JIMMA UNIVERSITY
JIMMA INSTITUTE OF TECHNOLOGY
FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING
ENVIRONMENTAL ENGINEERING CHAIR

EVALUATION OF GEOCHEMICAL AND BACTERIOLOGICAL GROUNDWATER QUALITY IN LINE WITH WATER DEMAND AND SUPPLY SYSTEM: A CASE OF ARSI ROBE DISTRICT, OROMIA, ETHIOPIA

BY:
DEREJE GEREMEW RETA

A THESIS SUBMITTED TO JIMMA UNIVERSITY, JIMMA INSTITUTE OF TECHNOLOGY, SCHOOL OF GRADUATE STUDIES IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR DEGREE OF MASTERS OF SCIENCE IN ENVIRONMENTAL ENGINEERING

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JIMMA, ETHIOPIA

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APPROVAL SHEET

As a thesis advisor, we her by approved that we have read and evaluated this thesis done, under our guidance, by Dereje Geremew Reta entitled Geochemical And Bacteriological Evaluation of Groundwater Quality for Domestic Use in Arsi Robe District, Oromia National Regional State, Ethiopia, we recommend that it can be submitted as fulfilling thesis requirement.

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As a member of board of examiner of MSc. thesis final defense examination, we certify that we have read, evaluate thesis done by Dereje Geremew Reta and examined the candidate. We recommend that, the Thesis could be accepted as fulfilling the thesis requirements for the degree of masters of Science in Environmental Engineering.

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Mr.Megersa Kebede --------------------- ---------------------
Chair Person Signature Date

DEDICATION

I dedicate this work to my family and friends. Thank you so much for your endless prayers and encouragement to hold firm to my dreams.

DECLARATION

This thesis is entitled “Geochemical and Bacteriological Evaluation of groundwater quality for Domestic Use in Robe District, Arsi zone Oromia National Regional State, Ethiopia”. It is my original work and has not been presented for a Masters or any other Degree in Jimma Institute of Technology (JIT) or any other University.

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ABSTRACT

For the existence of life, water is indispensible natural resource, which is essential and is a basic human entity. Groundwater is one of the major sources of drinking water all over the world. This work was done in an area called Robe district, with the objective of the evaluation of groundwater quality in line with water demand and supply and its suitability for domestic uses. Groundwater samples were recollected from Eight (8) ground water samples site and chemically analyzed for major physicochemical parameter. Physical and chemical parameters of groundwater were determined. These parameters were used to assess the suitability of groundwater for domestic purpose by comparing with the WHO and Ethiopian standard guideline. Water type of the study area was determined by using Aqua-chem2012.1modaelsoftware which develops piper diagram. The result of the finding indicated that; all water samples had pH value less than eight which is in WHO standard guide line except in two sample site. The Electric Conductivity of sampled water was below WHO standard guide line value (250 ***µS /cm****).TDS of water was below WHO the guide line value (<500 mg/L) which is fine while Temperature of all sampled water is above WHO guide line value. only two water samples had Iron concentration above WHO guide line value (0.3 mg/L) with maximum concentration of (o.78mg/L) in hand dug well of Abo Ali kebele. Two water samples exhibited high concentration of Manganese above Ethiopian guideline value (0.5 mg/L). The hydrogeological facies of water in the study area is dominated by alkaline earth metals. Generally water type of area is* $Na\text{-}Ca\text{-}HCO_3$ *in two kebeles (Ataba Robe and HabeDangasela) and the others are different in water type. All samples were had total coli forms and fecal coli forms beyond WHO guide line and dangerous for domestic use. The result also showed that, water demand and supply of the household is not comparable, in which the demand was greater than the proposed supply. Aquachem and Microsoft excel software was used to analyze and present the groundwater data. In general, to complete this study, it requires five months starting from May, 2017to the end of September.*

Key words: *ground water, geochemical characteristics, major ion chemistry,*

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LIST OF ABBREVIATIONS

APHA	American public health association
CAWST	Center for Affordable water and sanitation Technology
CFU	Colony Forming Unit
CSA	Central Senses Agency
EC	Electrical Conductivity
EDTA	Ethylenediamine tetra acetic acid
EPA	Environmental Protection Agency
FAO	Food and Agricultural organization
FC	Fecal coli form
GPS	Geographical Positioning System
HH	House Hold
IBE	Ion Balance Error
JU	Jimma University
GW	Ground Water
MDG	Millennium Development Goal
MF	Membrane Filtration Method
NGOs	Non-Governmental Organization
NTU	Nephelometric Turbidity Unit
pH	Power of Hydrogen
RADWQ	Rapid Assessment of Drinking Water Quality
SAR	Sodium Absorption Ratio
TC	Total Coli form
TDS	Total dissolved solids
UN	United Nation
UNEP	United Nations Environment Program
UNICEF	United Nations Children’s Fund
WaSH	Water Supply, Sanitation and Hygiene
WB	Word Bank
WHO	World health organization
WWC	Woreda Wash Consultant

WWI	WoredaWaSH Inventory
µS/cm	Micro Siemens per centimeter

CHAPTER ONE

INTRODUCTION

1.1. Background

Water is a chief natural resource which is inessential for the existence of life and is a basic human entity. Water resources are used for various purposes like drinking, agricultural, industrial, household, recreational, and environmental activities. Groundwater is one of the major sources of drinking water all over the world (Bear, 1979). It is estimated that approximately one third of the world's population use groundwater for drinking (Nick son *et al.*, 2005). Therefore, water quality issues and its management options need to be given greater attention in developing countries. Water quality is influenced by natural and anthropogenic effects including local climate, geology and irrigation practices (Ramesh and Elango, 2011).

Groundwater quality is based upon the physical and chemical soluble parameters due to weathering from source rocks and anthropogenic activities. Suitability of water for various uses depends on the type and concentration of dissolved minerals and groundwater has more mineral composition than surface water (Mirabbasi *et al.*, 2008; Salman, 2013). Groundwater quality reflects inputs from the atmosphere, soil and water rock reactions as well as pollutant sources such as mining, land clearance, agriculture, and acid precipitation, domestic and industrial wastes (Appelo and Postma, 1993).

Suitability of water for various uses depend on type and concentration of dissolved minerals and groundwater has more mineral composition than surface water The quality of groundwater is constantly changing in response to daily, seasonal and climatic factors. Continuous monitoring of water quality parameter is highly crucial because changes in the quality of water has far as reaching consequences in terms of its effects on man and biota.(Mirribasi *et al.*, 2008).

The extensive use of water has increased globally and the efficacy of supply side measure is questionable owing to drastic increase in population, technological advancement and economic growth; the demand for water supplies is continuously increasing, numerous researchers have emphasized on water demand management rather than the supply side management (Amin and Mahmud, 2011). The water demand study in relation to water supply enables us to estimate how much the increase in demand for water supplies. Water demand is the quantity that the treatment plant produce in order to meet all water needs in the community. Water demand includes water delivered to the system to meet the need of consumers, water Supply for firefighting and system flushing. On the other hand water supply refers to system for the collection, transmission, treatment, storage and distribution of water (Admassu, 1996). The term “domestic water demand” is usually taken to mean the amount of water required for various domestic uses (Amin, 2007). Domestic water use varies according to the living standards of the consumers in urban and rural areas. The use of water for domestic purpose may be subsidized in drinking, food preparation and cooking washing cloths and utensils, house cleaning and polishing vegetable gardening, livestock watering and other uses.

Similar to other areas of the world, groundwater is the major source of drinking water in Ethiopia. More than 80% of the country’s drinking water supply source is from ground water. This includes more than 25 major cities in the country (Kebede *et al*., 2004).Groundwater is the major source of domestic use water in Robe district. It supplies drinking water and water for domestic uses, livestock watering and, to some extent, for agricultural purposes. Water quality data is essential for the implementation of responsible water quality regulations for characterizing and remediating contamination and for the protection of the health of humans and the ecosystem.

The water quality analysis method is based on analytical standards. Water temperature, Electric Conductivity and pH are determined on the site using portable multi- parameter probe (HQ40d Model**)**, while other parameters are determined in the laboratory within 24-72 hours of the sampling following standard methods (APHA.2005). Total, dissolved and suspended solids were measured gravimetrically. Magnesium, bicarbonate, total alkalinity and chloride are determined by titer metric methods. Hardness (total and calcium) are determined by the EDTA titer metric method. Sodium, potassium and calcium were analyzed using Flame photometer. Interpretation of all water chemistry data is carried out using AquaChem 2012.1 software and Microsoft excel 2007.With regard to bacteriological parameters, samples were analyzed using membrane filtration (MF) method for water quality to determine the degree of contamination (WHO, 2006; APHA, 1998). For the water Demand and supply, a reconnaissance survey was conducted to be well acquainted with the study areas and to properly identify the areas to be surveyed.

Regular monitoring of groundwater resources thus plays a key role in sustainable management of water resources. This study seeks to evaluate the groundwater quality in terms of domestic use for a rapidly developing community located in Robe district.

1.2. Statement of the Problem

Safe water is a precondition for health and development and a basic human right, yet it is still denied to hundreds of millions of people throughout the developing world (UNICEF, 2008).

Water quality degradation is one of the major environmental problems of these days. Contamination of surface and groundwater is the most serious problems affecting the health of the population. Water related diseases caused by insufficient safe water supplies coupled with poor sanitation and hygiene cause 3.4 million deaths a year, mostly among children (UNICEF, 2008). Despite continuing efforts by governments, civil society and the international community, over a billion people still do not have access to improved water sources (UNICEF, 2008).In developing countries, sources of pollution from domestic, agricultural, industrial activities are unregulated (UNEP, 2005).

The problems of groundwater quality are much more acute in the areas, which are densely populated, thickly industrialized and have shallow groundwater tables (Patil, 2010). The rapid growth of urban areas has further affected groundwater quality due to overexploitation of resources and improper waste disposal practices. Hence, there is always a need for and concern over the protection and management of groundwater quality (Patil *et al*., 2001)**.** In Robe District, most of the community has their own hand dug well at their provinces, which are constructed by themselves. Government and different NGOs constructed hand dug wells and deep wells for the communities. The constructed water schemes are used for drinking, food preparation, bathing, and livestock. Community of the study area is using the water, which is not tested and chemically analyzed. Since the researcher is parts of this society and becomes one of the disadvantageous groups, further intensive study of the concerned area is required to have a detailed examination of groundwater quality for domestic use.

Therefore, it is important to conduct study in Robe District, which performs evaluation and analysis of the physical, chemical and bacteriological quality of ground water and the quantity of demand and supply of water for the community through administered questionnaire.

1.3. Objectives of the Study

1.3.1 General Objective

The general objective of this study is to evaluate the geochemical and bacteriological quality of ground water and it is suitability for domestic uses.

1.3.2. Specific Objectives

- To investigate the Physic-chemical constituents of GW composition
- To identify the geochemical processes that causes change in the water quality
- To evaluate the bacteriological quality of ground water
- To quantify the demand of the groundwater resource for domestic supply.

1.4. Research questions

- What are the Physic-chemical constituents of the GW?
- What is the geochemical process that cause change in water quality?
- What is the bacteriological quality of groundwater?
- What is the demand and supply of ground water for domestic use?

1.5. Significance of the study

Since there is no research that has been attempt on the quality assessment of groundwater in this area, data from this study will contribute for improvement of factors that control groundwater quality in domestic uses. Thus, it will contribute to the sustainable management of groundwater resources in this study area. This will helps to understand and implement by the local authorities and land planners easily. They represent an important preliminary tool in decision making pertaining to the management of groundwater quality. The research will be believed to provide policy makers with better information on water use and management in the study area.

This study will have undeniable importance in visualizing the hidden problems and understanding the ongoing activities of the study area, besides it will helps to define the status and level impact on the environment. The researcher also optimistically believes that, the primary beneficiary of this research will be the community of the study area in general and, a government structure in particular. Furthermore, it will serve as a lighting house for future researches in this particular area.

Finally, it will help as a reference or literature for practitioners who are interested on the related issues.

1.6. Scope of the Study

The research focuses on geochemical and bacteriological quality of ground water and it is suitability for and correlation of demand supply for domestic uses, throughout this study. For this purpose, Robe District, of which eight kebeles as sample site, has been selected. Moreover, available laboratory and field investigation questionnaires were employed to obtain representative results such that plausible correlation results were obtained.

1.7. Limitation of the study

The study did not fully cover the entire kebeles of Robe districts. The main reason for this is the constraints of budget and limitation of time. The study is also a cross-sectional study type in which samples were collected only in a single rainy season because of limitation of time and resources. The parameters assessed in this study are also specific and selected. This is, there were no complete assessment of all water quality parameters rather than the researchers focused on major components. The researchers also faced difficulties in obtaining depth and other geological profiles for water wells. Since sample collection period was in a wet season, it needs dry season assessment in order to reduce the problem of seasonal variability. But the research focused to obtain the necessary data and information during the entire study period with maximum effort.

CHAPTER TWO

LITRATURE REVIEW

2.1. Ground Water Resource

Ground water is a resource found under the land surface in the saturated zone. It constitutes about 95 percent of the freshwater on our planet (discounting that locked in the polar ice caps) (UNEP, 2003). Most of the Earth's liquid freshwater is found, not in lakes and rivers, but stored underground in aquifers. These aquifers provide a valuable base flow supplying water to rivers during periods of no rainfall. Therefore it is an essential resource that requires protection.

2.2. Ground water quality and sources of Pollution

Water quality is defined by the physical, chemical and biological characteristics and a composition of water sample (Hounslow 1995). Groundwater quality is a hidden issue inside a hidden resource, and as a result, too little attention is given to it. Once groundwater has become polluted, it is usually a very long, complex and expensive task to restore the water quality. For these reasons, the monitoring, prevention and remediation of groundwater pollution is a vital management issue (UNEP, 2003).The quality of water either it is surface water or ground water is affected by both natural influences and human activities (Chilton, 1996). Similarly, while water contains natural contaminants, it is becoming more and more polluted by human activities such as, inadequate wastewater management, dumping of garbage, poor agricultural practices, and chemical spills at industrial sites (CAWST, 2013). Even though, water may be clear, it does not necessarily mean that it is safe for us to domestic use. It is important to judge the safety of water by taking the following three types of parameters into consideration (CAWST, 2013).Microbiological is about bacteria, viruses, protozoa and helminthes (worms). Physical_ temperature, color, smells /odor/, pH, taste and turbidity. The chemical composition of groundwater is the combined result of water composition that enters the groundwater reservoir and the reactions with minerals present in the rocks (Iliopoulos et al., 2002). The chemical composition of groundwater is the combined result of water composition that enters the groundwater reservoir and the reactions with minerals present in the rocks (Iliopoulos et al., 2002). This is about minerals, metals, other chemicals. The sources of chemicals are divided into the following five groups (WHO, 2011). Naturally occurring, Agricultural activities, Industrial sources and human dwelling /residence/, Water treatment plant, Pesticides used in water for public Health.

Table 2.1: Sources of Chemical Contamination (source WHO, 2011)

Source of Chemicals	Example	Common Chemicals
Naturally occurring	Rocks and soils	Arsenic, chromium, fluoride, iron, manganese, sodium, sulphate, uranium
Agricultural Activity	Manure, fertilizer, intensive animal practice, pesticide	Ammonia, nitrate, nitrite
Industrial activities and Human Dwelling	Mining, manufacturing, and processing industries, sewage, solid waste, urban runoff, fuel leakage	Nitrate, ammonia, cadmium, cyanide, copper, lead, nickel, uranium
Water Treatment	Water treatment chemicals, piping material	Aluminium, chlorine, iodine, silver
Pesticide used in water for Public Health	Larvicides used to control insect vector of disease	Organophosphorus compound (eg. Chlorprifos, diazinon malathion) and carbamates (eg. Aldicarb, carbaryl, carbofuran,oxamyl)

2.3. Water Quality Parameters

2.3.1 Physical Water Quality parameters

Water for domestic use should be free of objectionable taste, odor, color and suspended materials. These are often called aesthetic parameters. Aesthetic parameters are those detectable by the senses, namely turbidity, color, taste, and odor. They are important in monitoring community water supplies because they may cause the water supply to be rejected and alternative (possibly poorer quality) sources to be adopted, and they are simple and inexpensive to monitor qualitatively in the field. Physical Parameter of water includes also such parameters as pH, TDS, salinity and hardness. The chemical quality influences also the physical quality. The appearance, taste, odor, and 'feel 'of water determine what people experience when they drink or use water and how they rate its quality other physical characteristics can suggest whether corrosion and encrustation are likely to be significant problems in pipes or fittings. The measurable characteristics that determine these largely subjective qualities are: true color (i.e. the color that remains after any suspended particles have been removed), turbidity (the cloudiness caused by fine suspended matter in the water), hardness (the reduced ability to get a lather using soap), total dissolved solids (TDS), pH, temperature, taste, odor and dissolved oxygen (ADWG, 2006).

2.3.2 pH

The parameter pH (negative base-10 logarithm of hydrogen ion activity in moles per liter) is one of the most fundamental Physical water-quality parameters. It is easily measured, indicates whether water was corrosive or will precipitate scale, determines the solubility and mobility of most dissolved constituents, and provides a good indication of the types of minerals groundwater has reacted with as it flows from recharge to discharge areas or sample sites. For these reasons it is one of the most important parameters that describe groundwater quality. The pH of neutral (neither acidic nor basic) water varies with temperature. For example, the neutral pH of pure water at 25°C (77°F) is 7.0. The neutral pH of pure water at 30°C (86°F) and 0°C(32°F) is 6.9 and 7.5, respectively (Hem, 1985).

2.3.2 Temperature

The temperature of water to a large extent determines the extent of microbial activity. Temperature is the measure of hotness or coldness of water measured either in degree Celsius or Fahrenheit by using a thermometer (APHA, 1985).

2.3.3 Electrical Conductivity (E.C)

Conductivity, which is also called Electrical Conductivity (EC), is reciprocal of resistance in ohms between the opposite faces of a 1 cm cube of an aqueous solution at specified temperature (usually 25 °C). It is temperature dependent and the international unit is Siemens per meter (Hounslow, 1995; Mazor, 1991).

2.3.4 Total Dissolved Solids (TDSs)

TDS is a measure of the amount of material dissolved in water. This material can include carbonate, bicarbonate, chloride, sulfate, phosphate, nitrate, calcium, magnesium, sodium, organic ions, and other ions (UNICEF, 2008).

The total concentration of dissolved minerals in water is a general indication of the overall suitability of water for many types of uses (Karthikeyan*et al.*, 2013).

2.3.5 Turbidity

Turbidity adversely affects the efficiency of disinfection of water. It is measured to determine what type and level of treatment are needed. It can be carried out with a simple turbidity tube that allows a direct reading in nephelometric turbidity units (NTU) (WHO, 2006). Turbidity in drinking-water is caused by particulate matter that may be present from source water as a consequence of inadequate filtration or from re-suspension of sediment in the distribution system. It may also be due to the presence of inorganic particulate matter in some groundwater or sloughing of bio-film within the distribution system. The appearance of water with a turbidity of less than 5 NTU is usually acceptable to consumers, although this may vary with local circumstances. No health-based guideline value for turbidity has been proposed; ideally, however, median turbidity should be below 0.1 NTU for effective disinfection, and changes in turbidity are an important process control parameter (WHO, 2006).

2.4 Chemical Water Quality parameters

The health concerns associated with chemical constituents of drinking water differ from those associated with microbial contamination and arise primarily from the ability of chemical constituents to cause adverse health effects after prolonged periods of exposure. There are few chemical constituents of water that can lead to health problems resulting from a single exposure, except through massive accidental contamination of a drinking-water supply (WHO, 2008).

2.4.1 Calcium (Ca^{2+}) as $CaCO_3$

Over 99% of total body calcium is found in bones and teeth, where it functions as a key structural element. The remaining body calcium functions in metabolism, serving as a signal for vital physiological processes, including vascular contraction, blood clotting, muscle contraction and nerve transmission. Inadequate intakes of calcium have been associated with increased risks of osteoporosis, nephrolithiasis (kidney stones), colorectal cancer, hypertension and stroke, coronary artery disease, insulin resistance and obesity (WHO, 2008).Calcium occurs in water mainly due to the presence of limestone, gypsum and dolomite minerals. Industrial, as well as water and wastewater treatment, processes also contribute calcium to surface waters and ground water. Acidic rainwater can increase the leaching of calcium from soils. Calcium concentrations in natural waters are typically less than 15 mg/L but for water associated with carbonate rich rocks, concentrations may reach 30 up to 100 mg/L. Salt water have concentrations of several hundred milligrams per liter or more (UNICEF, 2008).

2.4.2 Magnesium ($Mg^{2+)}$) as $CaCO_3$

Magnesium is usually less abundant in waters than calcium, which is easy to understand since magnesium is found in the Earth's crust in much lower amounts as compared with calcium. In common underground and surface waters the weight concentration of Cais usually several times higher compared to that of Mg, the Ca to Mg ratio reaching up to 10. Nevertheless, a common Ca to Mg ratio is about 4, which corresponds to a substance ratio of 2.4 (Pitter, 1999).Magnesium occurs typically in dark colored minerals present in igneous rocks such as plagioclase, pyroxenes, amphiboles, and the dark colored micas. It also occurs in metamorphous rocks, as a constituent of chlorite and serpentine (Perk, 2006). Magnesium is common in natural waters as $Mg^{2+,}$ and along with calcium, is a main contributor to water hardness. Natural concentrations of magnesium in fresh waters may range from 1 to 100 mg/L (UNICEF, 2008).

2.4.3 Bicarbonate (HCO_3^-) as $CaCO_3$

The bicarbonate content of ground water samples ranges from 14.20 mg/L to 54.30mg/L. The mean bicarbonate concentration of sample water is 31.52 mg/L. The case for the elevated TDS value in ground water is the existence of bicarbonates and other inorganic salts (principally Calcium, Magnesium, Potassium, Sodium, Chlorides and Sulfates) and small amounts of organic matter that are dissolved in water. Even though no clear cut standard guide line value for this; it is beloved to not to have more than 500 mg/L of bicarbonate in drinking water. Contentious and long term weathering of rocks will result in dissolution of rock minerals and results in formation of bicarbonate. It is showed that the tested water samples have bicarbonate concentration less than stated recommendable value and hence the tested water is still suitable for drinking (WHO, 2008).

2.4.4 Sodium (Na^+)

Although concentrations of sodium in potable water are typically less than 20 mg/L, they can greatly exceed this in some countries. The levels of sodium salts in air are normally low in relation to those in food or water. It should be noted that some water softeners can add significantly to the sodium content of drinking-water. No firm conclusions can be drawn concerning the possible association between sodium in drinking-water and the occurrence of hypertension. Therefore, no health based guideline value is proposed. However, concentrations in excess of 200 mg/L may give rise to unacceptable taste (WHO, 2006).

Sodium in the human body helps in maintaining the amount of water balance. Human intake of sodium is mainly influenced by the consumption of sodium as chloride or table salt. The treatment for certain heart condition, circulatory or kidney diseases or cirrhosis of liver may include sodium restrictions. Diets for these people should be designed with the sodium content of their drinking water taken in to account. The recommended maximum level for people suffering from certain medical conditions such as hypertensions, congestive heart failure or heart disease is 20mg/L (Zodape*et al*., 2013).

