JIMMA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
JIMMA INSTITUTE OF TECHNOLOGY
FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING
ENVIRONMENTAL ENGINEERIG STREAM

SUITABILITY ANALYSIS OF GROUNDWATER FOR DRINKING AND IRRIGATION PURPOSES: A CASE OF SABATA HAWAS DISTRICT, OROMIYA, ETHIOPIA

BY MILKESA KELBESSA

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

December, 2019
Jimma, Ethiopia

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December, 2019
Jimma, Ethiopia

DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

Approval page

This thesis entitled “Suitability analysis of groundwater for drinking and irrigation purposes: A case of Sabata Hawas District, Oromiya, Ethiopia.”

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ABSTRACT

Groundwater is an important natural resources serving as a reliable source of drinking and irrigation water for many people worldwide. Contamination of groundwater, either from anthropogenic or natural sources has now turned to be a major environmental challenge. Access to quality drinking and irrigation water is of major concern for sustainable development in developing countries like Ethiopia. Pollution of groundwater is the most serious problems affecting the health of the people. Therefore the objective of this study was examining suitability analysis of groundwater for drinking and irrigation uses. Groundwater samples were chemically analyzed for major physicochemical parameters in order to understand the different geochemical processes affecting the groundwater quality. For the purpose of this study10 samples were collected from 10 boreholes and the purposive sampling techniques was applied and 30 boreholes of previous published data by Oromiya water, Mineral and Energy Bauer in Sabata Hawas district also analyzed. The samples were analyzed for Mg^{2+}, Ca^{2+}, Na^{+} , K^{+}, *Cl,* $SO4^{2-}$, $HCO3^{-}$, $CO3^{2-}$, $NO3^{-}$, *F,* $PO4^{3-}$,*NH3,*$NH4^{+}$, *total Iron, total Manganese, hydrogen ion concentration , total dissolved solid , total hardness, electrical conductivity, temperature and turbidity were investigated. The Ethiopian standard (2001) and the WHO (2011) water standards were used as the basis of evaluating the suitability of groundwater for drinking purpose. For irrigation, Electrical Conductivity (EC), Sodium percentage (Na %), Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Kelley's Ratio (KR), Magnesium Ratio (MR) and Permeability Index (PI) were used to evaluate suitability. Lastly, the result was presented using Aquachem.software V2014.2 in order to showed water type (piper diagram) and Wilcox diagram of sodium hazard versus salinity hazard in the study area. The results showed that the groundwater is hard, alkaline in nature and that most of the samples are within the permissible range of both Ethiopian standard (2001) and WHO (2011). 6.9%,100%, 26.9%, 20%, 20% and 7.14% samples showed concentrations of* F^{-} , K^{+}, Mn^{2+}, *total hardness, turbidity,* Ca^{2+} *and* $NO3^{-}$ respectively were *above the guideline value as per WHO and national standards. 15% of the concentration of NH3 and* $NH4^{+}$ *were fells out of the WHO guideline recommended for drinking water supply. The quality of groundwater for irrigation purpose is suitable. However, based on Wilcox diagram 12.5% groundwater samples of the study area revealed under high salinity hazard and 10% of magnesium hazard is higher than the recommended and hence it is not suitable for irrigation due to the potential to cause alkaline soil which is known to have low infiltration capacity. Classical hydro-chemical methods revealed five hydro-chemical facies (water types) in the study area, which are Ca-Mg-HCO3, Ca-Na-Mg-HCO3, Ca-HCO3, Ca-Mg-SO4-HCO3 and Ca-Na-Mg-HCO3-Cl .The major ion chemistry analysis revealed that the main composition controlling processes in the study area is rock water interaction. It further revealed that the ionic concentration is due to silicate weathering, carbonate weathering, cation exchange, gypsum dissolution and halite dissolution.*

Keywords: *Drinking water quality, Irrigation water quality, ground water quality, physico chemical parameters.*

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LIST OF ABBREVIATION

APHA	American Health Association
CAWST	Center for Affordable Water and Sanitation Technology
DWS	Department of water and Sanitation
EC	Electrical Conductivity
ERA	Ethiopian Road Authority
ETB	Ethiopia Birr
ES	Ethiopian Standards
GW	Ground Water
KR	Kelley's Ratio
LULC	Land Use Land Cover
MDG	Millennium Development goals program
MH	magnesium Hazard
NTU	Nephelometric Turbidity Unit
SAR	Sodium Adsorption Ratio
RSC	Residual Sodium Chloride
PI	Permeability Index
pH	Hydrogen Ion Concentration
TDS	Total Dissolved Solid
TH	Total Hardness
TA	Total Alkalinity
UNEP	United Nations Environment Program
UNICEF	United Nations Children’s Fund
USSL	United State Salinity Laboratory
USGS	United State Geographic Survey
WHO	World Health Organization
WWDSE	Water Work Design and Supervision Enterprise

CHAPTER ONE

1.1. Back ground

Ground water is an important source of water supply throughout the world. Its uses in irrigation, industry, municipalities and municipals water supply demand continues to increase. There is a tendency to think of ground water as being the primary water source in arid regions.
Water is most vital for maintaining the life on the earth. Groundwater is one of the most important resources as it is being used for different purposes such as drinking, irrigation and industrial. About 97 % water exists in oceans that is not suitable for drinking and only 3% is fresh water where in 2.97% is comprised by glaciers and ice caps and remaining little portion of 0.03% is available as a surface and ground water for human use (Miller, 1997).

Water is one of the main resources that are important for sustainable development of a country. In order to make it sustainable proper investigation and utilization is vital. Recent studies indicate that groundwater is becoming the main source of water supply for many countries. Harmless drinking water is a basic need for good health and it is a rudimentary right of humans (WHO, 2001) In addition, it is impossible to imagine clean and sanitary environment without water.

Groundwater is the most important source of domestic, industrial and agricultural water supply in the world. Many communities in Africa depend heavily on groundwater for drinking and irrigation uses. Therefore, ground water is an important natural resource serving as a reliable source of drinking and irrigation water for many people worldwide, especially in developing countries. 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 according to KebedeTsehayu (2004).

Ethiopia is one of the participant countries that decided the millennium development announcement with its main impartial of poverty reduction. This resulted in prioritizing accessibility to improved drinking water quality. Therefore, to achieve these goals, drinking water quality concerns are often the most important component for measuring access to enhanced water supply sources and treatment distribution systems for the public. Acceptable water quality shows the safety of drinking water in terms of its physical, chemical, and bacteriological parameters (WHO, 2004). User communities" perceptions of quality also carry great weight in their drinking water safety (Doria, 2010).

Irrigated agriculture is dependent on an adequate water supply of usable quality. Just as all water is not suitable for human beings, in the same way; all water is not suitable for plant life.
The presence of soluble salts in irrigation water will have an effect on the crops and on the soil in which the irrigation is applied. Soils with high levels of salinity are called saline soils.
High concentration of salt in the soil can result in a "physiological" drought condition. It is, even thought that field appeared to have plenty of moisture; the plants wilt because the roots are unable to absorb the water. Water salinity is usually measured as TDS (total dissolved solid) or EC (electrical conductivity). Water containing impurities, which are injurious to plant growth, is not satisfactory for irrigation and called unsatisfactory water. The influence of soils on water quality is very complex and can be ascribed to the processes controlling the exchange of chemicals between the soil and water (Hester berg, 1998).

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. Regular monitoring of groundwater resources thus plays a key role in sustainable management of water resources. Therefore, the study was conducted seeks to serve as a preliminary study to assess the suitability of groundwater quality in terms of drinking and irrigation uses for a rapidly developing community located in Sabata Hawas district. Ground water quality needs to be given a primary research and quality Control attention due to possible contamination.

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. Groundwater is one of the most important resources as it is being used for different purposes such as drinking, irrigation and industrial. Its quality is mostly affected by the anthropogenic activities. Hence, the problem of groundwater pollution is aggravated due to municipal, industrial, agricultural and other miscellaneous sources and causes.

Urbanization and industrialization are important factor, for the increasing demand of groundwater, at the same time they are responsible for the degradation/pollution of ground water. Animal and human wastes, the application of chemical fertilizer and manure can play a significant role in promoting the migration of pathogens and increase in nitrate concentration in surface and groundwater. Contamination of groundwater often occurs in places where the groundwater table is shallow and activities on going at that particular area contributes to leaching of contamination to groundwater. This normally happens in industrial areas where a lot of produced contaminated water is channeled out into the surface water which will eventually infiltrate into the groundwater (Mahadevan and Krishnaswamy, 1984). Therefore to ensure that water is suitable for human consumption and use, standards and guidelines were developed by organizations such as Department of Water and Sanitation (DWS) and World Health Organization (WHO) as criteria to determine suitability.

