} = 73 \text{ then,} \quad n = \frac{n'}{1+\frac{n'-1}{N}} = \frac{73}{1+(\frac{72}{4301})} = 72$$

Sample size required (n) in the study area was based on the above formula is 72 HHs, but for better representation the number of HHs will be increased from 72 to 130 HHs. Therefore, the total sample size of the study area is 130 HHs.

Table 3-1 Total number of Sampling HHs for Target area

No.	Kebele	Village	Total HHs	Sampling HHs
1.	Dongora Elelicho	Lela	992	30
		Mulisa		
		Hanado		
		Waade		
		Cawa		
2	Rufo Chancho	Rufo	1278	39
		Chancho		
		Sike		
3	Gure	Gibito	805	24
		Negasha		
		Elelicho		
4	Makala	Shola	1226	37
		Bansha		
		Makala		
	Total		4301	130

3.4 Model specification to identify determinants of household water coverage

In this study, econometric model analysis were used to estimate relationship among demographic, economic, institutional and natural variables. Explanatory variables include selected socio-economic and biophysical factors that were assumed to influence water coverage of rural household in the study area. Changes in the dependent variables were explained by reference to changes in the explanatory variables. The available water consumption litre per capita per day of each sampled household was used as the dependent variable. The household water coverage determinants have done following the regression techniques in linear form. Because a linear regression model different from the logistic regression model is that the outcome variable in linear regression is continuous. Multiple regression analysis is more amenable, because it allows us to explicitly control for many other factors, which simultaneously affect the dependent variable. Furthermore, multiple regression models can accommodate many explanatory variables that may be correlated (Gujarati, 2004).

In the same reason multiple regression analysis has been applied by a number of other researchers in household water supply coverage studies such as Meseret (2012), Rashim and Sanatan (2013), Ashalew (2009) and Tarekegn (2014) among others.

3.4.1 Multiple linear regression analysis

Multiple Linear Regression (MLR) analysis is a statistical procedure that was used to examine more closely the relationship between a number of independent (explanatory) variables and the dependent (response) variable by fitting a linear (in the parameters) equation to observed data. The goal of MLR is to find an equation that can predict the dependent variable as a function of several independent variables (Coelho-Barros et al., 2008). The MLR equation, given n observations, given by:

$y_{i=\beta o+\beta_1}x_{1i}+\beta_2x_{2i}+\ldots+\beta_kx_{ki}+\in i$------------------------ (3.3)

Where, y is the dependent variable (water consumption litres per person per day). x_1, x_2, …..x_k are the independent variables (time required to fetch water in minute, functionality of the water supply schemes, purpose of using potable water, habit of household water use, income level birr per month, education, point characterization, consumer satisfaction, distance to the scheme in meter and size of household in number).i index the n sample observations. β_0 is the y intercept (the value of y when all of the explanatory variables x_1, x_2..., x_k are equal to zero). β_1, β_2, …, β_k are the estimated multiple regression coefficients (each regression coefficient represents the change in the dependent variable relative to a unit change in the respective independent variable) and the term ε is a random error term (Gujarati, 2004). The existence of multicolinearity problems were checked before entering the selected variables in to the model interms of variance inflation factor (VIF)for continuous and contingency coefficient for dummy and discrete variables, respectively. The reason for this is that the existence of multicolinearity affects seriously the parameters estimated.

3.4.2 Dependent variable for household water coverage

The dependent variable, water consumption liters per capita daily, were obtained by asking the total daily water consumption of the HH for different uses and dividing it by the number of people currently living in the family. HHs in rural area use bucket, clay jars (clay called ‘Ensira’ /‘Madiga’) or plastic jars ‘Jerikan’ to take water in to the house. It hypothesized to be a function of the following variables.

3.4.3 Independent variables for household water coverage

Time required for fetching water/waiting time:-It is the time it took/waiting time at the water source to fetch water. This implies that the more waiting time at the source and the longer one must queue, the less water from that source will be used (Gazzinelli etal., 1998). Thus hypothesized that the time for fetching water were negatively related to the quantity of water use.

Distance of water supply schemes:-Used to estimate how the water points/sources are spatially distributed in the Woreda. This means that those households located nearer to the water source are likely to use water more than others located farther away are. In a review conducted by Howard & Bartram (2003), it was revealed that distance is a crucial factor in determining access to water facilities. The further away the source of water is to a household, the less water consumed.

Household size:-The household size increase, the amount of water used per person per day significantly decrease. This implies that there was a negative relationship between household size and water consumption per capita (Aschalew, 2006).

Habit of household water use:-Household’s water use perception and attitude about water supply schemes and quality treatment. Adequate protection of the water sources improves the quantity and quality of water from the sources.

Consumers’ satisfaction:-Is the satisfaction of service takers using different indicators. Satisfaction with the quantity and quality of water namely; color of water, taste of water, smell, hardness of water, amount of water, time given for water service a day and general service of water points could be the main ones to mention.

Water point characterization:- is the character of water supply schemes namely either its micro schemes or macro schemes, catchment character of the scheme, source/points get prediction during dry and wet season.

Income:-The literature has shown a positive relation between wealth and water use.The wealthier families use more water per day.It assumed that poverty negatively affects water use because poor people cook less and often have less clothing to wash (Rashim and Sanatan, 2013).

Purpose of using potable water:-Water for multiple uses seems to depend on the capacity /quantity of water supply schemes. Some of the multiple uses are Drinking and cooking, washing clothes and bathing, animal watering and small irrigation.

Functionality of the schemes:-Technical preferences are likely to have effects on the sustainability of water facilities. Water source protection and maintenance taking into account both the operational status of water services and structural conditions as a whole. Together with construction of new drinking water and sanitation schemes to cover additional people deprived of the facilities, it requires maintaining functionality of the existing schemes for ensuring they serve the designed populations for the design period and possibly beyond.

Education: -It expected that, as the level of education increases among household members, the level of household awareness about the health benefits of water use (quantity and quality) also increases and water consumption per capita decrease (Rashim and Sanatan, 2013). Thus hypothesized that education level will affect negatively water consumption per capita.

3.5 Water Quality assessment

3.5.1 Sample Size

Temporal and spatial variation of water quality analysis are very important for the water sampling points to evaluate the water quality changes at different seasons and one sampling point to the next sampling points respectively.

To analyze selected physico-chemical and bacteriological parameters 11 major sampling points were selected to each of water source quality, storage quality, point of use quality and season based on the public complaint on the water quality.

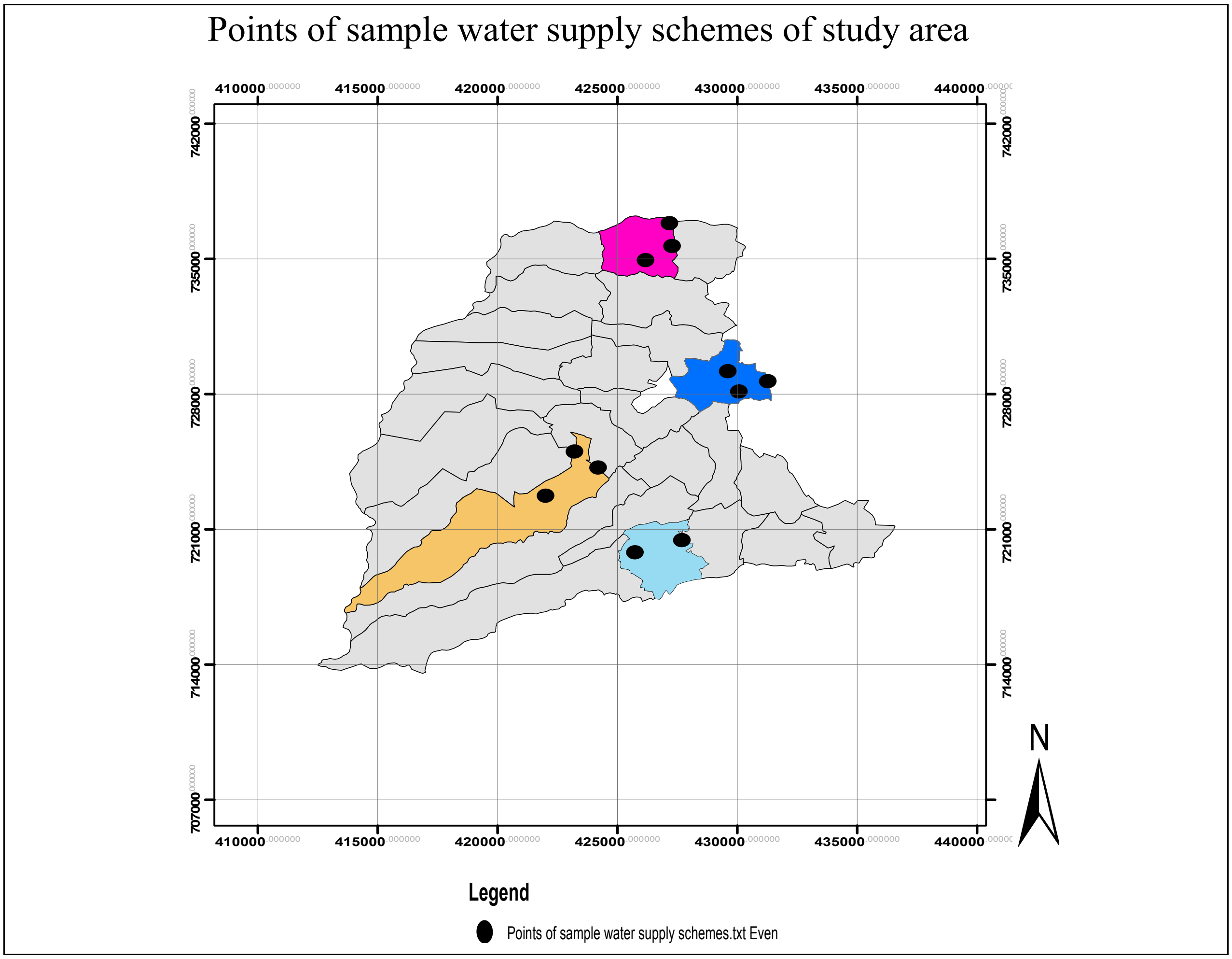

Figure 3-4 Water source/point mapping of the study area.

Table 3-2 Sampled water supply schemes for quality analysis

S. No	Sampling kebele	Existing water supply scheme	Sampled Water supply schemes	Total water supply scheme
1	Dongora Elelicho	1 On spot spring	1 On spot spring	3 water supply schemes
		1 Hand dug well fitted with hand pump	1 water point from hand dug well	
		1 Deep wells with 4 distribution points	1 water point from deep well	
2	Rufo Chancho	2 On spot spring	1 On spot spring	3 water supply schemes
		2 Hand dug well fitted with hand pump	1 water point from large spring	
		1 Deep wells with 7 distribution points	1 water point from	
3	Gure	3 On spot spring	1 On spot spring	3 water supply schemes
		17 Hand dug well fitted with hand pump	1 water point from large spring	
		1 Deep wells with 9 distribution points	1 water point from	
4	Makala	2 On spot spring	1 On spot spring	2 water supply schemes
		12 Hand dug well fitted with hand pump	1 water point from large spring	
			11 water supply schemes will be taken	

3.5.2 Water Sampling Procedure

Samples were collected in 1000ml polyethylene plastic bottles for different parameters from 11 sampling points. Triplicate water samples from each sampling sites were taken and analyzed for selected physio-chemical and bacteriological parameters. Water sampling and preservation techniques followed the standard methods of water sampling and preservation techniques (APHA, 1998; Hutton, 1996). Before collection, bottles were washed with concentrated nitric acid and distilled water to avoid contamination. The water samples were handled aseptically in sterile glass bottles, labeled and kept in an ice-box during transportation to the laboratory of school of Bio-system and Environmental Engineering Hawassa university for physicochemical quality analysis and bacteriological quality analysis.

Bottles were preserved using icebox and a water samples from sample sites of the study area were taken and studied for the selected physicochemical and bacteriological parameters. The water samples analyzed for both physicochemical and bacteriological parameters are listed in Table 3.2.

Table 3-3 Major Physiochemical and bacteriological parameters for the water sample

S. No.	**Physicochemical parameters**	**Bacteriological parameters**
1	PH	E.coli/Thermo tolerant coliform bacteria
2	Temperature	
3	Electrical conductivity	
4	Turbidity	
5	Total hardness	
6	Nitrate	
7	Chloride	
8	Fluoride	
9	Iron	
10	Manganese Phosphate	
11	Total /residual/free chlorine	
12	Total dissolved solids	

3.5.3 Method of water quality analysis and instruments

A. Analysis of Physico-chemical Parameters

Turbidity of collected water samples were measured by digital turbidity meter 2100A instrument, in which international standard samples with different turbidity ranges were observed from the reading instrument. EC and pH were measured by EC meter (JENWAY4200) and pH meter (JENWAY 430) respectively. EC meter were calibrated by using 0.01N KCl and pH meter were calibrated by buffer standards of pH of 4 and 7. Total solids and total dissolved solids (TDS) were determined by putting 50ml water sample to the crucible and put on the oven to vaporize the collected water and measuring the remaining solids on the crucible. Determination of total hardness and free residual chloride will be carried out by titration methods by which 0.02N of H2SO4, AgNO3, or EDTA used as a titer. Nitrate and Fluoride amount of the collected water sample were analyzed calorimetrically using HACH DR/4000 spectrophotometer by keeping their reaction periods and analytical reagents. A colorimetric method can be used to determine free chlorine in water at concentrations of 0.1–10 mg/liter.

B. Analysis of Bacteriological Parameters

Escherichia coli (or, alternatively, thermo tolerant coliforms) are generally measured in 100-ml samples of water. The procedures include membrane filtration followed by incubation of the membranes on selective media at 44°C to 45 °C and counting of colonies after 24 hours.

Composite samples were used to improve the precision of the estimated average contaminant concentrations. In the laboratory, the three samples from each site were mixed into one and a composite sample were subjected for membrane filter analysis of fecal coli forms (TTC). The composite samples were mixed thoroughly by shaking and filtered under laboratory hood, using WagTech Membrane Filtration apparatus and membranes, pore size 0.45µm, 47mm diameter, sterile and gridded. The membranes were transferred aseptically to m-FC agar with rosolic acid in glass Petri dishes for TTC. Prepared culture dishes were inverted and incubated for 24h at 44.5°C. Upon completion of the incubation period, typical blue colored for TTC on the surface of membrane filter were counted using a low power binocular wide field-dissecting microscope, with a cool white fluorescent light source for optimal viewing sheen.

3.6 Assessment of Sanitation Condition of the Woreda

In order to assess the sanitation condition of the study area, an interview were conducted with structured questionnaire. Accordingly, data related to sanitation and hygienic condition like toilet availability and type, hand washing facility and disposal of waste was collected from the households. The questionnaire was supported by household survey, key informant interview and personal observation.

3.7 Data Analysis

After gathering the data, relevant statistical methods of analysis were used in order to come up with the appropriate result. The results were presented in both quantitative and qualitative terms. The SPSS and statistical tools like percentages, arithmetic means, min, max, standard deviation, ratios, tables, maps, histograms, bar graphs, pie charts, time series graph and explanation building descriptive statistical methods and graphs were used to analyze findings. The inferential statistics like one way ANOVA and correlation were employed to see the statistical significances and associations of the variables respectively. Deduction were made from these measures and compared with the existing literature to arrive at the conclusion of the study. Results of water quality analyses of the source, storage and point of use(consumption) and two season were compared against standards set by WHO (2008) and the Ethiopian drinking water quality standards (ES, 2002).

4. RESULTS AND DISCUSSION

4.1 Household water use and collection

Domestic water use patterns are generally similar in the study area regardless of the type of the water supply schemes and the distances covered to reach it. The main uses of water in the households in the study area are drinking, cooking, and washing clothes and other activities like watering animals among others. All respondent households were using the water supply for drinking and cooking, for washing 76 %, for livestock watering 61% and for small irrigation 14.6%. While the fundamental priority of water use from the improved water sources is for human consumption. At many of the protected springs, the taps are used not only for domestic water needs but also for animal watering and small irrigation. These findings agreed with previous research in Tehuledere Woreda, northeast Ethiopia by Seid et al (2013) and in WA, Ghana by Joseph (2013).

Table 4-1 Different purposes for which respondents use water

S. No	Purpose of using water	Frequency	Percentage
1	Drinking and cooking	130	100
2	Washing clothes and bathing	99	76
3	Animal watering /livestock	83	61
4	Small irrigation/ for vegetable production	19	14.6

Households' reported that the individuals who were responsible for fetching water, mostly women, travel on average 2 times in a day to the water sources/points on normal condition. The average household water use in Dongora Elelcho is 39 litres/day, Rufo Chancho 30.13 litres/day, Gure is 37.92 litres/day and Makala is 41.9 litres/day. The maximum and minimum amount of household's water use in study area is 80 liters/day and 15 liters/day respectively. The average water use in study area is 36.96 litres/day and the standard deviation was 13.2 litres/day. However, this varied per household depending on the household size, the distance to the water point and the waiting time at the water sources/points. This finding was much lower than previously reported research in Tehuledere Woreda, northeast Ethiopia, (i.e., about 29 and 25 litres per capita per day in the rainy and dry seasons, respectively (Seid etal., 2013).

Table 4-2 The average water consumption of respondents in litres per household per day.

S. No	Statistical parameters	Dongora Elelcho n= 30	Rufo Chancho n= 39	Gure n= 24	Makala n= 37	Total N=130
1	Minimum	15	15	20	20	15
2	Maximum	60	50	70	80	80
3	Average	39	30.13	37.92	41.9	36.96
4	Standard deviation	12.48	9.87	12.24	14.25	13.185

4.1.1 Time required for fetching water

The respondents in the study area were asked to give information on the time it took them to fetch water from water supply schemes. Although the values obtained were not based on accurate measurement it is roughly used to estimate the time taken from rural water supply services. The researcher was so careful about over estimation and under estimation. The minimum and maximum time to fetch water from the supplied services including waiting time varies from 15 to 20 minutes and 100 to 120 minutes, respectively, with a mean duration varies from 64.33 to 84.49 minutes and standard deviation of 24.81 minutes. The mean duration to fetch water from the supplied services includes the time required for round trip from beneficiaries and waiting time at the water supply schemes. The standard deviation indicates there is great difference among the households for water fetching time. The time taken to fetch water from protected facilities in this study exceeded the guide line value recommended by WHO(2008),which is set at 15 minutes of walking distance, equivalent to a distance of about one kilometer.

Table 4-3 The average time to fetch drinking water

S. No	Statistical parameters	Time taken in minutes to fetch water				
		Dongora Elelcho n= 30	**Rufo Chancho n= 39**	**Gure n= 24**	**Makala n= 37**	**Total N=130**
1	Minimum for the scheme	20	20	15	20	15
2	Maximum for the scheme	110	120	100	110	120
3	Average for the scheme	64.33	84.49	70.83	68.11	72.15
4	Standard deviation	23.92	21.58	25.31	25.06	24.81

4.1.2 Water consumption (liter per capita per day)

All the households use ‘’jerrycans’’ to collect water; these jerrycans typically hold 20 litres. Children also use smaller jerrycans, 5 - 10 litres. The respondents were asked to tell the average number of litres in terms of “jerrycan” that their family used per day due to unfamiliarity of measuring in litres besides their inability to tell the amount in liters. The consumption per capita of water in a respondent’s household were then calculated by multiplying the number of “jerrycan” used per day with the amount of litres it contains and then dividing the result by the household’s family size. According to table 4.4, the volume of water used by litres per person per day ranged from 3 to 13.33 litres and the average water consumption per capita ranges from 6.01 to 7.61 litres and less used by the majority. This was significantly different from WHO guideline value set at least 20 litres per capita per day (WHO, 2008 and Webster et al., 1999).Inadequate drinking water adversely affects personal hygiene, clean food preparation and housing sanitation, hence favoring the transmission of water borne and water washed communicable diseases. Almost 100% of residents consume less than 20 litres of water in a day, as indicated in the table 4.4. The standard deviation was found to be 1.82 litres implying there is great variation in the pattern of water consumption per person per day among different households in the study area. Highest average values were recorded in Gure kebele and the lowest average value was recorded in Rufo Chancho kebele. According to Wallingford (2003), a minimum quantity of 25 l/capita/day domestic water supply is categorized as basic level of service. With regard to this value, the current average domestic water consumption of Aleta Chuko Woreda was not satisfies basic level of service to the people.