2.4.5 Potassium ($k^{+)}$)

Potassium is an essential element in humans and occurs widely in the environment, including all natural waters. The primary source of potassium for the general population is the diet, as potassium is found in all foods, particularly vegetables and fruits. Some food additives are also potassium salts like potassium iodide and it is also rarely occur in drinking water a level that could be a concern for healthy humans (Zodape*et al*., 2013). However the contamination of drinking water by potassium can occur due to the use of excessive potassium permanganate as an oxidant in water treatment and due to the consumption of water obtained from water softeners that uses potassium chloride (Zodape*et al*., 2013). Potassium is an essential element in humans and is seldom, if ever, found in drinking water at levels that could be a concern for healthy humans. Potassium occurs widely in the environment, including all natural waters and it can also occur in drinking-water as a consequence of the use of potassium permanganate as an oxidant in water treatment (WHO, 2009).

2.4.6 Nitrate (NO_3^-)

Nitrate and nitrite are naturally occurring ions that are part of the nitrogen cycle. Nitrate is used mainly in inorganic fertilizers, and sodium nitrite is used as a food preservative, especially in cured meats. The nitrate concentration in groundwater and surface water is normally low but can reach high levels as a result of leaching or runoff from agricultural land or contamination from human or animal wastes as a consequence of the oxidation of ammonia and similar sources. The formation of persistence of nitrite will be due to anaerobic environment. Chloramination may give rise to the formation of nitrite within the distribution system if the formation of chloramines is not sufficiently controlled. The formation of nitrite is as a consequence of microbial activity and may be intermittent. Nitrification in distribution systems can increase nitrite levels; usually by 0.2–1.5 mg/L. Guide line value for nitrate is 50 mg/L to protect against methaemoglobinaemia in bottle-fed nitrate infants (WHO, 2006).

2.4.7 Sulfate (SO_4^{-2})

Sulfates occur naturally in numerous minerals and are used commercially, principally in the chemical industry. They are discharged into water in industrial wastes and through atmospheric deposition; however, the highest levels usually occur in groundwater and are from natural sources. In general, the average daily intake of sulfate from drinking-water, air and food is approximately 500mg, food being the major source. However, in areas with drinking-water supplies containing high levels of sulfate, drinking-water may constitute the principal source of intake (WHO, 2006).

Sulfate is also a combination of sulfur and oxygen. It occurs naturally in many soil and rock formations. In groundwater, most sulfates are generated from the dissolution of minerals, such as gypsum and anhydrite. Saltwater intrusion and acid rock drainage are also sources of Sulfates in drinking water. Manmade sources include industrial discharge and deposition from burning of fossil fuels (WHO, 2011). Sulfate concentrations in natural waters are usually between 2 and 80 mg/L. High concentrations greater than 400 mg/L may make water unpleasant to drink (UNICEF, 2008).

2.4.8 Chloride (Cl^-)

Chloride in drinking water originates from natural sources, sewage and industrial effluents, urban runoff containing de-icing salt and saline intrusion. The main source of human exposure to chloride is the addition of salt to food, and the intake from this source is usually greatly in excess of that from drinking-water. Elevated concentration of chloride in increases the rates of metallic corrosion in water distribution system even though it depends on the alkalinity of the water. This can lead to increased concentrations of metals in the supply. No health-based guideline value is proposed for chloride in drinking-water. However, chloride concentrations in excess of about 250 mg/L can give rise to detectable taste in water (WHO, 2006).

2.4.9 Fluoride (F^-)

Fluoride contamination of groundwater is a serious problem in several countries spread throughout the world as ingestion of excess fluoride, most commonly, through drinking contaminated groundwater causes fluorosis. Mainly two factors are responsible for contamination of groundwater with fluoride- geological and anthropogenic. Rock geochemistry has a major control on geological fluoride contamination. Physiological conditions of rock, like decomposition, dissociation and subsequent dissolution along with long residence time may be the responsible factors for fluoride leaching (Madhnure, 2006).

Among anthropogenic factors industrialization, urbanization and improper utilization of water resources are of prime importance, in case of the developing countries (Giesen, 1999). Long term ingestion of fluoride in high doses can lead to severe skeletal fluorosis (Susheela, 2001).

2.4.10 Total Hardness

Hardness in water is caused primarily by the presence of carbonates and bicarbonates of calcium and magnesium, Sulfates, chlorides and nitrates. It is usually expressed as the equivalent quantity of calcium carbonate. Depending on pH and alkalinity, hardness above 200 mg/L can result in scale deposition particularly on heating. Soft waters with a hardness of less than 100 mg/L have a low buffering capacity and may be more corrosive to water pipes. A number of ecological and analytical epidemiological studies have shown a statistically significant inverse relationship between hardness of drinking-water and cardiovascular disease (WHO, 2006). The total hardness of water classified in to three ranges (0-300 mg/l, 300-600 mg/l and >600 mg/l) low, medium and high respectively (Karthikeyan*et al.*, 2013).

2.5. Heavy Metals Water Quality parameters

2.5.1 Iron ($Fe^{2+)}$)

Heavy metals like iron, which are found in natural water bodies occur at varying concentrations and usually monitored by measuring their concentrations in water, sediment and biota (Kalu*et al.*, 2015).Some of these metals are vital to keep up life such as Calcium, Magnesium, Potassium and Sodium, which are necessary for common body functions and others including Cobalt, Copper, Iron, Manganese, Molybdenum and in is needed at low level as catalyst for enzyme activities (Meghdad*et al.*, 2013). However when the concentrations of these metals exceeds the maximum permissible level or standard value, it becomes highly toxic to human health and environment. It also causes malfunctioning of enzymatic activities (Meghdad*et al.*, 2013).

The use of groundwater for drinking is in many cases limited by the presence of dissolved iron and to a lesser extent manganese. These give the water an unpleasant metallic taste and stain food, sanitary ware and laundry. Iron with concentration value greater than 0.3 mg/L can causes rusting and cancer (WHO, 2004).Dissolved iron in ground water is controlled by pH and redox conditions and is dependent on iron-bearing minerals in the aquifer (Eric *et al.*, 2003).

Iron is one of the most abundant metals in the Earth's crust. It is found in natural fresh waters at levels ranging from 0.5 to 50 mg/L. Iron may also be present in drinking-water as a result of the use of iron coagulants or the corrosion of steel and cast iron pipes during water distribution. Iron is an essential element in human nutrition. Estimates of the minimum daily requirement for iron depend on age, sex, physiological status and iron bioavailability and range from about 10 to 50mg/day (WHO, 2006).

The history of standard guideline development for concentration of Iron in water suggest in 1985 that, Iron concentration greater than 1.0 mg/L would markedly impair the suitability of the water and deteriorate the water quality. The 1963 and 1971 International Standards retained this value as a maximum allowable or permissible concentration. In the "first edition of the Guidelines for drinking-water Quality", published in 1984, a guideline value of 0.3 mg/L was established, as a compromise between iron's use in water treatment and aesthetic considerations. Iron stains laundry and plumbing fixtures at levels above 0.3 mg/L. There is usually no noticeable taste at iron concentrations below 0.3 mg/L (WHO, 2006).

2.5.2 Manganese ($Mn^{2+)}$)

Manganese is one of the most abundant metals in the Earth's crust. It is used principally in the manufacture of iron and steel alloys, as an oxidant for cleaning, bleaching and disinfection as potassium permanganate and as an ingredient in various products. More recently, it has been used in an organic compound, Methylcyclopentadienyl manganese tri-carbonyl (MMT), as an octane enhancer in petrol in North America. Manganese greensands are used in some locations for potable water treatment. Manganese is an essential element for humans and other animals and occurs naturally in many food sources. The most important oxidative states for the environment and biology are Mn^{2+}, Mn^{4+} and Mn^{7+}.Manganese is naturally occurring in many surface water and groundwater sources, particularly in anaerobic or low oxidation conditions, and this is the most important source for drinking water. The greatest exposure to manganese is usually from food. Manganese usually occurs in fresh water with typically level range from 1 to 200 mg/L, although levels as high as 10 mg/L in acidic groundwater have been reported; higher levels in aerobic waters usually associated with industrial pollution. The WHO standard guide line value for Manganese is 0.4 mg/L (WHO, 2006).

2.6. Microbiological Water Quality

The principal risk associated with water in small-community supplies is that of infectious disease related to fecal contamination. Hence, the microbiological examination of drinking water emphasizes assessment of the hygienic quality of the supply. This requires the isolation and enumeration of organisms that indicate the presence of fecal contamination (WHO, 2008). With regard to bacteriological parameters, samples were analyzed using membrane filtration (MF) method for water quality to determine the degree of contamination (WHO, 2006; APHA, 1998). All samples was analyzed for the presence of total coli forms (TC) and fecal coli forms (FC).The total coli form group was selected as the primary indicator bacteria for the presence of disease causing organisms in drinking water. It is a primary indicator of suitability of water for consumption. If large numbers of coli forms are found in water, there was a high probability that other pathogenic bacteria or organisms exist. The WHO and Ethiopian drinking water guidelines require the absence of total coli form in public drinking water supplies. The frequency of testing for public water supplies depends on the size of the population served (WHO, 2011).One hundred milliliter of water sample for each test was filtered through a sterile cellulose membrane filters with a pore size of 0.45µm to retain the indicator bacteria.

2.6.1 Total Coli form determination procedure

In this method, a number of a serial dilution of the sample was made and inoculated into a Lauryltryptose broth medium ferment lactose at35–37°C with the production of acid, gas, and aldehyde within 24–48 hours. Coli form organisms have long been recognized as a suitable microbial indicator of drinking-water quality, largely because they are easy to detect and enumerate in water. Then by gentle mixing or swirling the growth, gas production and acidic reaction was checked, and there was production of gas and acid formation which was positive. Then, the culture in tubes of positive presumption test was transferred to a fermentation tube (which contains brilliant green lactose bile broth) and then incubated at

35ºC for 24 hours. Formation of gas within 48 hours constitutes a positive confirmed phase. The colony forming unit value was then calculated according to APHA procedure for most probable number (APHA, 1999).

2.6.2 Fecal coli form determination procedure

Fermentation tubes showing positive presumptive phase for fecal coli form test was taken and culture was transferred to EC broth and incubated in a water bath at 44.5 °C ± 0.2°C for 24 ± 2hwithin 30 minutes after inoculation. Gas production within 24hour± 2hour or less will be considered a positive fecal coli form reaction. The MPN was calculated from the number of positive EC broth described in APHA procedure (APHA, 1999).

Membrane-filtration method

In the membrane-filtration (MF) method, a minimum volume of 10ml of the sample (or dilution of the sample) is introduced aseptically into a sterile or properly disinfected filtration assembly containing a sterile membrane filter (nominal pore size 0.2 or 0.45 µm). A vacuum is applied and the sample is drawn through the membrane filter. All indicator organisms are retained on or within the filter, which is then transferred to a suitable selective culture medium in a Petri dish. Following a period of resuscitation, during which the bacteria become acclimatized to the new conditions, the Petri dish is transferred to an incubator at the appropriate selective temperature where it is incubated for a suitable time to allow the replication of the indicator organisms. Visually identifiable colonies are formed and counted, and the results are expressed in numbers of "colony forming units" (CFU) per 100ml of original sample.

Table 2.2: Water quality colonies counts per 100ml and the associated risk

Counter per 100ml	Risk Category
0	In conformity with WHO guidelines
0-10	Low risk
11-100	Intermediate risk
101-1000	High risk
> 1000	Very high risk

4.7. Household Water Demand

Demand for a good or service is an economic function because it is influenced by an individual's budget, the price of the good and individual preferences. In terms of water supply, demand is defined as the quantity and quality of water householders will choose to consume at a given price. Price, as used here, signifies all valued resources" including an individual's time or labor given in exchange for service. Water, just like other commodities, is a normal commodity whose demand is complementary, that is, the demand is for the purpose of providing support services necessary for productive activities (Reinikka and Svensson, 1999; World Bank, 1994). The determinants of the demand for water can be viewed from both the macro and micro level. At the macro level, the most dominant factors that determine the demand for water in any society are the scarcity and the cost of purchase, large geographic coverage, and large number of residential buildings, population growth and density and the level of commercial and industrial activities (Seleth and Diner, 1993).

At the micro level, often referred to as the household level, the most dominant factors are the socio-economic and demographic characteristics of the households (which include the education of the family members, their occupation, the size and composition of the family), the income of the household members, the quality of water, the reliability of supply, the existence of water and the household attitude towards the government that provide the water which, to most of them, is supposed to be free or subsidized (World Bank, 1993). Empirical studies on factors that affect the demand for residential water of households are discussed as follows:

2.7. Costs of Water Collection

Collection time and distance to the source are found to be significant drivers of household choice of water source(s) (Mu, 1990).

2.8. Water Supply Scenarios

Human search for pure water began in pre historic times. Water was the root of human civilization, which sprang up only where abundant water supply was available. These areas of civilization were those which flourished on the banks of the Nile, the Tigris and Euphrates and in other countries like India and China (Admassu, 1996).

Access to safe and adequate potable water supply is a basic human right. In Pakistan, groundwater is the main source for drinking water. However, the cities of Karachi and

Hyderabad depend on surface water as a drinking source. Domestic water supply and demand is not uniform in different cities of Pakistan and varies significantly base on location, climatic change, house characteristics, and socio-economic variables. Water demand is increasing rapidly while the options for new development of water are limited. In Pakistan, the major contribution to water supply within the home comes from private hand which boost domestic water supply (World Bank, 2006).

2.9. Household Use of Domestic Water

In its guidelines for drinking water quality, WHO defines domestic water as “water” that being used for all usual domestic purposes including drinking, bathing and food preparation (WHO, 1993; 2002). This implies that the requirements with regard to the adequacy of water apply across all these uses and not solely in relation to drinking of water. The guidelines exclude some specific uses and elevated requirements for some particularly sensitive sub-populations (for instance the several immune-compromised). In the “Drawers of water” study on water use pattern in Africa, three types of use could be defined in relation to normal domestic supply (White, 1972):

i. Drinking and cooking
ii. Hygiene
iii. Amenity use (for instance car washing, lawn watering etc.).

In addition the Drawers of water supply, a forth category can be included of “productive use” which was of particular relevance to poor households in developing countries (Thompson 2001). Productive use of water includes uses such as brewing, animal watering, construction and small scale horticulture.

2.10. Average Water Consumed By Household

Access to water is measured by the number of people who have reasonable means of getting an adequate amount of water that is safe for drinking, washing and essential households activities expressed as a percentage of the total population. It reflects the health of a country’s people and the country’s capacity to collect, clean and distribute water to consumers. World Health Organization (WHO), defines basic access to potable water as the availability of drinking water at least 20litres per day per person, a distance of not more than 1km from the source to the house and a maximum time taken to collect round trip of 30minutes. The minimum absolute daily water need per person per day is 50liter

(13.2gallons) which include: 5litre for drinking, 20litres for sanitation and hygiene, 15litres for bathing and 10litres for preparing food (UNDP, 2008).

The total domestic water needs in homes with piped water and inside sanitation is at least 115litres per head per day. The actual amount used may be greater depending on the ease and convenience of supply (Ayoade and Oyebande, 1983). The international consumption figures released by the 4th World Water Forum (2006), indicates that a person living in an urban area, uses an average of 250liters per day; but individual consumption varies widely around the globe (THD, 2007).

Wide differences exist between water consumption levels in industrialized and developing countries. Average per capita daily water consumption (l/c/d) for Switzerland, the least among industrialized countries, is 110l/c/d, USA (668l/c/d) and Japan (342l/c/d) (World Bank, 1997 as cited by Rosen and Vincent, 1999). Studies in developing countries indicate that while 20 liters per person per day is considered adequate for domestic use, in Ethiopia, the average per person water consumption varies between 10 and 20 liters per person per day in some urban areas and 3 to 4 liters per person per day in rural areas (UN, 2001).

2.11. Time of Collecting Water

The amount of time spent by householders collecting water in order to secure water for the household is an evidence of water scarcity. In Zimbabwe, women spend approximately 91% of total time devoted for household chores to collect water (Mehretu and Mutambirwa, 1992). In Madagascar, women spend an average of 12 minutes daily collecting water (Minten, 2002). Women aged20 – 29 spend 56minutes daily fetching water; age 30 – 49 (69minutes); over 50years (77 minutes) (Boven, Collier and Gunning, 1989). In a village in Mozambique, about 5hours is devoted to water collection (return trip) from a public standpipe located 4kilometers (average of 131minutes per carrier per day) whilst a similar source located 300meters takes an average of 25minutes per carrier per day (Cairn cross and Cliff, 1987).

When drinking water is available at some reasonable distance, households saves time. Such substantial amount of time saved could improve the welfare through time and energy availability for education, high-status work and civic activities (WHO, 1995). Time saved by women is channeled into housework (for example, cooking and hygiene), rest, social and personal activities (Rosen and Vincent, 1999). Others allocated time saved to having quality time with the family and as well engaging themselves in income generating activities (Ariyabandu, 2001).

2.12. Water Scarcity and Its Associated Problems

Water scarcity is defined as the point at which the aggregate impact of all users impinges on the supply of water under prevailing institutional arrangement to the extent that the demand by all 20 Sectors, including the environment cannot be satisfied fully. Water scarcity is a relative concept and can occur at any level of supply or demand. Scarcity may be a social construct (a product of affluence, expectations and customary behavior) or the consequence of altered supply pattern streaming from climatic change for example (UN, 2011).

Water scarcity situation is severe in developing countries with an estimate of about 1.2billion people in developing countries without access to safe water (WHO, 1998). More than 1billion people in developing countries do not have access to clean water whilst 2billion people lack adequate sanitation (World Commission for Water, 2000). In the case of Sub-Saharan Africa, about 67% of the rural population (about 250million people) lack safe and accessible water supply whilst 81% do not have access to sanitation facilities (Rosen and Vincent, 1999). 20% of the urban population (322million people) does not have access to water supply whilst 37% lack access to sanitation facilities (WHO/UNICEF and JMP, 2010).

To determine how data on water source quality affect assessments of progress towards the MDG target 7c, data from five countries (Ethiopia, Jordan, Nicaragua, Nigeria and Tajikistan) on whether drinking water sources complied with WHO water quality guidelines were obtained from the Rapid Assessment of Drinking Water Quality (RADWQ) project (Ince *et al.*, 2010, Tadesse *et al.*, 2010b). Considering these data, the proportion of the population with access to safe drinking water resulted in lower values than the JMP estimate. The absolute reduction was 11% in Ethiopia, 16% in Nicaragua, 15% in Nigeria and 7% in Tajikistan. Microbial contamination was more common than the chemical one (Sorlini *et al.*, 2013b).In an attempt to enhance water security, households' device coping strategies that could enable them cope with water scarcity. In addition, in most situations the coping strategies are normally associated with some sort of costs, costs that can be of detriment to their health, time and socioeconomic activities.

2.13. Quantity of Water for Domestic Use

A water supply is an essential requirement for all people. Determining how much is needed is one of the first steps in providing that supply. Providing enough water to meet everybody's needs may be difficult in the short-term so water can be made Available in stages. Continuous checking, including talking to the various users of the supply (especially women), will enable limited resources to be focused effectively. Providing water is never free; the water needs to be collected, stored, treated and distributed. Providing too much water is a waste of money. Taking too much water from a limited source may deprive people elsewhere of water and have adverse environmental and health impacts.

2.14. Guidelines for Water Quality Parameters

Safe drinking water is required for all usual domestic purposes, including drinking, food preparation and personal hygiene. Every effort should be made to achieve drinking water that is as safe as practicable (WHO, 2011).The nature and form of drinking water standards may vary among countries and regions. There is no single approach that is universally applicable. It is essential in the development and implementation of standards that the current or planned legislation relating to water, health and local government is taken into account and that the capacity of regulators in the country is assessed. Approaches that may work in one country or region will not necessarily transfer to other countries or regions. It is essential that each country review its needs and capacities in developing a regulatory framework (WHO, 2011).

Based on the water quality standards stipulated by the WHO ranks were assigned for each parameter depending on the respective tested values, as given in the Table 2.

Table 2.3: Drinking Water Quality Standards of Ethiopia and WHO (sources: from Ethiopian standard guidelines ES 261:2001 and WHO, 2011)

Drinking WQ parameter	WHO standard(1993) (mg/L)	Ethiopian standard(1998) (mg/L)
Nitrate	50	50
Arsenic	0.01	0.01
Fluoride	1.5	1.5
Magnesium	50	50
Chloride	250	250
Calcium	75	75
Sodium	200	200
Sulphate	250	250
TDS	1000	1000
Ammonia (mg/L)	-	0.5
FC (CFU/100mL)	0	0
TC (CFU/100mL)	-	0
Turbidity (NTU)	<5 at disinfection point	<5
pH	pH 6.5-8,6.5-8	pH 6.5-8,6.5-8
EC	250	250
TH	200	200

2.15. Perception of drinking water

In terms of drinking water quality, user perception is one of the most important things, sometimes exceeding actual quality of water especially when it concerns the quality of drinking water for the user communities (Sheat, 1992; Doria, 2010). There are different factors that influence the perception of drinking water quality, including: Human sensory perceptions of taste, odor and color of water are related with mental factors and some extent taste, which is the more important because it may detect water contamination related to chemicals. People may perceive risks if they experience health problem caused by water.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Study area

A. Location, Accessibility& the Kebeles

This study was conducted at Robe District. Robe found in Oromia national regional state, middle part of Ethiopia. It is located 225km south of Addis Ababa. Arsi Robe is a District in south-eastern Ethiopia. It is named after the Robe River, 80 kilometers of which flows through the District. Part of the East Arsi Zone, Robe District is bordered on the south by the Shebelle River which separates it from the Bale Zone, on the southwest by Sherka, on the west by Tena, on the north by Sude, on the northeast by Amigna, and on the east by Seru. The administrative center of the District is Robe; other towns in Robe District include Habe and Sedika.RobeDistrict is situated at 07°48′-09°36′N latitude and 39°08′-40°21′E longitude (0568953 (Easting), 0870363 (Northing)) with an elevation of 2435 meters above sea level. The District is accessible by all-weather roads from Assela town (78km gravel road and 20km Asphalt road). Almost all of the District's kebeles are accessible only by dry weather roads. The District Consists of 32 Kebeles.