Guidelines are set to describe reasonable minimum requirements of safe practice to protect the health of consumers. The guidelines are in the form of numerical values for constituents of water or indicators of water quality (WHO, 2008). Likewise, chemical constituents in water can also have negative effects on plant life. Irrigation water can affect plant health directly through toxicity or deficiency, or indirectly by altering plants ability to take in nutrients (Rahman *at el.,* 2012). Excess Na^+ in irrigation water has been reported to cause hardening of the soil, so much that the soil becomes impervious and limits the ability of the roots to uptake water (Naseem *et al.,* 2010).

This study aims to conduct a suitability of the groundwater quality for drinking and irrigation purposes in Sabata Hawas district which is located in Oromiya Special Zone surrounding Finfinne, Oromiya Regional State, Ethiopia. The approach was involved the use of an appropriate assessment technique to determine the suitability for drinking and irrigation purposes of groundwater in the study area. This requires the concentrations of important parameters such as pH, electrical conductivity (EC) ,total alkalinity (TA) ,total dissolved solid (TDS), total hardness (TH), Ca^{2+}, Mg^{2+}, K^+, Na^+, Cl^-, HCO_3^-, F^-, CO_3^{2-} ,NO_3^- and SO_4^{2-} comparing the concentrations of these ions with WHO (2011) and Ethiopian (2001) guidelines/standards set for water consumption and use.

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 and the risks of water-associated diseases are serious public health concerns in many developing countries like Ethiopia. This is mainly due to lack of proper research and subsequent monitoring of water quality parameters for most of the district in Ethiopia. The problems of groundwater quality are much more acute in the areas which are densely populated; thickly industrialized and mass agriculture is practice.

Fast population growth of towns and cities, new settlement of residential and public centers and establishment of new factories and industries are the major challenges and deducted to the ground water contamination problem for drinking and irrigation purpose in Sabata Hawas district. In general the quality of drinking and irrigation water is a major determinant of health for humans and plants. Again there is no research that had been attempt on this topic in this area that is the other goal of the researcher to focus on this topic.
For this reason, periodic quality control measures are necessary.

1.3. Objectives of the study

1.3.1. General objective

The general objective of this study suitability analysis of groundwater for drinking and irrigation purposes in Sabata Hawas district, Oromiya Special Zone surrounding Finfinne, Oromiya Regional State, Ethiopia.

1.3.2. Specific objectives

- ❖ To characterize the physical and chemical properties of groundwater.
- ❖ To evaluate the suitability of ground water for drinking purpose.
- ❖ To assess the suitability of ground water for irrigation purpose.

1.4. Research questions

1. What is the use of characterize the physical and chemical properties of groundwater?
2. How does evaluate the suitability of ground water for drinking purpose?
3. How does assess the suitability of ground water for irrigation purpose?

1.5. Scope of the study

This research was mainly focused on the suitability analysis of ground water for drinking and irrigation purposes in Sabata Hawas District. In so doing ten kebeles studied. Water quality and the risk of water associated diseases are serious public health concerns in many developing countries like Ethiopia. This is mainly due to lack proper research and subsequent monitoring of water quality parameters for most of the districts in Ethiopia. The study area is limited to Sabata Hawas District. The study considered physical and chemical properties of GW quality those applied in terms of its parameters. Water sample parameters were analyzed in a laboratory. Some parameters such as water temperature, conductivity, alkalinity, hardness, TDS and turbidity were measured in the field. Interpretation of water chemistry data was carried out using AquaChem software V 2014.2. The analyzed data was presented using table, graphs, piper diagram and Wilcox diagram. Finally the analyzed results were compared with WHO (2011) guideline values and Ethiopian (2001) guidelines.

1.6. Siginfingance of the study

Groundwater quality data is necessary to establish baseline conditions in the groundwater protection and can also assist in identifying an environmental value and defining water quality objectives. Data from this study was contributed to improve the understanding of the factors that affect groundwater quality for drinking and irrigation purposes. Studying on water quality and sanitation is very important for providing clean and safe water for the community that helps to achieve one of the Millennium Development goals (MDG) program. The community living in the district to identify the water quality and to understand the possible source water to fill the gaps. The planner and designer who are engaged on the water and related activities of the district it can give them a clue for their future planning and implementation.

1.7. Limitations of the study

In these study main issues faced was lack of adequate information due to poor document
handled by the district water supply office. It was difficult to get source documents in an organized manner which was laborious to get real information. The study relied on the broad ground water quality in terms of its physiochemical parameters, however heavy metals like arsenic, cadmium and lead were not considered due to lack of laboratory. Also this study did not

include all kebeles of Sabata Hawas district to analyze all existed bore holes of the area. Finally, the main challenge was there is no accessible road to collect water samples and hence there is no transport and therefore more than 1.50 hrs walk on feet to collected water samples.

CHAPTER TWO

2. LITRATURE REVIEW

2.1. Ground water resource

Ground water is the water found underground in the cracks and spaces in soils, sand and rock. It is stored in and moves slowly through geologic formations of soil, sand and rocks called aquifers (Todd, 1995). The health of any community fully depends on the accessibility of adequate and safe water. Hence, water is predominately essential for life, health and for human self respect. Therefore, in addition to community health benefits, all people have the right to safe and adequate water retrieved in equitable manner for drinking, cooking, personal and domestic hygiene. In this case, both adequacy and safety of drinking water are equally important to reduce the incidence of water-related and water borne health problems especially diseases like diarrheal (Bharti *et al*, 2011).

Assessment of the groundwater resources involves an appreciation of the magnitude and quality of the resources, its recharge and discharge zones, its interactions with surface water and groundwater resources, environmental links and demands and present and future consumptive demands on the resources by all consumer groups. Groundwater is resource found under the land surface in the saturated zone. It constitutes about 95 percent of the fresh water 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 proved a valuable base flow supplying water to rivers during periods of no rainfall.
Therefore it is an essential resource that requires protection.

2.2. Groundwater quality

Water quality is defined based on a set of physical and chemical variables that are closely related to the water's intended use. The quality of groundwater is related to the purpose for which the groundwater is used. Whether a groundwater of a given quality is suitable for a particular purpose depends on criteria or standards of acceptable quality for the use. Soldotna (2002) defined a standard as a rule or principle considered by an authority and by general consent as model in comparative evaluation. Quality limit or portable water supply for drinking , industrial purpose and irrigation apply to ground water because of its extensive development for these purposes (Tank and Chandle, 2009). For each variable, acceptable and unacceptable values must then be defined. If the water meets the pre-defined standards for a given use, it is considered suitable for that use. If the water fails to meet these standards, it must be treated before use (Cordoba *et al*., 2010). The quality of groundwater depends on the composition of the recharge water, the interactions between the water and the soil, soil-gas and rocks which it comes into contact in the unsaturated zone and the residence time and reactions that take place within the aquifer.

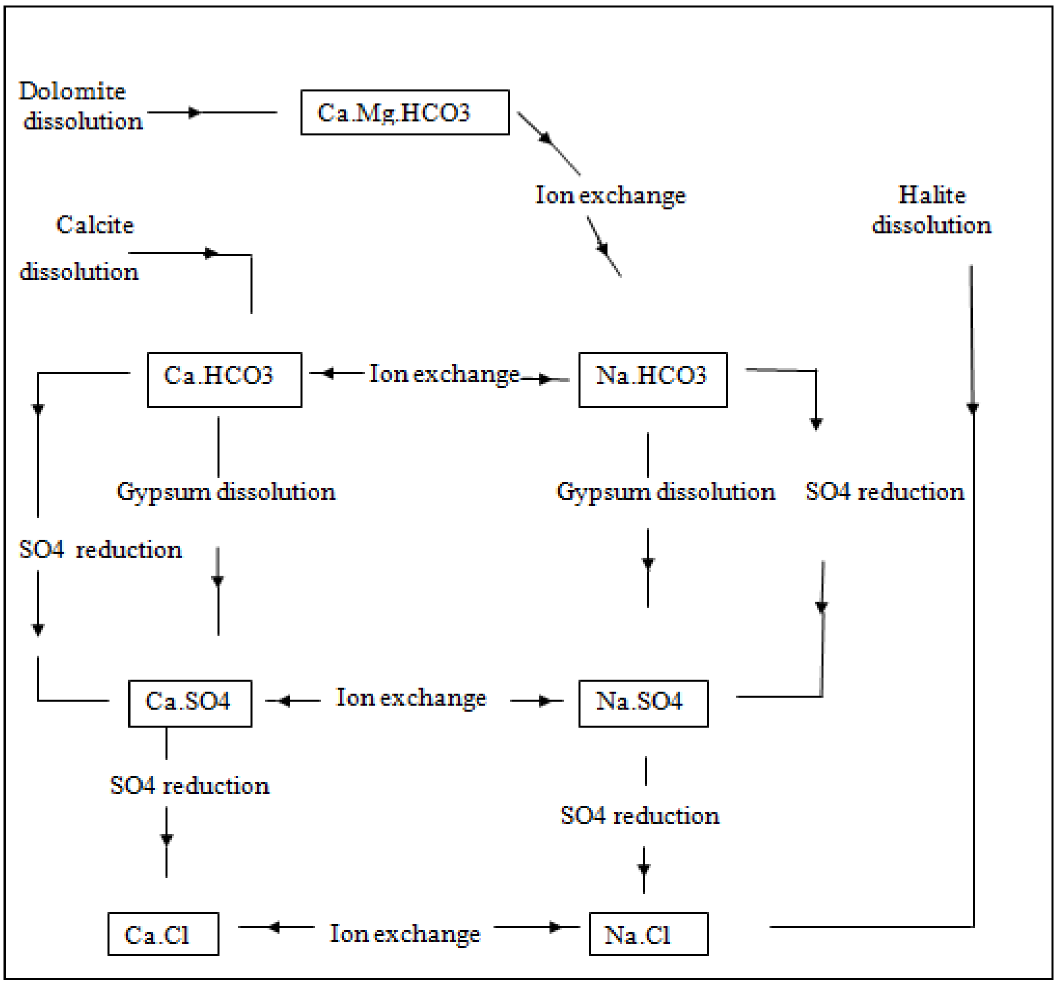

Figure 2.1: Rock water interactions and resulting water types (Elango and Kennan, 2007).