Table 4-4 Water consumption in litres per capita per day.

S. No	Statistical parameters	Amount in litres per person per day(l/c/d)				
		Dongora Elelcho n= 30	**Rufo Chancho n= 39**	**Gure n= 24**	**Makala n= 37**	**Total N=130**
1	Minimum volume	3	3.33	3.75	4.29	3
2	Maximum volume	10	10	12.5	13.33	13.33
3	Average volume	6.45	6.01	7.61	6.63	6.58
4	Standard variation	1.63	1.66	2.11	1.71	1.82

4.1.3 Habit of household water use

Water treatment is essential to improving water quality, which reduces risks of water borne diseases (WHO, 2003). According to the consumers' responses 92(70.8%) collect water which is in contact with their hands and majority of them 82(63.1%) have no separate water containers in their home to store it from the water used for other purposes. Most of them 99(76.2%) did not use any particular treatment at home before use. Although some people use water treatment in their home, general water treatment for all household basic needs is still limited in study area. Poor sanitation and poor hygiene were the main effects of the contaminated water during transportation and after storage in household. This finding was in agreement to the studies conducted elsewhere in Ethiopia (Dagnewet al., 2007 and Mengeshaet al., 2004). The results of sanitation and hygiene practices of the consumers at the households are shown in Table 4.5.

Table 4-5 Sanitation and hygiene practice of consumers.

S.No	Questions reflected to the consumers	Yes		No	
		Frequency	%	Frequency	%
1	Separate container for storage of drinking water	48	36.9	82	63.1
2	Have no contact with hand	38	29.2	92	70.8
3	Particular treatment for drinking water	31	23.8	99	76.2

4.1.4 Water supply system and consumer's satisfaction

It is a known fact that the water supply denation available to the customers in a day is an indicator of reliability of the water supply system, which in turn has a significant bearing on consumer attitudes. Consumer satisfaction can be accessed from service takers in different ways using different indicators. Satisfaction with the quality of water namely: color of water, taste of water, smell, hardness of water, amount of the water, time given for water service a day, general services of water points, whether they stand in line for long period of time to collect water could be the main one's to mention.

As UNDP (2005) noted control of water variability is important because poverty stricken and vulnerable households can have devastating effects in case of water related events like droughts and floods. With this regard, the survey found that only 22(16.9%) of respondents are satisfied with the provided amount of water, 94(72.3%) are satisfied with the quality of water namely taste, color, smell and hardness of water. This community satisfaction is a tool for the overall water supply services and projects. When the respondents were asked to tell the period through which the quantity of water supplied was not adequate to fulfill their demand, they specified the period i.e. during mid-day (4-10 o'clock) through which low quantity of water was obtained and 36(27.7%) of them complained the inconvenience of the water quality. The former problems most pronounced in two kebeles of the study area namely Dongora Elelcho and Rufo Chancho. A study carried out by Gulyanietal(2005) indicated that service availability, apart from easy access, strongly influences household water satisfaction. However, in the study area, water is available for limited time intervals. As a result, consumers were not satisfied with the duration of water availability in a day.

4.1.5 Water points characterization, their current status and coverage

There are two types of rural water supply schemes in the study area. The micro schemes are defined as those rural water schemes comprising point source supplies such as hand dug well equipped with hand-pumps, collection tanks, stand posts and protected springs whilst macro schemes are those schemes such as, gravity schemes or point sources with collection tanks supplying more than four communal standpipes (GOS, 2003).Springs, shallow wells, hand-dug wells and deep well were the main source of water for household used in the study area. Where the schemes are functional. When the protected springs, hand dug wells and shallow wells were not functional: unprotected springs and rivers were mentioned as alternative sources of water used by the respondents, as 14(10.77%) of the respondents in the study area were using rivers. This is the main problem in kebeles where the sources/water points were not functional or when the sources/ points get unpredictable in dry (Jan–March) time. The working hours of the sources/water points fall during this period and ease of use of water is erratic. These kebeles confront water scarcity due to non-functionality or abnormality of existing water supply schemes especially in Dongora Elelcho and Rufo Chancho kebeles. The normal maintenance period for a water facility as recommended by MoWR (2007) is 2 to 3 days. The long maintenance period observed to be in excess of 3 months during the study period might contribute to the non-reliability of water services in the study area. Observation and field visit result showed that most of the water points are not neat at all as demonstrated by poor drainage and water stagnation, bad smell and in some of the sources by the presence of livestock waste. Some of them have functional guards. Catchments rehabilitation with the aim of increasing ground water recharge was done around the surroundings of sample water supply schemes was only 5(45.5%). An illustration of sampled water points in the study area are shown in the following figures.

As far as water supply services are concerned ,some development activities has been done by Zonal, Woreda water resources office and NGOs to alleviate the problem of potable water in the Woreda. However, the problem of potable water supply is still very sounding in the Woreda. In addition to this the existing water supply schemes are characterized by very low service coverage, limited service over the day from public distribution points, poor operation and maintenance as specified by key personnel and site observation. In relation to this, the following adverse conditions were identified as problems related to operation and maintenance functions of

Woreda Water Resource Development Office; lack of awareness of beneficiaries, lack of spare parts, design problem, poor financial management, inadequate planning, lack of preventive maintenance and lack of trained personnel who fully understand how to operate the systems and low capacity of the schemes to satisfy the demand are the main ones. As per the official data of Woreda Water Resource Office, 6 hand dug well, 39 shallow well, 2 on-spot spring and 4 bore hole are non-functional. Hence, in the Woreda 77.3% of the water sources/points are functional, 22.7% of them are not functional. The Ministry of Water Resources estimates that 33% of water supply schemes in Ethiopia are non-functional at any time, with negative impacts on coverage and universal access due to lack of funds for operation and maintenance, inadequate community mobilization and commitment and a lack of spare parts (MoWR, 2007 and Moriarty etal., 2009).

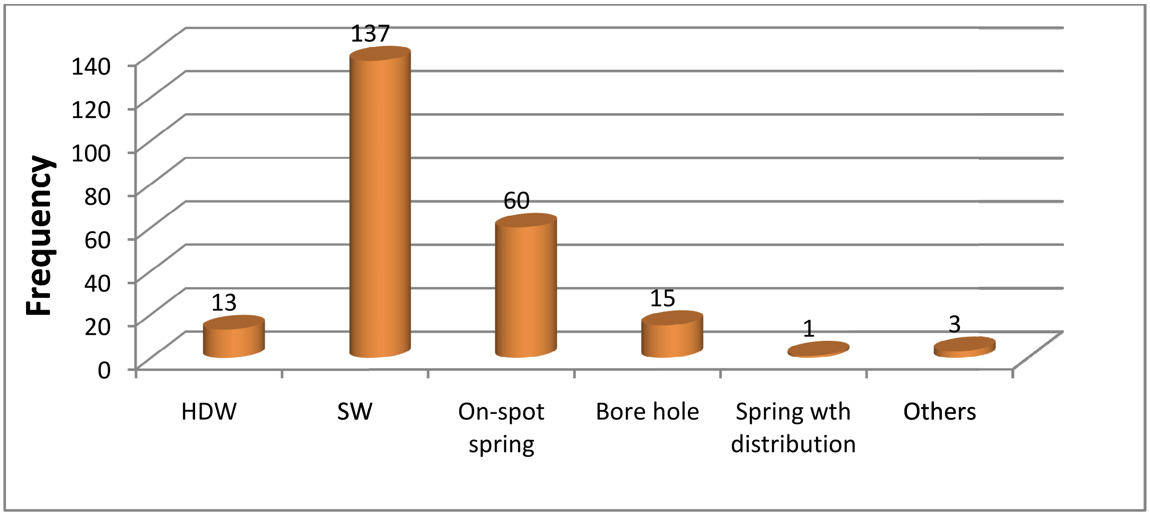

Figure 4-1 Schematic representations of types of schemes in the Woreda.

4.2 Factor analysis

Attempts were made to identify factors responsible for the determinations of rural household water coverage among the sampled households. Occurrence of strong multicolinearity problems was checked for the continuous explanatory variables prior to estimation of the model using VIF and contingency coefficient. The result showed there was no strong multicolinearity problems among the explanatory variables included in the model (Appendix 4).

The MLR model result showed that the coefficient of determination i.e. the adjusted R-values was 0.991. This implies that about 99.1% of the variation in the dependent variable is explained by the variation of the independent variables, indicating relatively high explanatory power of the model (Appendix 2).The econometric results were almost indicating that the homoscedasticity assumption was not violated (Appendix 4).

4.2.1 Determinants of household water coverage

The result indicated that, out of the 10 hypothesized variables which were included in the multiple linear regression models four variables were found to be statistically significant to influence the household water coverage(Appendix 4).These are functionality of water supply schemes, distance to the schemes, time required to fetch water and size of the household(Table 4.6).

Family size:-Family size was statistically significant at 1% probability level and had a negative coefficient of 0.813, which implies that for every increase in an individual in a household, water coverage decreases by 0.813 water consumption litres per capita(Table 4.6). Larger family size has a negative impact on household water availability. That means when the size of family members increase the household was less likely to be water covered. A study by Ashalew (2009) also found a strong negative relationship between family size and household water coverage respect to water consumption litres per capita. Another study by Meseret (2012) said,for every one-unit increase in the household size there is a decrease in the water consumption per capita by 1.9 times in urban and 1.7 times in rural areas.

Functionality of the schemes:-The study result showed that functionality of the schemes is positively related with water coverage and statistically significant at 5% probability level. The coefficient of the variable implies that increasing the number of function of the schemes, increases water coverage availability of the households by a factor of 0.295(Table 4.6). Aschalew(2009) pointed out thatone of the daunting challenges in the water supply sector is securing resources to manage and maintain frequently breaking water facilities and keeping the water sources operating ina sustainable manner, which determines rural water supply systems.

Time required for fetching water/waiting time:-Time was statistically significant at 1% probability level and had a negative coefficient of 0.255, which implies that for every increase of time in minute for a household, water coverage decreases by 0.255 water consumption litreper capita per day (Table 4.6). More water fetching time has a negative impact on household water availability. That means when the time required to fetch water increase the household was less likely to be water coverage. A study by Aschalew (2009) also found a strong negative relationship between fetching time and household water consumption per liter. The waiting time at the sources varies from 0 to 120 minutes, with a mean duration of 25 minutes and standard deviation of 23 minutes.

Distance to the schemes:-Distance was statistically significant at 5 % probability level and had a negative coefficient of 0.001, which implies that for every increase of distance in meter for a household, water coverage decreases by 0.001 litre per capita per day(Table 4.6). Larger distance to the water supply schemes has a negative impact on household water availability. That means when the distance required reaching water points the household was less likely to be water coverage .A study by Ashalew(2009) clearly observed that the per capita water use is negatively and significantly determined by the distance of water source from household (i.e., keeping other factors constant, as the distance of a water source from the household increases by a kilometer, the per capita water use significantly decreases by 6.2 liters).

Table 4-6 Determinants of household water coverage model result

Variables	Coefficient	Std. Err	T	P
Education	-.055	.104	-.524	.602
Income level (birr/ month)	.211	.392	.538	.129
Functionality of the water supply scheme	.295	.117	2.519	.014**
Consumer satisfaction	.260	.201	1.292	.200
Purpose of using potable water	-.193	.170	-1.131	.262
Distance to the scheme in meter	-.001	.0003	-2.651	.010**
Point characterization	.046	.180	.257	.798
Habit of household water use	.074	.160	.464	.644
Size of household in number	-.813	.085	-9.543	.000*
Time to fetch in minute	-.255	.026	-9.768	.000*

* Significant at less than 1% probability and** significant at less than5 % probability.

4.3 Water quality at the source, storage and point of use

4.3.1 Physico-chemical analysis for the source, storage and point of use during dry season

Water quality criteria, standards and the related legislation are used to interpret water quality characterization. The most common national requirements are suitability of water quality for drinking and domestic purpose. Many countries base their own standards on the standards of world health organization (WHO) guidelines for drinking water quality (WHO, 2004).

The World Health Organization (WHO), drinking water quality guidelines provide international norms on water quality and human health be used as the basis for regulation and standard setting in developing and developed countries worldwide. These guidelines adopted by many countries as national guidelines to follow. These countries including Ethiopia set drinking water quality guidelines based on the WHO guidelines but may modify these based on what is achievable in the country. The analyzed laboratory result were taken eleven samples from the source, eleven samples from storage(household containers) and eleven samples from point of-use(drinking cup). Totally, thirty-three samples were taken to evaluate the average mean values for selected physico-chemical and bacteriological parameters during dry season of January, then compared with the Ethiopia and WHO drinking water quality standards and interpreted in accordance with the result obtained.

Table 4-7 Mean value of physico-chemical parameters for the source, storage and point of-use during dry season.

Parameters	**Units**	**Source**		**Storage**		**Point of use**		**Standards**	
		Mean	**Std**	**Mean**	**Std**	**Mean**	**Std**	**ES**	**WHO**
Temp.	^{o}C	23.14	2.72	21.42	2.64	21.24	2.74	-	<15
EC	µs/cm	168.4	89.32	157.56	86.84	157.18	86.84	1500	1000
PH	pH	6.89	0.27	6.67	0.3	6.67	0.3	6.5-8.5	6.5-8.5
Turbidity	NTU	1.467	1.01	1.375	0.99	1.367	0.98	7	5
TDS	Mg/l	113.4	59.23	99.83	53.31	97.21	52.2	1000	1000
TH(CaCO3)	Mg/l	75.8	74.54	68.05	70.73	67.19	69.91	300	300
Nitrate	Mg/l	0.015	0.01	0.0134	0.009	0.0133	0.009	50	50
Chloride	Mg/l	7.876	1.03	7.36	0.96	7.29	0.89	250	250
Fluoride	Mg/l	1.288	0.63	1.17	0.6	1.16	0.6	3	1.5
Iron	Mg/l	0.0082	0.0125	0.007	0.011	0.0069	0.0106	0.4	0.3
Magnesium	Mg/l	31.9	24.39	29.24	22.48	29.05	22.45	50	50
Phosphate	Mg/l	0.596	0.216	0.525	0.182	0.523	0.183	0.02	0.005

Temperature

It was one of the physical parameters used to evaluate quality of drinking water. The mean values of temperature for the source, storage and point of-use were 23.14±2.72°C, 21.42±2.64 °Cand 21.24±2.74°C, respectively. Minimum is 18°C from the source of Dongora Elelcho kebele hand dug well and maximum is 27°C from the source of Rufo Chancho kebele on spot spring (Appendix 6,7,8 and 11).

A slightly higher temperature of 25.5°C reported from water source samples than the storage from Nigeria (Agbogu et al., 2006). There was a variation in the mean values of water temperature in most of sampled sites from the source to storage as they have different atmospheric temperature. As a result, the differences in the mean temperature for the source to storage sampled sites were significant at $p< 0.05$ significant level with $p=0.002$ (Appendix 12). Although the mean temperature values of the study area were above the recommended limit of WHO guideline.

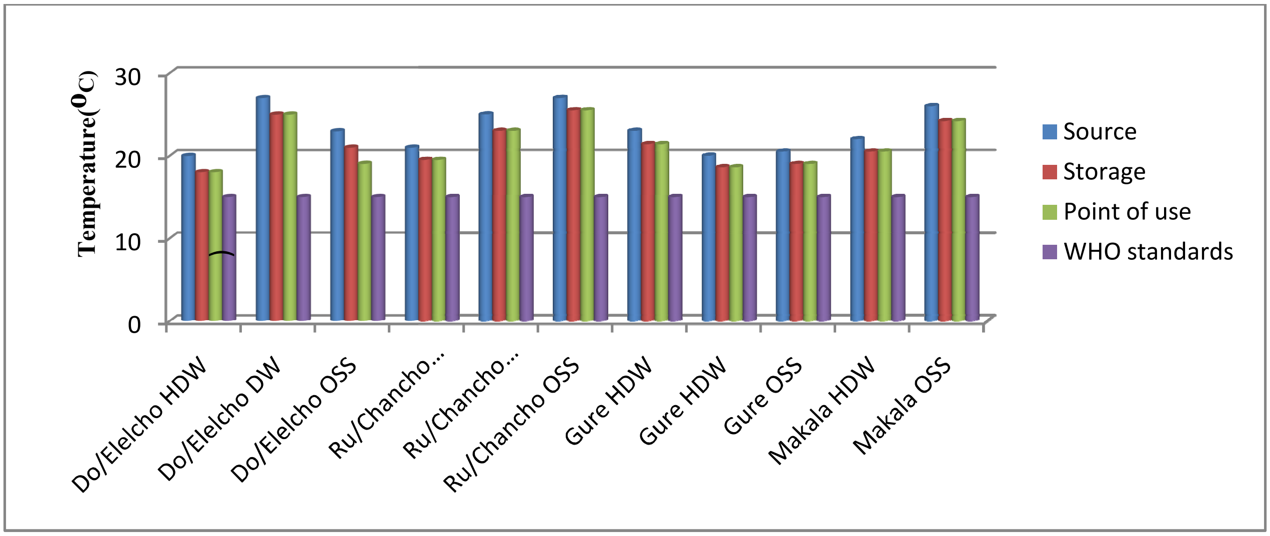

Figure 4-2 The value of temperature at the source, storage and point of-use

pH

The result of laboratory analysis revealed that the mean values of pH for the source, storage and point of-use were 6.89±0.27pH, 6.67±0.3pH and 6.67±0.3pH, respectively. This finding agreed to the ES and WHO standards. Among the thirty three sampled points the maximum pH value 7.55 was recorded in a water sample collected from a hand dug well of Rufo Chancho kebele at the source where as the minimum pH 6.4 was recorded in water sample collected from hand dug well of Dongora Elelcho kebele and on spot spring of Makala kebele. (Appendix 6,7,810 and 11). The study showed that a decrease of the pH value in stored water samples. Normally, the variation in pH is due to nitrates, carbon dioxide or dissolved minerals that normally affect the pH and may related to the bacterial development and activity. This finding agreed with previous research by Achadu et al (2013). However, the differences in the mean pH of the source, storage and point of use sampled sites were not significant at $p < 0.05$ significant level (Appendix 12).