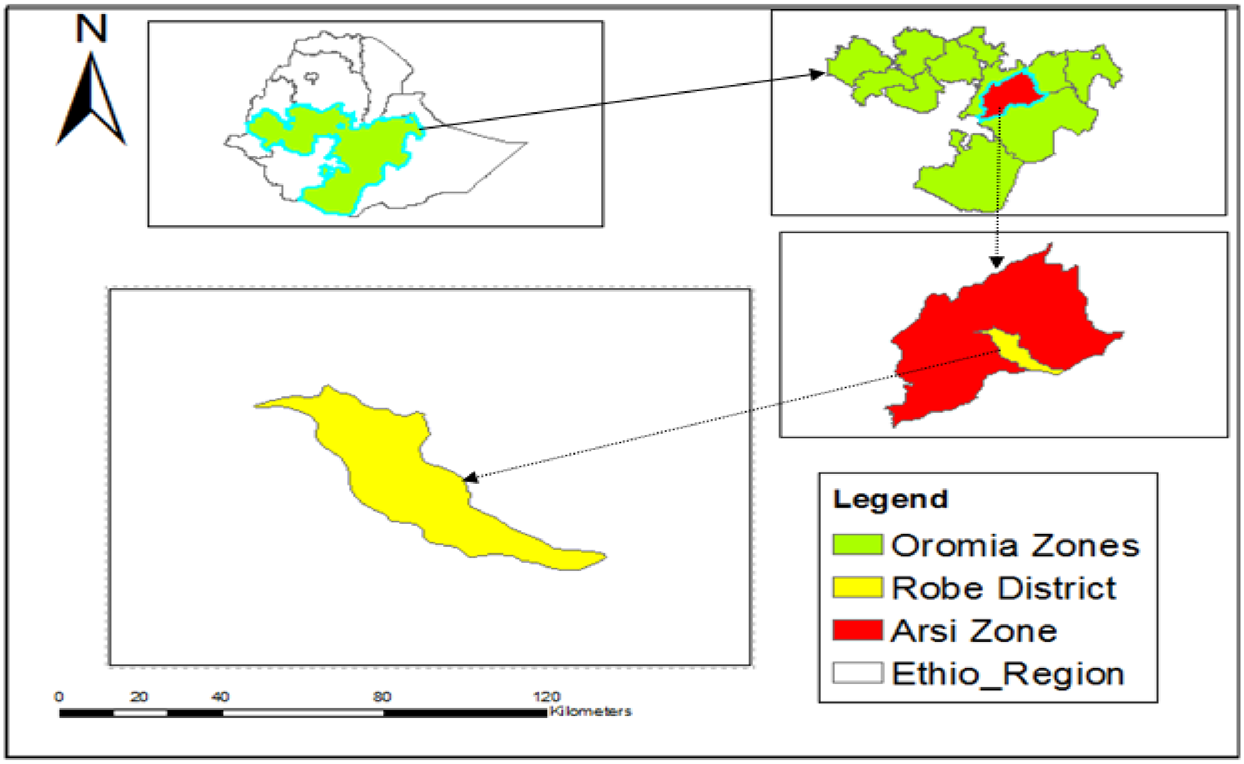

Figure 3.1: Study Area Map

B. Area, Topography & Land use

The District has an area extent of about 1275 km^2. The topography is characterized by undulating relief and dissected plateaus, plain and vertical cliff, up and down landforms in kola areas. It ranges from plain land to valleys/gorges and elevated landscape. As far as land use is concerned, the District has 0.52% vegetation cover, 39.66 % agricultural land, 11.58% grazing land, 48.24% for other uses (Wikipedia).

C. Climate and Hydrology

According to Robe Meteorological Station, data the maximum and minimum mean annual rainfall is about 1300mm and 700mm, respectively. Temperature of the District ranges from a minimum of 10.5°C to a maximum of 25°C. According to climatic classification Agro-ecologically, the District categorized into three agro-ecology; these are the Dega, Woina DegaandKola constituting 24%, 62% and 14% of the total area of the Districtrespectively (Wikipedia).

D. Geology and Hydrogeology

Geologically, the District is composed of Trap Basalts or Early Tertiary Volcanic Rocks. Alkali Olivine basalts, Tuffs and Rhyolites are in this group. But one can find Ambaradam formation (Clay, Silt, Sand and Conglomerates) along the South-Easternmost boundaries of the District. As far as hydrogeology is concerned, the geological formations in the Northern part of the Districtform poor aquifers with low permeability. The formations present in the Southeastern part form aquifers (dominantly Basalts) with moderate fractures and permeability. The Sand and Conglomerates found in the Southeastern boundary of District (Wikipedia).

E. Population and Socio-Economic Conditions

a) Population

The total population of the District is 206,939 of which 101,413Male and 105,525 Female giving sex ratio of 96 male to 100 female (CSA, 2008).186,245 (90%) of its population are rural and 20,694 (10%) are urban dwellers. The average population density of the District is 147 persons per km2 within an estimated area of 1,338.6 square kilometers (CSA, 2008). The growth rate of population of District is0.029 and the average family size of the District is 4.8 persons per household (Wikipedia).

b) Socio-Economy

The major source of income in the District is mixed farm/agriculture of Cash Crops, Cereal Crops and livestock production. Major products include such as, maize, wheat, and Teff. .Small-scale business activities are also common in the District town and other rural towns of the District.

3.2 Study period

The study was carried out from May to end of September 2017 in eight sub-areas of Arsi Robe District, namely: Abo Ali,AtabaRobe,JenaHulul,JenaBarbuko, SedikaTokuchuma, HabeDengazela, MeseranjeOda, and Robe town.

3.3. Study design

A cross sectional experimental study and Reconnaissance Surveydesignwas conducted.

Groundwater samples collection and sampling procedures

Table 3.1: Sampling points, collected water source type and their GPS

Sample code	Name of the location	Water sources	GPS Reading		
			Easting	Northing	Elevation
AASP	Abo Ali	Hand Dug borehole	571569	860333	2335
ARSP	Ataba Robe	Protected Spring	562985	864827	2437
JBSP	Jena Barbuqo	Hand Dug borehole	576754	864353	2338
JHSP	Jena Hulul	Hand Dug borehole	575676	856845	2329
HDSP	HabeDangazela	Hand Dug borehole	0562397	0868079	2435
MOSP	MeseranjeOda	Hand Dug borehole	0562687	0869065	2432
STSP	SedikaTokkichuummaa	Hand Dug borehole	0578477	0854787	2345
RTSP	Robe town	Protected Spring	564672	867952	2439

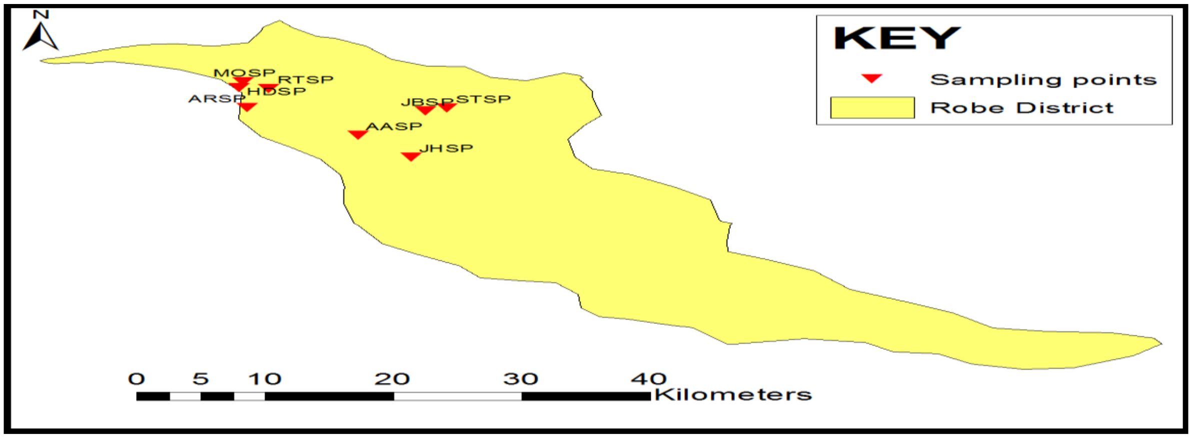

Figure 3.2 sampling points, GARMIN 72 Model Global Positioning System (GPS)

In eight kebeles of Robe District there are 251 hand dug wells (WASH, 2015). Groundwater samples was collected fromeight groundwater wells (two hand dug borehole, one hand pump well, three Hands dug well, one protected springs and one town water supply reservoir) which was selected by purposive and random sampling method sampling using excel.Each sample were collected based on the WHO/UNEP, 1996 standard protocol sampling, transportation, storage and analysis procedure. The location of each sampling points were recorded by GARMIN 72 Model Global Positioning System (GPS) instrument. Water samples were normally obtained from currently existing drilled and dug (shallow) wells fitted with hand pumps.

Pre cleaned polyethylene bottles were labeled based on the sampling station codes. The plastic sampling bottles were soaked in 1:1 HCl for 24 h and rinsed. The bottles were again cleaned by using distilled water. At the time of sampling, the bottles were thoroughly rinsed three times by using the water which is going to be sampled. The samples were filled up to the brim,1:1 Nitric acid solution was added to each sample and immediately sealed to avoid exposure to air. The bottles containing water samples were labeled, tightly packed, stored at 4 °C and transported to the laboratory (Brown et al., 1974).

The water demand and supply sample size and sampling technique are based on population number of Robe District. The population of Robe District was estimated to be 206,939 (CSA, 2008). In every 539people one person was chosen systematically. Meanwhile sample sizes of three hundred and eighty four (384) respondents were selected at random from the total population which again selected from the eight sampling site systematically. A simple random sampling technique was adopted in this study in which each element (members) of the population has an equal chance of being included in the desired sample. Therefore, the total retrieved questionnaires, which samples worked with, were three hundred and fifty persons in which one person was asked per household.

The secondary data on water supply was generated from the state public water, mineral and energy of Robe District, while data on demand was based on household water consumption lifestyle on cooking, washing, bathing and other domestic uses. This is because there is no rate measuring meters, which would have been accurate for determination of water use pattern. Questionnaire method was employed to facilitate the estimation of water use in the study area. The questionnaire method involved designing a set of questions. Then data were collected based on questioner administered.

Types of Data collected For Domestic water Demand and Supply

i. Basic demographic data like sex, age, marital status, occupation, level of education, household size and residential preference.

ii. Information on household socio-economic characteristics, access and sources of water, time spent daily in search for domestic water, distance covered and the amount of income spent to get water daily.

iii. Information on respondent’s water storage pattern.

Sources of Data

Primary Sources of Data

This provides firsthand information that was derived through observations, questionnaire administration and oral interviews.

Secondary Source of Data

The secondary data was obtained from related books, journals, published and unpublished texts, documents magazines, conference articles, government ministries and agencies. The ministries concern are the ministry of water ,mineral and energy of Robe District of local government and ministry of information sourced from published of the united nation, world bank, world health organization etc.

3.6. Study variables

3.6.1. Independent variables

Temperature
Electrical conductivity
TDS
Total alkalinity
PH
Total hardness (Calcium and Magnesium)
Iron
Manganese
Chlorine
Sulfate
Potassium
Sodium
Fecal coliform
Total coliform
Water Demand and supply

3.6.2. Dependent variables

Ground water quality for domestic uses

3.7. Samples analysis

All the water samples was analyzed for major cat ions (Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}), anions (Cl^{-}, HCO_3^{-}, SO_4^{2-}, NO_3^{-}, F^{-}, and heavy metals (Mn^{2+} and Fe^{2+}) in the Oromia Water Works Design And Supervision Enterprise (OWWDSE) (physic-chemical quality) and Asela Town Water Supply And Sewerage System (Bacteriological quality) Laboratories.

Water temperature, Electric Conductivity and pH were determined on the site using portable multi- parameter probe (HQ40d Model), while other parameters were determined in the laboratory within 24-72 hour of the sampling following standard methods (APHA.2005). Total, dissolved and suspended solids were measured gravimetrically. Magnesium, bicarbonate, total alkalinity and chloride were determined by titer metric methods. Hardness (total and calcium) were determined by the EDTA titer metric method. Sodium, potassium and calcium were analyzed using Flame photometer. Interpretation of all water chemistry data was carried out using AquaChem 2012.1 software and Microsoft excel 2007. AquaChem is a software package developed specifically for graphical, numerical analysis, and modeling of water quality data. It features a fully customizable database of physical and chemical parameters and provides a comprehensive selection of analysis tools, calculations and graphs for interpreting water quality data (AquaChem 2012.1 manual).Sampling for bacteriological examination was carried out using sterile container of glass or polyethylene. Samples were preserved under low temperature of 2 to 5^0C during transport and storage. With regard to bacteriological parameters, samples were analyzed using membrane filtration (MF) method for water quality to determine the degree of contamination (WHO, 2006; APHA, 1998). All samples were analyzed for the presence of total coli forms (TC) and fecal coli forms (FC). For the water Demand and supply, a reconnaissance survey was conducted to be well acquainted with the study areas and to properly identify the areas to be surveyed. Initially, some were reluctant to give information until when they realize the actual purpose of the visit they cooperated. The analyzed data were presented by using table, graphs, and pi-chart. Descriptive and inferential statistics were used in the analysis of generated field data for water demand supply. This is because the data that we recollected are both quantitative and qualitative in nature. The descriptive statistics was employed include percentage and frequency distribution table. Equally, the inferential test like correlation was employed in this research to determine whether the supplied water by the water, mineral, and energy sectorofRobe District meets people’s water demand. These analyzes sources of water for domestic uses which was analyzed using descriptive statistics like percentage, frequency distribution table, pie chart and bar graph, Assess factors affecting water demand and supply through descriptive statistics, frequency table, and percentage and examine the relationship between domestic water demand and supply. Thus, correlation analysis was employed to examine the extent of water demand and water supply.

Correlation is given as

$$r_{xy} = \frac{\sum[(x-\bar{x})(y-\bar{y})]}{\{[\sum(x-\bar{x})2][\sum(y-\bar{y})2]\}^{1/2}}$$

Where r_{xy} is the correlation coefficient of water demand and supply (i.e. X and Y)

X = water demand

Y = water supplied

3.8. Letter of consent

The study was conducted after getting permission from ethical committee of Jimma Institute of Technology, Faculty of civil and environmental engineering. District water officials and kebele administrations were informed about the purpose of the study. The respondents were asked for their willingness, based up on their permission they were oriented or informed with the objectives and aim of the study.

3.9. Data quality assurance

According to (APHA, 1995) proper quality assurance procedures and precautions were taken to ensure the reliability of the results. Data quality assurances were assessed carefully and triple measurements were performed to assure quality of data. The average of triplicate measurements of each of the sample analysis was reported. The accuracy of the chemical analysis was verified by calculating Ion Balance Error (IBE) and the analysis of chemicals with IBE of less than 5 % will be used (WHO, 1996).

$$IBE = \frac{\sum Cations - \sum Anions}{\sum Cations + \sum Anions} \times 100\%$$

3.10. Plan of Dissemination

The final result of this study will be presented to Jimma Institute of Technology Faculty of civil and environmental engineering, department of Environmental engineering and will be disseminated to concerning bodies, Oromia national regional state water buearo, East Arsi zone, Robe District water, Mineral and Energy Sector and other governmental and non-governmental organizations which are concerned with the study findings. Publication in national and international journals will also be considered.

CHAPTER FOUR

RESULTS AND DISCUSSION

In this study the physic-chemical, Geochemistry, Bacteriological, and Water Demand and supply of the study area were described which were gained from the laboratory test, questionnaires interviewed and field observation.

4.1 Ion Balance

The first step of the water analysis was an assessment of the quality of the data, which was accomplished by calculating the balance of positive and negative ions.

Water fulfills the principle of electro neutrality and is therefore always uncharged. The level of error in the data was calculated using the following formula (Appelo et al., 1996):

$$IBE = \frac{\sum Cations - \sum Anions}{\sum Cations + \sum Anions} \times 100\%$$

Based on the above formula, electro neutrality was calculated for each sample. Analysis of water samples with a percent BE of <5% is acceptable (Fetter, 2001). However, in very dilute or saline water, up to 10% error may be considered as acceptable due to the errors introduced in measuring major ions in dilute groundwater or in the multiple dilution require for analysis of concentrated groundwater (Fetter , 2001). The calculated IBE shows that 87.5% of the data falls within acceptable 5% criterion and the rest 12.5% falls within acceptable 10% criterion. Positive and negative errors are nearly equal in number that means equal distribution of cat ions and anions which suggest a good sampling and analytical procedures (Figure 4.1)

Figure 4.1 Ionic Balance Error for cat ion and anion in accepted range.

4.2.Physical Water Quality parameters

Water for domestic use should be free of objectionable taste, odor, color and suspended materials. These are often called aesthetic parameters. Aesthetic parameters are those detectable by the senses, namely turbidity, color, taste, and odor. They are important in monitoring community water supplies because they may cause the water supply to be rejected and alternative (possibly poorer quality) sources to be adopted, and they are simple and inexpensive to monitor qualitatively in the field(ADWG, 2006).

4.2.1 pH

From onsite measurement, pH of the sampled water varied from 5.32 to 7.67 with average value of 6.85. The highest value of pH reading (7.67)was observed in Robe Town water sample (RTSP) from piped Hama Raba spring ground water. The lowest value of pH (5.32) was recorded in Ataba Robe spring ground water. According to (WHO, 2004) and Ethiopian guide line the permissible limit of pH is from 6.5 (lowest value) to 8.5 (highest value). Therefore; even though the upper limit pH of sampled water is not out of standard guideline range, samples with pH value bellow the standard WHO guide line value (5.32 and 5.63) are not suitable for domestic use before treatment. Samples taken from Ataba Robe spring ground water and hand dug bore holes of Abo Ali recorded 5.32 and 5.63 respectively. The lowered of pH of these water samples may be due to the acidic nature of the rock that contain elevated concentration of dissolved iron in the strata from which water originates and presence of organic acids and dissolved carbon dioxide. Adjustment of Ph to neutralize acidic nature water should be performed. The ground water of study area has high concentration of Iron, which may acidify the water and reduce the pH.

Therefore, effective aeration will reduce Iron concentration and raise the pH.The remaining water samples have pH value within stated guideline range of WHO and Ethiopia. Hence, they are desirable and recommended for Domestic use. For drinking purpose, the pH value should be below 8 to allow disinfection with chloride process to be effective (UNICEF, 2008).

Since most of the water sample had pH value in guideline range, this water is suitable for effective chlorine disinfection.

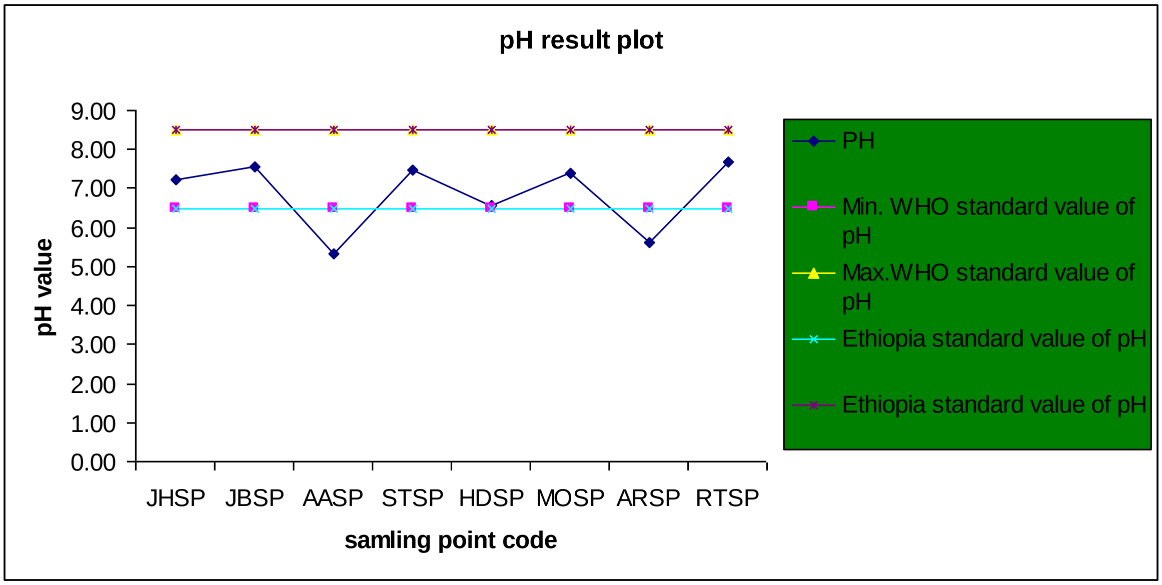

Figure 4.2: pH values of collected ground water samples

4.2.2. Temperature

The temperature of collected ground water samples ranges from 16.32°C to 25.06°C. The average temperature of water sample is 20.26°C. The least (16.32 °C) was recorded in Ataba Robe kebele spring water source (ARSP) located in spring ground water while maximum temperature (25.06°C) was recorded in Jena Barbuko kebele hand-dug borehole site (JBSP). The WHO (1997) guide value of drinking water with temperature above 15^0C is undesirable for human being and cause bone disease (pain and tenderness of bone) which children will get it more (Temitope *et al.*, 2012). Therefore according to the result obtained from sample water, whole water samples taken had temperature value above WHO standard guideline value.

As much as possible it is preferred not to use this for water source unless the water temperatures are regulated until use.

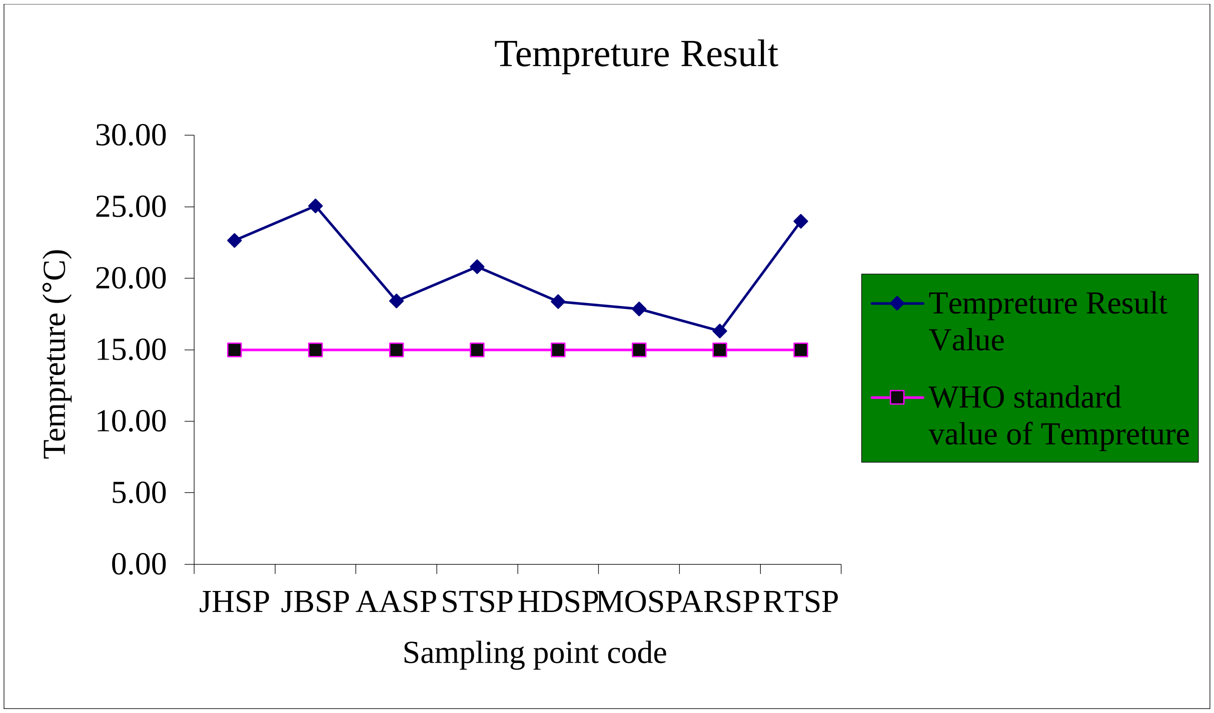

Figure 4.3: Temperature recorded values of collected ground water samples

4.2.3. Electrical Conductivity (EC)

The EC of wateris increased with dissolved ions, which is easily measured with a meter, so EC is often used as a substitute for TDS. The lowest conductivity value recorded was 89.4µS/cm in MeseranjeOda(MOSP) Kebele hand dug well. But maximum conductivity value recorded was249.11µS/cm which is in Ataba Robe (ARSP) kebele’s spring ground water. The mean value recorded was 125.22µS/cm as it is indicated on (Figure 4.4). The lowered EC value is preferable for health of consuming community because elevated value of conductivity above 250µS/cm can cause Anemia, liver, kidney or spleen damage, changes in blood (WHO, 1997).