The groundwater type is determined by the percentage of chemical constituents present in it. Generally, Ca-HCO_3, Ca-Mg-HCO_3, Ca-Cl, Na-HCO_3, Na-Cl, Ca-SO_4 and Na-SO_4 are the most important groundwater types found throughout the world. Dissolution of calcite, dolomite, gypsum and halit give rise to Ca-HCO_3, Ca-Mg-HCO_3, and Ca-SO_4 and Na-Cl type of groundwater respectively. Na-HCO_3, Ca-Cl and Na-SO_4 may result from cation exchange processes and reverse exchange processes (Elango and Kennan, 2007).

2.3. Source of ground water pollutions

Groundwater pollution is usually caused by natural or human activities. There are two sorts of sources, point and non point sources. Point sources discharge pollutants at specific locations through pipelines or sewers. Nonpoint sources are sources that cannot be traced to a single site of discharge. Examples of point sources are: factories, sewage treatment plants, under ground mines, oils wells, oil tankers and agriculture. Examples of nonpoint sources are: acid deposition from the air, traffic, pollutants that are spread trough rivers and pollutants that enter the water through groundwater. Nonpoint source pollution is hard to control because the perpetrator cannot be traced (Almasri and Kaluarachchi, 2004; 2007).

The problem of groundwater pollution is aggravated due to municipal, industrial, agricultural and other miscellaneous sources and causes. Groundwater quality is a hidden issue inside hidden resources and as a result far too little attention is given to it. The chemical composition of groundwater is the combined result of water composition that enters the groundwater reservoir and the reactions with mineral present in the rocks (Iliopoulos, Zhu, 2002).

Deterioration of drinking and irrigation water quality arises from introduction of chemical compounds into the water supply system through leaks and cross connection.
Similarly (CAWST, 2013) stated that while water contains natural contaminants, it is becoming more and more polluted by human activities such as, in adequate wastewater management, dumping of garbage, poor agricultural practices and chemical spills at industrial sites.
Rainfall is one of the factors affecting water quality as it can wash dissolved nutrients into the watershed and increase organic carbon level and can also depress alkalinity levels and stimulate corrosion. The chemical parameters must be taken into consideration in the assessment of water quality, such as source protection, treatment efficiency and reliability and protection of the distribution network (WHO, 1996).

Microbiological bacteria, viruses, protozoa and helminthes (worms) and chemical minerals, metals, pH and physical such as temperature, color, odor, taste and turbidity are the major factor affected water quality. The World Health Organization (WHO, 2011) divides the source of chemicals into following five categories: naturally occurring, agricultural activities, industrial source and human dwelling, water treatment or material in contact with drinking water and pesticides used for public health.

Table 2.1: Sources of chemical contamination of groundwater (WHO, 2011)

Sources of chemicals	Examples	Common chemicals
Naturally occurring	Rocks and Soils	Arsenic, Chromium, Fluoride, Iron, Manganese, Sodium, Sulfate and Uranium
Agricultural activities	Manures, Fertilizers, Intensives animal practices and Pesticide	Nitrite, Nitrate, potassium
Industrial source and human dwelling	Mining, Manufacturing and processing industries, Sewage solid waste, urban runoff and fuel leakage	Nitrate, Cadmium, Cyanide, Copper, Lead, Nickel and Mercury
Water treatment or material in contact with drinking water	Water treatment chemicals and piping materials	Aluminum, Chloride , Iodine and Silver
Pesticide used in water for public health	Larvicides used to control insect vector of disease	Organo phosphorus, Chlorpyrifos and diazinon

2.4. Water quality sampling

Sampling could be defined as a process of selecting a portion of material small enough volume to be transported conveniently and handled in the laboratory. However, the main difficult with sampling is representativeness and integrity (Madrid and Zayas, 2007).

The number of samples to be taken for a given investigation must be determined from both statistical and economic considerations (Hounslow, 1995). Water samples collection procedures (how often and when); type of container and method of preservation must be known before water sample collection. Besides, data must also be collected at a minimum level of sensitivity and completeness to satisfy the information needed for the sampling program (Barcelona, 1985). According to Hounslow (1995), some chemical variables including temperature, dissolved gases, pH and alkalinity must be determined in the field at time of sampling.

2.5. Description ground water quality parameters

Water quality parameters are classified into three aspects such as physical, chemical and biological characteristics of water in association to the set of standards. Water parameters are analyzed in a laboratory.

Temperature

The rate of chemical reaction generally increases at higher temperature. Water, particularly groundwater with higher temperatures can dissolve more minerals from the rocks.

Water temperature is an important factor in determining whether a body of water is acceptable for human consumption and use. Temperature is the measure of hotness or coldness of water measured either in degree Celsius or Fahrenheit by using a thermometer (APHA, 1985).

Hydrogen ion concentration

The pH of pure water refers to states of acidity and alkalinity of solutions with respect to hydrogen and hydroxide ions can be expressed by a series of positive numbers" between 0 to 14". In general, water with a pH of 7 is considered neutral while lower than this referred acidic and a pH greater than 7 known as basic. Drinking water with a pH range 6.5 to 8.5 is generally satisfactory. It is noticed that water with low pH tends to be toxic and with high degree of pH, it is turned into bitter taste. It controls by carbon-dioxide, carbonate and bicarbonate equilibrium. The combination of CO_2 with water form carbonic acid, which affects the pH of the water. If the pH is not within the prescribed, it damages mucous membrane present in eyes, nose, mouth, abdomen and anus.

Electrical Conductivity

Electrical conductivity is a measure of water capacity to convey electric current. EC value is manifestation to signify the concentration of soluble salts in water. The electrical conductance is an indication of total dissolved solids which is a measure of salinity that affects the taste of potable water. Therefore, according to WHO standards EC value of drinking water quality should not exceeded 400 μS/cm and the conductivity of potable waters varies generally from 50 to 1500 μS/cm (Gaur, 2008).

Total dissolved solids (TDS)

Total dissolved solids indicate the salinity behavior of groundwater. Water containing more than 500 mg/L of TDS is not considered desirable for drinking water supplies, but in unavoidable cases 1500 mg/L is also allowed. Generally, the higher TDS decrease palatability and causes gastrointestinal irritation in the human beings. It has also laxative effect, especially upon transits. But, the prolonged intake of water with the higher TDS can cause kidney stones, which are widely reported from different parts of the country.

There is no contract have been developed on bad or optimistic effects of water that exceeds the WHO standard of maximum permissible level is 1,000 mg/L. A total dissolved solid (TDS) in drinking water originates in numerous ways from sewage and urban industrial wastewater. Hence, TDS test is mostly an indication to control the general quality of the water (Muhammad *et al*., 2013).

Total Hardness (TH)

Hardness may be considered as a physical or chemical parameter of water. It represents total concentration of calcium and magnesium ions. Hardness in water primarily affects consumer preferences and the condition of water pipes. The Ethiopian national standard for hardness in drinking water is 300 mg/L (as CaCO3). The hardness of the water is due to the presence of alkaline earths such as sulphates, chlorides and nitrates, calcium and magnesium.

Table 2.2: Summary of hardness and softness categorize range (Dezuane, 1996)

No	Total hardness (TH) Range of concentration(mg/L)	Categorized of hardness
1	0-50	Soft water
2	50-150	Moderately hardness
3	150-300	Hardness
4	>300	Very hardness

Table 2.3: Classification of water based on TH by Sawyer and McCarthy (1967).

No.	Total hardness TH (mg/l)	Classification
1	<75	Soft
2	75-150	Moderately hard
3	150-300	Hard
4	> 300	Very hard

Magnesium (Mg)

Magnesium is considered to be an essential metal at lower concentration where as it becomes toxic when it is at higher range and also gives unpleasant taste in the drinking water. 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 water as Mg^{2+} and along with calcium is a main contributor to water hardness. Natural concentration of magnesium in fresh water may range from 1 to100 mg/L (UNICEF, 2008). According to WHO international standard of drinking water (2011), the maximum acceptable level is 50 mg/L.