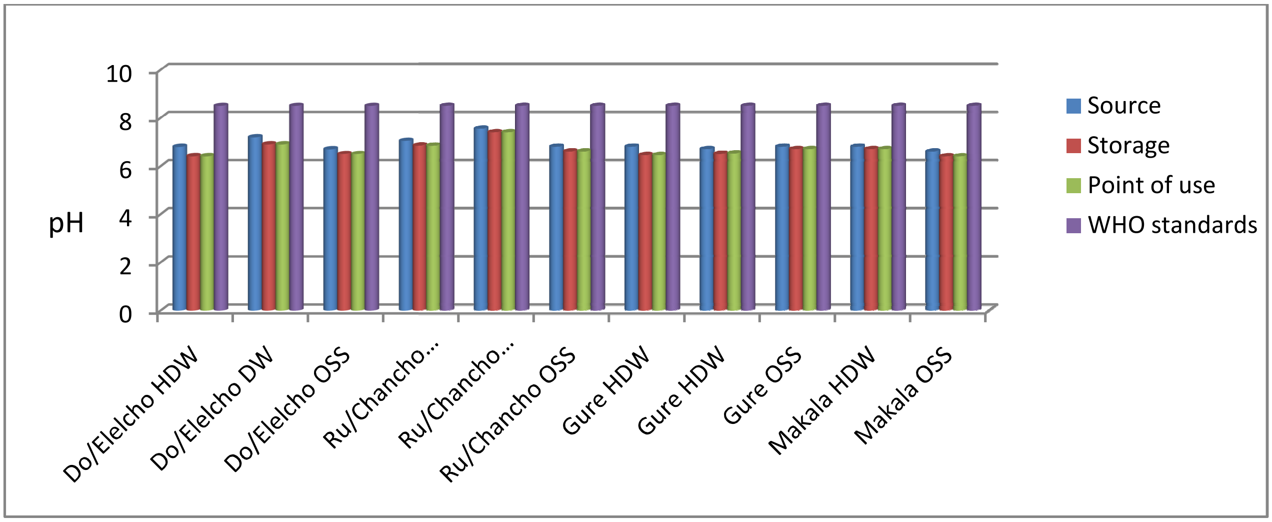

Figure 4-3 The value of pH at the source, storage and point of-use.

Turbidity

Turbidity in drinking water is due to by particulate matter that present from water source of inadequate filtration. These particulates can protect microorganisms from the effects of disinfection and can stimulate bacterial growth (Hunter etal., 2009).Mean value of turbidity for source to storage were 1.47±1.01NTU to 1.375±0.99NTU, respectively. However, the differences in the mean turbidity of the source, storage and point of use sampled sites were not significant at $p<0.05$ significant level (Appendix 11 and 12). The correlation result for the association between turbidity and nitrate revealed that there was a positive relationship between them with the correlation value of 0.856 (Appendix 12). Some forms of primary treatment like coagulation and flocculation, therefore needed to be carried out on this water sources before any disinfection treatment can be done, otherwise, high turbidity values will shield the pathogenic organisms from chemicals and render the treatment ineffective (Hunter etal., 2009).

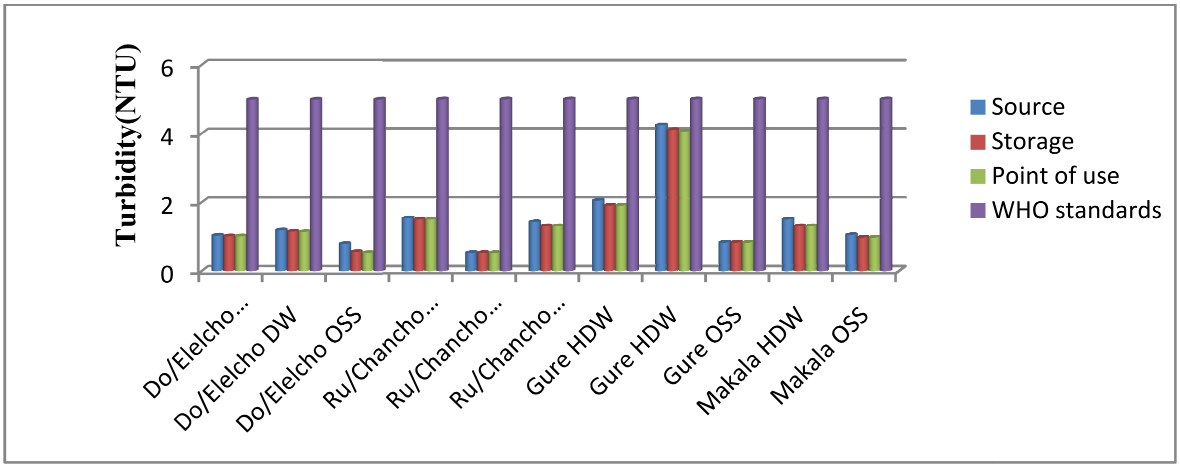

Figure 4-4 The value of Turbidity at the source, storage and point of-use.

Electrical conductivity (EC)

Conductivity is a measure of the ability of water to pass an electrical current and affected by the presence of dissolved solids. Mean value of EC for source, storage and point of-use were 168.37±89.32µs/cm, 157.56±86.84µs/cm and 157.18±86.84µs/cm, respectively. In thirty-three sampled points, EC minimum value was 69.5µs/cm from hand dung well at Gure kebele and maximum value was 329µs/cm from deep well at Rufo Chancho kebele (Appendix 6,8,9 and 11). In fact, the laboratory results showed that decrease of the electrical conductivity level in stored water samples. This is due to conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) and magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Also, when water temperature increases, so will conductivity. For every 1°C increase, conductivity values can increase 2-4% and the reverse is also true (Barron and Ashton, 2005). However, the differences in the mean EC of the source, storage and point of use sampled sites were not significant at $p < 0.05$ significant level (Appendix 12).The correlation result for the association between electrical conductivity and TDS revealed that there was a positive relationship between them with the correlation value of 0.995 (Appendix 13). The analyzed value is in far below the ES and WHO guideline value prescribed for drinking purpose. The EC value was rated under excellent classes for all human, livestock and poultry watering purposes (WHO, 2008),i.e.,<1000 µS/cm.

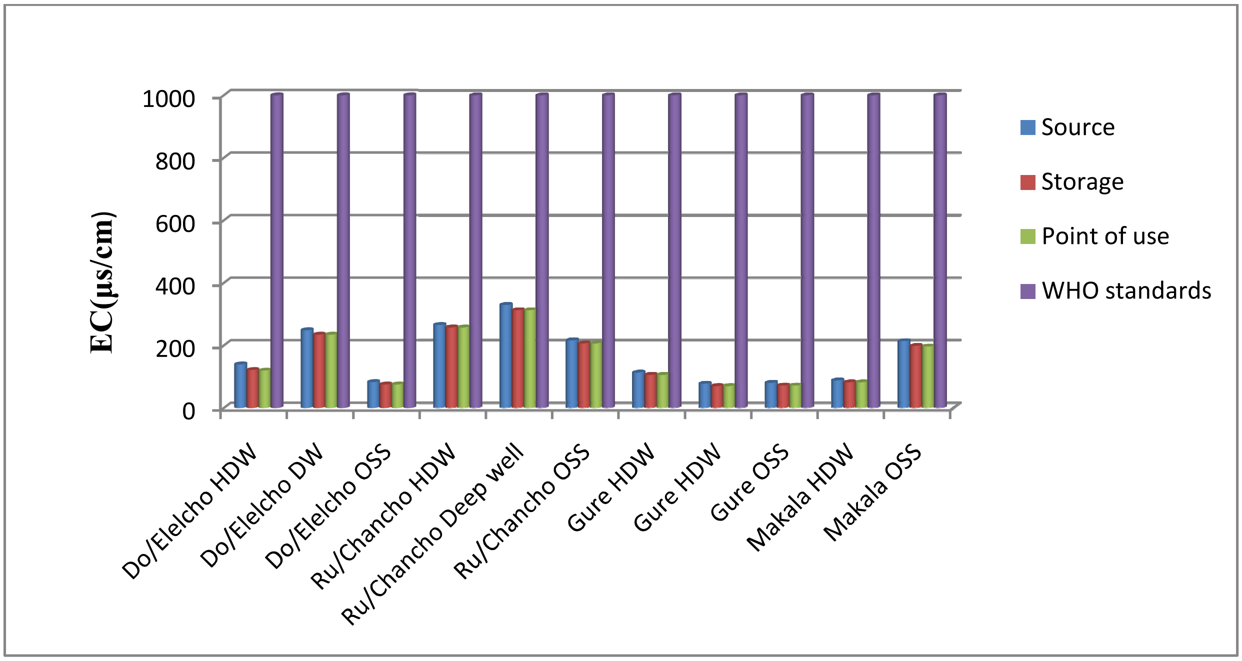

Figure 4-5 The value of EC at the source, storage and point of-use.

Total dissolved solids (TDS)

Total dissolved solids values <1000 considered fresh water and values >1000 mg/l considered brackish water (Dagnewet al., 2007).Mean value of TDS for source, storage and point of-use were 113.4±59.23mg/l, 99.83±53.31mg/l and 97.21±52.2mg/l, respectively. From the result of analyzed samples the value of TDS was found within the acceptable range of WHO and also according to this studied result it is possible to consider the Woreda water supply as fresh water with respect to TDS concentration. The minimum and maximum TDS value obtained on the site were 48.3mg/L to 220.4mg/L at Makala kebele and Rufo Chancho kebele,respectively (Appendix 8, 9 and 11). After storage, it has varied between 33.5mg/l and 81mg/l (Appendix 6). The concentrations of TDS decrease from source to storage.However, the differences in the mean TDS of the source, storage and point of-use sampled sites were not significant at $p<0.05$ significant level (Appendix 12).

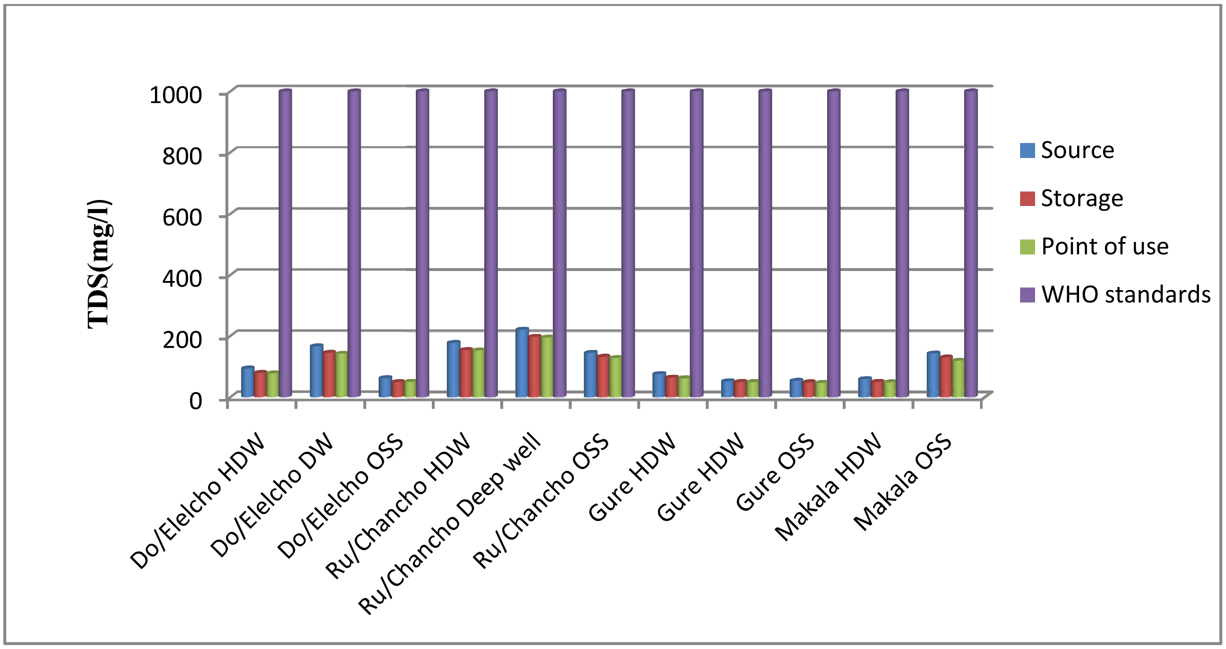

Figure 4-6 The value of TDS at the source, storage and point of-use.

Total Hardness

The result of laboratory analysis revealed that the mean value of TH for the source, storage and point of-use were 75.8± 74.54mg/l, 68.05± 70.73mg/l and 67.19± 69.91mg/l, respectively. The maximum and minimum hardness value recorded from Dongora Elelcho kebele were 281.4mg/l from hand dung well and 5.8mg/l from deep well (Appendix 6,7 and 11).After storage, it has varied between 18 and 85mg/l (Appendix 6 and 7). Total hardness level showed that there is variation from source to storage. The source has high value of total hardness due to high quantity of magnesium or calcium ions on the source than storage and point of-use value. However, the differences in the mean TH of the source, storage and point of use sampled sites were not significant at $p<0.05$ significant level (Appendix 12). This finding agreed with previous research by Douhri et al (2015), i.e. the total Hardness at source varied between 8.17 and 70.31 (mg/l) and between 8.06 and 60.90 (mg/l) after storage. The entire analyzed sample has their total hardness values far less than the recommended limit of both Ethiopian and WHO standards.

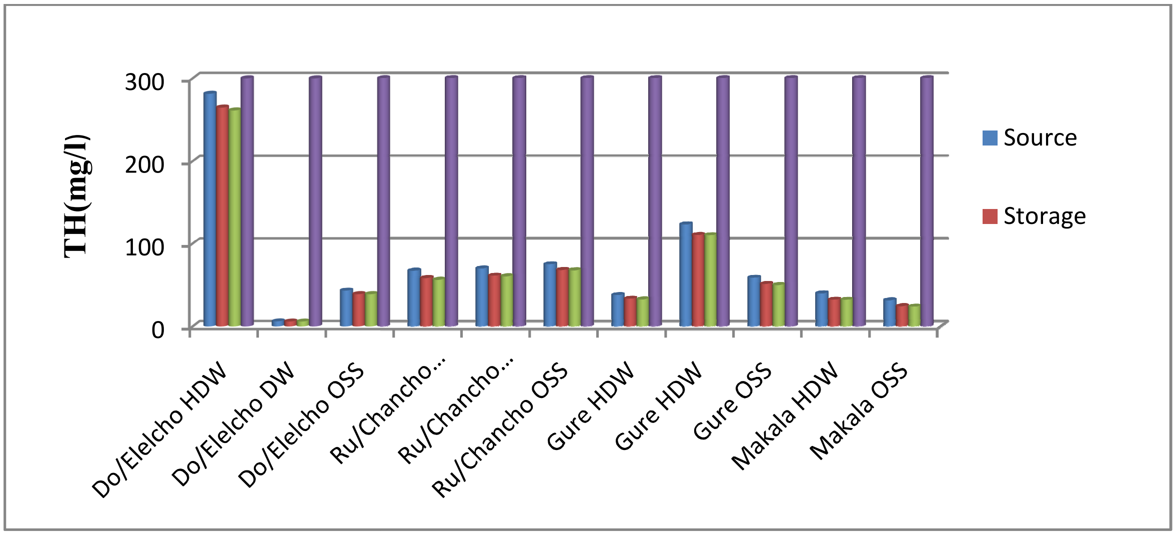

Figure 4-7 The value of TH at the source, storage and point of-use.

Nitrate

The result of laboratory analysis revealed that the mean values of nitrate for the source, storage and point of-use were 0.015±0.01mg/l, 0.0134±0.009mg/land 0.0133±0.009mg/l, respectively. The minimum and maximum values for nitrate were 0 mg/l at Dongora Elelcho kebele deep well and Rufo Chancho hand dung well to 0.031mg/l at Gure kebele hand dung well respectively(Appendix 6,7,8,9 and 11). After storage, it has varied between 1mg/l and 2.3mg/l (Appendix 6).The laboratory result showed that within the acceptable limits of ES and WHO for potable water quality.

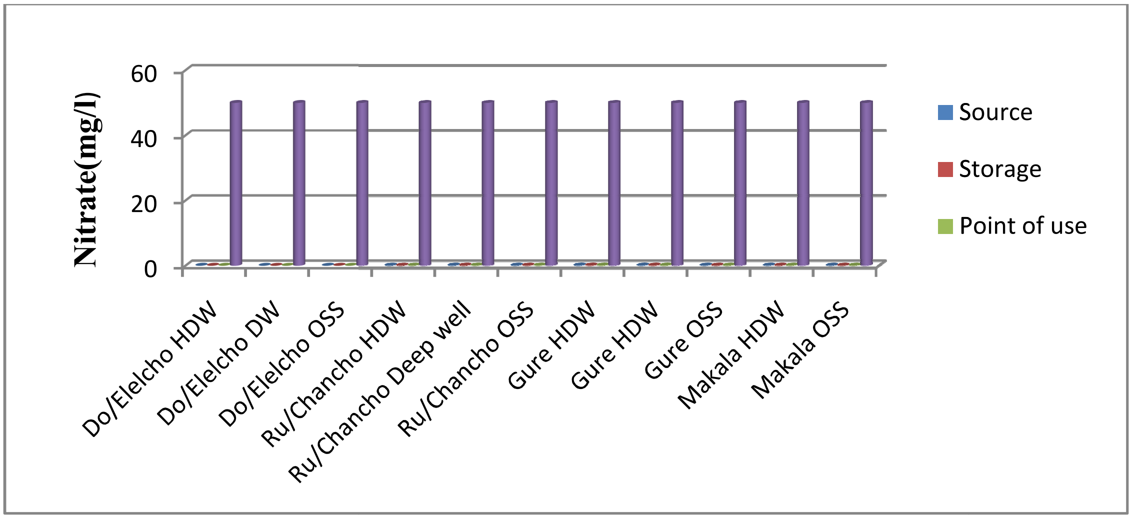

Figure 4-8 The value of Nitrate at the source, storage and point of-use.

Phosphate

The result of laboratory analysis revealed that the mean values of phosphate for the source, storage and point of-use were 0.596±0.216mg/l, 0.525±0.182mg/l and 0.523±0.183mg/l respectively. The minimum and maximum values for phosphate were 0.19mg/l Makala kebele on spot spring to 0.91mg/l Rufo Chancho kebele on spot spring, respectively (Appendix 6,8,10 and 11).The finding of this study was in agreement to previous research by Douhri et al (2015). The laboratory result showed that above the acceptable limits of ES and WHO for potable water quality. Statistical analysis showed that, the differences in the mean from source, storage and point of use value of nitrate and phosphate from sampled sites were not significant at p<0.05 significant levels (Appendix 12).

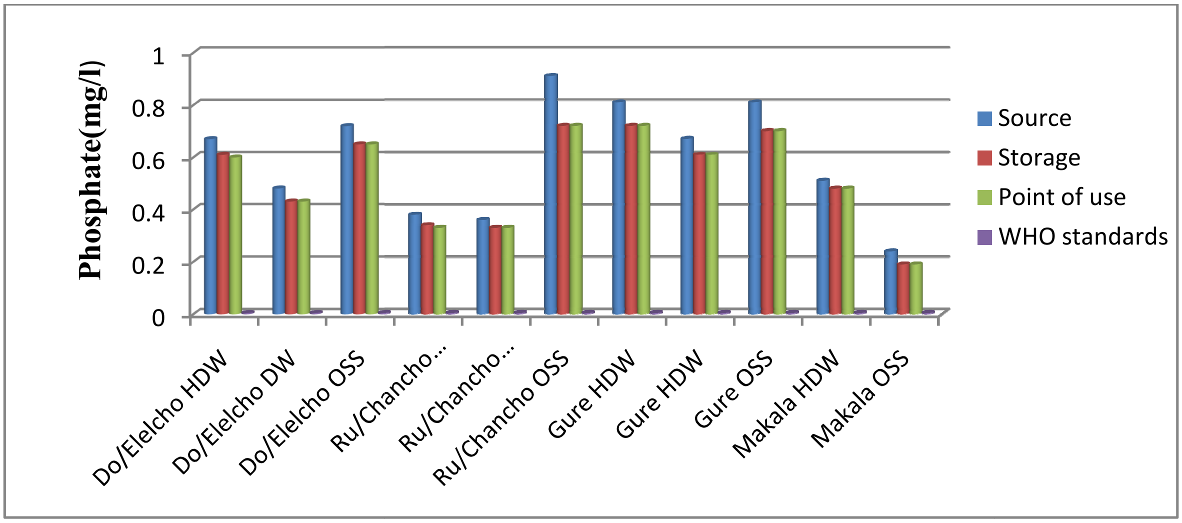

Figure 4-9The value of phosphate at the source, storage and point of-use.