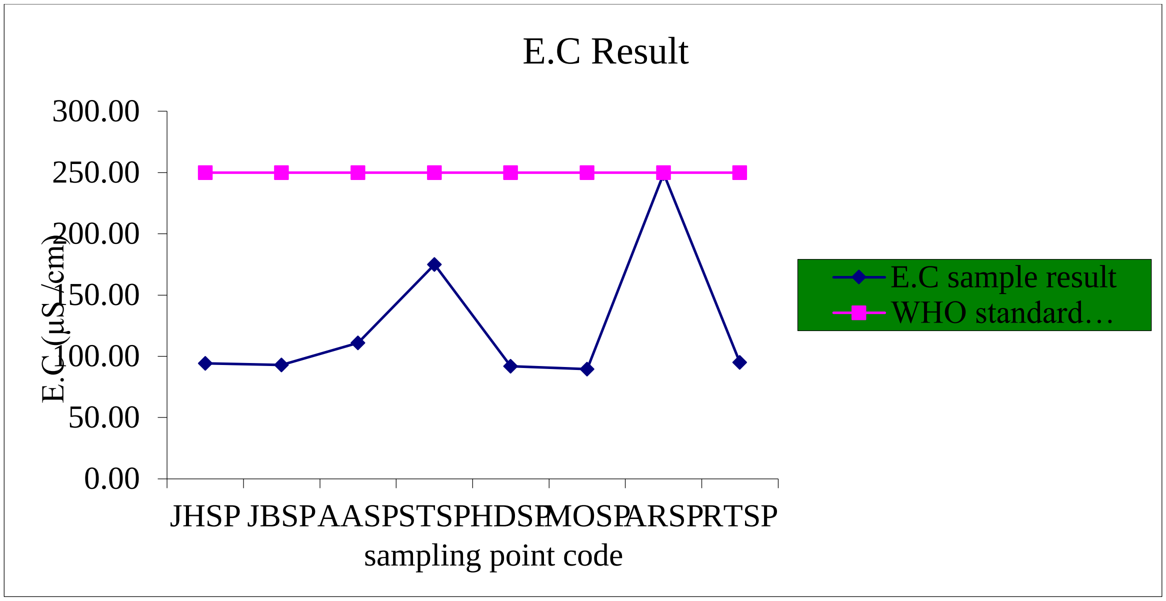

Figure 4.4: Electrical Conductivity values of collected ground water samples

4.2.4. Total Dissolved Solids (TDS)

The result of study showed that the minimum TDS value of water was47.55mg/L, which was recorded in JenaHululkebele hand, dug well (JHSP). However, the maximum value was 356.11mg/L, which recorded in Ataba Robe (ARSP) kebele's spring ground water. The average value of TDS was166.30mg/L.theWHO (2004) recommended that TDS value above 500 mg/L was not suitable for drinking and Ethiopian drinking water guideline value prohibits water with TDS value above 1500 mg/L for drinking purpose. Water with TDS value above 1000 mg/L will cause stomach discomfort (Temitope*etal.*, 2012). However, all of water samples were within permitted guide line values both by WHO and Ethiopian standards (Figure 4.5).

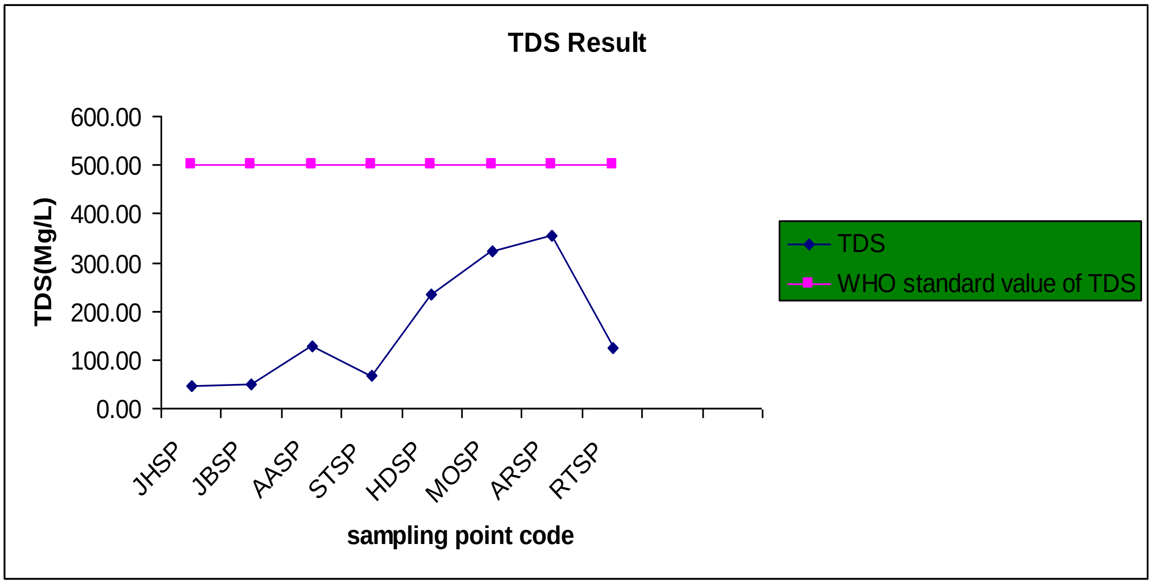

Figure 4.5: TDS values of collected ground water samples

4.2.5. Turbidity

Colors above 15 true color units was detect by most consumers, though more colored waters may be acceptable (UNICEF, 2008). The guideline of WHO (2004) and Ethiopian drinking water standard indicate water with turbidity value greater than 5 NTU is not recommended for domestic use. Result obtained from the study showed that, the lowest turbidity value is 0.96NTU, whichwas recorded in Robe Town (RTSP) protected spring piped water. The maximum turbidity was recorded in Jena Barbuko (JBSP) hand dug well located in Jena BarbukoKebele with value of 10.03NTU. The Average turbidity value of sampled water was 5.45NTU.

Dissolved organic matter such as humic and fulvic acids is the main component of color and highly colored waters may indicate a high potential for formation of byproducts following disinfection. Turbidity or cloudiness is also caused by suspended particles in water (UNICEF, 2008).Results from Jena Hulul (JHSP),JenaBarbuko (JBSP), Abo Ali (AASP), SadikaTokichuma (STSP) and Masaranje Oda (MOSP) Hand dug well sampled water had turbidity value of 7.89NTU10.03NTU6.11NTU6.93NTU4.01NTU and5.84NTUabove WHO maximum permitted level (Figure 4.6) respectively, which are not recommended to use these water sources for Domestic purpose with criteria of turbidity standard. The rest sampled water results were within WHO standard value and were suitable for domestic purpose.

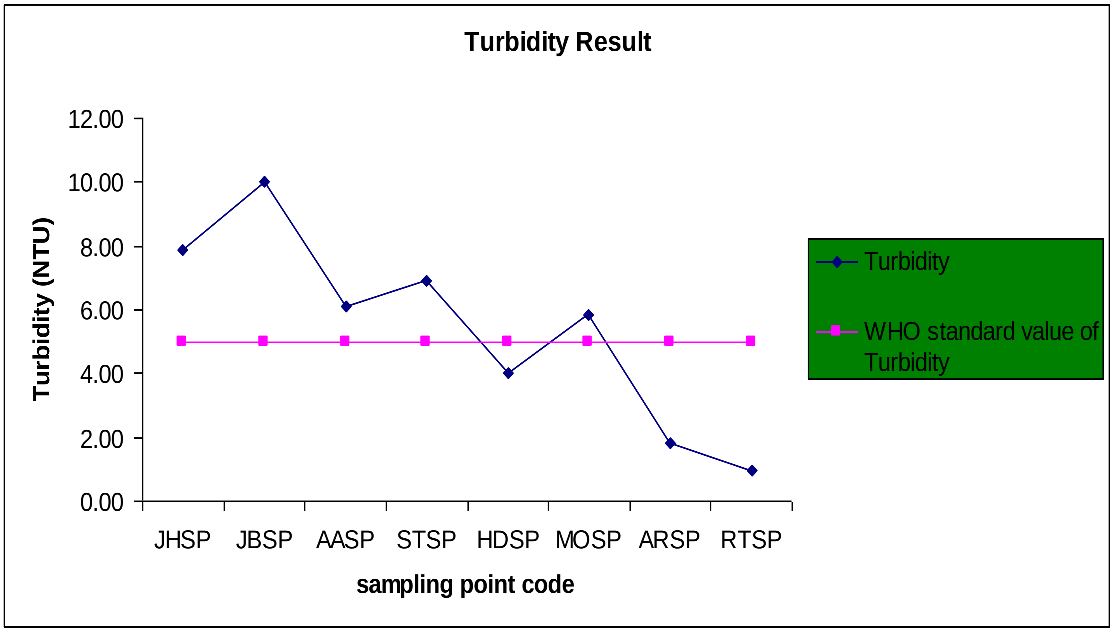

Figure 4.6: Turbidity values of collected ground water samples

4.3. Chemical Water Quality parameters

There are many chemicals that may occur in drinking water; however, only a few are of immediate health concern in any given circumstance. The priority given to both monitoring and remedial action for chemical contaminants in drinking water should be managed to ensure that scarce resources are not unnecessarily directed towards those of little or no health concern (WHO, 2008).

4.3.1 Calcium ($Ca^{2+)}$)

The minimum calcium concentration in sampled water was2.95mg/L which was recorded in hand dug well of sadikaTokichuma (STSP) but, Maximum concentration of calcium ion was 12.00mg/L which was recorded in hand dug well of Ataba Robe (ARSP)kebele and the average value was 5.67mg/L.

The threshold value permitted for the calcium ion concentration in water is within the range of 100–300 mg/L (UNICEF, 2008).According to this value; all water samples had the calcium concentration below the stated threshold value and fine for utility. Drinking water with calcium concentration above 200mg/L will cause indigestibility of fat in the body (WHO, 1997).

However, all water samples in study area had calcium concentration below 200mg/L and are safe for drinking which was shown in figure 4.7.

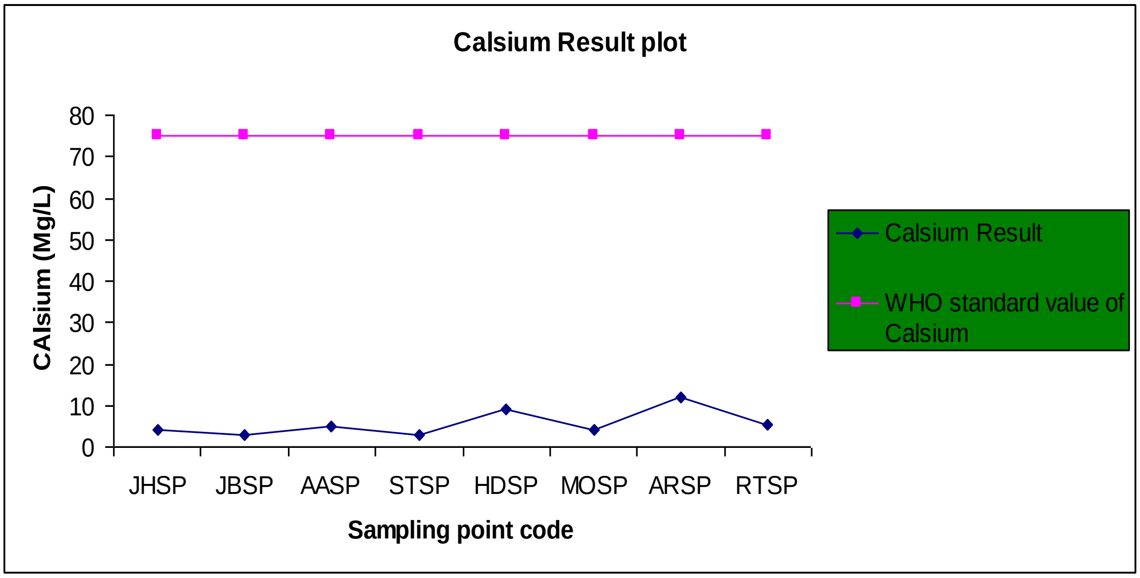

Figure 4.7: Calcium ion (Ca^{2+}) concentration values of collected ground water samples

4.3.2 Magnesium (Mg^{2+})

Presence of Magnesium ion in drinking water will result in hardness of watereven in lesser extent not exceeding the amount of calcium. It is usually expressed as the equivalent quantity of calcium carbonate. Drinking water can be a contributor to calcium and magnesium intake and could be important for those who are marginal for calcium and magnesium. Although there is evidence from epidemiological studies for a protective effect of magnesium or hardness on cardiovascular mortality, the evidence is being debated and does not prove causality (WHO, 2004).According to WHO standards the permissible range of magnesium in water should be 50 mg/L. Drinking water with magnesium concentration above stated limit will results in gastro intestinal, liver or kidney damage (WHO, 1997).The result obtained from water samples shows that the minimum concentration was2.27mg/L recorded in Jena Hulul (JHSP) hand dug well located in Jena HululKebele while the maximum value was7.22mg/L recorded in protected spring ground water sample taken from Ataba Robe Kebele(ARSP). Mean value of Magnesium ion measured among all samples is 3.72mg/L. Still the measured values are not exceeding the stated guideline and hence the all water is recommended for domestic use (Figure 4.8).

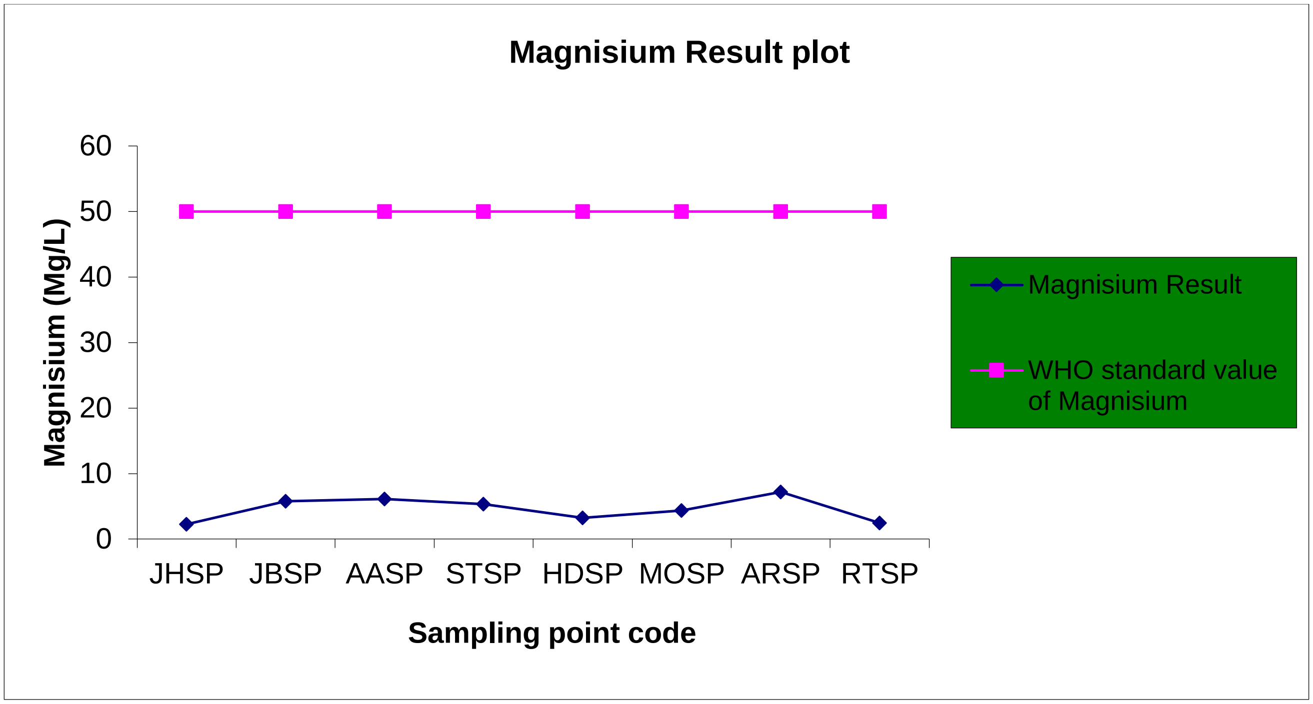

Figure 4.8: Magnesium (Mg^{2+}) concentration values of collected ground water samples

4.3.3 Bicarbonate (HCO_3^-)

Average bicarbonate concentration of sample water is 82.77mg/L. The case for the elevated TDS value in ground water is the existence of bicarbonates and other inorganic salts (principally Calcium, Magnesium, Potassium, Sodium, Chlorides and Sulfates) and small amounts of organic matter that are dissolved in water. Even though no clear-cut standard guide line value for this, it is advisable not to have more than 500 mg/L of bicarbonate in drinking water. Long-term weathering of rocks will result in dissolution of rock minerals and results in formation of bicarbonate. It is showed that the tested water samples have bicarbonate concentration less than stated recommendable value and hence the tested water is still suitable for domestic use.

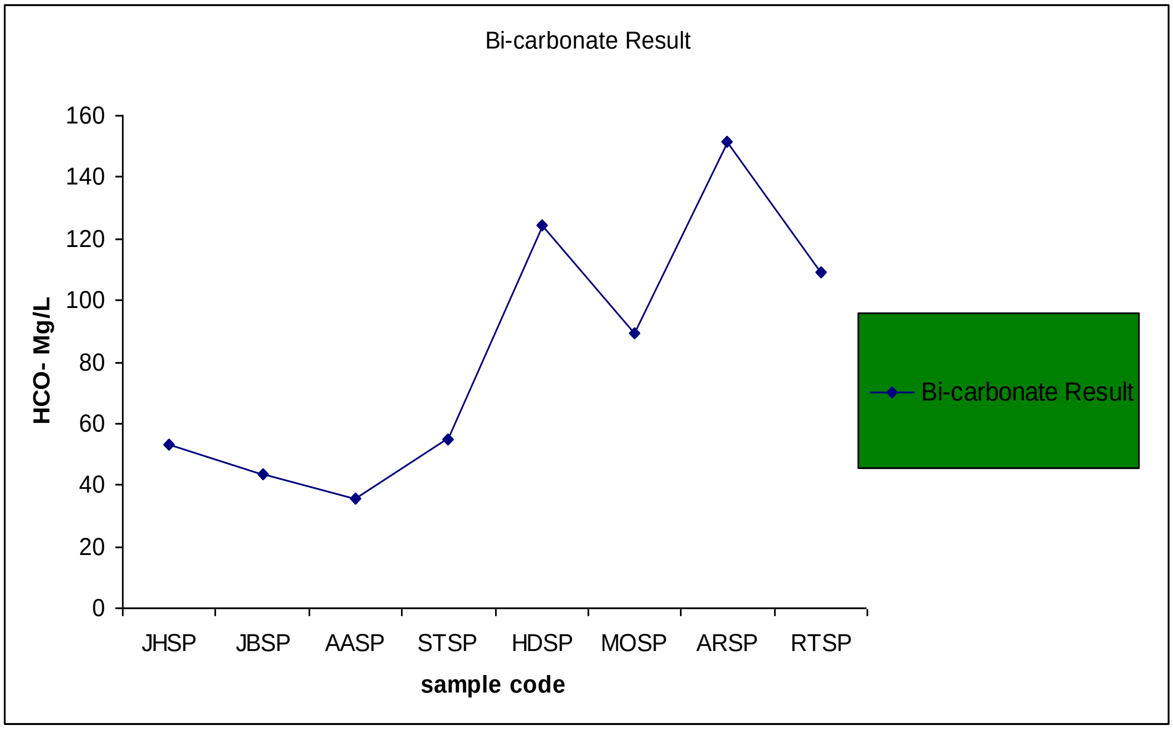

Figure 4.9: Bicarbonate (HCO_3) concentration values of collected ground water samples

4.3.4 Sodium (Na^+)

. It should be noted that some water softeners can add significantly to the sodium content of drinking-water(WHO,2011).In the study area the minimum sodium content of water was recorded in SadikaTokicuma (STSP)Kebele with 8.84mg/L. Maximum sodium concentration was recorded in Ataba Robe (ARSP) spring ground water source with concentration of 32.85mg/L. The average sodium concentration of sampled water was 16.95mg/L. Even though sodium has no health concern problems at a level, found in drinking water (WHO, 2004) all water sample schemes are below the range of WHO standard (200 mg/L). By considering sodium concentration of water, the water is so fine to use.

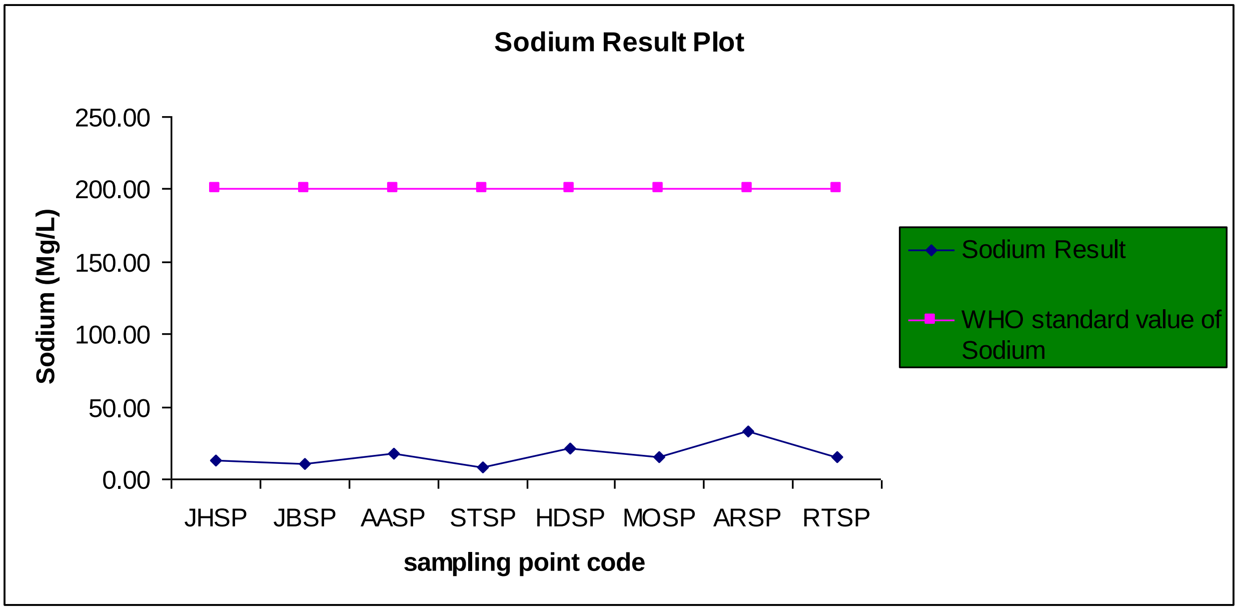

Figure: 4.10: Sodium (Na) ion concentration values of collected ground water samples

4.3.5 Potassium (K^+)

Potassium is an essential element in humans and is seldom, if ever, found in drinking water at levels that could be a concern for healthy humans. It occurs widely in the environment, including all natural waters. Although technologies are available to remove potassium, they are generally more expensive and redundant when combined with the softening treatment (WHO, 2009).Potassium occurs in drinking water at concentrations well below those of health concern (WHO, 2004). WHO standard permit 10 mg/L of potassium in drinking water while Ethiopian water quality standard guideline permits 1.5 Mg/l.