Calcium (Ca)

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 ground water. Acidic rainwater can increase the leaching of calcium from soils. The maximum daily requirement of the order of 1- 2 grams and come from mostly dairy products. There is certain evidence to indication that the incidence of heart disease is reduced in areas served by a public water supply with a high degree of hardness, the primary constituent of which is calcium, so that the presence of the element in a drinking water supply is advantageous to health (Environmental Protection Agency, 2001). The desirable limit of Ca^{2+} concentration for drinking water is specified as75 mg/L. The higher Ca^{2+} content cause abdominal ailments (chronic diseases) and are undesirable for domestic uses as it causes encrustation (hardness coating) and scaling.

Potassium (K)

High concentrations of potassium can cause heart problems in humans. Potassium can also have an effect on irrigated plants (Robert, 2007).

Sodium (Na)

All groundwater contains sodium because most rocks and soils contains sodium compounds from which sodium is easily dissolved. In concentration it is normally lower than calcium and magnesium in fresh water (Kennan and Joseph, 2009). The most common sources of elevated sodium levels in groundwater include weathering of sodium bearing rocks, irrigation returns, and pollution by sewage effluent and sea water intrusion (Dinka, *et al*., 2015).

Iron and Manganese

Groundwater usually contains more of these two minerals than surface water. Iron and manganese are irritants that should be avoided if in excess of 0.3 mg/L and 0.1 mg/L correspondingly. They stain clothing and plumbing fixtures, and the growth of iron bacteria causes strainers, screens to clog, and metallic conduits to rust. The appearance of a reddish brown or black precipitate in a water sample after shaking indicates, respectively, the presence of iron or manganese (Alan *et al*., 2000).

Sulphate

Sulphate occurs naturally in water as a result of leaching from gypsum and other common minerals. Discharge of industrial wastes and domestic sewage tends to increase its concentration WHO (1999). Drinking water with excess sulphate concentrations often has a bitter taste and a strong" rotten-egg " odor. Sulphate can also interfere with disinfection efficiency by scavenging residual chlorine in distribution systems. Sulphate salts are capable of increasing corrosion on metal pipes in the delivery system and concrete pipes. Sulphate-reducing bacteria may produce hydrogen sulphate, which can give the water an unpleasant odor and taste. According to WHO (2011) guidance level the maximum permissible limit of sulphate in drinking water supply is limited to 250 mg/L.

Phosphate

Ground water usually contains insignificant concentrations of phosphates, unless they have become polluted. Phosphorous one of the crucial nutrients for algal growth and can contribute significantly to eutrophication of lakes and reservoirs (Alan *et al*., 2000).

Nitrate (NO_3^-)

Nitrate is one of the extreme significant disease causing parameters of drinking water quality, particularly blue baby syndrome in babies and has been used as an indicator for the presence of organics. Nitrates can cause methemo globinemia at greater than 100 mg/L where a baby cannot take breaths enough oxygen (Roberts, 2006). The sources of nitrate are nitrogen cycle, industrial waste, nitrogenous fertilizers. The WHO guide lines maximum permissible values of nitrate in drinking water is 50 mg/L as $NO3^-$ for nitrate and 3 mg/L as $NO2^-$ for nitrite (Alan *et al* .,2009).

Bicarbonate

The dominance of bicarbonate (HCO_3^-) among anions in groundwater suggests either silicate weathering or carbonate weathering and sometimes this may be a combination of both processes (Elango and Kennan, 2007). Generally, bicarbonate is released together with calcium when carbonic acid reacts with calcium carbonate ($CaCO_3$+$H2CO_3$=Ca^{2+} + $2HCO_3$).

Fluoride

Fluoride is present universally in almost water, earth crust, many minerals and bedrock. It is also present in most of the everyday needs, viz. tooth paste, drugs and chewing gums, mouth washes (colligate) and cosmetics. The formation of high fluoride in groundwater is governed by geochemical dissolution of fluoride containing minerals, fast urbanization and modern industrialization. A small amount of it is beneficial for human health for preventing dental carries and high concentration of F^- causes dental fluorosis. The desirable limit for fluoride in drinking water is 1.5 mg/L.

Alkalinity

Alkalinity is a measure of the ability of water to absorb hydrogen ions without significant pH change. Simply stated, alkalinity is a measure of the buffering capacity of water and is thus a measure of the ability or capacity of water to neutralize acids. The major chemical constituents of alkalinity in natural water supplies are bicarbonate, carbonate and hydroxyl ions.

These compounds are mostly the carbonates and bicarbonates of magnesium and calcium.

These constituents originate from carbon dioxide (from the atmosphere) and occurring as a byproduct of microbial decomposition of organic material or minerals primarily from chemical compounds dissolved from rocks and soil.

From the portability view point, alkalinity is not significant parameter. Moderate concentration of alkalinity is desirable in most drinking water supplies to stable the corrosive effects of acidity. However, excessive quantities may cause a number of damages. The concentration of alkalinity varying from 5 mg/L to 125 mg/L is expected and extremes of these values are tolerated in water supplies. Titration with Sulpheric acid or other strong acids determine total alkalinity. According to the portability of drinking water set by WHO (2011) standard guideline, the maximum permissible limit should not be exceeded 200 mg/L.

2.6. Aesthetic parameters of drinking water quality

Aesthetic limits are those obvious by the senses, namely turbidity, color, taste and odor. They are important in monitoring public water supplies because they may cause the water supply to be disallowed and alternative (possibly poorer-quality) sources to be adopted and they are simple and cheap to monitor qualitatively in the field.

Turbidity

For water to be aesthetically accepted, its clarity must be ensured. Turbidity is defined as the light scattering and absorbing property that prevents light from being transmitted in a straight lines through the sample. Turbidity may be due to organic or inorganic constituents. Organic particulates may harbor microorganisms. Thus, turbid conditions may increase the possibility for waterborne diseases. For effective disinfection, median turbidity should be below 1 NTU although turbidity of less than 5 NTU is usually acceptable to consumers (WHO, 2004).

Color

Color is due to the presence of colored substances in solution, such as vegetables matter and Iron salt. It does not necessarily have detrimental effects on health. Color intensity could be measured through visual comparison of the samples to distilled water. Colored water is not acceptable for drinking (aesthetic as well as toxicity reasons). Therefore, drinking water should be colorless. Intended for the purposes of investigation of public water supplies, it is useful simply to note the presence or lack of observable color at the time of sampling. Changes in the color of water and the appearance of new color serve as indicators that additional investigation is needed (WHO Edition4th, 2004).

Odor: should be absent or very weak for water to be satisfactory for drinking purposes.

Pure water is odorless; hence, the presence of unwanted odor in drinking water is symptomatic of the existence of contaminants.

Tastes: pure water is tasteless; hence, the presence of unwanted taste in water shows the presence of contaminants. Taste problems relating to water could be indicators of changes in the water source or in the treatment process. Inorganic compounds such as magnesium, calcium, sodium, copper and iron are usually detects by the taste of water. Algae, decomposing organic matter, dissolved gases, and phenol material may cause tastes (Gaur, 2008).

2.7. 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). 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. It is essential that each country review its needs and capacities in developing a regulatory framework (WHO, 2011).

Table 2.4: Drinking water quality standards and Ethiopian Standard guidelines (2001) and WHO, (2011).

Drinking water quality parameter	WHO (2011) standard (mg/L)	Ethiopian (2001) standard (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
Sulfate	250	250
TDS	1000	1000
Electrical Conductivity (EC)	-	-
Total hardness as $CaCO_3$	300	300
Total Iron as (Fe)	0.3	0.3
Manganese (Mn)	0.1	0.5

2.8. 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, Dorian 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.

2.9. The use of ground water for irrigation purpose

Irrigation water whether derived from springs, diverted from streams, or pumped from wells and contains appreciable quantities of chemical substances in solution that may reduce crop yield and deteriorate soil fertility. In addition to the dissolved salts, which has been the major problem for centuries, irrigation water always carry substances derived from its natural environment or from the waste products of man's activities (domestic and industrial effluents). These substances may vary in a wide range; but mainly consist of dirt and suspended solids resulting into the emitters' blockages in micro-irrigation systems and bacteria populations and coli forms harmful to the plants, humans and animals (Ayers, 1976). The most damaging effects of poor-quality irrigation water excessive accumulation of soluble salts and sodium in soil. Highly soluble salts in the soil make soil moisture more difficult for plants to extract and crops become water stressed even when the soil is moist.

When excessive sodium accumulates in the soil, it causes clay and humus particles to float into and plug up large soil pores. This plugging action reduces water movement into and through the soil, thus crop roots do not get enough water even though water may be standing on the soil surface (Zhang, 1990). To measure the chemical concentrations like total dissolved solids, electric conductivity, sodium concentration, calcium concentration, bicarbonates, sulphate, chloride and other trace chemicals need to be found out by making analysis of the water in the laboratory.