Chloride and Fluoride

The result of laboratory analysis revealed that the mean values of chloride for the source, storage and point of-use were 7.876±1.03mg/l, 7.36±0.96mg/l and 7.29±0.89mg/l, respectively. At the source, it varied between 6.38mg/l to 9.5mg/l and between 5.8mg/l to 9.3mg/l after storage (Appendix 6).

The laboratory result showed that mean value of Fluoride for source, storage and point of-use were 1.288±0.63mg/l, 1.17±0.6mg/l and 1.16±0.6mg/l, respectively. Statistical analysis showed that the differences in the mean of chloride and fluoride at the source, storage and point of-use sampled sites were not significant at p<0.05 significant levels (Appendix 12).All sampled test of chloride and Fluoride was within the acceptable limits of Ethiopia and WHO standards for potable water quality.

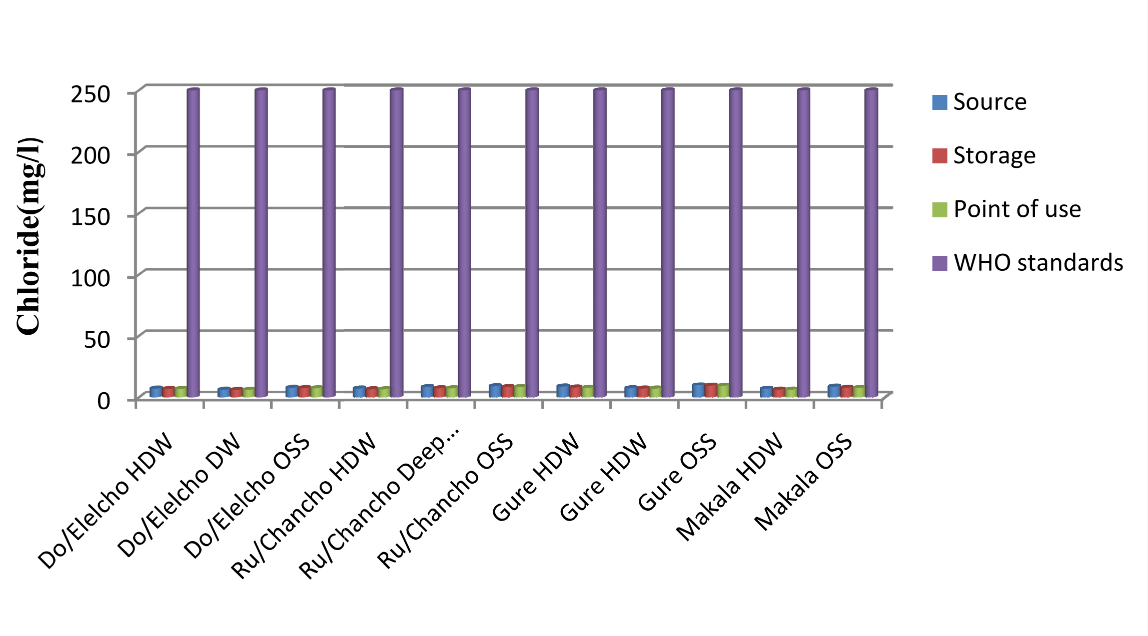

Figure 4-10 The value of chloride at the source, storage and point of-use.

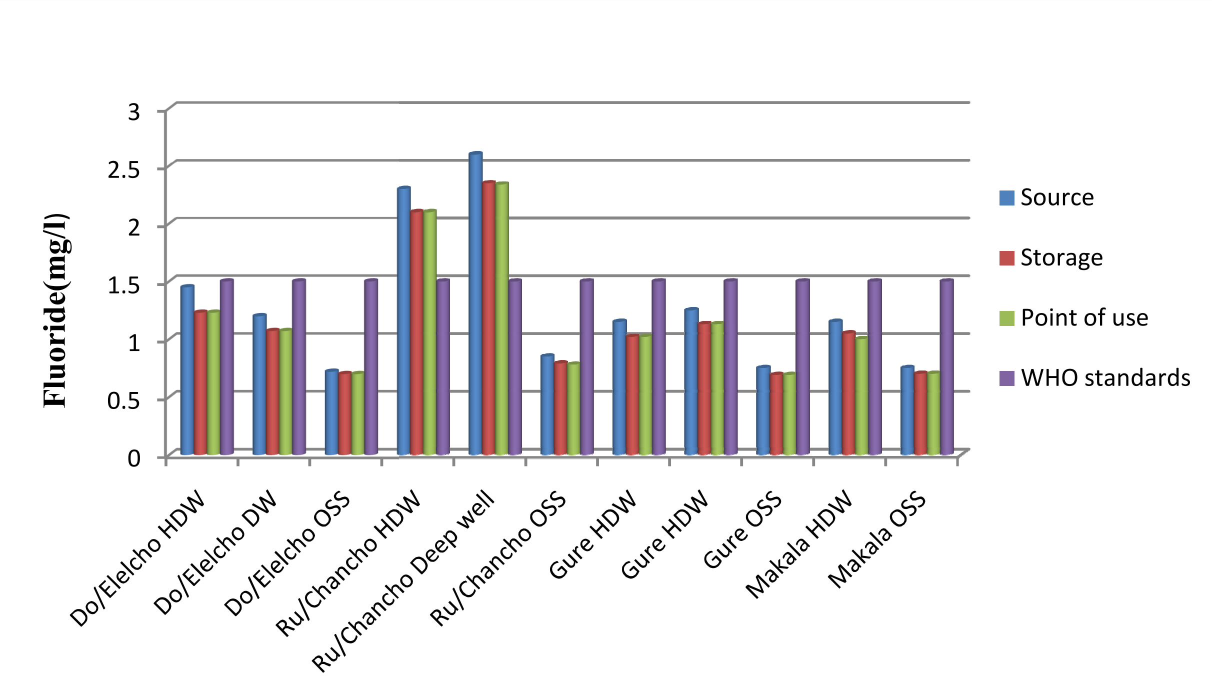

Figure 4-11 The value of fluoride at the source, storage and point of-use.

Iron and Magnesium

Tiny amount or trace levels of dissolved metals in surface water are essential for proper biological functioning. Many are important in basic physiological functions in both plants and animals, as blood components or cofactors in enzyme reactions (Dagnew et al, 2007). The registered mean concentration values of iron and magnesium for source to storage were (0.0082±0.0125mg/l and 0.007±0.0011mg/l) to (31.9±24.39and 29.24±22.48mg/L), respectively. The statistical analysis showed that the mean difference from the source, storage and point of-use for iron and magnesium of the sampled sites were not significant at p<0.05 significant level (Appendix 6 and12).The analyzed laboratory result of iron and magnesium concentration obtained from the sampled sites was below the maximum permissible limit of ES and WHO standards.

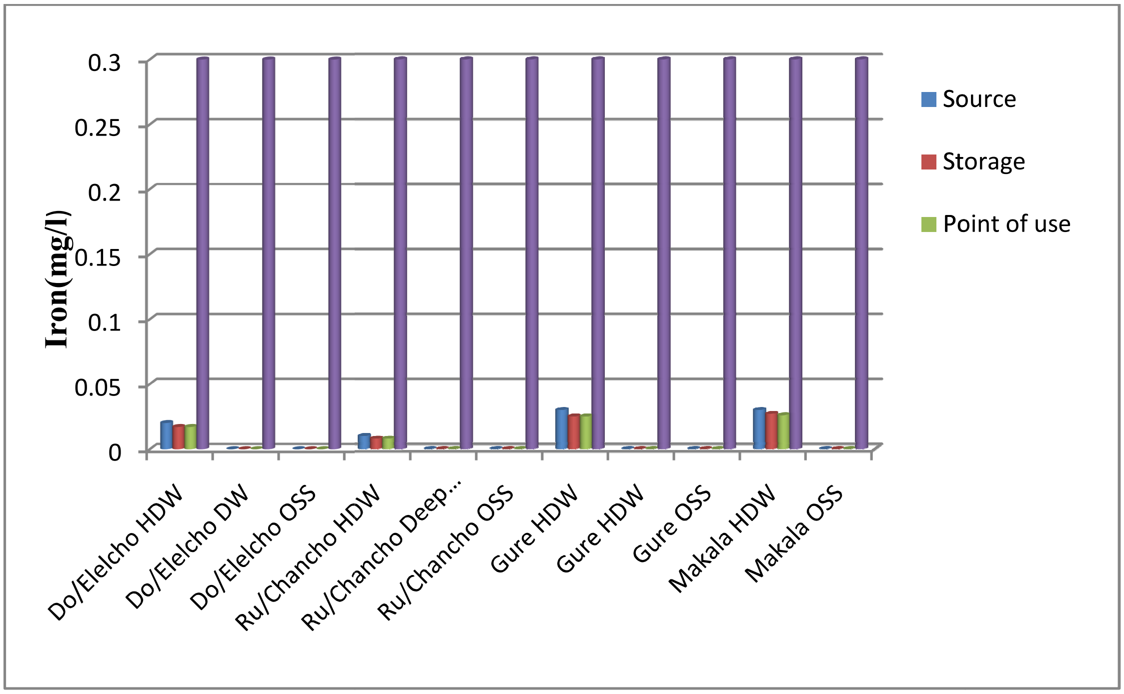

Figure 4-12 The value of Iron at the source, storage and point of-use.

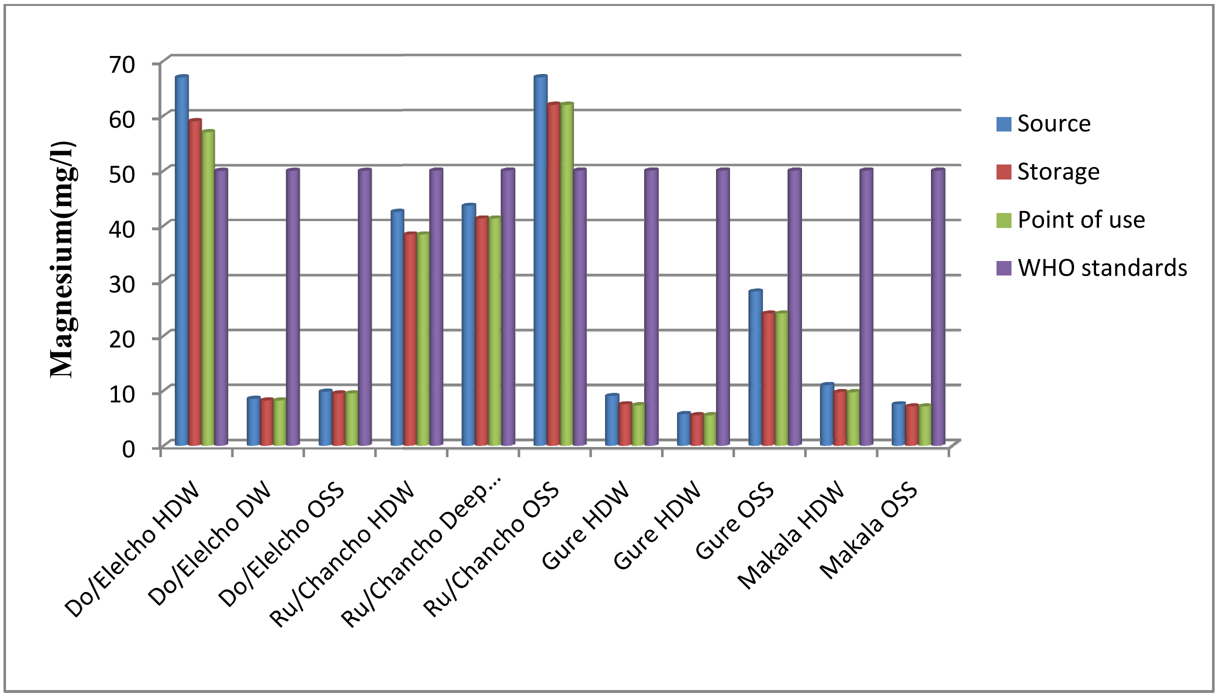

Figure 4-13 The value of magnesium at the source, storage and point of-use.

4.3.2 Bacteriological analysis for the source, storage and point of-use

For water to be potable, it must be free of any bacterial contaminants. An important indicator of water quality is the number of bacteria present in the water. Though it would be difficult to determine the presence of all bacteria in a sample, certain types of microorganisms can serve as indicators of pollution. Chief among these are the coliform bacteria, which survive better, longer and are easier to detect than other pathogens (Kegley and Andrews, 1998).

In Aleta Chuko Woreda, the contamination of water source with excreta from people or animals introduces a great variety of bacteria, viruses, protozoan worms. Insufficient protection of water sources or inadequate treatment, handling and storage, thus puts the community risk of contracting infectious diseases. An important problem is that the communities not perceive the risk of bacteriological contamination as the pollution is often not visible. Local people may value the taste and appearance of the water but not its bacteriological quality unless they understand the risk.

Water quality parameter are vary in type and dependent on natural factors (geological, topographical, meteorological, hydrological and biological) and human intervention. Testing at households' storage water was done to characterize the quality of water coming out of the source and analysis at point of-use i.e. drinking cup done to characterize the quality of water coming out of household containers. For all of sites inspected, there was change in the total coliforms counts from source to household storage containers and from household storage containers to point of-use. The result obtained for the microbial analysis indicated that all the water samples contaminated with E.coli/thermo tolerant coliform. There are free total coliform registered at Dongora Elelcho at deep well and at on spot spring, Rufo Chancho at hand dung well and Gure at hand dung well. The maximum total coliform registered at Rufo Chancho kebele deep well were 6 CFU/100ml from the source, 8 CFU/100ml from the storage and 10 CFU/100ml from the point of-use (Appendix 6).In addition, the mean value of TC for the source, storage and point of-use were 2.182±2.36CFU, 2.909±3.06CFU and 3.845±3.99CFU,respectively. As a result, the differences in the mean from the source, storage and point of-use TC of the sampled sites were not significant at $p<0.05$ significant level with $p= 0.237$(Appendix 12).

Similar research conducted by Mengesha et al (2004) also identifies the least coliform count seen was 13 coliform per 100 ml. In addition, previous researches have reported a significant deterioration of water quality after collection. Deterioration of the water quality has been detected during its storage and drinking cup at home in rural and urban areas throughout Africa, Asia and Latin America(Trevettetal.,2004;Hoqueetal.,2006;Mc Garveyetal.,2008 and Kausar et al., 2012) among others.

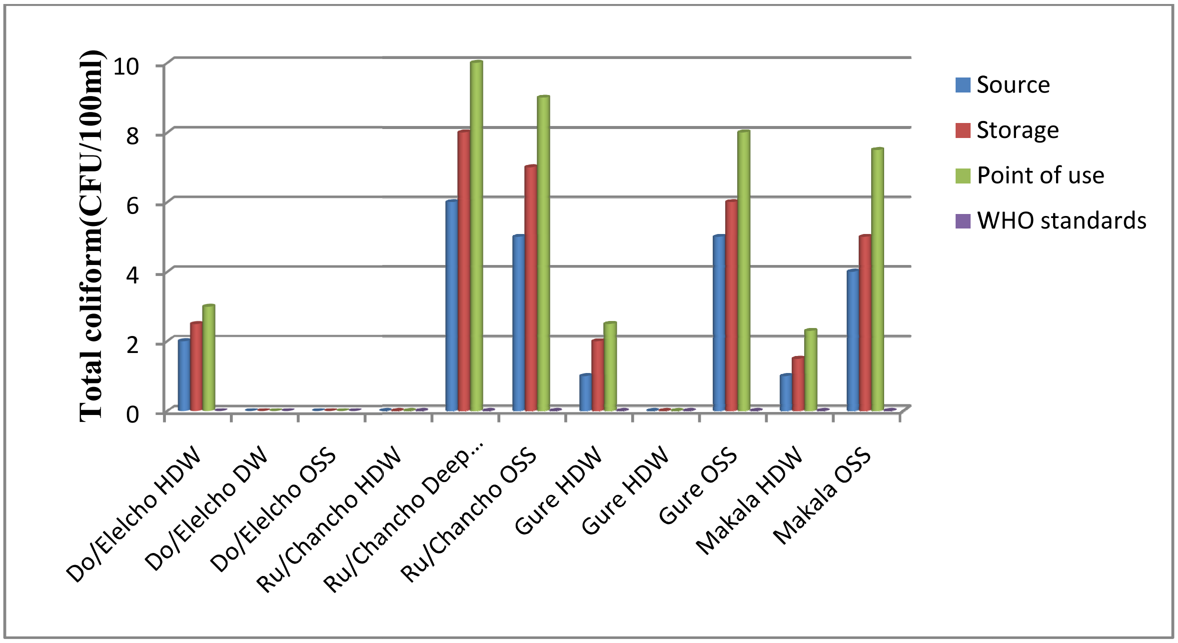

Figure 4-14 The value of TC at the source, storage and point of-use.

The medical officers in charge of the health centers in the Woreda confirmed frequent occurrence of water-borne diseases especially dysentery and diarrhea. They treat an average of thirty-eight cases of these diseases every week and the children are majorly affected (ACWHO, 2016). These cases showed that there is problem of potable water quality in the study area.

Research has shown that these bacteria cannot with stand high temperature (Schmidt and Cairncross, 2008). It is therefore necessary to encourage the water user always boil their water before using it for domestic purposes. Of the thirty-three samples analyzed in this study, 100% complied with the Ethiopia standard and WHO guideline value for total coliforms. Compliance was significantly higher for source and household containers than for the point of use (100%).

In conclusion, the result of the laboratory analysis showed that all the physico-chemical water quality parameters considered in this study from all sampled sites varies from the source to household storage and showed the same value from household storage to point of use. However, the differences in the mean values of the sampled sites were not significant at $p<0.05$ significant level except temperature (Appendix 12).All bacteriological water quality analysis showed significant deterioration of water quality from source to household storage and from household storage to point of use. Although the Woreda's water supplies service office did not apply any kind of water treatment method on regular basis. It is therefore necessary to encourage the water user regularly add chlorine and boil their water before using it for domestic purposes and basic water supply; safe water storage and clean washing of storage containers and drinking cups are needed.

4.4 Water quality in dry and wet season

4.4.1 Physico-chemical analysis in dry and wet season

The water samples were analyzed for selected physico-chemical parameters during the dry month of January and wet month of April to study drinking water quality variation with the seasonal difference.

Table 4-8 The seasonal mean of physico-chemical parameters.