In collected water sample for this study, the minimum potassium concentration was recorded in Jena Hulul (JHSP) kebele hand dug well value of 0.34mg/L while maximum concentration was recorded in Ataba Robe (ARSP) spring ground water3.44mg/L. Average concentration of potassium in study area is 1.75mg/L. According to WHO guide line it is observed that all water samples have under maximum permitted limit value of potassium concentration. Hence all water sources can be used to drinking with potassium concentration criteria. However, result showed in Jena Barbuko,SadikaTokichuma, MasaranjeOda and Ataba Robe with value of 2.01mg/L,2.64mg/L,3.05mg/L,3.44mg/L respectively were above Ethiopian water quality standard guide value which are not recommended for domestic use.

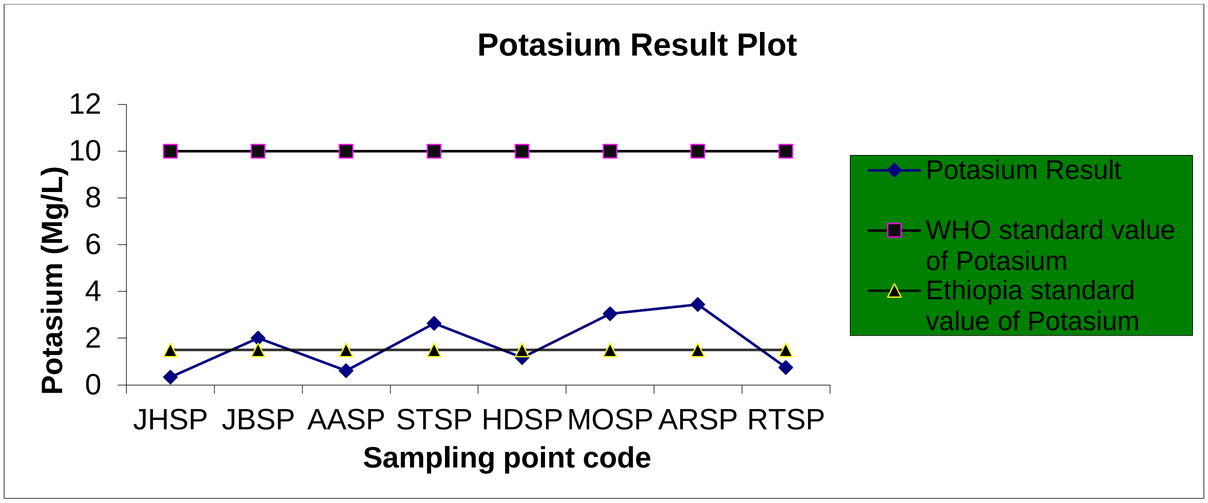

Figure: 4.11: Potassium (K) ion concentration values of collected ground water samples

4.3.6 Nitrate (NO_3^-)

Chemicals are used in agriculture on crops and in animal husbandry. Nitrate may be present because of cultivation when there is no growth to take up nitrate released from decomposing plants, from the application of excess inorganic or organic fertilizer and in slurry from animal production (WHO, 2004). The presence of nitrate and nitrite in water has been associated with methaemoglobinaemia, especially in bottle-fed infants or blue baby syndrome (WHO, 2006).

World Health Organization recommended no more than 10 mg/L of nitrate in our drinking water. According to this study the minimum nitrate concentration is 3.65mg/L recorded in Ataba Robe spring ground water and the maximum nitrate concentration is recorded in Abo Ali (AASP) hand dug well with value of 8.34mg/L. This site is in rural area in which application of excess inorganic or organic fertilizer and in slurry from animal production from year to year takes over it. The average nitrate concentration in study area is 5.07mg/L.

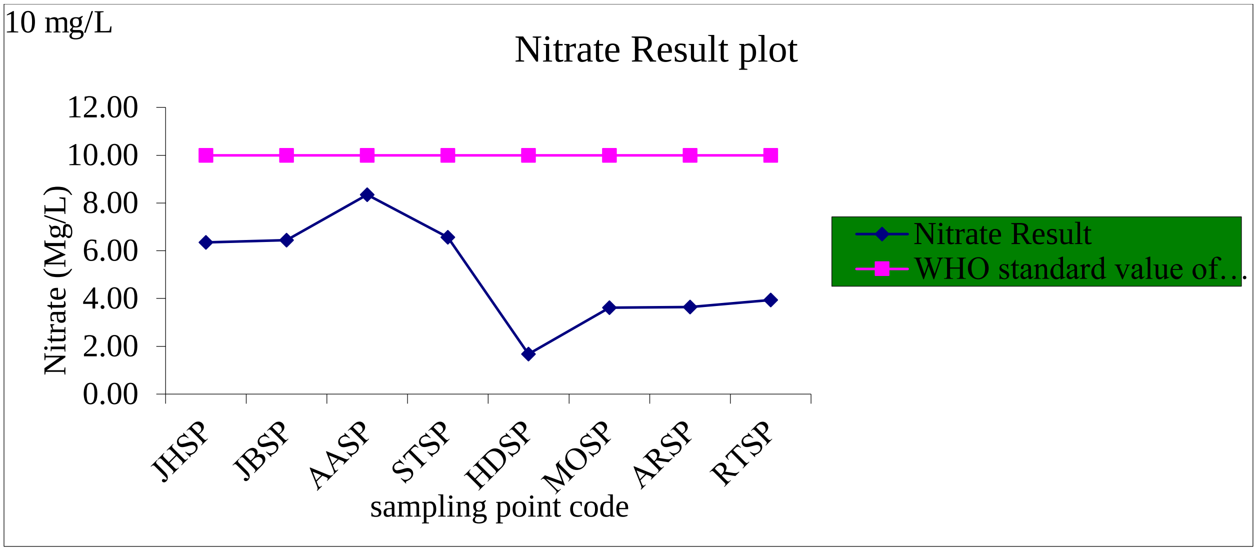

Figure: 4.12 Nitrate (NO_3) concentration values of collected ground water samples

4.3.7 Sulfate (SO_4^{2-})

A potentially huge source of contamination remains in the soils in both buried and ploughed disposal areas due to increased concentrations of chloride and sulphate because of sewage sludge application. There is a need for continual monitoring of ground water to evaluate the long-term effects of waste disposal on water quality and to provide a background and database for ascertaining environmental impacts on surface and ground water quality of potential future sites from sewage sludge disposal (Tindall*et al.* 1994). The presence of sulfate in drinking water can cause noticeable taste, and very high levels might cause a laxative effect in unaccustomed consumers (WHO, 2004). Sulfate in drinking water can cause a noticeable taste above concentrations of about 250 mg/L. In the absence of oxygen and free chlorine, bacteria can convert sulfate to hydrogen sulfide, which causes a distinctive “rotten-egg” odor at concentrations as low as 0.05 mg/L. There are no health-based guide line value for sulfate or sulfide (UNICEF, 2008).It is investigated that the minimum sulfate concentration in water sample was 3.50mg/L recorded in water sample of Robe Town (RTSP) spring piped water and maximum value (19.03mg/L) was recorded in MasaranjeOda(MOSP) hand dug well found in masaranjeOdaKebele. The mean concentration of sulfate in sample water is 14.19mg/L. All values of sulfate for sample water are below WHO standard guide line and it is permitted to use these water sources for drinking (Figure 4.13).

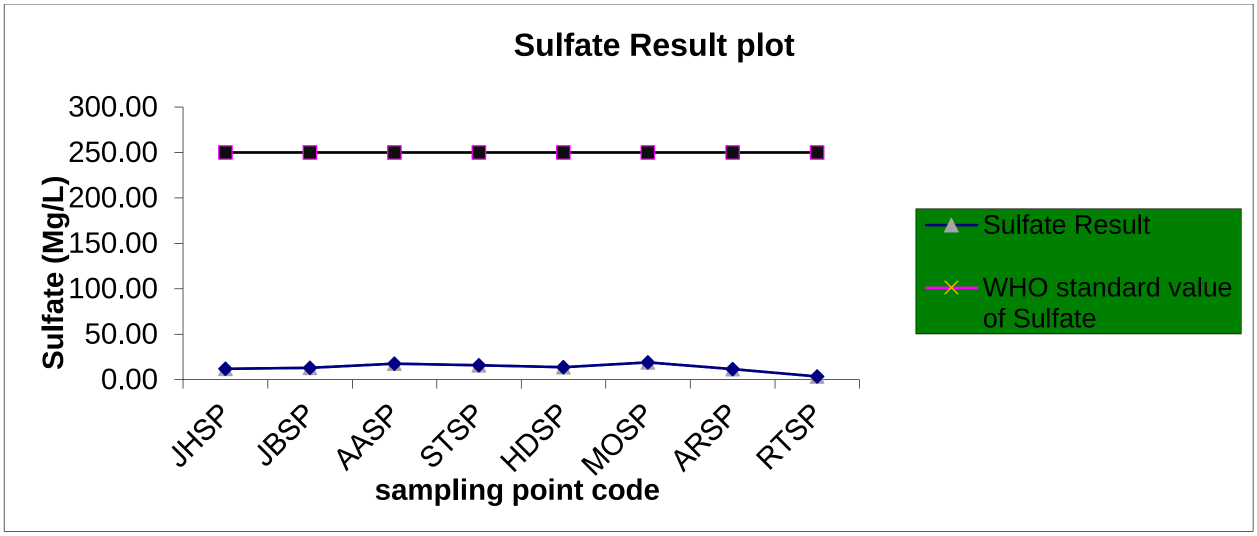

Figure 4.13: Sulfate (SO_4^{2-}) concentration values of collected ground water samples

4.3.8 Chloride (Cl^-)

An extensive amount of chlorides is added in ground water receiving municipal waste, farm drainage, and sewage effluent. The sewage effluent to water sources is bound to increase the chloride concentration in ground water. Chlorides are habitually present in water in the form of sodium chloride. These impart a salty taste to water. The taste may be objectionable to several consumers. It would point towards the possibility of organic pollution of a water source. Chlorides coupled with sodium bring to bear salty taste, when its concentration is more than 250 mg/1.There is no identified authentication that chlorides constitute any human health hazard. For this reason, chlorides are generally limited to 250 mg/1 in supplies intended for public use (IS 14543:2004). In many areas of the world where water supplies are scarce, sources containing as much as 2 000 mg/1 of chloride are used for domestic purpose, once the human system becomes adopted to the water (Mizumura, 2003).Chloride in drinking-water originates from natural sources, sewage and industrial effluents, urban runoff containing de-icing salt and saline intrusion. The main source of human exposure to chloride is the addition of salt to food, and the intake from this source is usually greatly in excess of that from drinking water. The standards concentration of chloride should not exceed 250 mg/L (WHO, 2004).In study area, the minimum chloride concentration in sample water is 4.07mg/L, which was recorded in MasaranjeOda (MOSP) hand dug well, and the maximum concentration of chloride was recorded in AtabaRobe (ARSP) spring ground water located in Ataba Robe Kebele with value of 21.5mg/L while the mean chloride concentration value is

13.03mg/L. All the results of the sampled water had low chloride concentration compared with WHO guide line value. Therefore, the water is permitted for domestic use which was showed in figure 4.14.

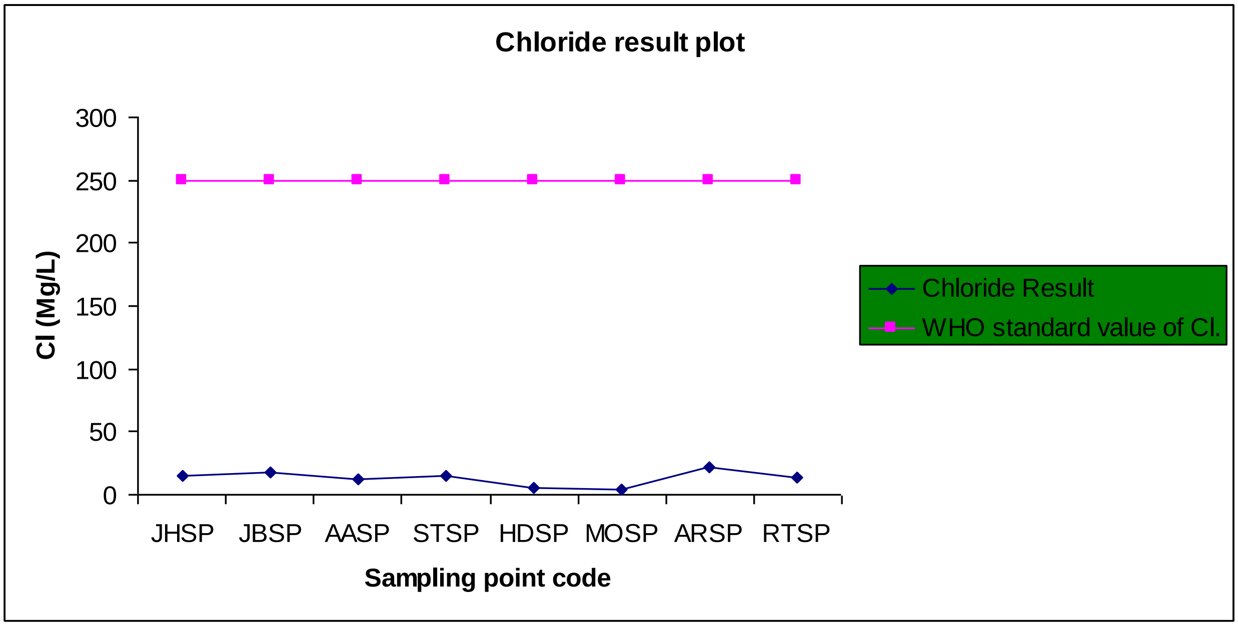

Figure 4.14: Chloride (Cl^-) ion concentration values of collected ground water samples

4.3.9 Fluoride (F^-)

Fluoride contamination of groundwater is a serious problem in several countries which spread throughout the world as ingestion of excess fluoride, most commonly, through contaminated drinking groundwater and causes fluorosis. Mainly two factors are responsible for contamination of groundwater with fluoride; geological and anthropogenic. Rock geochemistry has a major control on geological fluoride contamination. Physiological conditions of rock, like decomposition, dissociation and subsequent dissolution along with long residence time may be the responsible factors for fluoride leaching (Madhnure, 2006). The standards concentration of fluoride should not exceed 1.5 mg/L (WHO, 2004).In study area the minimum fluoride concentration in sample water is 0.10mg/L which was recorded in Jena Barbuko (JBSP) hand dug well and the maximum concentration of fluoridewas recorded in Ataba Robe (ARSP) spring ground water located in AtabaRobeKebele with value of 0.79mg/L while the mean fluorideconcentration value is 0.28mg/L.

All the results of the sampled water had low fluoride concentration compared with WHO guide line value. Therefore the water is permitted for domestic use which was showed in figure 4.14.

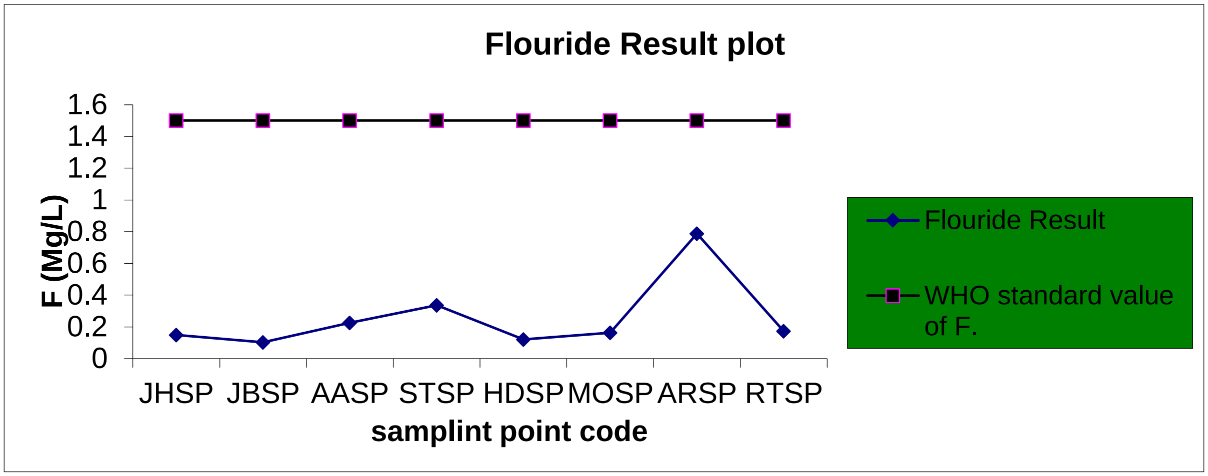

Figure 4.15: Fluoride (F^-) ion concentration values of collected ground water sample

4.3.10 Total Hardness

Hardness is the sum of polyvalent metallic ions in water. Calcium and magnesium are the principal components, and hard waters are most common in groundwater, especially when derived from limestone, dolomite or chalk aquifer (UNICEF, 2008). Hardness in water is usually expressed as the equivalent quantity of calcium carbonate. Depending on pH and alkalinity, hardness above about 200 mg/L can result in scale deposition, particularly on heating. Soft waters with a hardness of less than about 100 mg/L have a low buffering capacity and may be more corrosive to water pipes (WHO, 2004).

No health-based guideline value is proposed for hardness. However, water with the maximum hardness above 500 will result in increase in blood pressure of consumers (WHO, 1997). Some evidence suggests that hardness in drinking water may be protective with respect to cardiovascular disease, but the data are inadequate to prove a causal association (UNICEF, 2008).Hardness is expressed in terms of milligrams of calcium carbonate equivalents per liter. The taste threshold for the calcium ion is in the range of 100–300 mg/L and the taste threshold for magnesium is probably lower. In some instances, consumers tolerate water hardness in excess of 500 mg/L. Soft water may also have a salty taste. The WHO standard guideline for hardiness is 200 mg/L $CaCO_3$.

In the study area the minimum hardness value (15.47mg/L $CaCO_3$) is observed in Robe town spring piped water and maximum value (73.67mg/L $CaCO_3$) was observed in Ataba Robe (ARSP). Average total hardness value is 22.64mg/L $CaCO_3$.

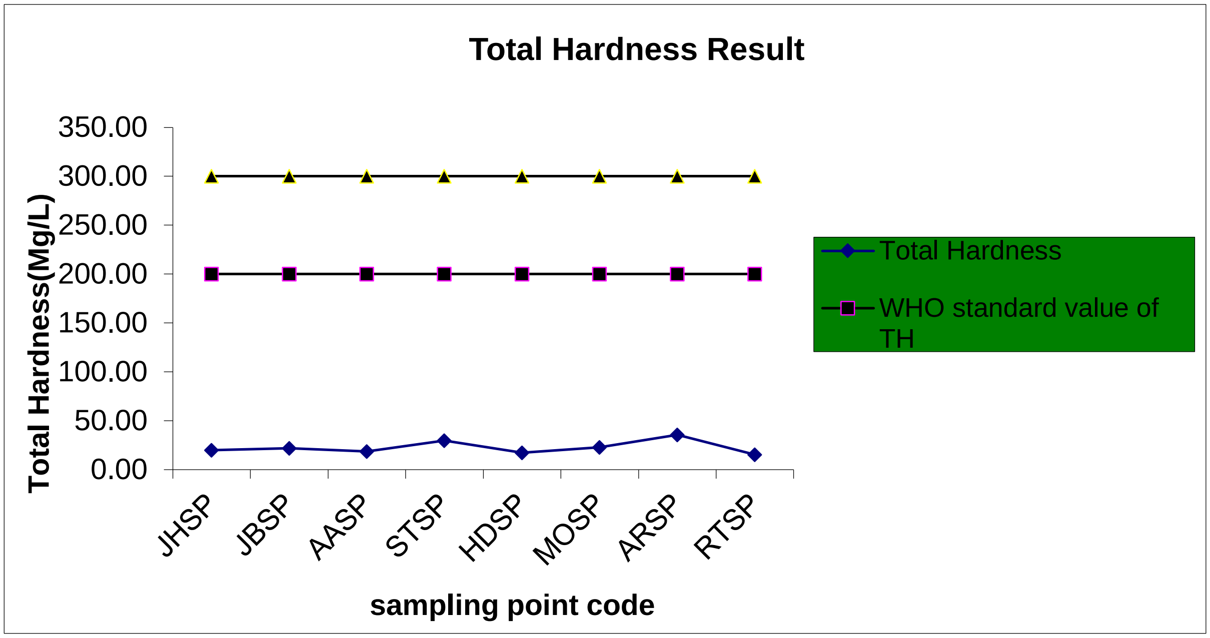

Figure 4.16: Total Hardness (TH) concentration values of collected ground water

4.4. Heavy Metals Water Quality parameters

Iron (Fe) and Manganese (Mn) in Groundwater

Iron (Fe) and Manganese (Mn) are metals that occur naturally in soils, rocks and minerals. In the aquifer, groundwater comes in contact with these solid materials dissolving them, releasing their constituents, including Fe and Mn,to the water. At concentrations approaching 0.3 mg/L Fe and 0.05 mg/LMn, the water's usefulness may become seriously impacted, e.g., theremaybe a metallic taste to the water and staining of plumbing fixtures may become common. At these concentrations, however, the health risk of dissolved Fe and Mn in drinking water is insignificant (WHO, 1997).

4.4.1. Iron (Fe^{2+})

Dissolved metals may contribute to color in drinking water, and can stain laundry and Plumbing fixtures. Metal precipitates may also form coatings on pipe walls that can slough off as fine particulates, contributing to turbidity. Iron above 0.3 mg/L can cause staining, and may impact color and turbidity at lower levels (UNICEF, 2008).

In study area among water sample taken from different sites, the lowest value with iron concentration was, 0.06mg/L in Robe Town (RTSP) spring pipe ground water. Maximum iron concentration value (0.78mg/L) was recorded in Abo Ali (AASP) hand dug well. Two ground water samples (Figure 4.16) showed iron concentration above WHO permissible limit(0.3 mg/L).Water samples in which their iron concentrations elevated above permissible value are AASP and ARSP with values of 0.78 mg/L and 0.375 mg/L respectively. The cause of high iron concentration in ground water of in this area may be due to natural occurrence or abundance of Iron in the rock. Dissolution of this rock will results Iron to dissolve in water.High concentrations of iron in groundwater suppliesEthiopiawere recorded in different regions of the country (FMoWR, 2000; 2001). Drinking water with concentration above 0.3mg/L will cause rusting forms cancer in human body (WHO, 1997).Therefore it is important not to use water of the study area with iron concentration above permitted limit. There should be effective aeration system to oxidize high concentration of Iron from the water sources prior to use it.