Major ions

Ground water contains a variety of chemical constituents at different concentration. The greater part of the soluble constituents in groundwater comes from soluble minerals in soils and sedimentary rocks. A much smaller part has its origin in the atmospheres and surface water bodies. For most ground water, 95% of the ions are represented by only a few major ionic species: the positively charged cations sodium (Na^{+}), potassium (K^{+}), calcium (Ca^{2+}) and magnesium (Mg^{2+}), and the negatively charged anions chloride (Cl^{-}), sulfate (SO_4^{2-}), bicarbonate (HCO_3^{-}) and nitrate (NO_3^{-}). These ionic species when added together account for most of the salinity that is commonly referred to as total mineralization or total dissolved solids (TDS).

Sodium Adsorption ratio (SAR)

SAR is a measure of suitability of water for irrigation, because sodium concentration can reduce the soil permeability and soil structure (Todd, 1980; Arveti *et al*., 2011). Continued use of water with a high SAR value leads to break down in the physical structure of the soil. Sodium adsorption ratio (SAR) is a measure of the suitability of water for irrigation use, because sodium concentration can reduce the soil permeability and soil structure (Todd, 1980). SAR is a measure of alkalinity/sodium hazard to crops and the sodium adsorption ratio (SAR) is computed using the following equation.

$$\mathbf{SAR = Na^{+}/\ [(Ca^{2+} + Mg^{2+})\ /2]^{\ 1/2}} \quad \mathbf{(1)}$$

(All ionic concentrations are expressed in meq/l) where, $[Na^{+}]$, $[Ca^{2+}]$ and $[Mg^{2+}]$ are concentration of sodium, calcium and magnesium in meq/l. The SAR value of water for irrigation purposes has a significant relationship with the extent to which sodium is absorbed by the soils. Irrigation using water with high SAR values may require soil amendments to prevent long-term damage to the soil, because the sodium in the water can displace the calcium and magnesium in the soil. As described in USSL (US Salinity Laboratory) (1954), water having SA R values <10 is considered excellent, 10 to 18 good, 18 to 26 as fair and > 26 unsuitable for irrigation use.

Percent of sodium (% Na)

In all natural waters, Na% is a common parameter to assess its suitability for irrigation purposes since sodium reacts with the soil to reduce permeability (Wilcox, 1955; Janardhana Raju *et al*., 1992). Excess sodium combining with carbonate, leads to formation of alkalis soils, where as with chloride, saline soils are formed (Wilcox, 1955). According to Wilcox (1955), the sodium percentage (Na %) values was obtained by using the following equation.

$$\mathbf{\%Na= [(Na^{+} + K^{+})\ x\ 100]/(Ca^{2+} + Mg^{2+} + Na^{+} + K^{+})} \quad \mathbf{(2)}$$

(all ionic concentrations are expressed in meq/l). Generally, percent of Na^{+} should not exceed 60 % in waters intended for irrigation purpose.

Table 2.5: Sodium percent water class (Wilcox, 1955).

Sodium percent (%)	Water quality classes
< 20	Excellent
20-40	Good
40-60	Permissible
60-80	Doubtful
> 80	Un suitable

Residual Sodium Carbonate (RSC)

The excess sum of carbonate and bicarbonate in groundwater over the sum of calcium and magnesium also influences the suitability of groundwater for irrigation. When the excess carbonate concentration becomes too high, the carbonate combines with calcium and magnesium to form solid materials which settles out of the water. The relative abundance of sodium with respect to alkaline earths and the quantity of bicarbonates and carbonates in excess of alkaline earths also influence the suitability of water for irrigation. RSC is an important parameter to evaluate the suitability of irrigation water. To calculate residual sodium carbonate by the following equation.

$$\mathbf{RSC=[\ (HCO_3+CO_3) - (Ca+Mg)\ ]\ (meq/l)} \qquad (3)$$

Generally, >2.5 meq/l of RSC is unsuitable for irrigation purposes.

Permeability Index (PI)

Soil permeability is affected by long-term use of irrigation water with high salt content as influenced by Na^+, Ca^{2+}, Mg^{2+} and $HCO3^-$ contents of the soil. To calculate PI value the following equation was applied.

$$\mathbf{PI = [(Na+HCO3^{1/2})\ X100]/Ca^{\ 2+}+ Mg^{2+}+Na^+ \quad (meq/l\ )} \qquad \mathbf{(4)}$$

The PI values >75% comes under class I and indicates that the excellent quality of water for irrigation. The PI value between 25% - 75% comes under class II indicates that the good quality of water for irrigation and the PI value less than 25% comes under class III indicates that the unsuitable nature of water for irrigation.

Magnesium Ratio (MR)

The use of water with high magnesium content for irrigation may pose a threat to crop yield as it may cause alkaline condition in the soil. Paliwal (1972) developed an index for calculating the magnesium ratio.

MR is calculated using the formula:

$$\mathbf{MR = Mg^{2+} / (Mg^{2+} + Ca^{2+}) \times 100} \qquad \textbf{(5)}$$

Where, all ionic concentrations are expressed in meq/l. A value of MR less than 50% is considered suitable for irrigation while more than 50% MR is considered unsuitable for irrigation practice.

Kelly's Ratio

Kelley's ratio assess irrigation water quality based on the level of Na^+ against $Ca^{2+}$and Mg^{2+}. Kelley's ratio more than 1 indicates an excess level of Na^+ in the water and therefore the water can be considered unsuitable for irrigation.

This was calculated employing the equation (Kelley's, 1963) as:

$$\mathbf{KR= Na^{+}/ (Ca^{2+}+ Mg^{2+})} \qquad \textbf{(6)}$$

Where, all concentrations are in meq/l.

CHAPTER THREE

3.1. MATERIALS AND METHODS

3.1.2. Description of the study area

Sabata Hawas district is found in Oromiya Special Zone surrounding Finfinne, Oromiya Regional State, Ethiopia. It is found 45 Km South West of Finfinne along Jimma main road. The total surface of the district is 87,572 hectare. The district found at latitude of 8° 37'-9^0 1'30" N and longitude 38^0 24' 30" – 38^0 45' 30"E.