Parameters	Units	Dry season		Wet season		Standards	
		Mean	Std	Mean	Std	ES	WHO
Temp.	^oC	21.93	2.76	20.66	2.34	--	<15
EC	µs/cm	161.04	85.05	142.23	84.93	1500	1000
PH	PH	6.74	0.127	5.6	0.0289	6.5-8.5	6.5-8.5
Turbidity	NTU	1.403	0.056	7.3	0.375	7	5
TDS	Mg/l	103.48	8.69	94.88	4.849	1000	1000
TH ($CaCO_3$)	Mg/l	70.35	4.74	76.4	1.73	300	300
Nitrate	Mg/l	0.014	0.00095	0.042	0.462	50	50
Chloride	Mg/l	7.51	0.32	7.5	0.12	250	250
Fluoride	Mg/l	1.21	0.071	1.23	0.0058	3	1.5
Iron	Mg/l	0.0074	0.00072	0.0068	0.0003	0.4	0.3
Magnesium	Mg/l	30.06	1.59	28.2	1.026	50	50
Phosphate	Mg/l	0.549	0.042	0.644	0.0058	0.02	0.005

Temperature

Is one of the physical parameter used to evaluate quality of drinking water. The value of temperature varied from 18 to 27^oC and 16 to 25.7.^oC in dry and wet season, respectively (Appendix 14 and 15). Mean concentrations were 21.93^oC in dry season and 20.66^oC in wet season. The statistical analysis showed that there was no significant difference at $P < 0.05$ between the dry and wet seasons (Appendix 16).A similar study conducted in Ziway town, which is located near the study area showed a mean temperature of 23.2^0C from different water source samples (Kassahun, 2008). All the above-mentioned studies were from the tropics, where the climate is characterized by high temperature and rainfall. These factors might have contributed to the high temperature records of water samples that did not meet the WHO standard of $< 15^0$C.

pH and Turbidity

The concentration of pH varied from 6.4 to 7.55 pH and 5.6 to 7.35pH in dry and wet season, respectively (Appendix 14 and 15). Mean concentrations were 6.74pH in dry season and 6.57pH in wet season. The statistical analysis showed that there was no significant difference at $P < 0.05$ between the dry and wet seasons (Appendix 16). All the pH values collected at two seasons showed that within the permissible limit of ES and WHO drinking water guideline except Makala kebele hand dug well which is slightly acidic (5.6 during wet season). The lower concentration during wet season was probably due to rainwater dilution.

Turbidity is one of the important physical parameter that affect not only the quality of water, but also other chemical and bacteriological parameters and efficiency of the treatment of water (WHO, 2008). High turbidity indicates the presence of organic suspended material, which promotes the growth of microorganism. It is used as a crude indicator of contamination with organisms such as *Cryptosporidia* (Mombaetal.,2006). The concentration of turbidity varied from 0.52to 4.24NTU and 3.77 to 7.3NTU in dry and wet season, respectively (Appendix 14 and 15). Mean concentrations were 1.403NTU in dry season and 5.41 NTU in wet season (Table 4.9). Similarly, the study conducted by Joseph (2013) mean turbidity values recorded for wet season wells were 14.50±21.51 NTU and that of the dry season recorded 4.01±4.96 NTU. Lower turbidity values during the dry season are probably due to less groundwater recharge and the filtration. The statistical analysis showed that there was no significant difference at $P < 0.05$ between the dry and wet seasons (Appendix 16). All the turbidity values collected at different seasons showed that within the permissible limit of ES and WHO drinking water guideline except HDW at Rufo Chancho kebele.

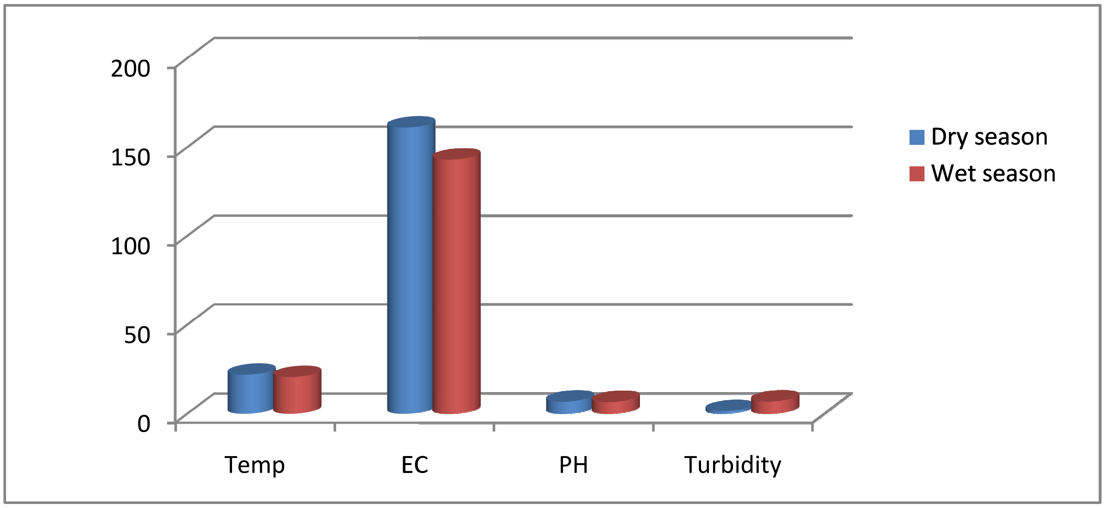

Figure 4-15 The mean value of physical parameters in dry and wet season

Electrical conductivity (EC) and Total dissolved solids (TDS)

The concentration of EC varied from 69.5 to 329µs/cm and 43.1 to 309.5 µs/cm in dry and wet season, respectively (Appendix 14 and 15). Mean concentrations were 161.04µs/cm in dry season and 142.23µs/cm in wet season. This result is in agreement with previous study conducted in WA, Ghana by Joseph (2013) and in Blantyre district, Malawi by Mkandawire (2008). The statistical analysis showed that there was no significant difference at $p<0.05$ between the dry and wet seasons (Appendix 16). All the EC values collected at different seasons showed that within the permissible limit of ES and WHO drinking water guideline.

The concentration of TDS varied from 46.2 to 220.4mg/l and 30.7 to 208.6mg/l in dry and wet season, respectively (Appendix14 and 15). Mean concentrations were 103.48 mg/l in dry season and 94.9mg/l in wet season. This result is in agreement with previous study conducted in WA, Ghana by Joseph (2013) and in Blantyre district, Malawi by Mkandawire (2008). The statistical analysis showed that there was no significant difference at $p<0.05$ between the dry and wet seasons (Appendix 16). All the TDS values collected at different seasons showed that within the permissible limit of ES and WHO drinking water guideline. The TDS values were lower in the wet season compared to the dry season probably due to the dilution effect of rainwater (Mkandawire, 2008).

Total hardness

The concentration of TH varied from 5.8 to 281.4mg/l and 5.8 to 296.4mg/l in dry and wet season, respectively (Appendix 14 and 15). Mean concentrations were 70.35mg/l in dry season and 76.4 mg/l in wet season. This result is in agreement with previous study in Ruiru County, Kenya by Otieno et al (2015)in Blantyre district, Malawi by Mkandawire (2008). The statistical analysis showed that there was no significant difference at $P< 0.05$ between the dry and wet seasons (Appendix 16).Lower value during wet season may due to dilution effect of calcium and magnesium ions. All the TH values collected at different seasons showed to be within the permissible limit of ES and WHO drinking water guideline.

Nitrate and Phosphate

The concentration of nitrate varied from 0 to 0.03 mg/l and 0 to 0.1 mg/l in dry and wet season, respectively (Appendix 14 and 15). Mean concentrations were 0.014mg/l in dry season and 0.419mg/l in wet season. The statistical analysis showed that there was no significant difference at $P< 0.05$ between the dry and wetseasons (Appendix 16). All the Nitrate values collected at different seasons showed to be within the permissible limit of ES and WHO drinking water guideline. In this study, the concentration of nitrate was at some extent increased in the wet season by 0.405mg/l. This was due to the organic wastes, surface runoff from agricultural land with fertilizer into the spring through the subsurface flow (Otieno et al., 2015). The value of nitrate content of water source samples measured in this study is less compared to the maximum values of 6.1 mg/l from the source of two wells of Debreziet (Desta, 2009) and 10.8mg/l and 12.9mg/L from source waters of Ziway town (Kassahun,2008).

The concentration of phosphate varied from 0.19 to 0.91mg/l and 0.28 to 1.05 mg/l in dry and wet season, respectively (Appendix 14 and 15). Mean concentrations were 0.548mg/l in dry season and 0.644 mg/l in wet season. The statistical analysis showed that there was no significant difference at $P< 0.05$ between the dry and wetseasons (Appendix 16).The value increased by 0.096 mg/L. This was may be due to the use of detergents and soaps to wash their clothes and intensive agricultural activities around the source (Adimasu, 2015). Based on the current value obtained,the value of phosphate content of water source samples measured in this study was exceeded to the maximum permissible limit of ES and WHO guidelines.

Chloride and Fluoride

Mean concentrations of chloride were 7.51mg/l to 7.506mg/l in dry and wet season respectively. An increase in the mean value of chloride content of water may due to addition from human sewage, animal manure and agricultural wastes (WHO, 2008).

Mean concentration of fluoride were 1.21 to 1.233mg/l in dry and wet season, respectively. The statistical analysis showed that there was no significant difference at $P < 0.05$ between the dry and wetseasons (Appendix 16). All the values of chloride and fluoride collected at different seasons showed that within the permissible limit of ES and WHO drinking water guideline.

Iron and Magnesium

The concentration of iron varied from 0 to 0.03mg/l and 0 to 0.03 mg/l in dry and wet season, respectively (Appendix14 and 15). Mean concntrations were 0.0074mg/l in dry season and 0.0068mg/l in wet season. The statistical analysis showed that there was no significant difference at $P < 0.05$ between the dry and wet seasons (Appendix 16). The lower concentration during wet weather was probably due to rainwater dilution. All the iron values collected at two seasons showed that within the permissible limit of ES and WHO drinking water guideline.

The concentration of magnesium varied from 7.1 to 67mg/l and 5.5 to 64 mg/l in dry and wet season, respectively (Appendix 14 and 15). Mean concentrations were 30.06 mg/l in dry season and 28.2 mg/l in wet season. The lower concentration during wet weather was probably due to dilution. The statistical analysis showed that there was no significant difference $P < 0.05$ between the dry and wet seasons (Appendix 16). All the magnesium values collected at two seasons showed that within the permissible limit of ES and WHO drinking water guideline.

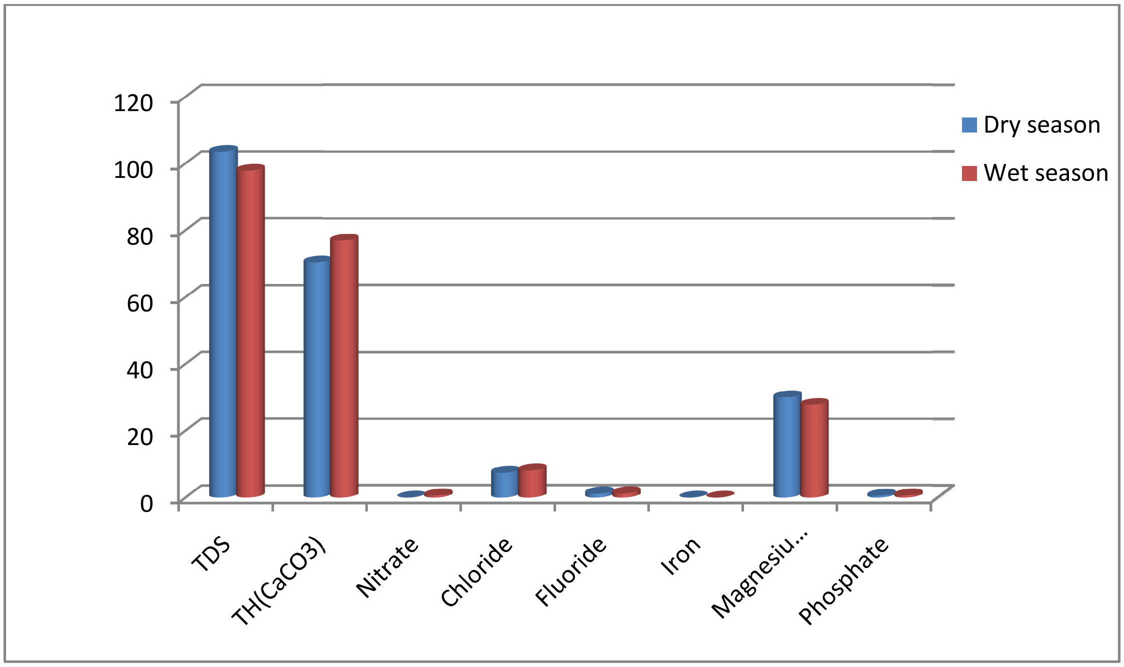

Figure 4-16 The value of chemical parameters in dry and wet season

4.4.2 Bacteriological analysis in dry and wet season

The water samples were analyzed for selected bacteriological parameter during the dry month of January and wet month of April to study drinking water quality variation with the seasonal difference.

It is the critical issue in the quality of water in the study area and any areas of Ethiopia. Bacteriological analysis of water samples showed that all samples of water sources were positive for total coliforms in two rounds of triplicate sampling. The concentration of TC varied from 0 to 10 and 0 to 10.5 per 100ml in dry and wet season, respectively (Appendix 14 and 15). The mean values for dry and wet season were 3±0.834CFU and 4.92±0.945CFU respectively. This indicates the presence of contamination in two seasons and the concentration of TC increase from dry to wet season. However, the statistical analysis showed that there was no significant difference $p<0.05$ between the dry and wet seasons (Appendix 16). In two different seasons the value was beyond the recommended maximum permissible limits of ES and WHO(ES, 2002 and WHO, 2008), zero/100 ml for the drinking.

The study conducted in Ruiru County,Kenya showed that the mean total coliform values for the sampled shallow well are 0.05 CFU/100ml (dry season) and 31.49 CFU/100ml (wet season) (Otieno et al, 2015). A similar study conducted by Getnet (2008) from Bahir Dar town showed that the analyzed water samples from the source of wet season had a mean total coliform count of 35.5 CFU/100ml which was above the acceptable level recommended by WHO (2008). The high amount of these coliform during the wet season could be because water availability favors the movement and reproduction of the organisms especially from surface run off, sewage and waste material(Otieno et al, 2015) and may be due to the site selection, inadequate protection of water sources and unhygienic practices near the water sources (Richards, 1996).

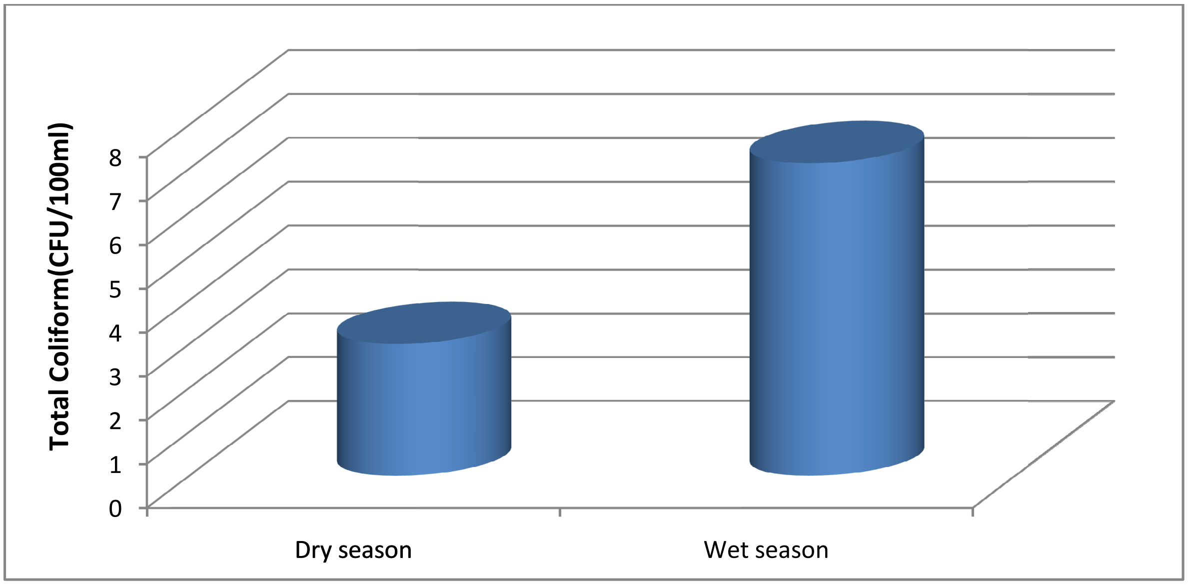

Figure 4-17 The value of total coliform in dry and wet season

4.5 Sanitary and hygienic practices

In addition to the analysis of physical, chemical and biological aspect, sanitary inspections carried out at all supply points visited during the study. Sanitary inspections are visual assessments of the infrastructure and environment surrounding a water supply, taking into account the condition, devices and practices in the water supply system that pose an actual or potential danger to drinking-water quality and thus to the health and well-being of the consumer.

4.5.1 Existence of latrines

The results presented in this section based on household survey and personal observation. The results revealed that 84.6% (110) of the respondents that are included in this survey reported the existence of latrine in the household compound. However, this does not mean that the sanitation coverage mostly and successfully achieved. Although the latrine coverage is 86.4%, sanitation problems like poor awareness on sanitary and hygienic practices, lack of using hand-washing facility after defecation and poor disposal method of wastes are still there. The results of household survey and personal observation revealed that the public toilets available in different parts of Aleta Chuko rural area are dirty and filled with faces.

4.5.2 Types of latrines constructed

In the study area, three types of latrine commonly constructed; pit latrine with walls but without roof, pit latrine with closed wall and roof and open pit latrine without house. On the average, 29.7% (33) of the households had latrines with a wall and roof; 31.5% (35) of the respondents had pit latrines with closed walls but without roof, 38.7%(43) of the households had open pit latrines. Usually bowls used to avoid bad smell around the latrines. Moreover, covering might prevent bad smells from spreading beyond the latrine. However, bowls not covered in most latrines observed in the study area. Latrine with bowls covered is only 8 %(9). The sanitation technologies said to improve if those sanitation facilities prevent humans, animals and insects from coming in contact with human excreta (UNICEF, 2008). However, such improved technologies not mostly been observed in the study area. The sanitation condition is not pleasing as some of the toilets are simply made of local materials without any facilities. As sanitation is highly linked to water supply, people in the community are suffering from sanitation problems. Therefore, lack of proper access to sanitation is the major cause of potable water quality problem and spreading of diseases in Aleta Chuko Woreda, which are harmful to human life. This finding agreed with previous study by Tegegn (2009) in twenty villages of Ethiopia and Joseph (2013) in WA, Ghana. The correlation result of the association of the type of latrine with other sanitation influencing factors showed that there is positive relationship between them (Appendix 18).

Table 4-9 Type of pit latrine in the study area

S. No	Types of pit latrine	Dongora Elelcho n= 30	Rufo Chancho n= 39	Gure n= 24	Makala n= 37	Total N=130
1	Pit latrine with walls but without roof	19.2%	40.6%	28.6 %	34.4 %	31.5%
2	Pit latrine with walls and roofs	34.6%	28.1%	28.6%	28.1 %	29.7%
3	Open pit latrine without house	46.2 %	31.3%	42.9%	37.5 %	38.7%

4.5.3 Disposing of liquid and solid wastes

Good hygiene practices (especially hand washing with soap after defecating and before preparing food, and safe disposal of children's faeces) prevent diarrhea (UNICEF, 2006). It has been reported that baby faeces that is not properly disposed might put household members at risk of diarrhea (Tumwine etal., 2003). Disposal of solid and liquid wastes in open field is a usual activity in the study area. During his stay in the study area, the researcher observed the people that were disposing wastes of different type in open field outside their houses. Of the total respondents, 24.6% (32) used private sanitary pit to dispose waste generated from their house. The remaining 75.4% (98) of the respondents did not have private sanitary pit; as a result, they disposed the waste generated from their house including the baby feces anywhere else. Households that used the private sanitary pit for disposing wastes did not worry about the dimension of the pit and the frequency of disposing the compost from the pit. They said that they have enough space to construct another pit in their compound. As a result, they constructed pits of small dimension. This situation results in a continuous transmission of communicable diseases. This enabled to indicate the condition of environmental sanitation in Aleta Chuko Woreda mainly in relation to water supply and sanitation. The situation in most cases was very poor. Hence, there is a need to educate the people on how to handle the wastes properly and dispose off the waste in proper ways and places. This finding agreed with previous study by Tegegn (2009) in twenty villages of Ethiopia. The correlation result of the association of the disposing of liquid and solid wastes with other sanitation influencing factors showed that there is positive relationship between them (Appendix 17).