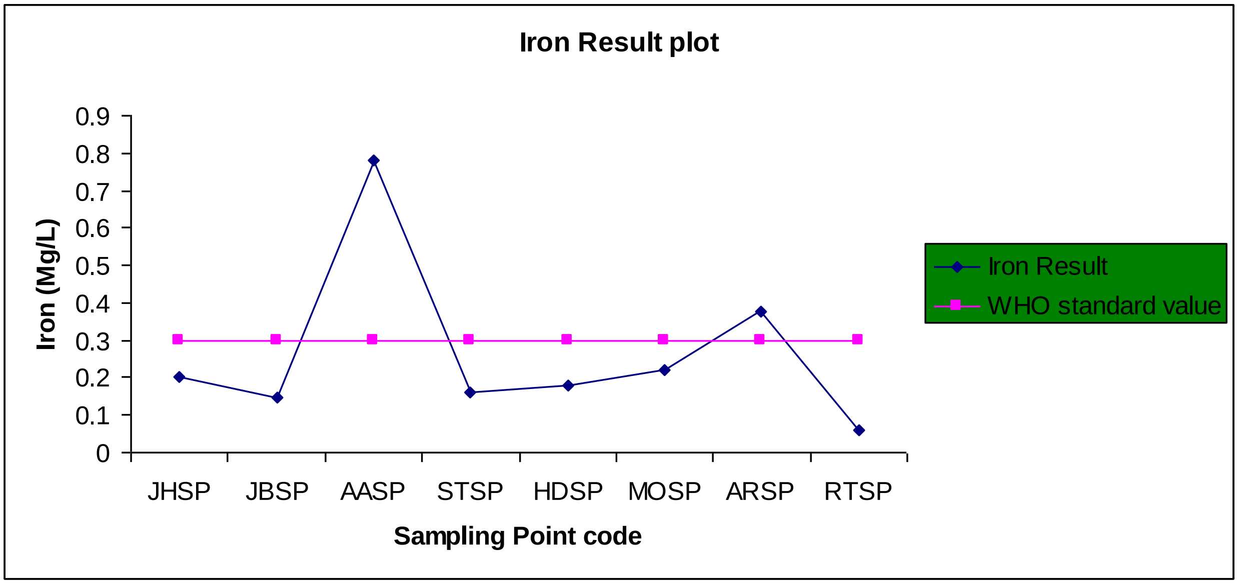

Figure 4.17: Iron (Fe) concentration values of collected ground water samples

4.4.2. Manganese (Mn^{2+})

Dissolved manganese is often associated with iron, which is also soluble under anaerobic conditions. Manganese above 0.1 mg/L can cause staining, and may impact color and turbidity at lower levels (UNICEF, 2008).Concentrations below 0.05–0.1 mg/L are usually acceptable to consumers from a taste perspective but may sometimes still give rise to the deposition of black deposits in pipe. High levels of manganese in water can also have neurological effects (Wasserman *et al.*, 2006).

It was observed that the minimum concentration of Manganese in the study area was 0.02mg/L and the maximum concentration was 0.67mg/L, which was recorded in Robe Town and Abo Ali sample site respectively. The average concentration of Manganese in sampled ground water was 0.341mg/L. Three domestic use water sources had Manganese concentration above the permissible value Ethiopia guideline value and except one sample site, Robe Town; all had Manganese concentration above the permissible value of WHO water quality guideline value. The raised concentration may be due to dissolution of the rock in to water. Dissolved Manganese is soluble under anaerobic conditions (UNICEF, 2008).Therefore water sources with high Manganese concentrations should be supplied enough oxygen to remove manganese. Common sedimentary rocks, carbonate rocks particularly dolomite have high concentration of Manganese (Wikipedia of geochemistry, 2017).

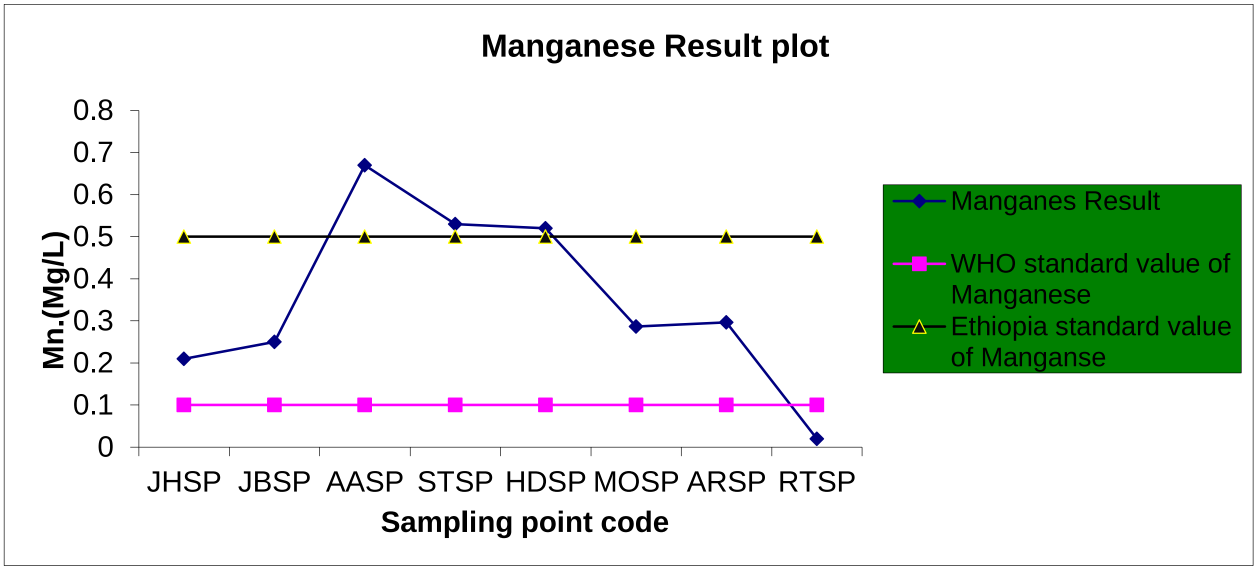

Figure 4.18: Manganese (Mn^{2+}) concentration values of collected ground water samples

4.5. Microbiological Water Quality

The principal risk associated with water in small-community supplies is that of infectious disease related to fecal contamination. Hence, the microbiological examination of drinking water emphasizes assessment of the hygienic quality of the supply. This requires the isolation and enumeration of organisms that indicate the presence of fecal contamination (WHO, 2008).

4.5.1 Fecal coliform

In drinking water, presence of fecal coli form should not be ignored as the basic assumption that pathogens would not be presented in drinking water. However, this result shows the presence of fecal coli form. The results of analyzed sample indicated that the values of fecal coli form (FC) in colony forming unit per milligram was very large in sample. As shown in figure 4.17 the minimum number of CFU/100ml was recorded at Robe Town (RTSP) spring piped ground water with the value of 1CFU/100mland maximum number of CFU/100ml was at HabeDangasela (HDSP) hand dug borehole with the value of 625.67CFU/100ml. The average value of E-coli was 365.46CFU/100ml. Results from all water sample had CFU E-coli/100ML above WHO guide line which were extremely prohibited for domestic use (Figure 4.17).This may be because of open defecation by the surrounding community in which the excreted waste was taken by run off to the nearby borehole water source. Therefore, this water should not be used by the community without treatment or should be boiled before used. In drinking water, FC should be absent (WHO, 2004). The danger of coli form presence can rest on the health or sensitivity of the user.

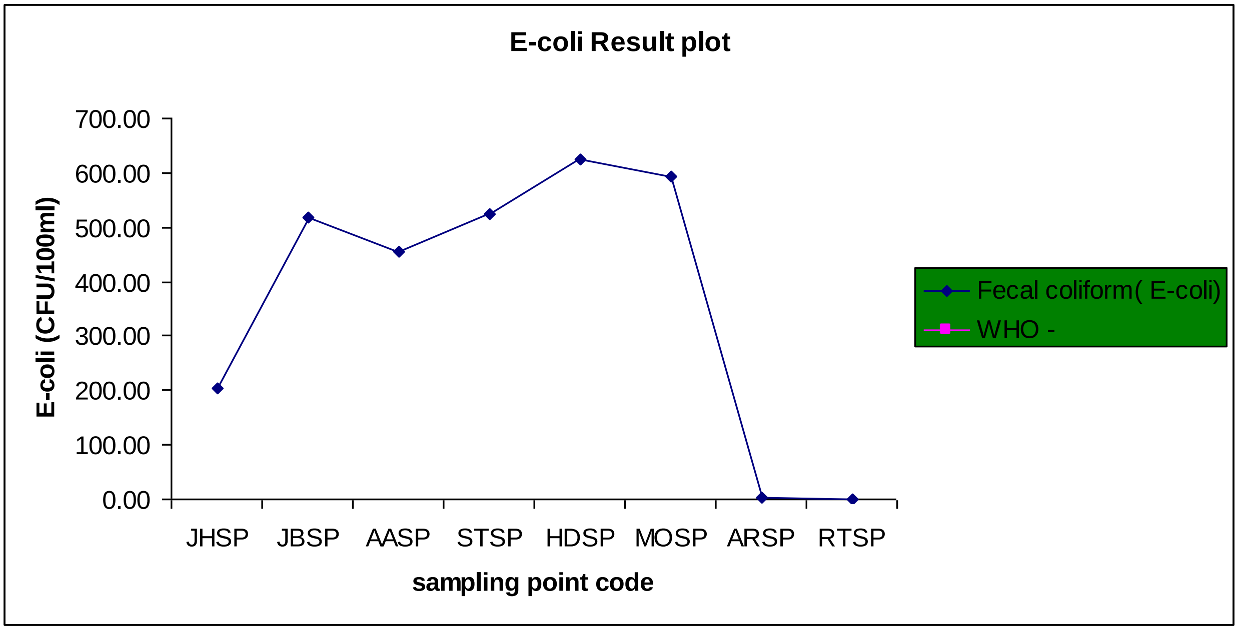

Figure 4.19: Fecal coli form in CFU/100ml of collected ground water samples

4.5.2 Total coli form

Total coli forms were used as indicator bacteria to assay the level of bacteriological contamination of the water supplies. A total of eightwater samples were analyzed for Total coli forms and the result indicates that all water sources were contaminated to a significant extent. The results of analyzed sample indicated that the values of Total coli form in colony forming unit per milligram was large in sample. as shown in (figure 4.18). The minimum number of CFU/100ml was recorded at Robe Town (RTSP) spring piped ground water with the value of 2.67CFU/100ml and maximum number of CFU/100ml was at HabeDangasela (HDSP) hand dug borehole with the value of 700.33CFU/100ml. The average value of E-coli was 458.29CFU/100ml. Results from all water sample had CFU E-coli/100ML above WHO guide line which were extremely prohibited for domestic use (Figure 4.17). In drinking water, TC and FC should be absent (WHO, 2004). The presence of bacteria in water not only can cause objectionable odors but also may indicate a breakdown in the disinfection system (Corzatt, 1990). Total coli forms do not positively indicate contamination of fecal origin (Amundson, 1988). Only fecal bacteria can positively indicate contamination by feces of humans or other warm-blooded animals (Weigman and Kroehler, 1990). The highest TC may be because of the refuse dump, human faeces scattered nearby the spring in the forest, dog excrement, decomposition of plant material by the action of microbial washed down into the soil and domestic animals that normally visit the site to drink and defecate around the water source (Regunathan, 1983).

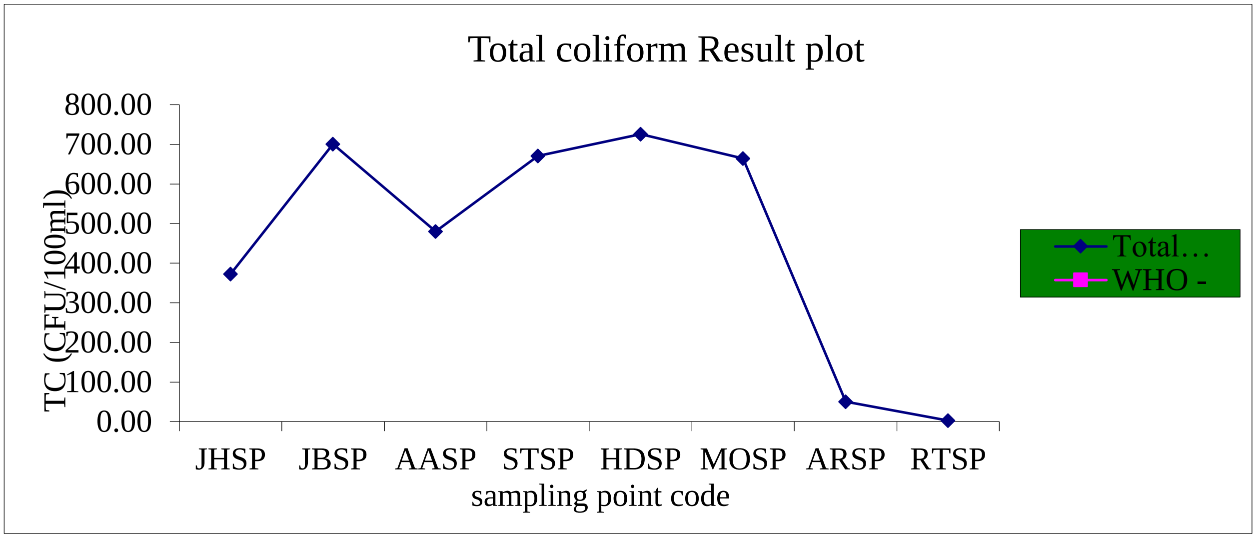

Figure 4.20: Total coli form in CFU/100ml of collected ground water samples

4.6. Hydro-geochemistry facies of water in study area

In order to understand the hydro geochemical facies of the study area, the value of major oxides in groundwater samples were plotted and compared through Piper tri-linear diagram

(Piper, 1994). The diagram consists of two lower triangles show the percentage distribution of the major cat ions (Mg^{+2}, Ca^{+2}, and Na^{+} plus K^{+}) and the major anions (Cl^{-}, SO_4^{-2} and CO_3^{-2} plus HCO_3^{-}) and a diamond-shaped part above that summarizes the dominant cat ions and anions to indicate the water type. The water types are designated according to the area in which they occur on the diagram segments. The tri-linear diagram is useful in highlight the chemical relationship among groundwater samples in terms that are more specific. The cat ion distribution indicates that the groundwater samples range in composition from sodium/potassium and sodium/calcium to predominantly mixed cat ions and anion. In the anion triangle, bicarbonate/chloride water type predominant and small fraction of mixed anion-type of water (Figure 4.20). Further, the groundwater can be classified into following category based on the combined points located in diamond shaped field.

The groundwater of the study area (different sample sites of domestic use water in Robe District) is dominated by alkaline earth metals and anion (Na, HCO_3, $Cl^{-}$and SO_4). Hydrogen bicarbonate and Sodium dominates in soil of groundwater formation in almost all sites but few sample sites with other geochemical constituents. Ca-HCO3-SO4 is found in one sample of groundwaterofMasaranjeOda(MOSP-6).The major contributing geochemical component in water of study area is Na-Ca-HCO3(Table:- 4.2).Therefore, water type of Robe District is dominantly described as Na-Ca-HCO3 and to some extentNa-Mg-HCO3-Cl-SO4

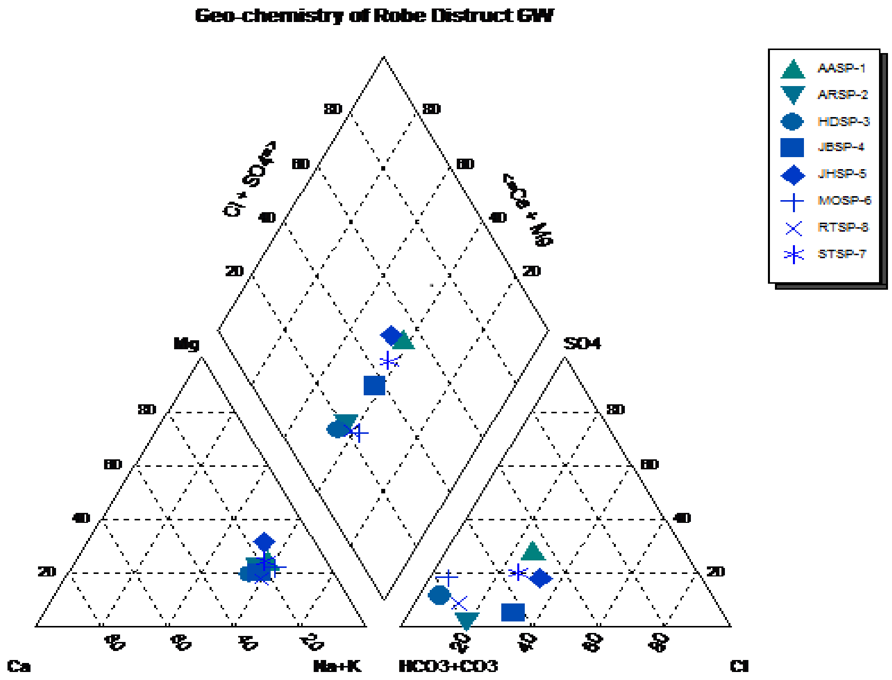

Figure: -4.21 Piper diagram showing water type of study area

Table: -4.1Water type of study area

Sample ID	Location of water sample	Water Type
AASP-1	Abo Ali	Na-Mg-HCO_3-SO_4-Cl
ARSP-2	Ataba Robe	Na-Ca-HCO_3
HDSP-3	Habedangasela	Na-Ca-HCO_3
JBSP-4	Jena Barbuko	Na-HCO_3-Cl
JHSP-5	Jena Hulul	Na-Mg-HCO_3-Cl-SO4
MOSP-6	MasaranjeOda	Na-HCO_3-SO_4
RTSP-7	Robe Town	Na-HCO_3
STSP-8	SadikaTokichuma	Na-HCO_3-Cl-SO_4

According to the result obtained from analysis, the alkaline earth metal (Na) ion is dominating all water sources.

Only two water sources are occupied with other cat ion one with Mg and the other without dominating cat ion. Calcium is the principal component, and hard water is most common in groundwater, especially when derived from limestone, dolomite or chalk aquifers (UNICEF, 2008).

4.7. Household Water Demand and Supply

This section presents the analysis of data and interpretation of findings based on the research questions.

4.7.1 SOCIOECONOMIC CHARACTERISTICS OF THE RESPONDENTS

The study examined the socio-economic characteristics of the respondents in the study area. The result is presented in Table 4.2. The key issues analyzed are: sex, age, and marital status, and household size, level of income, occupation and educational background. From Table 4.2 the sex is unevenly distributed across the gender with a majority of respondents being Female61% of the respondents. This revealed that 61%of the Female struggle for water. On the distribution of respondent based on age it could be seen that there is an uneven distribution of ages across the age groups with a majority 29.43% of the respondents within the age range of 15 – 25 years.

Table 4.2Socio-Economic Characteristics of the Respondents.

RESPONDENTS BACKGROUND	**FREQUENCY**	**PERCENTAGE**
SEX		
Female Male	214 136	61 39
Total	**350**	**100**
AGE RANGE (IN YEARS)		
≤15 15 – 25 26 – 35 36 – 45 ≥46	50 103 88 60 49	14.28 29.43 25.15 17.14 14.00
Total	**350**	**100**
MARITAL STATUS		

Married	182	52.00
Single	56	16.00
Divorced	33	9.43
Widow	51	14.57
Widower	28	8.00
Total	**350**	**100**
HOUSEHOLD SIZE		
1 – 3	114	32.58
4 – 6	144	41.14
7– 9	53	15.14
≥9	39	11.14
Total	**350**	**100**
LEVEL OF INCOME (birr) PER MONTH		
0 – 500	87	24.86
500 – 1000	105	30.00
1000 –1500	102	29.14
>1500	56	16.00
Total	**350**	**100**
OCCUPATION		
Farming	171	48.86
Trading	74	21.14
Civil service	29	8.29
Full housewife	44	12.57
Artisan	13	3.71
Others	19	5.43
Total	**350**	**100**
EDUCATIONAL BACKGROUND		
illiterate	92	11.71
read and write	113	26.29
Primary(1-8)	41	32.29
Secondary(9-12)	61	17.43
Above Secondary	43	12.29
Total	**350**	**100**

Source: *Filed Survey, 2017.*

About 17.14% of respondents were within 36 – 45 years, 25.15%of respondents were within the26–35,14.28% of respondents were less than 15 years and about 14.00% of respondents were equal or above 46 years.

On distribution of respondents based on marital status,52.00% were married, 16.00% single, 9.43% divorced14.57%, widowed andabout8.00% were widower.

With respect to household sizes, the majority,41.14% of the households comprises 4–6 persons, followed by 32.58% which comprises of 1–3 persons, 15.14% comprises of 7–9 persons and 11.14% were greater or equals to 9 persons. On the distribution of respondents based on income level 24.86% of the respondent earn0-500birrper month; 30.00% of the respondents earn 500-1000 birr per month,29.14% of the respondents collected more than 1000-1500birr per month and 16.00% of the respondents collected more than 1500birrper month. It could be seen on the distribution of respondents based on occupation, none of the respondents were jobless, and this implies that all of the respondents had something doing to earn an income. 48.86%wereFarmer, 21.14% were merchants,8.29% were civil servants, 12.57% were full house wives,and 3.71 were Artisan while 5.43% falls to other categories of occupation.

With respect to the educational level attained by the respondents, only 11.71% of the respondents wereilliterate, 26.29% of the respondentscouldread and write, 32.29% of the respondent had primary education, 17.43% of the respondents had secondary education, and 12.29% of the respondents had only above secondary education.

From the above analysis it was revealed that the majority of the respondents were females owing to the fact that they are the one majorly involved with Household activities. Also, the level of income of the household is low. This could be attributed to the fact that majority of the respondents were Primary school certificate holders. Finding also revealed that majority of the respondents were farmers who mainly depend on the agricultural based earners.

4.7.2 THE ANALYSIS OF WATER DEMAND BY HOUSEHOLD

Issues discussed under this section includes the sources of water demand, distance of source, who responsible for the water collection, payment mode by households source for water, the duration or time taken to collect water demand according to household usage, water storage and the methods of storage.

4.7.3 Source of water supply for domestic use in Robe District

From the Figure 4.19, 67.71% of the people of Robe District acquired water from Hand dug well, 11.89% of the respondents acquired water from Hand pump borehole, 7.66% of the respondents acquired water from spring piped ground water, 9.00% of the respondents acquired water from protected spring and only 3.34% of the respondents got water from other water sources. It shows that highest number of people in the study area depends on Hand dug well water.