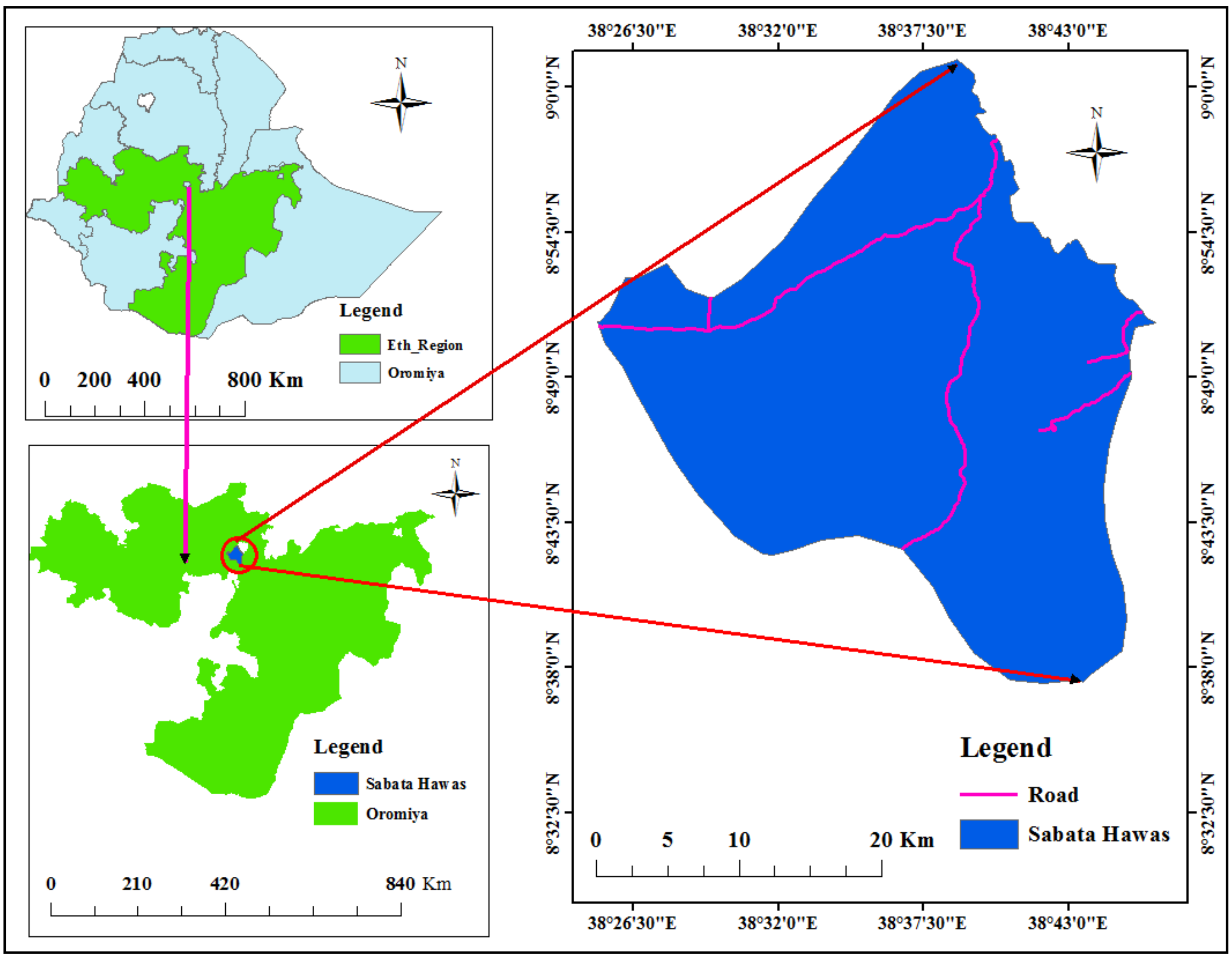

Figure 3.1: Location map of the study area

3.1.3. Climate

The elements of climate temperature, relative humidity, wind speed and sunshine hour are varying from season to season in the study area. Ethiopia has five climate divisions depending on altitude (Daniel Gemechu, 1977). These divisions are desert that measures less than 800 m.a.s.l, tropical that measures between 1500-1800 m.a.s.l, subtropical that measures between 1800-2400 m.a.s.l, the temperate that measures between 2440-3500 m.a.s.l, and the alpine that measures over 3500 m.a.s.l. The average of the elevation of the district is ranged between 1800 m. a. s .l to 3385 m. a. s. l, these climatic divisions, the study area has subtropical and temperate with dominance of subtropical division. The annual maximum and minimum rainfall of the district was between 950 mm to 1050 mm respectively while its mean annual rain fall was 1033 mm (National Metrological Agency, 2013). The annual maximum and minimum temperature of the area was 18 and 15°C, respectively. The mean annual temperature of the study area was 16.5°C (National Metrological Agency, 2013).

3.1.4. Soil

The major soil types in the area are scoria, fractured basalt, fractured ignimbrite, basalt and rhyolite and residual clay rich in organic materials, gravelly sand soil and fractured rock with big boulders and cobbles. These different soils occupy the flat, gentle-moderate and moderate steep slopes respectively.

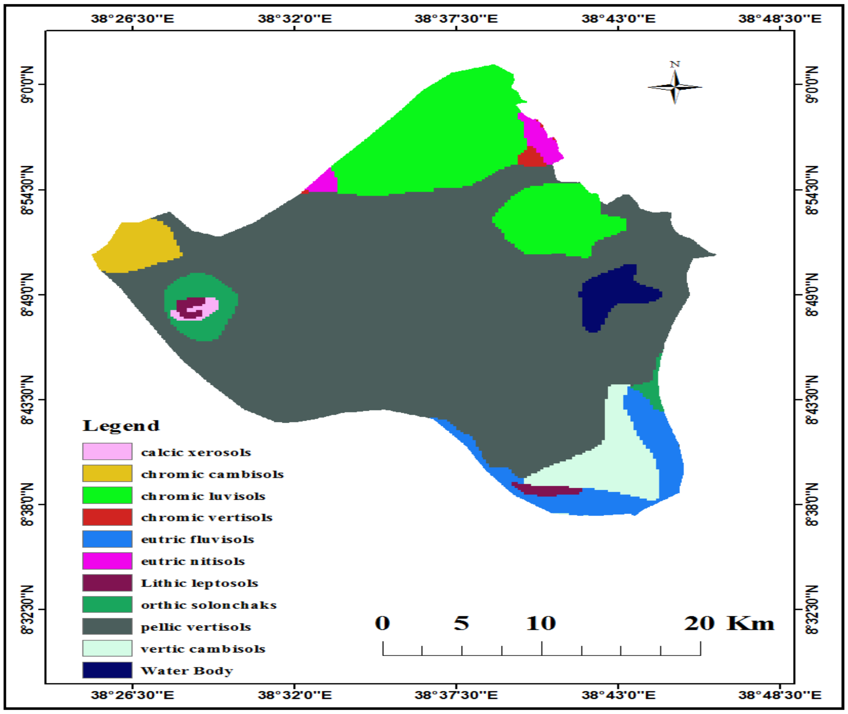

Figure 2.2: Map of types of the soil of the study area

3.1.5. Geology of the study area

Lineaments are dominant in the study area. Most of these lineaments are related to the development of the Main Ethiopian Rift valley system resulting in a different type of eruption. Majority of the tributaries of Awash River and drainage system follows such lineaments in the study area.

Trachytes

The central volcanoes units are mainly trachytic lava exposed at Wechecha and Gebiso area forming an elevated ridges or mountain picks. The south and southern Western ridges are a watershed divide between the Omo-Gibe and Awash River basins. It is grayish color fine to medium grained trachyte with subordinate ash falls and ignimbrite (WWDSE, 2008). A petro graphic study conducted by Tsegaye Abebe *et al*. (1999 cited in Abel Abebe, 2017) indicates that trachyte of Wechecha and Furi are composed of plagioclase and sanadine phenocrysts predominating the trachyte, alkaline pyroxene and rare olivine. The groundmass varies from glassy to microcrystalline and is constituted mainly by alkali feldspar, pyroxene, and amphiboles and opaque.

Rhyolite

The rhyolite in the Becho plain forms isolated cones of Debel kejima. Obsidian across is common at the picks of the cones. Data on the ages of the rhyolite are not available; however, from the crosscutting relationship they can be younger than the adjacent ignimbrite.

Tarmaber Basalt

It mainly consist scoraceous lava flows and at places where it is columnar olivine bearing basalt as pockets within the scoraceous components. This basalt is highly weathered, fractured, and pinkish to grayish in color. Alkaline basalt in the upper part and trachyte and trachyte basalt, per alkaline rhyolite and alkaline basalt in the lower part are the main geological type of the study area.

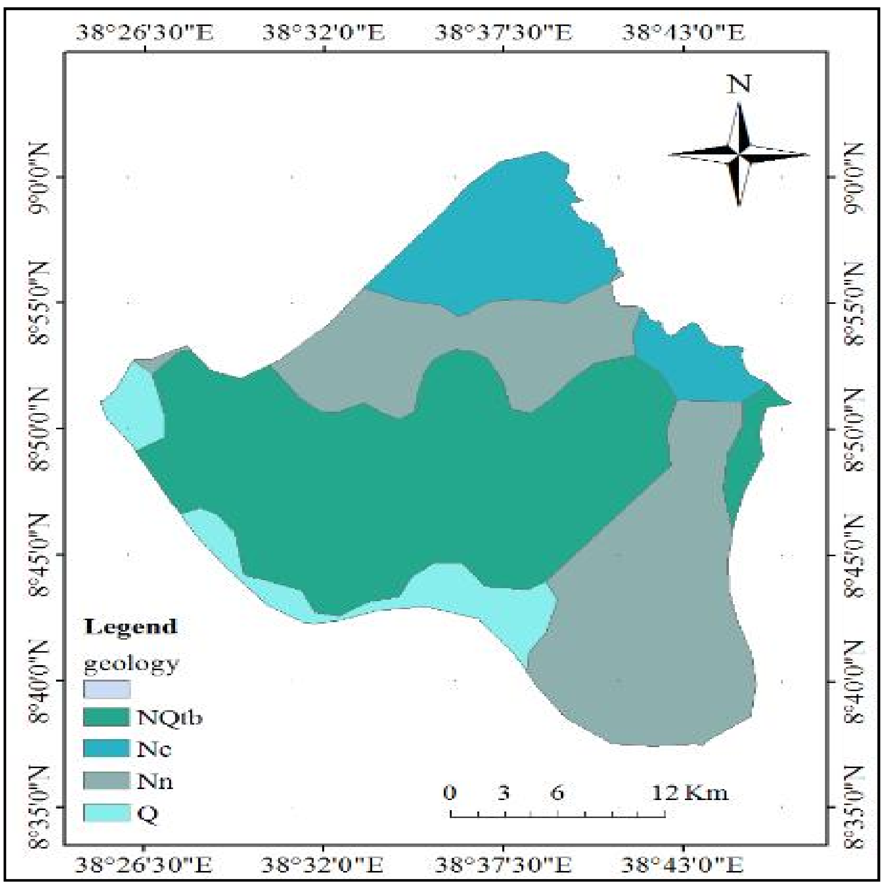

Figure 3.3: Map of the geology of the study area

Where, NQtb = Alkaline basalt and trachyte, Nc= Alkaline basalt in the upper part and trachyte and trachybasalt, per alkaline rhyolite and alkaline basalt in the lower part, Q =Sand, Silt, Clay, Diatomite and Beach sand Nn =Fissural basalts, with beds of detrital lacustrine sediments, rhyolite flows and ignimbrites.