4.5.4 The habit of using pit latrines

The survey showed that if latrine was constructed, it did not mean it used regularly. Only 29.2% (33) of those who constructed a latrine used it regularly. 61.1%(69) of the respondents who had constructed a latrine used it rarely. The reasons for not using the latrine regularly were in order of importance: bad smell around the compound, feeling uncomfortable in using the latrine, and the large distance between agricultural fields and their home and latrine (Table 4.12). The correlation result of the association of the habit of using pit latrine with other sanitation influencing factors showed that there is positive relationship between them (Appendix 17).

Table 4-10 Reasons of the respondents who have latrine for not using it regularly

		Habit of using house pit latrine				
S. No	Questions reflected to respondents	Dongora Elelcho n= 30	Rufo Chancho n= 39	Gure n= 24	Makala n= 37	Total N=130
1	Feel uncomfortable using latrine	35%	33.3%	33.3%	25 %	31.7 %
2	Farther distance between farming place and home	15%	12.5%	11.1 %	15%	13.4%
3	Bad smell developed around the compound	50%	54.2%	55.6%	60%	54.9%

4.5.5 Materials used for washing hands after defecation

More than 62(47.7 %) of respondents in all the study area don't use water at all for hand washing after defecating (Table 4.13). 32(24.6%) of the respondents were using water only, 13(10%) of the respondents were used water and ash and the remaining respondents were used water and soap 23 (17.7%) for hand washing after attending toilet. The number of respondents who do not use water at all after attending toilet was the smallest in Rufo Chancho and higher in Gure kebeles. This result is different from the finding of Tehuledere woreda, northeast Ethiopia, i.e. is most of the households 141(73.4%) rinsed their collection containers and wash their hands 123(64.1%) before and after water collection and after defection (Seid et al., 2013).

Table 4-11 The hand washing materials after defecation

S. No	Washing material used after defection	**Do/Elelcho n= 30**	**Rufo Chancho n= 39**	**Gure n= 24**	**Makala n= 37**	**Total N=130**
1	Water only	30%	20.5%	29.2%	21.6%	24.6%
2	Water and ash	10%	10.3%	8.3%	10.8%	10%
3	Water and soap	13.3%	17.9%	16.7%	21.8%	17.7%
4	Don't use water at all	46.7%	51.3%	45.8%	45.9%	47.7%

The number of households who were using water and soap after attending the toilet was small due to use of soap was limited because soap was reportedly expensive and was only used for laundry purposes. For those who used it for hand washing after attending toilet, soap was not kept at the toilet because of the fear that someone might visit the toilet and decide to take it. Majority of the households who did not use water for washing their hands after defecation were illiterate. Besides, they have poor awareness on hygienic practices. Therefore, awareness creation and educating the community about hygiene and sanitation with their combined impact on health at household level is of great importance.

Hygiene improvement is a comprehensive approach to prevent diarrheal disease by promoting improvements in hand washing, treatment and safe storage of water, sanitation, improved access to water and sanitation technologies and products, and fostering an enabling environment. Studies have documented that hand washing at critical times with soap reduce the risk of diarrheal diseases (Curtis and Cain cross, 2003).

Therefore, education alone does not motivate people to wash their hands regularly. Regular follow-up and provision of soap particularly those who lack income is required to encourage and strengthen this behavior. Soap is a critical component of effective hand washing. Therefore, consideration should give to provide soap particularly to those who lack income. Furthermore, follow up evaluations are important to assess the degree to which hygienic behaviors are adopted and continued. The correlation result of the association of the materials used for washing hands after defection with other sanitation influencing factors showed that there is positive relationship between them (Appendix 17).

5. CONCLUSION AND RECOMMENDATIONS

Based on the findings of the results presented in the above chapters, this chapter attempts to draw general conclusions and recommendations.

5.1 Conclusion

People in the study area largely depend on improved water sources developed from groundwater for drinking and other domestic activities. As observed from this research, Aleta Chuko Woreda rural water supply service could not meet water consumption per capita with existing capacity. At present, the coverage of water supply is only 47%. The existing water supply schemes are characterized by very low service coverage as only 16.9% and 72.7% of the respondents satisfied with provided amount and quality of water, respectively and poor operation and maintenance as 22.7% of the water supply services are non-functional. The data analysis showed that the Woreda water use at the household level significantly influenced by family size ($p=0.01$), waiting time at the schemes ($p=0.01$), distance to the schemes ($p=0.05$) and functionality of the schemes ($p=0.05$).

Water safety in a community depends on different factors i.e. from the quality of water at the source to transport, storage and handling practices at household level. The physico-chemical parameters showed that drinking water from the source to household storage decrease and it is the same from household containers to point of use.The ANOVA test indicated that there were no significant differences for mean values of all physico-chemical parameters among various sampled points for the source, storage and point of use at $p< 0.05$ significant levels with the exception of temperature ($p=0.036$). However, total coliform increased in all sampled points from the source to storage and from storage to point of use. The variability analysis (ANOVA) test also indicated that there were significant differences for mean values of all bacteriological parameter among various sampled points of source, storage and point of use at $p< 0.05$ significant level ($p=0.024$).

In addition, the results of seasonal analysis showed that most of the parameters have higher mean values during the dry season, except for turbidity, nitrate, chloride, phosphate and TC, which had higher mean values during the wet season. The ANOVA test indicated that there were no significant differences for mean values of all physico-chemical and bacteriological parameters of dry and wet season among various sampled sites at $p < 0.05$ significant levels.

Most of the physical and chemical parameters measured were with in the recommended range of ES and WHO standards. Except temperature (at all samples> $15^{o}C$), turbidity (HDW =7.2NTU, and HDW =6.8NTU at Rufo Chancho and Dongora Elelicho kebeles, respectively), phosphate (at all samples > 0.02mg/l) and pH (HDW=5.6 pH at Makala kebele), which were found to be unacceptably high in case of temperature, turbidity and phosphate and unacceptably low in the case of pH.Unlike the physico-chemical parameters, bacteriological analysis showed that the studied source, storage, point of use, dry and wet season's drinking water were found to be contaminated as it was indicated by high total coliform (at most samples > 0 CFU/100mg).This study demonstrated that supply of water alone could not guarantee that the water at the source, storage and in the household for drinking purpose is safe as well. An irregular and inadequate water supply compels people to store water for long periods and microbial contamination was found to be higher in stored and point of use water than in source water.

Sanitation and hygienic condition in the Woreda was not good and encouraging. The finding revealed that lack of private sanitary pit, poor hand washing practice, lack of community latrine, improper handling and disposal of wastes and lack of drainage facilities around water points were identified as the major factors responsible for poor sanitation and hygiene and which contributes to the deterioration of drinking water quality in the Woreda. The study showed that Aleta Chuko Woreda was not provided with access to adequate water supply and basic sanitation.

5.2 Recommendations

Based on the findings discussed above, the following recommendations can be drawn to enhance improved water supply coverage and its quality at source and household level. The possible areas of intervention include:

- The development of new water source and expansion of the existing sources should take place in order to improve low water provision and consumption of the Woreda (l/p/d).
- The available quantity of water from all sources of supply schemes should be accessed to all the people on fair distribution basis.
- Despite maintaining strong physical structure, many schemes are in need of different types of repair. Therefore, the management system needs to review its approaches on how to establish institutional mechanisms related to operation and maintenance and ensure that they remain active throughout the designated lifespan of each scheme.
- Attempts are necessary to improve the safety of all water supply schemes from the source. This can be made by source disinfection mechanisms like chlorination, point of use disinfection mechanisms such as boiling and other household water treatment measures to decrease the bacteriological health hazards and regular cleaning of water containers and drinking cup system may improve the conditions significantly.
- Giving 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 and there is a need to build community capacity on water treatment to improve water quality.
- To sustain service delivery of water points by maintaining good quality water, water point construction should follow proper planning complemented by design treatments such as locating water points at reasonable distance from potentially contaminating sources such as pit latrines and runoff and proper construction of spring capping structure.

- More private sanitary pit and community latrine have to be established to ensure proper solid and liquid waste collection.
- Many awareness creation activities should be done on sanitation and hygiene through all concerned bodies and extension workers for not only preparing latrines but also regular use of the latrines and hand washing practices.

The present work is limited to few physico-chemical and bacteriological parameters and sampling frequency. Therefore, year round sampling and analysis of additional water quality parameters should be undertaken.

References

Abed, M.A. and Jamil, A. 2005. The Assessment of Drinking Water Quality and Availability in NWFP, RWSSP, Peshawar.

ACWRAS, 2016. Aleta Chuko Woreda Rural And Agricultural Sector, Chuko. Sidama.

ACWFEDO,2016.Aleta Chuko Woreda Finance and Economic Development Office,Chuko.

ACWHO,2016 Aleta Chuko woreda Health Organization, Chuko. Sidama.

ACWWMEIO, 2015 Aleta Chuko woreda water, Mines, Energy, and Irrigation office, Chuko. Sidama.

Agbogu N., Veronoica J., Charles A. and Stella I., 2006.Study of the bacteriological and physicochemical indicators of pollution of surface waters in Zaria, Nigeria.

APHA.1998.Standard methods for the examination of water and waste water 20thed. washington.

Asthana, D.K. and W. Asthana, 2001. Environment: Problems and Solutions. Second Revised Edition. S. Chand and Company Ltd, New Delhi. ISBN: 81-219-1654-2.

Alula Sebhatu ,2008.The implementation of Ethiopia`s Health Extension Program: An overview. Partners in Population Development Africa Regional Office, A south initiative.http://ppdafrica.org/index.php/en/publications/documents/139-ethiopiahep.

Boe-Hansen, R. , 2002. Microbial Growth in Drinking Water Distribution Systems. Ph.D. Environment and Resources, Danish Academy of Technical Sciences, Journal of Water Supply, Research and Technology, AQUA 51(7): 399-406..

Brooks,D. B. ,2002. Water: Local-Level Management International Development Research Centre.Ottawa,Canada.

Bureau of Health, 2015. Annual report, Hawassa, SNNPR.Ethiopia.

Bureau of Water and Irrigation, 2014. Annual report, Hawassa, SNNPR.Ethiopia.

Cairncross, S. 1990, "Water Supply and the Urban Poor," The Poor Die Young, S. Cairncross, J.E. Hardoy, and D. Satterthwaite, eds., Earthscan Publicalions, Ltd., London, U.K, 1990, pp. 109-126.

Cech, T. V. 2005. Principles of Water Resources: History, Development, Management, and Policy. 2nd Edition. John Wiley and Son, Inc, Hoboken.

Chapman,D. 1996. Water Quality Assessment. A Guide to the use of Biotic,Sediments and Water in Environmental Monitoring 2nd.ed., Chapman and Hall,London.

Clasen, T., Bastable, A., (2003). "Faecal contamination of drinking water during collection and household storage: the need to extend protection tothe point of use." Journal of Water and Health 3(1): 109-115.

Clesceri, L., Greenberg ,A.E. and Eaton,A.D. 1998. Standard methods for examination of Water and waste water 20th edition.

Chinn T.D. ,2003. Water supply. Environmental Engineering. J.A Salvato, N.L. Nemerow and F. j. Agardy, New Jersey, John Wiley and Sons, Inc.

Cochran, W. G.1977. Sampling techniques (3rd ed.). New York: John Wiley & Sons.

CSA . ,2007. Ethiopian Population Census commission:population and housing census.

Dagnew T, Assefa D, Woldemariam G, Solomon F, Schmoll O. 2007. Rapid Assessment of Drinking-Water Quality in theFederal Republic of Ethiopia. Federal Democratic republic of Ethiopia, Ministry of Health, Environmental health Department. Country report. Addis Ababa, 19

Davis, J., G, Garveyand and M. Wood. 1993. Developing and Managing Community Water Supplies. (Oxfam DevelopmentGuidelines No. 8). Oxford: Oxfam.

Diersing Nancy. 2009. Water Quality Frequently Asked Questions. PDA NOAA. http://floridakeys.noaa.gov/pdfs/wqfaq.pdf [Accessed October 18, 2010].

Erah OP, Akujieze CN, Oteze GE.2002. The Quality of Groundwater in Benin City:A Baseline study on inorganic chemicals and microbial contaminants of health Importance in Boreholes and open wells. Trop. J. Pharmaceu. R., 1(2): 75-8.

Eric,T. ,2011.Visualization of Construction of a Gravity Fed Water supply and Treatment System in Developing Countries.

Esrey, S., Potash, J., Roberts, L., &Shiff, C. (1991).Effects of Improved Water Supply and Sanitation on Ascariasis, Diarrhoea, Dracunculiasis, Hookworm Infection, Schistosomiasis, and Trachoma. Bulletin of the World Health Organization, 69 (5)

Ethiopian Standards (ES). 2002.”DrinkingWater Specifications” Quality and Standards Authority of Ethiopia.

Gebreselassie, W. ,2007. ‘Mainstreaming Hygiene andSanitation into Preventative Health Care Programmes: The Incremental but Exciting Path to Achieving the Hygiene and Sanitation Related

Getachew, B. ,2002. Integrated Water and Land Management Research and Capacity Building Priorities for Ethiopia, Proceedings of Mowr/EARO/IWMI/ILRI International Workshop Held at ILRI, Addis Ababa, Ethiopia.

Harvey, A. and Reed, A. , 2007. Community-Managed Water Supplies in Africa: Sustainable or Dispensable Community Development Journal Vol.42, No 3; July 2007.

Haysom, A. 2006. A Study of the Factors Affecting Sustainability of Rural Water Supplies in Tanzania. Bedfordshire, UK: Cranfield University, p. 54.

Howard. G and Bartram. J, 2003. Domestic Water Quantity, Service, Level and Health. World Health Organization, Geneva, 2003.

Hutton .1996. Field water sampling techniques for developing countries.

Jensen, P., et al. ,2002. "Domestic transmission routes of pathogens: the problem of in house contamination of drinking water during storage in developing countries" Tropical Medicine and International Health 7(7): 604-609.

JMP. ,2006. Meeting the MDG Water and Sanitation Target: Urban and Rural Challenge of thdecade.Http://Www.Who.Int/Water_Sanitation_Health/Monitoring/Jmp final.Pdf[Accessed 20 March 2011].

JMP. ,2010. Progress on sanitation and drinking water, 2010 update: Geneva/ New York: World Health Organization/ United Nations Children’s Fund.

Jonas Förare,2009 Drinking Water-Sources,Sanitation and Safeguarding R4:2009, printed in August 2009ISBN 978-91-540-6034-4ISSN 1653-3003The Swedish Research Council Formas.

IRC. ,1987. International Rescue Committee. An Approach to Sustainable piped Water Supplies :(Technical paper series No.28.), The Hague, the Netherland, IRC international water and sanitation center.

Katte V. Y., M. F. Fonteh and G. N. Guemuh. 2003. Domestic Water Quality in Urban Centers In Cameroon: Case Study of Dschang in the West Province. African Water Journal. ISBN 92-1-125089-7.

Keith B., 2004. Physicochemical parameters of natural waters. On line at: http://www.stevenswater.com/articles/waterparameters.aspx.

Kleemeier, M, Lizz . ,1995. From supply driven to demand provision of rural drinking water. Center for development research working paper, 95:8 Copenhagen.

Melinda M. Foran 2007 An analysis of the time to disinfection and the source water and environmental challenges to implementing a solar disinfection technology (SolAgua).

MoH (Ministry of Health) . ,2008. Water supply safety measures extension package. The Federal Democratic Republic of Ethiopia ministry of health. Addis Ababa, Ethiopia.

Momba MNB, Tyafa Z, Makala N, Brouckaert BM, Obi CL. 2006. Safe drinking water stills a dream in rural areas of South Africa. Case Study: The Eastern Cape Province J Water Sci Res Tech, 2006; 32(5): 1816-7950.

Moriarty, P., M. Jeths, Habtamu Abebe and Israel Deneke. 2009. Literature review: Ethiopia's Universal Access Plan in theSouthern Nations, Nationalities, and People's Region (SNNPR). Research-inspired Policy and Practice Learning in Ethiopia and the Nile region (RiPPLE). Addis Abeba,Ethiopia.

MoWR. 2001. National Water Supply and Sanitation Master plan Status Report.

MoWR. ,2007. Water Sector Development Program Reports, Addis Abeba, Ethiopia.

Niehaus, M., S. Moore, et al. , 2002. Early childhood diarrhea is associated with diminished cognitive function 4 to 7 years later in children in a northeast Brazilian shantytown. American Journal of Tropical Hygiene and Medicine 66(5): 590-93.

Okun, D. A. 1988. The Value of Water Supply and Sanitation in Development: An Assessment. American Journal of Public Health, vol. 78, no. 11, pp. 1463-1467. In: Andrea, C. T. 2002 .ed. A Water Supply and Sanitati on Study of the Village of Gouansolo in Mali,West Africa. MSc Thesis. Michigan Technological University.

Oluyemi, E.A., Adekunle, A.S., Adenuga, A. A. and Makinde, W.O. 2010. Physico Chemical Properties and Heavy Metal content of water sources in Ife North Local Government Area of Osun State, Nigeria : African Journal of Environmental Science and Technology vol 4 (10) Pp 691-69.

Paccker, P. J., Mackerness, C. W., Riches, M.and Keevil, C. W. ,1995. Comparison of Selective agars for Isolation and Identification of Klebsiella Oxytoca and

Pathak B, Rajola V. and Rajnish, K. 2002. Water supply & Sanitation status in five African nations; Sulabh International Academy of Environmental Sanitation In collaboration with United Nations Human Settlements Program (UN-Habitat).

Pollitt, E., ed. ,1995. The Relationship Between Under nutrition and Behavioral Development in Children. United Nations University.

Rahmato, D. , 1999. Water Resource Development in Ethiopia: Issues of sustainability and Participation, Forum for Social Science studies (FSS) Addis Ababa, Ethiopia.

Sandra, D. 1996. Water quality assessment to determine the nature and extent of water Pollution by agriculture and related activities.

Schuster-Wallace, C. J., I. V. Grover, Z. Adeel and U. Confalonieri. 2008. Safe Water as the Key to Global Health. United Nations University International Network on Water, Environment and Health (UNU-INWEH). Ontario Canada.

Selamawit, Assefa. ,2007. Evaluation of technical sustainability of rural water supply projects in the Amhara regional state case study in South Wollo: M.Sc thesis(unpublished). Addis Ababa University. Series No. 26. UNDTCD, United Nations, New York.

Shiferaw, T. M., 2003: 'Assessment of Health Problems Associated with Water Supply, Sanitation, and Hygiene Education in SNNPR'.

Sobsey M. D., 2002. In water , sanitation and health department of protection of the human enviroment WHO, Geneva.

South African water quality guidelines (SAWQG),1996.Volume1: Domestic Water use Second Edition

Solomon Tilahun, 2011. Assessment of Selected Bacteriological and Physicochemical Characteristics of Sululta Town Drinking Water from Source to Pipe Water.Master of Science Thesis. Addis Ababa University, Ethiopia.

Stephanie,S.,Bryan,R.,and William E. ,2007. Spring Development and Protection, Pennsylvania State University,USA.

Stevens, M., Ashbolt, N., and Cunliffe, D. 2003. Microbial Indicators of Drinking Water Quality. National Health and Medical Research Council. Australian Government.

Tefera, W. ,2008, 'Technical Issues of Sanitation and Hygiene in Mirab Abaya and Alaba; a case study report from the Southern Nations region (SNNPR) of Ethiopia', RiPPLE Working Paper no 2., March 2008.