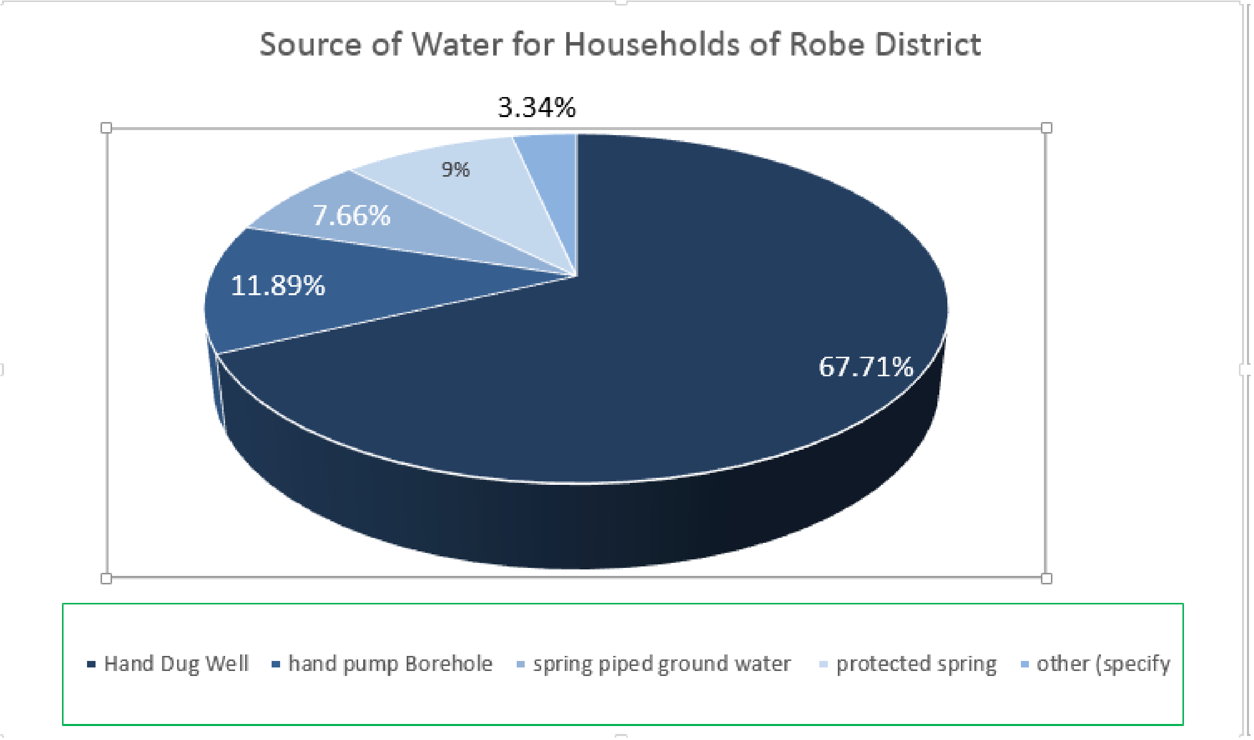

Figure: - 4.22pie chart showing Sources of water in study area

4.7.4 Distance to Water Sources for domestic uses in Robe District

With respect to distance covered Figure 3 reveals that 75.71% of the household members trek a distance between 1km – 2km, about 12.89% of the households trek a distance less than or equal to 1km, 4.89% of the household member trek between 3km – 4km, and 6.62% of the household member trek above 4km. This shows that the people in some areas of study trekked long distance before they can get clean water because it’s far from their residential area.

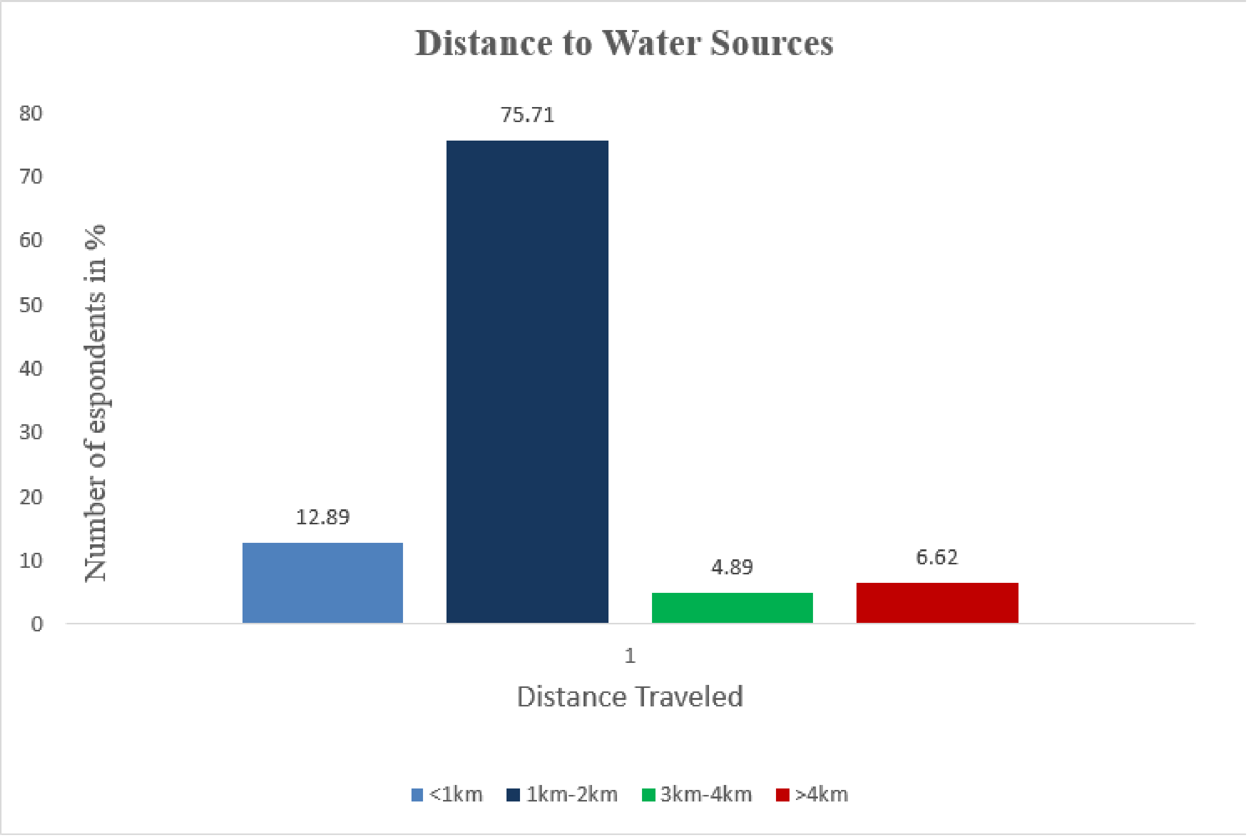

Figure: - 4.23 Bar Graph showing Distance to Water Sources in study area

4.7.5 Water collection responsibility among household members

The responsibility on collection of water showed by Figure 4.21indicates that 81.14% of water collectors were housewives, followed by 12.57% were children, as only 1.43%) were husband while 4.86% falls to other categories. This indicates that women were responsible for collection of water in the study area as could be seen in percentage recorded compared with their men counterpart.

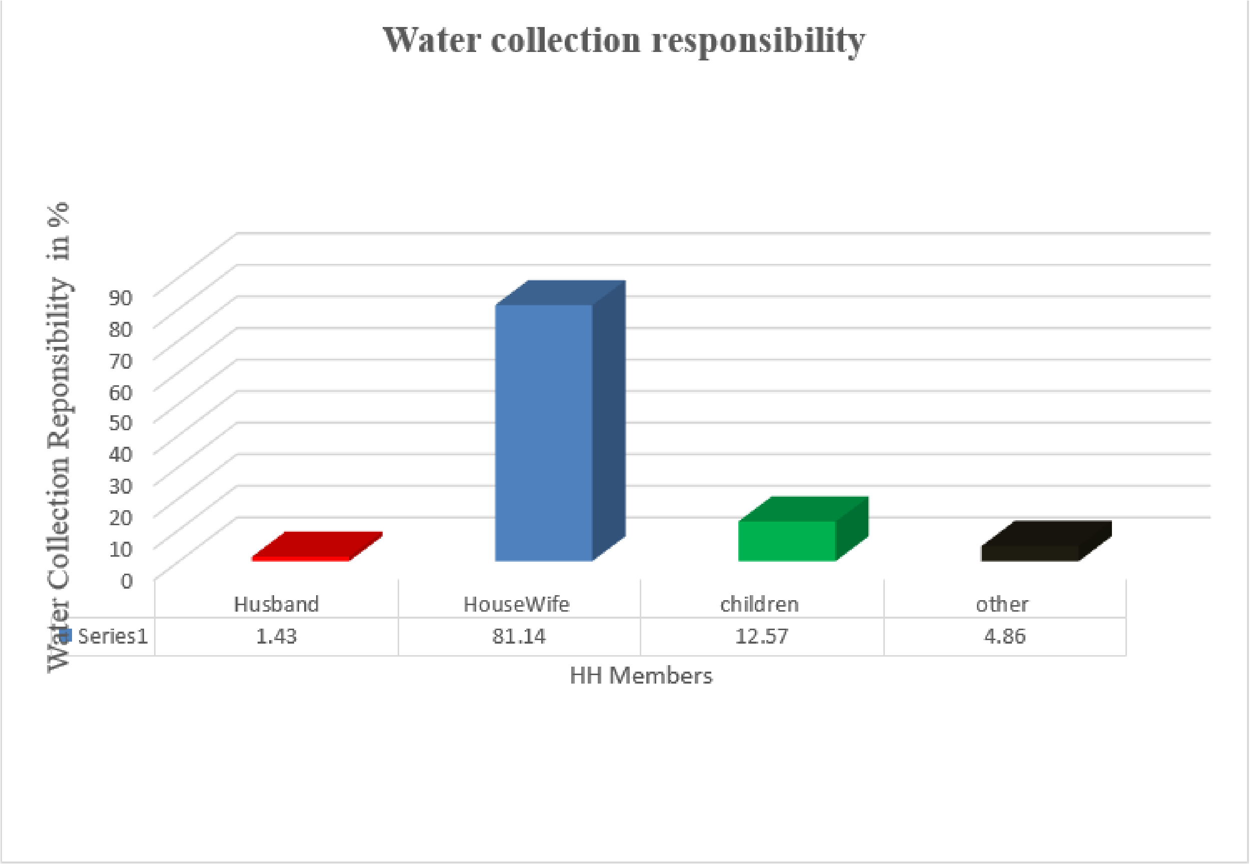

Figure: - 4.24 Bar Graph showing Water collection responsibility among household members in study area

4.7.6 Time taken to get water services by households in Robe District

The duration or time spent for the collection of water, Figure 4.22, reveals that 55.78% of the respondents spend between 3hour to 4:30 hour to get water, 24% of the respondents spent 1:30 hour to 3hour to get water, 10% of respondent spend less than 1: 30 hour to get water, while 10.22% of the respondents spent greater than5hour to get water. In an area where 55.78% of respondent spend 3hour to 4:30 hour to get water was revealed that they do experience long trained coupled with massive crowd of people struggling to fetch domestic use water.

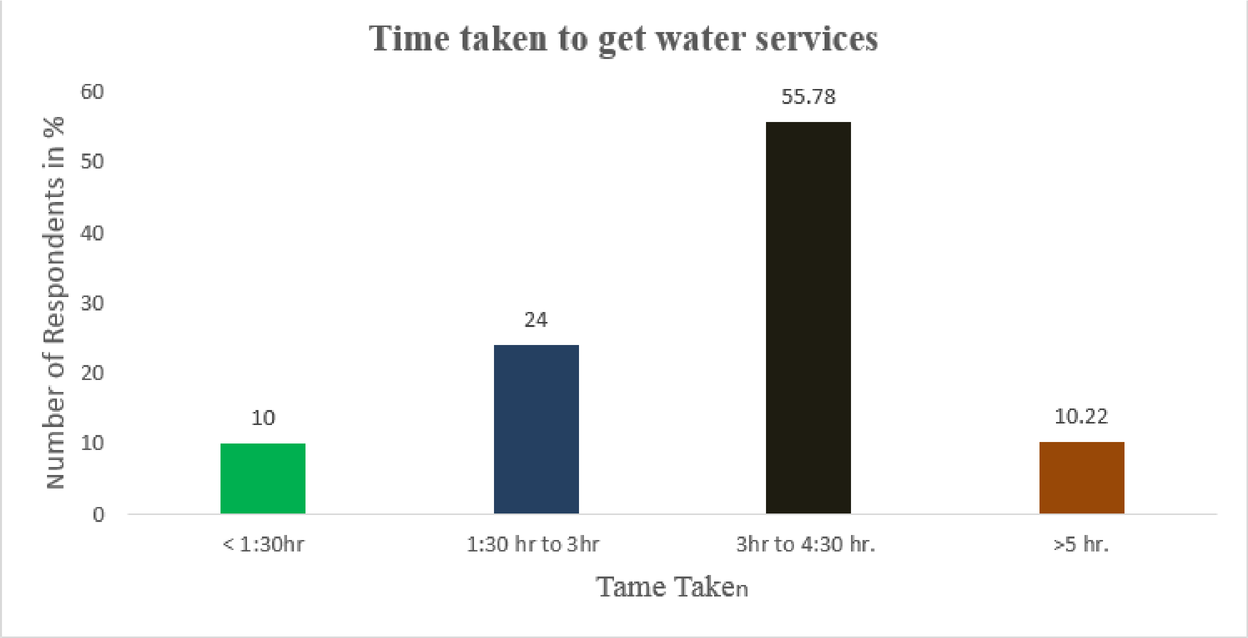

Figure: - 4.25 Bar Graph showing Time taken to get water services in study area

4.7.7 Water storage by households in Robe District

On the issue of water storage, it was revealed that 92.29% of the household did not store water while only 7.71% did store water. In addition, reasons for did not storing water by the respondents was most of the households have used hand dug well and spring water for domestic purpose from long distance and daily water was fetched from the source by the household members specially women.

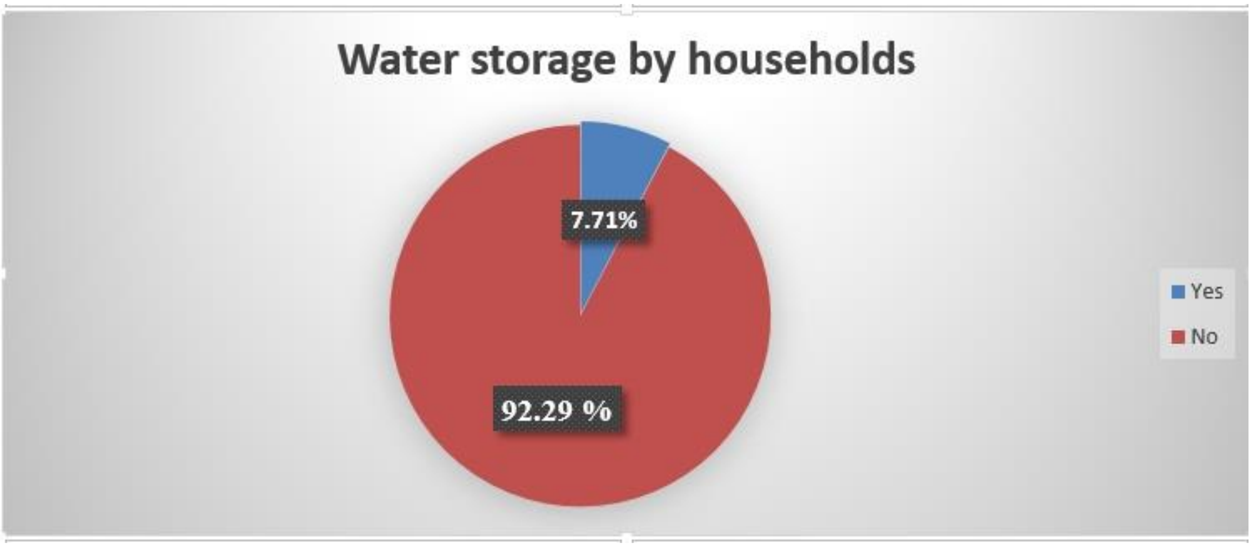

Figure: - 4.26 Pie Chart showing Water storage in study area

4.7.8 Method of Storage of water among respondents in Robe District

On the method used for water storage 5.24% make use of jerry can, 2.47% use bucket for storage while 92.29% did not store at all. The method of water storage is employed in order to reserve water in case of shortage.

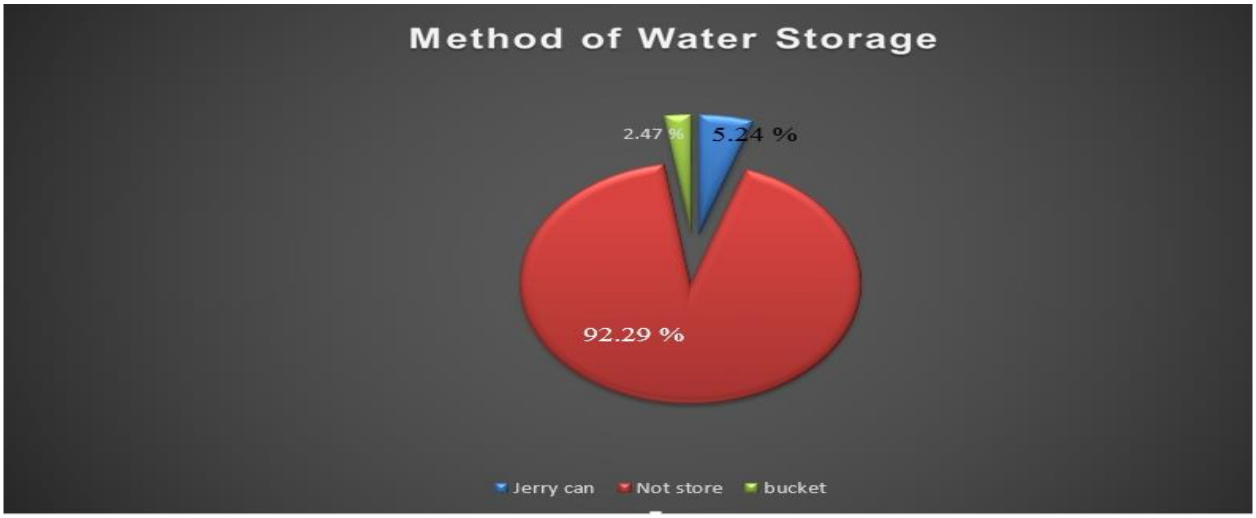

Figure: - 4.27Pie Chart showing Method of Storage of water in study area

Table 4.3 Key Uses of Water among the Households of Robe District

Water demand according to HH usage	Number of HH	Quantity in liter	Percentage
Drinking	350	3994.35	9.2
Cooking	350	5340.27	12.3
Washing	350	22294.54	51.35
Other	350	11787.67	27.15
Total		43416.83	100

The table shows that, the total water needed by the households was 43416.83per day.

With respect to water demand according to household usage, it was revealed that 9.2% of liter was used for drinking, 12.39% liter was used for cooking, and 51.35% 0f liter was used for washing while 27.15% of liter was used for other domestic purpose. From the above analysis, it was revealed that total water demanded for domestic use by 350 household is 43416.83 liters.

4.8. Analysis of Water Supply by Water, Mineral and Energy sector

The study examined the water supply by the Water Board within the period under study. Issues discussed under this section include the sources of water supply and estimate of water supplied to household per liter per day. Based on the oral interview conducted, it was revealed that the major sources of water supply are through hand dug well and spring ground water. Also, the number of households in the District was 39,592 and estimate of water supplied to the household in liters per day was estimated to 320,000 liters to 10,000 household per day(WWC).

4.9. Factors Affecting Water Demand and Supply

Table 4.4 Factors Affecting Water Demand.

FACTORS	FREQUENCY	PERCENTAGE
Topography of the area	93	26. 57
season	168	48.00
Water wastage by the households	65	18.57
Quality of water	24	6.86
Total	350	100

Source: Author’s Field Work, 2017

The study investigated the factors influencing water demand in the study area and the result is presented in Table 4.3. It shows that 26.57% of the respondents stated that season is the strong factor, 26.57% of the respondents said topography of the area was the factor that hindering the constant demand of water, closely followed by 18.57% who assume the factors to be as a result of Water wastage by the households, 6.86% linked the factor to the quality of water.

Table 4.5 Factors Affecting Water Supply

FACTORS	FREQUENCY	PERCENTAGE
Number of population	153	43.71
Topography of the area	110	31.43
season	21	6.01
Quality of water	20	5.71
Capital	46	13.14

Source: Author's Field Work, 2017

43.71% of the respondents were said that number of population is one factor affecting adequate water supply as it can be seen from the above Table 4.4. 31.43% of the respondents link the factor hindering the supply of water to the Topography of the area. 6.01% of the respondents link the factor threatening water supply seasonal variation. 5.71% of the respondents assumed the factor to be as a result of quality of source water,13.14% of the respondents presumed the factor of inadequate water supply by corporation to be as a result of insufficient fund or capital made available for the water mineral and energy sector.

4.10. Relationship between Water Demand and Supply

The study investigated the relationship between water supply and demand during the period using the correlation analysis technique. The result is presented in Table 4.5

Correlation Analysis of Water Supply and Demand

Table 4.6 Correlation Analysis of Water Supply and Demand

Survey Area	TWD(X)In(L)	TWS(Y)in(L)	$(x-\bar{x})$	$(x-\bar{x})^2$	$(\bar{y}-\bar{y})$	$(y-\bar{y})^2$	$(x-\bar{x})\,(y-\bar{y})$
AbooAlii	4093.59	1056	-333.51	1778258.92	-344	118336	458728.73
Jena Barbuko	4465.73	1152	-961.37	924239.4872	-248	61504	238420.69
Jena Hulul	4837.88	1248	-589.22	347184.6276	-152	23104	89562.01
SadikaaTokichu	3597.39	928	-1829.71	3347852.407	-472	222784	863624.89
HabeDangazela	5830.26	1504	403.16	162534.9619	104	10816	41928.25
MasaranjeeOda	3721.44	960	-1705.66	2909288.828	-440	193600	750492.05
Ataba Robe	4837.88	1248	-589.22	347184.6276	-152	23104	89562.01
Robe Town	12032.66	3104	6605.56	43633373.37	1704	2903616	11255867.85
Total	43416.83	11200	0.00	53449917.23	0	3556864	13788186.48
Average	5427.10	1400					

Source: Field Survey, 2017.