3.1.6. Geomorphology

Land forms are the most common features encountered by any one engaged in geological field works. If they are properly interpreted they throw light upon the geologic history, structure and litho logy of a region (William, 1986). The land surface form classes of USGS are derived by combining slope and local relief to create seven landform classes: smooth plains (gently sloping and 15 m < local relief ≤ 30 m), irregular plains (gently sloping and 30 m < local relief ≤ 90 m), escarpments (gently sloping and local relief > 90 m), hills (not gently sloping and 30 m < local relief ≤ 90 m), breaks/foothills (not gently sloping and 90 m < local relief ≤ 150 m), and low mountains (not gently sloping and local relief > 150 m) (***http://pubs.usgs.gov/sim/30851***).

Hence, by using USGS Africa land surface form class map the study area was further extracted and subdivided into seven land surface form classes.

i. Smooth plain (valley floor): broad, nearly level stretches of land that have no great changes in elevation.

ii. Irregular plain: a land surface with no great changes in elevation but with ups and downs.

iii. Escarpment: a steep slope or long cliff that occurs from faulting, tilting or warping and resulting erosion and separates two relatively level areas of differing elevations.

iv. Breaks: a landscape or large tract of steep, rough or broken land dissected by ravines and gullies and marks a sudden change in topography as from an elevated plain to lower hilly terrain, or a line of irregular cliffs at the edge of a mesa or a river.

v. Hills: Elevations of the earth's surface that have distinct summits, but are lower in elevation than mountains.

vi. Low Mountain: a large landform that stretches above the surrounding land in a limited area, usually in the form of a peak.

vii. High Mountain: land form that rises prominently above its surroundings, generally exhibiting steep slopes, a relatively confined summit area, and considerable local relief.

3.1.7. Land use Land cover

The major land use/cover (LULC) of the study area consist the cultivated agricultural land, grass land, wetland and shrub land. The main crops grown in this area are teff, wheat, barley, oil seeds, peas and bean. Because of the rapidly growth of population the demand for increase of the cultivation area is growing and even steeply sloped areas are being ploughed to be cultivated. More over the use of woods for fuel consumption and as a construction material is influencing the land use land cover pattern of the area. The vegetation cover of the area includes eucalyptus, acacia and juniper trees cover a small area bushes and shrubs cover the larger area proportion.

3.1.8. Crops and vegetables

Crop production activity in Sabata Hawas district is mainly depends on the cultivation of annual crops. The dominant crops that are produced in the district are teff, maize, barely, wheat, peas, chat, beans and oilseeds. Some vegetation such as onions, cabbage, tomato, carrot, and potato are also cultivated in the major farmer's compound during summer season.

3.1.9. Population size

The district's total population census for 2007 is 133,746 of which 68,908 (51.5%) are males while 64,838 (48.5%) are females.

3.2. Study design

In terms of its approach, an experimental research type was used for this study. So that, the research design was carried out in the specific area of Sabata Hawas district focused on the suitability analysis of ground water for drinking and irrigation purposes. The research was applied both qualitative and quantitative method of data collection from its samples groups

An experimental design is a study design that gives the most reliable proof for causation. Experimental research takes place in the laboratory because its aims at finding out the relationship existing between two factors under controlled conditions. Thus, the experimental research strictly adopted the scientific method in its investigation.

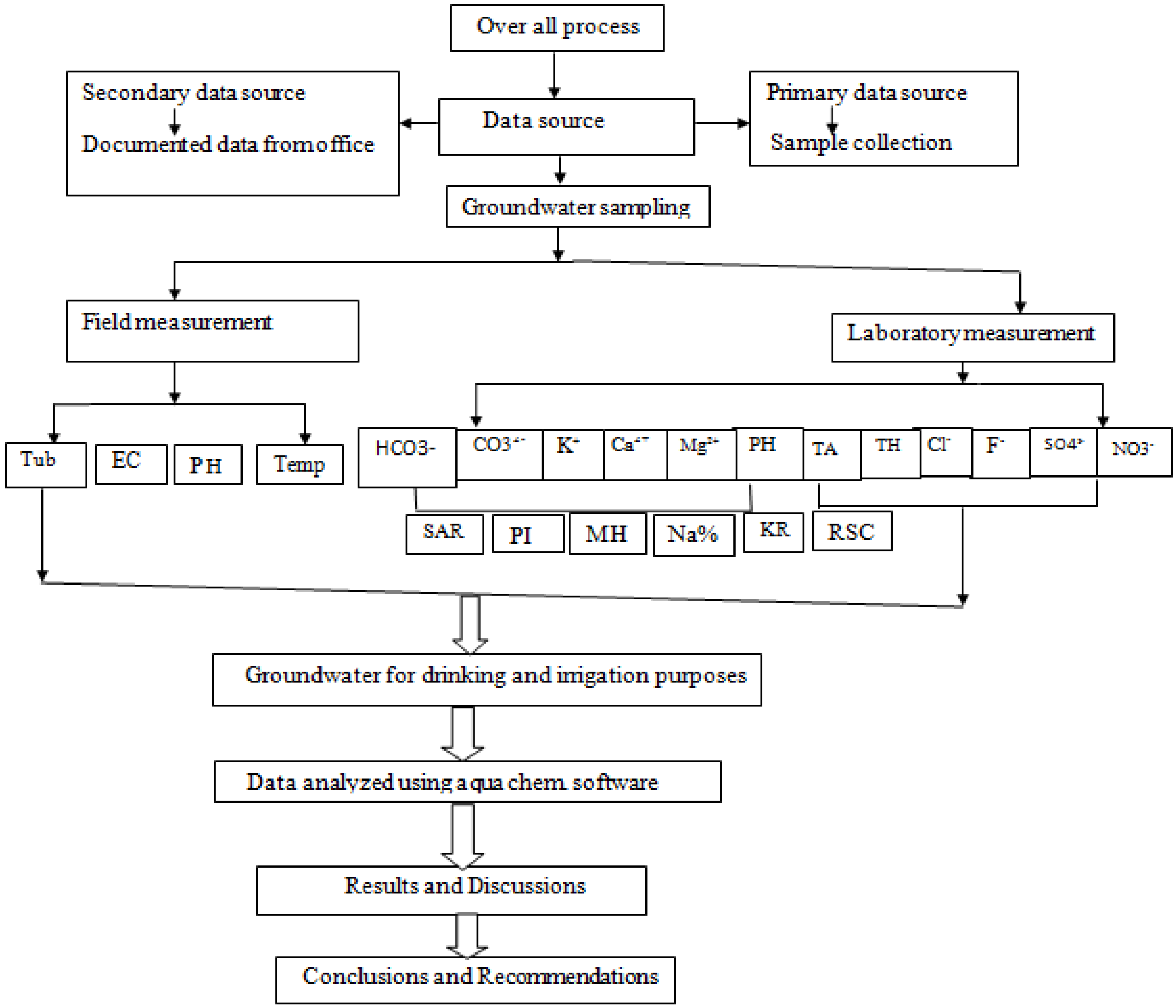

Figure 3.4: Flow chart showing the methodology adopted for groundwater quality analysis

Where, EC = Electrical Conductivity, TA = Total Alkalinity, TH = Total Hardness, Temp = Temperature, SAR= Sodium Absorption Ratio, PI = Permeability Index, MH = Magnesium Hazards, KR = Kelley's Ratio, RSC = Residual Sodium Carbonate and Tub= Turbidity

3.3. Water samples collection and samples size

To assess the water chemistry, purposive water samples techniques was done parallel to on the spot groundwater samples collected. Groundwater samples were collected from pumping wells after minimum of 5 to 10 minutes of pumping prior to sampling. This was done to remove stagnant water stored in the wells. The samples were filtered using 0.45 µm pore size membrane filters and stored in polyethylene bottles that were initially washed with nitric acid and rinsed carefully with distilled water. However, the main difficult with sampling is representativeness and integrity (Madrid and Zayas, 2007).

Accordingly , ten (10) ground water samples were collected from 6 shallow wells and 4 deep wells, from site name , Tefki, Tefki golden1, Tefki golden2, Dima magno1, Gora harkiso2, Haro Jila, Bole, Fulaso, Boneya1 and Boneya 2, ground water points of the study area using containers such as plastic bottles for collecting water samples. From a single site, two litters volume of water samples were taken. The parameters of water samples collected were analyzed in Ethiopian Public Health Institute (EPHI) laboratory. For the assessment ground water quality, the published data of Oromiya Water, Mineral and Energy Bureau on 30 ground water from Sabata Hawas district is also used. The locations of sampling sites are showed in fig 3.3 (only groundwater samples locations present study total of 10) and the results of the analyzed are presented in appendix 3. Moreover available chemical and physical data had been taken from Oromiya water, mineral and energy Bureau and previous studied (Keradin Dida, 2015). These secondary data were presented in appendix 7.