Trevett, A., R. C. Carter, et al. ,2004. "Water quality deterioration: a study of household drinking water quality in rural Honduras." International Journal of Environmental Health Research 14(4): 273-278.

UNEP GEMS. 2008. Water Quality for Ecosystem and Human Health, 2nd Edition. Burlington, Canada.

UNICEF. 2006. Meeting the MDG Drinking Water and Sanitation Target, the Urban and Rural Challenge of the Decade, Geneva, Switzerland.

UNICEF. 2008. United Nations Children's Fund (UNICEF) hand book on water quality, New York, 2008.

Volk, C.J., Hofmann, R., Chauret, C., Gagnon, G.A., Ranger, G. and Andrews, R.C . ,2002. Implementation of Chlorine Dioxide Disinfection: Effects of the Treatment Change on Drinking Water Quality in A Full-Scale Distribution System, Journal of Environmental Engineering and Science, 1:32330Http://Jees.Nrc.Ca/.

Water Aid Ethiopia . ,2010. Regional Water Supply and Sanitation Coverage in Ethiopia: according to 2001 EFY reports.

WaterAaid . ,2011. Sustainability framework URL: http:// www.wateraid.org/publications Accessed 14 April 2017).

WHO. 2003 Water, sanitation and health. Geneva, World Health Organization

WHO. 2004. Guidelines for Drinking Water Quality, 3rd Edition. World Health Organization Geneva:143.

WHO/UNICEF. 2006. Meeting the MDG water and sanitation target: the Urban and rural challenge of the decade. http://www.who.int/water_sanitation_health /monitoring /jmpfinal.pdf [Accessed 20 March 2017.

WHO. (2008). Access to Improved Drinking-Water Sources and Improved Sanitation (Percentage)‟Http://Www.Who.Int/Whosis/Indicators/Compendium/2008/2 wst/En/[Accessed10, May 2017], Switzerland, Geneva.

WHO. ,2010. Progress on Sanitation and Drinking-water; WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation Geneva, Switzerland.

Yewondwossen Tesfaye, 2012. A comparative study on woreda managed and Community managed rural water supply projects, MA thesis, Addis Ababa University.

Younger,PL. ,2007. Pro-poor Water technology working both ways: Lessons from a two-way,south-north interchange. Geoforum, 38:828-840).

Zenaw Tessema. ,1997. Lake Water and Surface water interaction, Master's thesis, university of Birmingham, England.

APPENDICES

1. Appendix 1 Socio-demographic characteristics of respondents

S. No	Characteristics	Frequency	Percentage
1.	**Gender (N=130)**		
	Male	67	51.5
	Female	63	48.5
2.	**Age category**		
	< 20	6	4.6
	20-29	29	22.3
	30-39	34	26.2
	40-49	35	26.9
	50-59	17	13.1
	> 60	9	6.9
3.	**Marital status**		
	Married	130	100
	Single	0	0
	Divorce	0	0
4.	**Educational level**		
	Primary	77	59.2
	Secondary	4	3.1
	Tertiary	2	1.5
	Never been to school	47	36.2
	Total	130	100
5.	**Occupation**		
	Farming	122	93.8
	Small scale business	6	4.5
	Government employee	2	1.5
	Total	130	100
6.	**Household size**		
	≤ 4	30	23.1
	5	24	18.5
	6	36	27.7
	7	20	15.4
	8	10	7.7
	≥9	10	7.7

Appendix 2 Multiple linear regression adjusted R square

Model	R	R^2	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R^2 Change	F Change	df1	df2	Sig. F Change
1	.706[a]	.498	.469	9.604	.498	17.302	7	122	.000

Appendix 3 ANOVA for multiple linear regressions

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	11171.529	7	1595.933	17.302	.000[b]
	Residual	11253.278	122	92.240		
	Total	22424.808	129			

a. Dependent Variable: Ave water consumption of HH per day in liter

b. Predictors: (Constant), How long does it take (in minutes) to go source of water and to come back, Are you satisfied this with amount of water for dink,cook& san, Education level, Occupation, Purpose of using water supply, Number of people live in your HH, Average waiting time (in minutes) at water source.

Appendix 4 Multiple linear regression model result

Model	Unstandardized coefficient		Standardized coefficient	T	Sig.	Collinearity statistics	
	B	Std. error	Beta			Tolerance	VIF
(Constant)	27.991	.985		28.418	.000		
Education	-.055	.104	-.006	-.524	.602	.911	1.097
income level birr /month	.211	.392	.025	0.538	.129	.403	2.479
functionality of the water supply scheme	.295	.117	.031	2.519	.014	.719	1.390
consumer satisfaction	.260	.201	.026	1.292	.200	.277	3.615
purpose of using potable water	-.193	.170	-.019	-1.131	.262	.411	2.433
distance to the scheme in meter	-.001	.00037	-.068	-2.651	.010	.170	5.893
point characterization	.046	.180	.005	.257	.798	.315	3.170
habit ofHH water use	.074	.160	.007	.464	.644	.426	2.345
size ofHH in number	-.813	.085	-.415	-9.543	.000	.058	1.227
time to fetch in minute	-.255	.026	-.486	-9.768	.000	.044	2.532

a. Dependent Variable: Ave water consumption of HH per day in liter

Appendix 5 Sample water supply schemes for coverage and quality analysis

Kebele Name	Type of water supply	GPSx	GPSy	GPSz	Current status
Do/Elelicho	DW	426180	734959	1749	Functional
	On spot spring	427170	736873	1734	Functional
	Hand dug well	427288	735653	1787	Functional
Rufo Chancho	On spot spring	422008	722760	1711	Functional
	Deep well	423213	725054	1844	Functional
	Hand dug well	424199	724215	1792	Functional
Gure	Hand dug well	429603	729212	1879	Functional
	Hand dug well	430065	728160	1903	Functional
	On spot spring	431276	728692	1863	Functional
Makala	On spot spring	425730	719828	1707	Functional
	Hand dug well	427688	720457	1865	Functional

Appendix 6 Dry season water quality test result

			Dongora Elelicho			Rufo Chancho			Gure			Makala	
Parameters	**Units**		HDW	DW	OSS	HDW	DW	OSS	HDW	HDW	OSS	HDW	OSS
Physical		Source	20	27	23	21	25	27	23	20	20.5	22	26
Temp.	°C	Storage	18	25	21	19.5	23	25.5	21.4	18.6	19	20.5	24.2
		Point of use	18	25	19	19.5	23	25.5	21.4	18.6	**19**	20.5	24.2
EC	µs/cm	Source	139.8	249	83.4	265	329	216	112.6	76.9	79.9	87.5	213
		Storage	122	235	75.8	257	312	206	105.3	69.5	71.2	81.4	198
		Point of use	120	235	75.8	257	312	206	105.1	69.5	**71.2**	81.4	196
PH	PH	Source	6.8	7.2	6.7	7.05	7.55	6.8	6.8	6.7	6.8	6.8	6.6
		Storage	6.4	6.9	6.5	6.85	7.4	6.6	6.45	6.5	6.7	6.7	6.4
		Point of use	6.4	6.9	6.5	6.84	7.4	6.6	6.45	6.52	**6.7**	6.7	6.4
Turbidity	NTU	Source	1.03	1.19	0.79	1.53	0.52	1.42	2.05	4.24	0.82	1.5	1.05
		Storage	1.01	1.15	0.56	1.5	0.52	1.3	1.9	4.1	0.82	1.3	0.97
		Point of use	1.01	1.14	0.53	1.5	0.52	1.3	1.9	4.05	**0.82**	1.3	0.97
TDS	Mg/l	Source	93.7	167	62.4	178	220.4	144.7	75.4	51.5	53.5	58.8	142.7
		Storage	79.4	146	49.7	154	197	132	63.8	49	48.4	49.4	129.5
		Point of use	77.9	142	49.7	153	194.8	127.9	61.7	49	**46.2**	48.3	118.9
TH(CaCO3)	Mg/l	Source	281.4	6	43.1	67.2	70	75	37.8	123	58.8	39.8	31.5
		Storage	264.7	5.8	38.8	58.4	61.2	68.1	33.4	111	51.2	32.2	24.3
		Point of use	261.3	5.8	38.8	56.3	60.5	67.8	32.6	110	**49.9**	32.1	23.8
Nitrate	Mg/l	Source	0.018	0	0.01	0	0.018	0.013	0.031	0.03	0.01	0.018	0.013
		Storage	0.017	0	0.01	0	0.017	0.011	0.027	0.03	0.01	0.015	0.01
		Point of use	0.017	0	0.01	0	0.016	0.011	0.027	0.03	**0.01**	0.015	0.01
Chloride	Mg/l	Source	7.2	6.3	7.8	7.1	8.2	8.9	8.7	7.3	9.7	6.84	8.6
		Storage	6.9	6.15	7.6	6.5	7.3	8.2	7.9	7.1	9.4	6.21	7.7
		Point of use	6.9	6.15	7.5	6.5	7.3	8.2	7.6	7.1	**9.2**	6.21	7.5
Fluoride	Mg/l	Source	1.45	1.2	0.72	2.3	2.6	0.85	1.15	1.25	0.75	1.15	0.75
		Storage	1.23	1.07	0.7	2.1	2.35	0.79	1.02	1.13	0.69	1.05	0.7
		Point of use	1.23	1.07	0.7	2.1	2.34	0.78	1.02	1.13	**0.69**	1	0.7
Iron	Mg/l	Source	0.02	0	0	0.01	0	0	0.03	0	0	0.03	0
		Storage	0.017	0	0	0.01	0	0	0.025	0	0	0.027	0
		Point of use	0.017	0	0	0.01	0	0	0.025	0	**0**	0.026	0
Magnesium	Mg/l	Source	67	8.5	9.8	42.5	43.6	67	9	5.7	28	11	7.5
		Storage	59	8.2	9.5	38.4	41.3	62	7.5	5.5	24	9.7	7.1
		Point of use	57	8.2	9.5	38.4	41.3	62	7.3	5.5	24	9.7	7.1
Phosphate	Mg/l	Source	0.67	0.48	0.72	0.38	0.36	0.91	0.81	0.67	0.81	0.51	0.24
		Storage	0.61	0.43	0.65	0.34	0.33	0.72	0.72	0.61	0.7	0.48	0.19
		Point of use	0.6	0.43	0.65	0.33	0.33	0.72	0.72	0.61	**0.7**	0.48	0.19
E.coli/TTC	CFU/	Source	2	0	0	0	6	5	1	0	5	1	4
	100ml	Storage	2.5	0	0	0	8	7	2	0	**6**	1.5	5
		Point of use	3	0	0	0	10	9	2.5	0	**8**	2.3	7.5

Appendix 7 Mean value of physico-chemical and bacteriological parameters for the source, storage and point of use from Dongora Elelicho kebele during dry season.

Parameters	Units	Source		Storage		Point of use		Standards	
		Mean	Std	Mean	Std	Mean	Std	ES	WHO
Physical Temp.	°C	23.3	2.87	21.3	2.87	20.7	3.09	-	<15
EC	µs/cm	157.4	68.74	144.26	66.87	143.6	67.1	1500	1000
PH	PH	6.9	0.22	6.6	0.22	6.6	0.22	6.5-8.5	6.5-8.5
Turbidity	NTU	1	0.16	0.91	0.25	0.89	0.26	7	5
Chemical TDS	Mg/l	107.6	43.7	91.6	40.2	90.1	38.98	1000	1000
TH(CaCO3)	Mg/l	110.2	122	103.1	115	102	113.46	300	300
Nitrate	Mg/l	0.02	0.007	0.009	0.007	0.009	0.007	50	50
Chloride	Mg/l	7.1	0.62	6.88	0.59	6.85	0.55	250	250
Fluoride	Mg/l	1.12	0.3	1	0.22	1	0.22	3	1.5
Iron	Mg/l	0.0067	0.01	0.006	0.008	0.0056	0.008	0.4	0.3
Magnesium	Mg/l	28.4	27.3	25.6	23.6	24.9	22.7	50	50
Phosphate	Mg/l	0.62	0.1	0.56	0.95	0.56	0.094	0.02	0.005
Biological E.coli/TTC	CFU/ 100ml	0.67	0.94	0.83	1.2	1	1.4	0	0

Appendix 8 Mean value of physico-chemical and bacteriological parameters for the source, storage and point of use from Rufo Chancho kebele during dry season.

Parameters	Units	Source		Storage		Point of use		Standards	
		Mean	Std	Mean	Std	Mean	Std	ES	WHO
Physical Temp.	°C	24.3	2.5	22.67	2.46	22.67	2.46	-	<15
EC	µs/cm	270	46.27	258.3	43.28	258.3	43.28	1500	1000
PH	PH	7.13	0.31	6.95	0.33	6.94	0.335	6.5-8.5	6.5-8.5
Turbidity	NTU	1.16	0.45	1.1	0.42	1.1	0.42	7	5
Chemical TDS	Mg/l	180.9	31	161	26.98	158.4	27.63	1000	1000
TH(CaCO3)	Mg/l	180.87	31	161	26.98	158.4	27.63	300	300
Nitrate	Mg/l	0.01	0.0076	0.009	0.0076	0.009	0.0067	50	50
Chloride	Mg/l	8.067	0.74	7.3	0.69	7.3	0.69	250	250
Fluoride	Mg/l	1.92	0.76	1.74	0.68	1.74	0.68	3	1.5
Iron	Mg/l	0.003	0.004	0.002	0.003	0.002	0.003	0.4	0.3
Magnesium	Mg/l	51	11.3	47.2	10.5	47.2	10.5	50	50
Phosphate	Mg/l	0.55	0.25	0.46	0.18	0.46	0.18	0.02	0.005
Biological E.coli/TTC	CFU/100ml	3.67	2.62	5	3.6	6.3	4.5	0	0

Appendix 9 Mean value of physico-chemical and bacteriological parameters for the source, storage and point of use from Gure kebele during dry season.

Parameters	Units	Source		Storage		Point of use		Standards	
		Mean	Std	Mean	Std	Mean	Std	ES	WHO
Physical									
Temp.	^{o}C	21.17	1.31	19.67	1.23	19.67	1.23	-	<15
EC	µs/cm	89.8	16.16	82	16.5	81.9	16.39	1500	1000
PH	PH	6.76	0.047	6.55	0.108	6.55	1.05	6.5-8.5	6.5-8.5
Turbidity	NTU	2.37	1.41	2.27	1.36	2.26	1.34	7	5
Chemical									
TDS	Mg/l	60.13	10.82	53.73	7.12	52.3	6.74	1000	1000
TH(CaCO3)	Mg/l	73.26	36.33	65.03	32.96	64.23	33.26	300	300
Nitrate	Mg/l	0.025	0.0085	0.022	0.0078	0.022	0.078	50	50
Chloride	Mg/l	8.567	0.98	8.13	0.95	7.967	0.89	250	250
Fluoride	Mg/l	1.05	0.216	0.947	0.187	0.947	0.187	3	1.5
Iron	Mg/l	0.01	0.014	0.0083	0.0118	0.0083	0.00118	0.4	0.3
Magnesium	Mg/l	41	22.63	39.17	22.39	39.1	22.49	50	50
Phosphate	Mg/l	0.76	0.066	0.68	0.048	0.677	0.0478	0.02	0.005
Biological									
E.coli/TTC	CFU/100ml	2	2.16	2.67	2.49	3.5	3.34	0	0

Appendix 10 Mean value of physico-chemical and bacteriological parameters for the source, storage and point of use from Makala kebele during dry season.

Parameters	Units	Source		Storage		Point of use		Standards	
		Mean	Std	Mean	Std	Mean	Std	ES	WHO
Physical									
Temp.	^{o}C	24	2	22.35	1.85	22.35	1.85	-	<15
EC	µs/cm	150.25	62.75	139.7	58.3	138.7	57.3	1500	1000
PH	PH	6.7	0.1	6.55	0.15	6.55	0.15	6.5-8.5	6.5-8.5
Turbidity	NTU	1.275	0.225	1.135	0.165	1.135	0.165	7	5
Chemical									
TDS	Mg/l	100.75	41.95	89.45	40.05	83.6	35.3	1000	1000
TH(CaCO3)	Mg/l	35.65	4.15	28.25	3.95	27.95	4.15	300	300
Nitrate	Mg/l	0.0155	0.0025	0.0125	0.025	0.0125	0.0025	50	50
Chloride	Mg/l	7.72	0.88	6.955	0.745	6.855	0.645	250	250
Fluoride	Mg/l	0.95	0.2	0.875	0.175	0.85	0.15	3	1.5
Iron	Mg/l	0.015	0.015	0.0135	0.0135	0.013	0.013	0.4	0.3
Magnesium	Mg/l	9.25	1.75	8.4	1.3	8.4	1.3	50	50
Phosphate	Mg/l	0.375	0.135	0.335	0.145	0.335	0.145	0.02	0.005
Biological									
E.coli/TTC	CFU/ 100ml	2.5	1.5	3.25	1.75	**4.9**	**2.6**	0	0

Appendix 11 Descriptive Statistics for the source, storage and point of use during dry season.