For water demanded

Total water demanded = 43416.83
Number of respondents 350
= 124.05 liters per person per day

For water supplied

Total water supplied=320,000
Estimated household 10,000
= 32 liters per households

This implies that water supply to individual in thearea= 320,000
1723
= 185.72liters per person per day

$$r_{xy} = \frac{\sum[(x-\bar{x})(y-\bar{y})]}{\{[\sum(x-\bar{x})2][\sum(y-\bar{y})2]\}^{1/2}}$$

$$= \frac{13788186.48}{[(53449917.23)(\,3556864)]^{1/}}$$

$$= 0.9999995$$

It can be observed from the result of the correlation coefficient (0.9999995) that there exist a very high positive linear relationship between the household’s water demand and water supplied in the study area

Test of significance of correlation coefficient

Hypothesis

Ho: P = 0 (There is no significance, relationship between water demand and water supply in the study area

Level of significance is set at 0.05

Decision rule is that, reject null hypothesis if calculated t is greater than critical value at 0.05 significance level with n – 2 degree of freedom

$$\text{Statistics} = t_{cal} = \frac{r\sqrt{(n-2)}}{\sqrt{(1-r)}}$$

Computation

N=8, r= 0.9999995, α = 0.05

$$T_{cal} = \frac{0{,}9999995\sqrt{(8-2)}}{\sqrt{(1-0.9999995)}}$$

$$T_{cal} = \frac{0.9999995(2.4495)}{0.0007}$$

$$T_{cal} = \frac{2.4495}{0.0007}$$

$$T_{cal} = 3499.29$$

$T_{tabulated}$ at 0.05 was 1.86

Since T_{cal} (3499.29) >$T_{tabulated}$ 0.05(1.86), therefore, the null hypothesis (Ho) is reject and concluded that the estimated correlation coefficient is statistically significant and the conclusion of the estimate was reliable

5. CONCUSSIONS AND RECOMMENDATIONS

5.1. Conclusions

Most of the communities of the study area are depended on ground water source. Physico-chemical parameters, anion and cat ions bacteriologies are evaluated in laboratory. According to result recorded the parameters like pH, E.C and TDS are below WHO guide line value and are safe for domestic use, except samples taken from Abo Ali and Ataba Robe which had pH values of 5.63 and 5.32 respectively. Temperature of all sample water was above WHO guide line value and water sample from Jena Hulul, Jena Barbuko, Abo Ali, SadikaTokichuma and MasaranejeOda are turbid which values are exceed WHO guide line value while samples from HabeDangasela, Ataba Robe and Robe Town have turbidity value below WHO guide line value. All the chemical parameters recorded from the result have values below WHO guide line value while some are above Ethiopian water quality guide line value. Metallic cat ion evaluation of sampled water relatively good to use for domestic purpose except water samples whose Iron concentration is above WHO permitted limit of 0.3 mg/Land water samples showed elevated Manganese concentration above the standard limit which is 0.1 mg.

Regarding bacteriology all water sample have value above WHO guide line value which are dangerous for drinking and not safe for domestic purpose. Based on domestic water demand and supply the study found that the study area depends mostly on hand dug well of ground water. The study also found that season had been the strongest factor influencing water demand in the study area based on the respondent view. While number of population is the strongest factor hindering the supply of water as stated by water, mineral and energy sector of the district. The study further found that, there exist very high positive linear relationship between the household water demand and water supply. Hand dug well water supply in the study area is inadequate to meet the demand of households. In view of these therefore, there is a need for improvement in the quantity of water supply in the whole district.

5.2. Recommendations

The quality and quantity of ground water and it’s suitability for domestic use in the study area is evaluated based on the field based and laboratory based measurements with addition of analysis computed, and questionnaire recovered, the following recommendations were stated.

- Latrine is required for the community to avoid open defecation, which pollutes the water source.
- It is important to prepare run off prevention trenches or construction of elevated slab for the existing hand dug well to prevent entrance of human and animal excreta and waste.
- The result shows that the existing water supply of study area is slightly turbid. Therefore, since these sources are not safe for domestic use treatment water with chemical such as “uha agar” is requiredto treat the water.
- It is necessary to protect water points and schemes from entrance of different animals in order to prevent damage and entrance of animal waste into it.
- Aeration treatment process or other treatment alternative is needed for water in areas at which Iron and Manganese concentration is above WHO guideline value.Robe District Water Mineral and energy sector and other concerned bodies responsible for the treatment options.
- The government should endeavor to come to water board aid by proper funding so as to construct water treatment plant for the community; special allocation of fund should be made available to the water board so as to improve their service.

CHAPTER SIX
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7. ANNXES

ANNXES I: Recorded Laboratory results of the samples

P	L.R	units	JHSP	JBSP	AASP	STSP	HDSP	MOSP	ARSP	RTSP	WHO	ETH
PH	LR1		7.6	7.72	7.71	7.74	6	7.34	7.51	7.67		
	LR2		6.8	7.1	7.23	7.8	6.75	7.56	7.77	7.44		
	LR3		7.3	7.8	7.9	6.89	6.98	7.26	7.22	7.9		
	AVRG		7.23	7.54	7.61	7.48	6.58	7.39	7.50	7.67	6.5-8.5	6.5-8.5
Tem	LR1	T^0	22.6	25.1	18.6	20.6	18.2	17.2	15	24.12		
	LR2	T^0	21.9	24.9	18.9	21	18.6	17	14.5	24		
	LR3	T^0	23.4	25.2	17.8	20.9	18.3	19.3	15.2	23.86		
	AVRG	T^0	22.6	25.0	18.4	20.8	18.4	17.9	14.9	23.99	15	
E.C	LR1	µs/cm	93.4	92.4	112.5	176.5	90.5	88.9	248.4	93.8		
	LR2	µs/cm	95.3	92.6	121.6	169.6	91.3	92.5	269.6	96.12		
	LR3	µs/cm	94.1	94.11	98.87	178.4	93.54	86.76	238.7	95.45		
	AVRG	µs/cm	94.3	93.04	110.9	174.9	91.78	89.4	252.3	95.12	250	250
Turb.	LR1	(NTU)	7.56	9.65	6.33	7.33	4.32	6.12	2.11	1.5		
	LR2	(NTU)	7.89	10.11	6.32	6.54	4.2	5.6	1.67	0.93		
	LR3	(NTU)	8.21	10.34	5.67	6.91	3.78	5.8	1.75	0.45		
	AVRG	(NTU)	7.89	10.03	6.11	6.93	4.10	5.84	1.84	0.96	5	5
TDS	LR1	Mg/L	46.7	52.3	126.	68.4	231.	321.	124.4	354.7		
	LR2	Mg/L	50.2	48.8	127.	72.1	229.	336.	127.5	356.9		
	LR3	Mg/L	45.8	46.3	130.9	60.5	238.8	315.7	125.3	356.76		
	AVRG	Mg/L	47.6	49.2	127.9	67.02	232.9	324.1	125.7	356.11	1000	1000
TS	LR1	Mg/L	3.2	2.5	4	2.7	3.4	2.42	2.42	2.67		
	LR2	Mg/L	4.5	2.6	3.8	2.5	3	2.33	2.8	2.54		
	LR3	Mg/L	3.8	1.7	3.2	2.6	3.21	2.57	2.12	2.73		

	AVRG	Mg/L	3.83	2.27	3.67	2.6	3.20	2.44	2.45	2.65		
HCO3	LR1	Mg/L	50	43.65	38.56	52.3	121.54	98.3	150	134.6		
	LR2	Mg/L	58	42.6	32.21	55.21	123.65	103.6	155.34	138.65		
	LR3	Mg/L	51	45	36.43	56.4	128.12	99.54	149.76	132.28		
	AVRG	Mg/L	53	43.75	35.73	54.64	124.44	100.48	151.7	135.18	200	
TA	LR1	Mg/L	50	43.65	38.56	52.3	121.54	98.3	150	134.6		
	LR2	Mg/L	58	42.6	32.21	55.21	123.65	103.6	155.34	138.65		
	LR3	Mg/L	51	45	36.43	56.4	128.12	99.54	149.76	132.28		
	AVRG	Mg/L	53	43.75	35.73	54.64	124.4	100.4	151.8	135.18	200	200
TH	LR1	Mg/L	19.4	22.1	18.7	29.55	17.45	23.11	35.67	15.21		
	LR2	Mg/L	21.2	21.55	19.54	28.79	16.89	24.21	36.45	14.95		
	LR3	Mg/L	18.85	22.45	17.34	30.56	17.25	20.91	34.97	16.24		
	AVRG	Mg/L	19.82	22.03	18.53	29.63	17.20	22.74	35.70	15.47	200	300
NO3	LR1	Mg/L	6.2	5.67	14.65	4.56	1.34	3.25	3.3	3.9		
	LR2	Mg/L	7.11	7.33	15.1	5.51	2	4.11	4.1	4.12		
	LR3	Mg/L	5.75	6.32	15.32	5.1	1.67	3.51	3.55	3.8		
	AVRG	Mg/L	6.35	6.44	15.02	5.06	1.67	3.62	3.65	3.94	50	50
Cl	LR1	Mg/L	7.5	9.21	5.75	7.75	3.15	1.85	10	7.5		
	LR2	Mg/L	8.1	8.23	6.11	7.23	2.5	2.22	11.5	5.67		
	LR3	Mg/L	6.78	8.45	75.95	7.11	2.11	1.9	12.67	6.79		
	AVRG	Mg/L	15.6	17.44	11.86	14.98	5.65	4.07	21.5	13.17	250	250
F	LR1	Mg/L	0.05	0.12	0.23	0.33	0.08	0.13	0.74	0.19		
	LR2	Mg/L	0.1	0.11	0.3	0.37	0.1	0.16	0.8	0.23		
	LR3	Mg/L	0.09	0.08	0.15	0.31	0.07	0.2	0.82	0.1		
	AVRG	Mg/L	0.08	0.10	0.23	0.34	0.08	0.16	0.79	0.17		1.5
SO4	LR1	Mg/L	3.21	12.67	17.3	15.7	13.5	19.3	2.42	12.31		

	LR2	Mg/L	3.76	13.1	17.5	16.1	14.1	19.1	3.5	12.1		
	LR3	Mg/L	3.52	12.9	18	15.9	14.2	18.7	2.92	11.8		
	AVRG	Mg/L	3.50	12.89	17.6	15.9	13.93	19.03	2.95	12.07	250	250
Na	LR1	Mg/L	12.9	10.8	18.12	8.65	21.83	15.67	32.5	14.6		
	LR2	Mg/L	13.1	11.21	17.68	8.76	22.11	15.58	33.21	14.59		
	LR3	Mg/L	12.6	10.75	17.79	9.12	20.98	16.31	32.85	15.11		
	AVRG	Mg/L	12.87	10.92	17.86	8.84	21.64	15.85	32.85	14.77	200	200
K	LR1	Mg/L	0.3	2.13	0.57	2.45	1.33	3.13	3.2	0.6		
	LR2	Mg/L	0.52	2.11	0.76	2.6	1.21	2.87	3.6	0.75		
	LR3	Mg/L	0.2	1.79	0.48	2.87	0.98	3.14	3.52	0.91		
	AVRG	Mg/L	0.34	2.01	0.60	2.64	1.17	3.05	3.44	0.75	10	1..5
Ca	LR1	Mg/L	4.3	2.81	4.85	2.56	8.57	3.91	11.7	4.9		
	LR2	Mg/L	3.78	3.11	5.12	3.41	9.33	4.33	11.86	5.31		
	LR3	Mg/L	4.34	3.23	4.57	2.89	9.34	4.12	12.43	5.42		
	AVRG	Mg/L	4.14	3.05	4.85	2.95	9.08	4.12	12.00	5.21	75	75
Mg	LR1	Mg/L	2.1	3.5	4.3	2.4	4.23	3.67	7.5	2.1		
	LR2	Mg/L	2.39	4.1	3.8	2.21	4.18	3.54	6.89	2.73		
	LR3	Mg/L	2.32	3.8	4.27	2.43	4.25	2.87	7.26	2.48		
	AVRG	Mg/L	2.27	3.80	4.12	2.35	4.22	3.36	7.22	2.44	50	50
Fe	LR1	Mg/L	0.2	0.15	0.61	0.22	0.21	0.31	0.1	0.06		
	LR2	Mg/L	0.17	0.1	0.73	0.09	0.18	0.29	0.08	0.09		
	LR3	Mg/L	0.23	0.19	1.01	0.16	0.15	0.28	0.12	0.03		
	AVRG	Mg/L	0.2	0.15	0.78	0.16	0.18	0.29	0.10	0.06	0.3	0.3
Mn	LR1	Mg/L	0.2	0	0.5	0.51	0.47	0.29	0.3	0.2		
	LR2	Mg/L	0.24	0.01	0.48	0.45	0.54	0.31	0.32	0.23		
	LR3	Mg/L	0.19	0.04	0.52	0.63	0.5	0.26	0.27	0.16		

	AVRG	Mg/L	0.21	0.02	0.50	0.53	0.50	0.29	0.30	0.20	0.4	0.5
FC	LR1	Col./ml	202	525	447	511	631	572	4	1		
	LR2	Col./ml	213	531	463	542	597	582	3	2		
	LR3	Col./ml	201	495	451	521	649	623	5	0		
	AVRG	Col./ml	205.33	517.00	453.67	524.67	625.67	592.33	4.00	1.00	NO	NO
TC	LR1	Col./ml	353	696	461	672	658	721	57	3		
	LR2	Col./ml	401	693	507	659	673	731	45	2		
	LR3	Col./ml	363	712	473	681	662	724	49	3		
	AVRG	Col./ml	372.33	700.3	480.33	670.67	664.33	725.33	50.33	2.67	NO	NO

RL=Laboratory Record

P=parameters

ANNXES II: Results of the physical analysis of domestic use sample for the study area.

Sample Code	**Name Of Kebeles**	**Water Resource**	**Ph**	**Temp**	**E.C**	**Turbidity**	**TDS**
JHSP	Jena Hulul	Hand Dug Well	7.23	22.64	94.27	41.38	47.55
JBSP	Jena Barbuko	Hand Dug Well	7.54	25.06	93.04	41.88	49.15
AASP	Abo Ali	Hand Dug Well	7.61	18.42	110.99	45.68	127.91
STSP	SadikaTokichuma	Hand Dug Well	7.48	20.82	174.86	67.72	67.02
HDSP	HabeDangasela	Hand Dug Well	6.58	18.37	91.78	38.91	232.89
MOSP	MasaranjeOda	Hand Dug Well	7.39	17.85	89.4	38.21	324.13
ARSP	Ataba Robe	Spring GW	7.50	14.91	252.31	91,57	125.67
RTSP	Robe Town	Spring Piped GW	7.67	23.99	95.12	42.26	356.11

ANNXES III: Results of chemical analysis of domestic use sample for the study area.

SC	WR	HCO3	TA	TH	NO3	Cl	F	SO4	Na	k	Ca	Mg	Fe	Mn
JHSP	HD Well	53	53	19.82	6.35	15.6	0.1	3.50	12.1	0.34	4.14	2.27	0.2	0.21
JBSP	HD Well	43.75	43.75	22.03	6.44	17.44	0.10	12.89	10.9	2.01	3.05	3.80	0.15	0.02
AASP	HD Well	35.73	35.73	18.53	15.02	11.86	0.23	17.6	17.86	0.60	4.85	4.12	0.78	0.50
STSP	HD Well	54.64	54.64	29.63	5.06	14.98	0.34	15.9	8.84	2.64	2.95	2.35	0.16	0.53
HDSP	HD Well	124.44	124.44	17.20	1.67	5.65	0.08	13.93	21.6	1.17	9.08	4.22	0.18	0.50
MOSP	HD Well	100.5	100.48	22.74	3.62	4.07	0.16	19.03	15.85	3.05	4.12	3.36	0.29	0.29
ARSP	Spring GW	151.7	151.7	35.70	3.65	21.5	0.79	2.95	32.85	3.44	12.00	7.22	0.1	0.30
RTSP	Spring PW	135.18	135.18	15.47	3.94	13.17	0.17	12.07	14.77	0.75	5.21	2.44	0.06	0.20

HD= hand Dug

WR=Water Resource

SC=Sample Code

PW=Piped Water

ANNXES IV:Rangesand Average of Physic-Chemical Parameter Values RecordedIn Study Area Compared with Standards of WHO (2004) and Ethiopian Standards.

Parameter	Range		Average	WHO	Ethiopian
pH	6.58	7.67	7.37	6.5-8.5	6.5-8.5
Temp	14.91	25.06	20.26	15	15
E.C	89.40	252.31	125.22	250	250
Turbidity	38.21	91.57	50.95	5	5
TDS	47.55	356.11	166.30	1000	1000
HCO3	35.73	151.70	87.36	-	-
Total Alkalinity	35.73	151.70	87.36	200	200
Total Hardness	15.47	35.70	22.64	200	300
Nitrate	1.67	15.02	5.72	50	50
Chloride	4.07	21.50	13.03	250	250
Fluoride	0.08	0.79	0.24		1.5
Sulfate	2.95	19.03	12.23	250	250
Sodium	8.84	32.85	16.95	200	200
Potassium	0.34	3.44	1.75	10	1..5
Calcium	2.95	12.00	5.67	75	75
Magnesium	2.27	7.22	3.72	50	50
Iron	0.06	0.78	0.24	0.3	0.3
Manganese	0.02	0.53	0.32	0.4	0.5
Fecal Coliform	1.00	625.67	365.46	NO	NO
Total Coliform	2.67	725.33	458.29	NO	NO

ANNXE V: Questionnaires to Be Filled by Smallholder Households

JIMMA UNIVERSITY
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SCHOOL OF GRADUATE STUDIES
FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING
ENVIRONMENTAL ENGINEERIG CHAIR

QUESTIONARIERS TO BE FILLED BY SMALLHOLDER HOUSEHOLDSON ACCESS TO THE IMPACT OF DOMESTIC WATER DEMAND IN ROBE DISTRICT

You have been selected to participate in the study designed to collect information on the domestic water use Practices of communities in reference to some selected kebeles of Robe District. As a result, I kindly ask you to share me your opinion and experiences, taking few minutes from your schedule of time. Your genuine cooperation is very important, because you represent many other peoples who have similar knowledge. The genuine response you provide is highly valuable and determines the effectiveness of this investigation. Please, be assured that I will treat your responses confidentially and will not be used for any purpose other than research. You are not expected to write your name on the questionnaire. Thank you in advance for your cooperation!

Section One: Respondents Background.

1. Survey point: …………………………………………………………………….

2. Sex: Male [ ] Female [ ]

3. Age (Years) ≤15 [ ] 15-20 [ ] 26-35 [ ] 36-45 [ ] ≥46 [ ]

4. Marital status: Married [ ] Single [ ] Divorced [ ] Widow [ ] Widower [ ]

5. House hold size 1-3 [ ] 4-6 [ ] 7-9 [ ] ≥9 [ ]

6. Level of income (birr) per month; 0 to 500 [ ], 500 to 1000 [ ],1000 to 1500 [ ],1500 to 2000[ ],above 2000 [ ].

7. Occupation Farming [ ] Trading [ ] Civil Service [ ] Full house wife [ ] Artisan [ ] others (specify) …………………………..

8. Educational background illiterate [ ] read and write [ ] Primary [ ] Secondary [ ] Above Secondary [ ]

Section Two: Water Use and Demand

9. Sources of water: Hand Dug Well [ ] hand pump Borehole [ ] spring piped ground water [ ] protected spring [ ] other (specify)

10. ……….. How much water do you use in household on the following activities? Please estimate in liters / jerry can of 20liters.

Activities: (i) Drinking _________ liters or _________ jerry can (ii) cooking _________ litres or _________ jerry can

(iii) Washing _________litres or _________ jerry can

11. Distance of water source(s) from your household?

Please specify in metre / kilometer ………………………………………………………

12. Who is responsible for collection of water in your household?

i) Husband [ ] ii) wife [ ] iii) children [ ] iv) other specify ………………………..

13. Do you pay for the water? Yes / No

14. If yes please specify how much in Birr …………………………

15. How long does it take you to get the water (i) Less than 30minutes [ ] (ii) 30 minutes to 1hr [ ] iii) 1hr minutes to 2 hour [ ] iv greater than 2hr

Above 1hour [ ]

16. Do you have to store the water i) Yes ii) No

17. If yes in question above, what are your reasons ……………………………………………..

……………………………………………………………………………………………

18. What method do you employ in storing water?

i) Jeri can [ ]

ii) Bucket [ ]

iv) Pot [ ]

v) Others specify ……………………………………………………………………..

19. What are the factors affecting water demand? Please state ……………………………….

……………………………………………………………………………………………..

Thank you so much for your time and ideas.

ANNXE VI: Questionnaires to Be Filled by Water Board Staff

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ENVIRONMENTAL ENGINEERIG CHAIR

QUESTIONARIERS TO BE FILLED BY WATER BOARD STAFF MEMBERSON ACCESS TO THE IMPACT OF DOMESTIC WATER SUPPLYIN ROBE DISTRICT

You have been selected to participate in the study designed to collect information on the domestic water use Practices of communities in reference to some selected kebeles of Robe District. As a result, I kindly ask you to share me your opinion and experiences, taking few minutes from your schedule of time. Your genuine cooperation is very important, because you represent many other peoples who have similar knowledge. The genuine response you provide is highly valuable and determines the effectiveness of this investigation. Please, be assured that I will treat your responses confidentially and will not be used for any purpose other than research. You are not expected to write your name on the questionnaire. Thank you in advance for your cooperation!

Please tick appropriately [ ] where necessary.

Source(s) of water

1. What is the source of your water supply?

(i) Hand dug well [ ] (ii) Borehole [ ] (iii) spring [ ](iv) Others [ ]

2. What is the estimate of water supply to a household (in liters) please estimate …………………..

3. A. Is the source of water supply enough to meet up with the demand of water? Yes / No

3. B. If no, suggest on how to increase the source of water supply. ………………………….

4. Do seasonal variations affect water availability in the source? ……………………….

5. Who is responsible for the construction of the facilities? I) Government [ ] ii) NGO [ ] (iii) Private Individual [ ] (iv) Others please specify ……………….

6. Who is responsible for the repairs of damaged route of water supply? ……………..

7. How do you feel about self-supply or private investment in water supply construction and management? ………………………………………………………….. .

8. How does the information get to you on the problems associated with supply of water? …………………………………………………………

9. What are the factors influencing the supply of water: please state ……………………….

Thank you so much for your time and ideas.

ANNXE VII: Used Water According to the Number of Persons in the Household

DRINKING =2LITRES PER PERSON				
Members	Mid-point	Frequency	Multiple	Total (litre)
1 – 3	2	114	2(114) =228 (2)	456
4–6	5	144	5(144) = 720(2)	1440
7– 9	8	53	8(53) = 424(2)	848
≥9		39	39(9) = 351(2)	702
Total		**350**	**1723**	**3446**
COOKING ONE PERSON = 1.5LITRES				
Members	Mid-point	Frequency	Multiple	Total (litre)
1 – 3	2	114	2(114) =228 (1.5)	342
4–6	5	144	5(144) = 720(1.5)	1080
7– 9	8	53	8(53) = 424(1.5)	636
≥9		39	39(9) = 351(1.5)	527
Total		**350**		**2585**
WASHING = 9 LITERS PER PERSON				
Members	Mid-point	Frequency	Multiple	Total (litre)
1 – 3	2	114	2(114) =228 (**9**)	2052
4–6	5	144	5(144) = 720(**9**)	6480
7– 9	8	53	8(53) = 424(**9**)	3816
≥9		39	39(9) = 351(**9**)	3159
Total		**350**		**15507**
OTHERS= 5.2 LITERS PER PERSON				
Members	Mid-point	Frequency	Multiple	Total (litre)
1 – 3	2	114	2(114) =228 (**5.2**)	1185.6
4–6	5	144	5(144) = 720(**5.2**)	3744
7– 9	8	53	8(53) = 424(**5.2**)	2204.8
≥9		39	39(9) = 351(**5.2**)	1825.2
Total		**350**		**8959.6**

Source: Field Survey, 2017

Annex VIII: Field and laboratory based activities

Field based measurement of non-conservative parameters

Field based measurement of non-conservative parameters

Bacteriological Quality laboratory analysis