Parameters		Statistic					Bootstrap[a]			
		N	Mini	Maxi	Mean	Std. Devi	Bias	Std. Error	95% Confidence Interval	
									Lower	Upper
Temperature	Source	11	20.00	27.00	23.1364	2.72113	.0021	.7765	21.6818	24.6818
	Storage	11	18.00	25.50	21.4273	2.64390	.0041	.7562	20.0273	22.9089
	Point of use	11	18.00	25.50	21.2455	2.74312	.0115	.7792	19.8366	22.8452
EC	Source	11	76.90	329.00	168.3727	89.32027	.4031	25.1234	120.0310	216.2327
	Storage	11	69.50	312.00	157.5636	86.84013	.3862	24.4805	110.6925	204.0609
	Point of use	11	69.50	312.00	157.1818	86.84465	.3822	24.4894	110.3287	203.6567
PH	Source	11	6.60	7.55	6.8909	.27461	.0003	.0775	6.7591	7.0591
	Storage	11	6.40	7.40	6.6727	.29611	.0016	.0842	6.5273	6.8500
	Point of use	11	6.40	7.40	6.6736	.29442	.0016	.0838	6.5273	6.8518
Turbidity	Source	11	.52	4.24	1.4673	1.01252	-.0045	.2842	1.0118	2.1254
	Storage	11	.52	4.10	1.3755	.98890	-.0043	.2781	.9337	2.0235
	Point of use	11	.52	4.05	1.3673	.97791	-.0041	.2752	.9255	2.0036
TDS	Source	11	51.50	220.40	113.4000	59.22957	.2466	16.6818	81.9489	144.8541
	Storage	11	48.40	197.00	99.8273	53.30683	.2611	15.0160	71.0496	128.6490
	Point of use	11	46.20	194.80	97.2091	52.19646	.2391	14.7127	69.4909	124.8814
TH	Source	11	6.00	281.40	75.8000	74.53803	.2568	21.7296	41.3937	125.8314
	Storage	11	5.80	264.70	68.0545	70.73028	.2088	20.6327	35.9851	115.2786
	Point of use	11	5.80	261.30	67.1909	69.91167	.2065	20.3942	35.5643	113.8543
Nitrate	Source	11	.00	.03	.0152	.01005	.0000	.0029	.0095	.0214
	Storage	11	.00	.03	.0134	.00903	.0000	.0026	.0082	.0189
	Point of use	11	.00	.03	.0133	.00899	.0000	.0026	.0081	.0188

Parameters		Statistic					Bootstrap[a]			
		N	Mini	Maxi	Mean	Std. Devi	Bias	Std. Error	95% Confidence Interval	
									Lower	Upper
Chloride	Source	11	6.30	9.70	7.8764	1.03138			7.3165	8.4581
	Storage	11	6.15	9.40	7.3600	.95609	.0028	.2744	6.8509	7.9224
	Point of use	11	6.15	9.20	7.2873	.89100	.0033	.2565	6.7976	7.7954
Fluoride	Source	11	.72	2.60	1.2882	.62549	.0030	.1773	.9682	1.6499
	Storage	11	.69	2.35	1.1664	.55909	.0028	.1588	.8809	1.4953
	Point of use	11	.69	2.34	1.1600	.55889	.0025	.1588	.8745	1.4890
Magnesium	Source	11	7.50	67.00	31.9000	24.39475	.1914	7.2461	18.2021	47.3210
	Storage	11	7.10	62.00	29.2455	22.48606	.1732	6.6778	16.8282	43.3625
	Point of use	11	7.10	62.00	29.0455	22.24749	.1731	6.6078	16.7737	43.1599
Iron	Source	11	.00	.03	.0082	.01250	.0001	.0036	.0018	.0155
	Storage	11	.00	.03	.0070	.01081	.0001	.0031	.0015	.0133
	Point of use	11	.00	.03	.0069	.01063	.0000	.0031	.0015	.0131
Phosphate	Source	11	0.24	.91	.5964	.21598	-.0012	.0627	.4746	.7200
	Storage	11	.19	.72	.5255	.18228	-.0012	.0527	.4164	.6282
	Point of use	11	.19	.72	.5236	.18288	-.0012	.0528	.4155	.6272
TC	Source	11	.00	6.00	2.1818	2.35874	.0415	.6617	1.0000	3.5455
	Storage	11	.00	8.00	2.9091	3.05629	.0542	.8554	1.3636	4.6364
	Point of use	11	.00	10.00	3.8455	3.98908	.0727	1.1173	1.8007	6.0727

a. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Appendix 12 ANOVA results for the source, storage and point of use

Parameters		Sum of Squares	Df	Mean Square	F	Sig.
Temptature	Between Groups	219.530	20	10.976	5.580	.002
	Within Groups	23.607	12	1.967		
	Total	243.136	32			
EC	Between Groups	151431.820	20	7571.591	1.135	.422
	Within Groups	80069.438	12	6672.453		
	Total	231501.259	32			
PH	Between Groups	1.716	20	.086	.912	.587
	Within Groups	1.129	12	.094		
	Total	2.845	32			
Turbidity	Between Groups	14.717	20	.736	.591	.856
	Within Groups	14.945	12	1.245		
	Total	29.662	32			
TDS	Between Groups	59554.972	20	2977.749	1.088	.454
	Within Groups	32849.143	12	2737.429		
	Total	92404.115	32			
TH	Between Groups	150981.972	20	7549.099	22.785	.000
	Within Groups	3975.810	12	331.318		
	Total	154957.782	32			
Nitrate	Between Groups	.002	20	.000	1.334	.309
	Within Groups	.001	12	.000		
	Total	.003	32			
Fluoride	Between Groups	6.316	20	.316	.957	.551
	Within Groups	3.961	12	.330		
	Total	10.277	32			
Magnesium	Between Groups	15511.136	20	775.557	18.558	.000
	Within Groups	501.500	12	41.792		
	Total	16012.636	32			
Iron	Between Groups	.003	20	.000	5.518	.002
	Within Groups	.000	12	.000		
	Total	.004	32			
Phosphate	Between Groups	.864	20	.043	1.688	.177
	Within Groups	.307	12	.026		
	Total	1.171	32			
TC	Between Groups	231.113	20	11.556	1.501	.237
	Within Groups	92.362	12	7.697		
	Total	323.475	32			

Appendix 13 Correlation of physico-chemical and bacteriological parameters for source, storage and point of use

Parameters		Temp.	EC	PH	Turbd.	TDS	TH	Nitrate	Chloride	Fluoride	Mg^{2+}	Iron	Phosphate	TC
Temp.	Pearson Correlation	1	.586**	.353*	-.282	.607**	-.488**	-.291	.107	-.059	-.185	-.299	-.193	.299
	Sig. (2-tailed)		.000	.044	.112	.000	.004	.100	.553	.744	.302	.091	.282	.091
	N	33	33	33	33	33	33	33	33	33	33	33	33	33
EC	Pearson Correlation	.586**	1	.690**	-.350*	.995**	-.168	-.502**	-.189	.673**	.167	-.330	-.599**	.320
	Sig. (2-tailed)	.000		.000	.046	.000	.349	.003	.292	.000	.352	.061	.000	.069
	N	33	33	33	33	33	33	33	33	33	33	33	33	33
PH	Pearson Correlation	.353*	.690**	1	-.274	.709**	-.195	-.248	-.089	.747**	.097	-.191	-.298	.200
	Sig. (2-tailed)	.044	.000		.123	.000	.276	.164	.621	.000	.593	.288	.092	.264
	N	33	33	33	33	33	33	33	33	33	33	33	33	33
Turbd.	Pearson Correlation	-.282	-.350*	-.274	1	-.346*	.138	.555**	-.158	-.042	.298	.070	.217	-.419*
	Sig. (2-tailed)	.112	.046	.123		.048	.443	.001	.381	.818	.092	.700	.224	.015
	N	33	33	33	33	33	33	33	33	33	33	33	33	33
TDS	Pearson Correlation	.607**	.995**	.709**	-.346*	1	-.150	-.482**	-.152	.670**	.185	-.350*	-.578**	.317
	Sig. (2-tailed)	.000	.000	.000	.048		.405	.004	.398	.000	.302	.046	.000	.073
	N	33	33	33	33	33	33	33	33	33	33	33	33	33
TH	Pearson Correlation	-.488**	-.168	-.195	.138	-.150	1	.303	-.070	.153	.710**	.194	.234	-.022
	Sig. (2-tailed)	.004	.349	.276	.443	.405		.086	.700	.395	.000	.280	.189	.903
	N	33	33	33	33	33	33	33	33	33	33	33	33	33
Nitrate	Pearson Correlation	-.291	-.502**	-.248	.555**	-.482**	.303	1	.251	-.102	.185	.363*	.424*	.030
	Sig. (2-tailed)	.100	.003	.164	.001	.004	.086		.159	.572	.304	.038	.014	.869
	N	33	33	33	33	33	33	33	33	33	33	33	33	33
Chloride	Pearson Correlation	.107	-.189	-.089	-.158	-.152	-.070	.251	1	-.330	.086	-.258	.471**	.530**
	Sig. (2-tailed)	.553	.292	.621	.381	.398	.700	.159		.061	.636	.147	.006	.002
	N	33	33	33	33	33	33	33	33	33	33	33	33	33

Parameters		Temp.	EC	PH	Turbd.	TDS	TH	Nitrate	Chloride	Fluoride	Mg^{2+}	Iron	Phosphate	TC
Fluoride	Pearson Correlation	-.059	.673**	.747**	-.042	.670**	.153	-.102	-.330	1	.336	.045	-.446**	.030
	Sig. (2-tailed)	.744	.000	.000	.818	.000	.395	.572	.061		.056	.803	.009	.867
	N	33	33	33	33	33	33	33	33	33	33	33	33	33
Mg^{2+}	Pearson Correlation	-.185	.167	.097	.298	.185	.710**	.185	.086	.336	1	-.187	.259	.226
	Sig. (2-tailed)	.302	.352	.593	.092	.302	.000	.304	.636	.056		.298	.145	.206
	N	33	33	33	33	33	33	33	33	33	33	33	33	33
Iron	Pearson Correlation	-.299	-.330	-.191	.070	-.350*	.194	.363*	-.258	.045	-.187	1	.162	-.284
	Sig. (2-tailed)	.091	.061	.288	.700	.046	.280	.038	.147	.803	.298		.369	.110
	N	33	33	33	33	33	33	33	33	33	33	33	33	33
Phosphate	Pearson Correlation	-.193	-.599**	-.298	.217	-.578**	.234	.424*	.471**	-.446**	.259	.162	1	-.078
	Sig. (2-tailed)	.282	.000	.092	.224	.000	.189	.014	.006	.009	.145	.369		.667
	N	33	33	33	33	33	33	33	33	33	33	33	33	33
TC	Pearson Correlation	.299	.320	.200	-.419*	.317	-.022	.030	.530**	.030	.226	-.284	-.078	1
	Sig. (2-tailed)	.091	.069	.264	.015	.073	.903	.869	.002	.867	.206	.110	.667	
	N	33	33	33	33	33	33	33	33	33	33	33	33	33

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix 14 Descriptive Statistics for the source, storage and point of use during wet season

Parameters		Statistic					Bootstrap[a]			
		N	Mini	Maxi	Mean	Std. Devi	Bias	Std. Error	95% Confidence Interval	
									Lower	Upper
Temperature	Source	11	17.60	25.70	21.5727	2.65936	.0308	.7939	20.1727	23.2455
	Storage	11	16.00	24.00	20.2000	2.13495	.0262	.6407	19.0550	21.5545
	Point of use	11	16.00	24.00	20.2000	2.13495	.0262	.6407	19.0550	21.5545
EC	Source	11	57.80 43.10	309.50 297.00	150.8091 137.9364	87.59473 87.43098	1.2273	26.4274	101.5421	205.4192
	Storage	11		297.00	137.9364	87.43098	1.1569	26.3961	89.1183	191.2700
	Point of use	11	43.10				1.1569	26.3961	89.1183	191.2700
PH	Source	11	5.6	7.35	6.6636	.29740	-.0021	.0857	6.5182	6.8481
	Storage	11	5.6	7.25	6.5118	.30499	-.0021	.0883	6.3646	6.7063
	Point of use	11	5.6	7.25	6.5118	.30499	-.0021	.0883	6.3646	6.7063
Turbidity	Source	11	3.96	7.30	5.5291	1.32057	-.0093	.3696	4.8246	6.2517
	Storage	11	3.77	7.05	5.3573	1.30902	-.0094	.3662	4.6428	6.0736
	Point of use	11	3.77	7.05	5.3573	1.30902	-.0094	.3662	4.6428	6.0736
TDS	Source	11	40.50	208.60	101.0364	56.05303	.7973	16.8084	69.9289	136.1243
	Storage	11	30.70	197.00	91.8000	54.61791	.7536	16.2957	62.2368	125.5441
	Point of use	11	30.70	197.00	91.8000	54.61791	.7536	16.2957	62.2368	125.5441
TH	Source	11	9.00	296.40	80.4182	77.74909	.7158	22.2325	46.4633	130.4850
	Storage	11	5.80	291.00	74.3909	77.24537	.7336	22.0736	41.4687	124.1384
	Point of use	11	5.80	291.00	74.3909	77.24537	.7336	22.0736	41.4687	124.1384

Nitrate	Source	11	.00	.10	.0419	.03522	-.0003	.0102	.0209	.0624
	Storage	11	.00	.10	.0419	.03522	-.0003	.0102	.0209	.0624
	Point of use	11	.00	.10	.0419	.03522	-.0003	.0102	.0209	.0624
Chloride	Source Storage	11	6.12	9.23	7.6500	1.00988	.0056	.2837	7.0565	8.1709
	Point of use	11	5.95	9.05	7.4336	1.02835	.0058	.2887	6.8391	7.9590
		11	5.95	9.05	7.4336	1.02835	.0058	.2887	6.8391	7.9590
Fluoride	Source	11	.69	2.55	1.2327	.60460	-.0008	.1781	.9355	1.6181
	Storage	11	.69	2.55	1.2327	.60460	-.0008	.1781	.9355	1.6181
	Point of use	11	.69	2.55	1.2327	.60460	-.0008	.1781	.9355	1.6181
Magnesium	Source	11	6.40	64.00	29.4636	23.48401	.3196	6.7134	16.5356	42.2229
	Storage	11	5.50	61.00	27.5636	22.30992	.3021	6.3863	15.2978	39.8511
	Point of use	11	5.50	61.00	27.5636	22.30992	.3021	6.3863	15.2978	39.8511
Iron	Source	11	.00	.03	.0068	.01047	-.0001	.0029	.0014	.0129
	Storage	11	.00	.03	.0068	.01047	-.0001	.0029	.0014	.0129
	Point of use	11	.00	.03	.0068	.01047	-.0001	.0029	.0014	.0129
Phosphate	Source	11	.28	1.05	.6436	.24659	.0003	.0706	.5027	.7772
	Storage	11	.28	1.05	.6436	.24659	.0003	.0706	.5027	.7772
	Point of use	11	.28	1.05	.6436	.24659	.0003	.0706	.5027	.7772
TC	Source	11	.00	9.50	4.6291	3.88180	.0153	1.0994	2.4258	6.7359
	Storage	11	.00	10.50	5.0727	4.26945	.0205	1.2060	2.6727	7.2543
	Point of use	11	.00	10.50	5.0727	4.26945	.0205	1.2060	2.6727	7.2543

a. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Appendix 15 Descriptive values of dry and wet seasons

Parameters		Statistic					Bootstrap[a]			
		N	Mini	Maxi	Mean	Std. Devi	Bias	Std. Error	95% Confidence Interval	
									Lower	Upper
Temperature	Dry	33	18.00	27.00	21.9364	2.75645	.0184	.4839	21.0001	22.8724
	Wet	33	16.00	25.70	20.6576	2.34321	.0149	.4159	19.8636	21.4727
EC	Dry	33	69.50	329.00	161.0394	85.05536	-.2183	14.9725	131.2174	191.4274
	Wet	33	43.10	309.50	142.2273	84.93142	-.2213	14.9412	112.9016	172.7960
PH	Dry	33	6.40	7.55	6.7458	29819	.0003	.0504	6.6492	6.8518
	Wet	33	5.6	7.35	6.5624	30176	-.0001	.0515	6.4673	6.6760
Turbidity	Dry	33	.52	4.24	1.4033	.96278	.0027	.1648	1.1113	1.7484
	Wet	33	3.77	7.30	5.4145	1.27385	-.0001	.2179	4.9937	5.8423
TDS	Dry	33	46.20	220.40	103.4788	53.73666	-.0841	9.5027	85.2014	122.8674
	Wet	33	30.70	208.60	94.8788	53.53368	-.1289	9.3985	76.6393	114.2212
TH	Dry	33	5.80	281.40	70.3485	69.58758	-.2071	11.9820	49.0126	95.3879
	Wet	33	5.80	296.40	76.4000	75.01095	-.2252	12.9192	53.6221	103.4942
Nitrate	Dry	33	.00	.03	.0139	.00911	.0000	.0016	.0108	.0170
	Wet	33	.00	.10	.0419	.03410	.0000	.0058	.0310	.0533
Chloride	Dry	33	6.15	9.70	7.5079	.96803	-.0007	.1735	7.1868	7.8533
	Wet	33	5.95	9.23	7.5058	.99518	-.0044	.1760	7.1692	7.8490
Fluoride	Dry	33	.69	2.60	1.2048	.56670	-.0041	.0959	1.0246	1.4093
	Wet	33	.69	2.55	1.2327	.58540	-.0010	.0989	1.0497	1.4436
Magnesium	Dry	33	7.10	67.00	30.0636	22.36951	-.1161	3.8698	22.3905	37.7416
	Wet	33	5.50	64.00	28.1970	22.00576	-.1230	3.8008	20.5162	35.4385
Iron	Dry	33	.00	.03	.0074	.01100	-.0001	.0019	.0041	.0112
	Wet	33	.00	.03	.0068	.01013	.0000	.0017	.0036	.0102
Phosphate		33	.19	.91	.5485	.19130	.0002	.0329	.4827	.6109
		33	.28	1.05	.6436	.23876	.0001	.0415	.5640	.7257
TC	Dry	33	.00	10.00	2.9788	3.17940	-.0181	.5501	1.8942	4.0089
	Wet	33	.00	10.50	4.9248	4.01828	-.0190	.7070	3.4824	6.1881

Appendix 16 ANOVA results for dry and wet seasons

		Sum of Squares	df	Mean Square	F	Sig.
Temptature	Between Groups	273.765	29	9.440	1.975	.027
	Within Groups	172.054	36	4.779		
	Total	445.819	65			
EC	Between Groups	234740.999	29	8094.517	1.248	.262
	Within Groups	233426.628	36	6484.073		
	Total	468167.627	65			
PH	Between Groups	3.782	29	.130	1.855	.040
	Within Groups	2.532	36	.070		
	Total	6.314	65			
Turbidity	Between Groups	233.571	29	8.054	2.555	.004
	Within Groups	113.500	36	3.153		
	Total	347.071	65			
TDS	Between Groups	92539.784	29	3191.027	1.238	.269
	Within Groups	92792.026	36	2577.556		
	Total	185331.810	65			
TH	Between Groups	191725.761	29	6611.233	1.654	.076
	Within Groups	143888.825	36	3996.912		
	Total	335614.586	65			
Nitrate	Between Groups	.038	29	.001	3.336	.000
	Within Groups	.014	36	.000		
	Total	.053	65			
Chloride	Between Groups	45.081	29	1.555	3.372	.000
	Within Groups	16.598	36	.461		
	Total	61.679	65			
Fluoride	Between Groups	12.697	29	.438	1.842	.041
	Within Groups	8.559	36	.238		
	Total	21.256	65			
Magnesium	Between Groups	18380.876	29	633.823	1.731	.059
	Within Groups	13185.363	36	366.260		
	Total	31566.239	65			
Iron	Between Groups	.006	29	.000	8.751	.000
	Within Groups	.001	36	.000		
	Total	.007	65			
Phosphate	Between Groups	1.940	29	.067	1.998	.025
	Within Groups	1.205	36	.033		
	Total	3.145	65			

Appendix 17. Correlations result for sanitation and hygiene

		What type of laterine facility do you have	Methods for refusal of disposal	Often do you use the latrine	When it is important to wash hands	Where do you dispose feces of the children	How often do you take the bath
What type of laterine facility do you have	Pearson Correlation	1	.117	-.015	.[a]	-.194[*]	-.089
	Sig. (2-tailed)		.223	.878	.	.041	.356
	N	111	111	110	111	111	111
Methods for refusal of disposal	Pearson Correlation	.117	1	.012	.[a]	.034	-.076
	Sig. (2-tailed)	.223		.899	.	.702	.392
	N	111	130	113	130	130	130
Often do you use the latrine	Pearson Correlation	-.015	.012	1	.[a]	-.224[*]	-.187[*]
	Sig. (2-tailed)	.878	.899		.	.017	.047
	N	110	113	113	113	113	113
When it is important to wash hands	Pearson Correlation	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]
	Sig. (2-tailed)	.	.	.		.	.
	N	111	130	113	130	130	130
Where do you dispose feces of the children	Pearson Correlation	-.194[*]	.034	-.224[*]	.[a]	1	.104
	Sig. (2-tailed)	.041	.702	.017	.		.238
	N	111	130	113	130	130	130
How often do you take the bath	Pearson Correlation	-.089	-.076	-.187[*]	.[a]	.104	1
	Sig. (2-tailed)	.356	.392	.047	.	.238	
	N	111	130	113	130	130	130

*. Correlation is significant at the 0.05 level (2-tailed).

a. Cannot be computed because at least one of the variables is constant.

BIOGRAPHICAL SKETCH

Feleke Lelamo was born in Shebedino Woreda, Sidama Zone, South Nation Nationalities and People's Region. He attended his elementary school at Midire Genet Primary and Junior School and completed his high school at Leku Senior Secondary and Preparatory School. Then he joined Hawassa University,Wondo Genet College of Forestry and Natural Resources Faculty of Natural Resource Management with Bachelor of Science in 2010.

He was employed by the Ministry of Agriculture and Natural Resources Department in Sidama Zone. Since then, he has been working as watershed development expert.

After enormous commitment and hard work, he continued his studies in a Master's program at School of Biosystems and Environmental Engineering, Institute of Technology of Hawassa University in 2016.