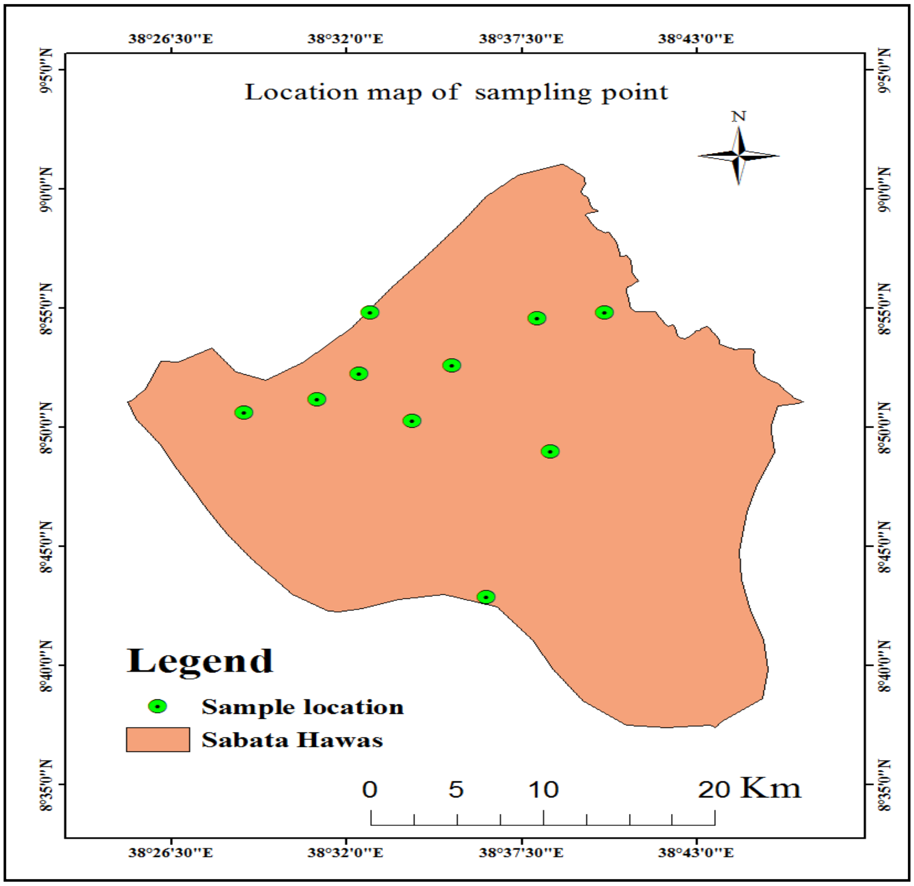

Figure 3.5: Location map of sampling point

3.4. Instruments used and Procedures

The apparatus used for the experiments were: evaporating dishes, analytical balance, beaker, graduated cylinder, standard flasks, funnel, wash bottle, forceps, measuring jar, Burette with burette stand, pipette with elongated tips, pipette bulb, gooch crucibles, filter, conical flasks, Spectrophotometric tube, drying oven, desiccator, pH meter with a combination of pH electrode and temperature compensation probe, Petri dish, filter unit, Flame photometer 082, Ion meter 3345 and Photo cameras. The test method that flow experimental analysis groundwater quality tabulated under appendix 1 and since it is to bulk to show procedure chart for all parameters analyzed, so that only showed for total alkalinity as example and expressed details under appendix 2 hence it was bulk to mention all parameters had been done.

3.5. Study variables

3.6. Dependent variables

Suitability analysis of groundwater for drinking and irrigation purposes.

3.7. Independent variables

Physical parameters: Temperature, Electrical conductivity and TDS.

Chemical parameters: Total alkalinity, Total hardness (Calcium + Magnesium), Sodium, Potassium, pH, Calcium, Magnesium, Fluoride, Bicarbonate, Carbonate, Chloride, Nitrate and Sulfate, Total Iron, Total Manganese , Phosphate, Ammonium and Ammonia.

3.8. Laboratory analysis

Water samples were collected from different location of study area and analyzed for major captions (Ca^{+2}, Mg^{+2}, Na^{+}, K^{+} and anions (Cl^{-}, F^{-}, $HCO3^{2-}$, $CO3^{2-}$, $NO3^{-}$, $SO4^{2-}$) and also PH, TDS, total alkalinity, EC ,turbidity and temperature were analyzed in Ethiopian Public Health Institute

(EPHI) laboratory. $HCO3^{-}$ and $CO3^{2-}$ ions were determined by titration with standard hydrochloric acid and Cl^{-} by silver nitrate titration method. Ca^{2+} and Mg^{2+} ions were measured using atomic absorption spectrophotometer and Na^{+} and K^{+} was analyzed using flame photometer (Jackson, 1967). Fluoride ion (F^{-}) was measured by ion meter 3345 and turbidity was measured by portable turbidity meter, pH, EC and temperature were measured by pH meter method. Finally all the result from the laboratory analysis was recorded under appendix3.

3.9. Water quality data analysis

Interpretation of all water chemistry data was carried out using Aqua Chem. software.

Aqua chem. software **V2014.2** is fully integrated software package developed specifically for graphical and numerical analyses and interpretation of aqueous geochemical data sets.

Micro soft excel used to show temperature variation of the study area, pH, EC, variation and to showed TDS and EC relationship on the graph and GIS 10.3 used to map groundwater sampling location, geology and soil type of the study area.

Ground water quality for irrigation purpose was analyzed based on different approaches like:

- ✓ Sodium adsorption ratio (SAR) method

$SAR = Na^+ / [(Ca^{2+} + Mg^{2+}) /2]^{1/2}$ (3.1)

- ✓ Sodium percentage (% Na) method

$\%Na = [(Na^+ + K^+) \times 100]/(Ca^{2+} + Mg^{2+} + Na^+ + K^+)$ (3.2)

- ✓ Permeability Index (PI) method

$PI = [(Na + HCO3^{1/2}) X100]/Ca^{2+} + Mg^{2+} + Na^+$ (meq/l) (3.3)

- ✓ Magnesium ratio (MR) method

$MR = Mg^{2+} x100 / (Ca2^+ + Mg^{2+})$ (3.4)

- ✓ Residual Sodium Carbonate (RSC) method

$RSC = HCO3^- – (Ca^{2+} + Mg^{2+})$ (3.5)

- ✓ Kelley's Ratio (KR) method

$KR = Na^+ / (Ca2^+ + Mg^{2+})$ (3.6)

- ✓ USSL (United State Salinity Laboratory 1954) method

3.10. Data quality assurance and quality control

Proper quality assurance procedures and precautions were taken to ensure the reliability of the results. Samples were handled carefully and analysed within holding time to avoid physical and chemical change occur and for the sake of data quality assurance data was assessed carefully.

To evaluate the data quality, the accuracy of the chemical analysis results of both the present and preexisted was checked with the anion-cation balance (Equation 3.6). The principle of the anion cation balance is that the sum of cat ions and sum of anions are equal because the solution must be electrically neutral. In an electrically neutral solution, the sum of the cat ions should be equal to the sum of anions in me/l (Hounslow, 1995).

$$Electroneutrality(\%) = \frac{\sum Cations - \sum Anions}{\sum Cations + \sum Anions} * 100 \qquad (3.6)$$

Based on the electro neutrality, analysis of water samples with a percent balance error < ±5% is regarded as acceptable (Fetter, 2001). The cat ions and anions balance results of the water samples analyzed from Sabata Hawas district found to be reliable as the charge balance error from 95% of the samples was within the accepted limits of <±5 %. Analyzed data of 40 groundwater samples were used to determine groundwater chemistry in Sabata Hawas district.

3.11. Ethical consideration

The study was conducted after getting permission from ethical committee of Jimma institute of technology, faculty of civil and environmental engineering. In order to ensure the confidentiality of data collection and to keep the right of the respondents the following ethical protocols was carefully applied:

- 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.
- Letter of confirmation for conducting the study was presented for respondents.

3.12. Plan for dissemination of finding

The finding of this study can be distributed through internet, magazines, Medias and different seminar for stake holder of the water resource office and work behavior problems which leads to the achievement of the outcomes of the study. The final result of this study was presented to Jimma institute of technology faculty of civil and environmental engineering, department of water supply and environmental engineering and was disseminated to concerning ministers, Oromia regional state, Sabata Hawas district and other governmental and non-governmental organizations which are concerned with the study findings. Publications in national and international journals were also considered.

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

4.1. Groundwater quality for drinking purpose

4.1.1. Temperature

The rate of chemical reaction generally increases at higher temperature. Water, particularly groundwater with higher temperatures can dissolve more minerals from the rocks. Temperature has impact on the acceptability of a number of other inorganic constituents and chemical contaminants that may affect a taste. The parameters such as turbidity, odor and electrical conductivity may affected by temperature. The temperature of water samples of the study area was found to be18.5°C to 23°C which is below permissible limit 30°C water temperature for drinking purpose.

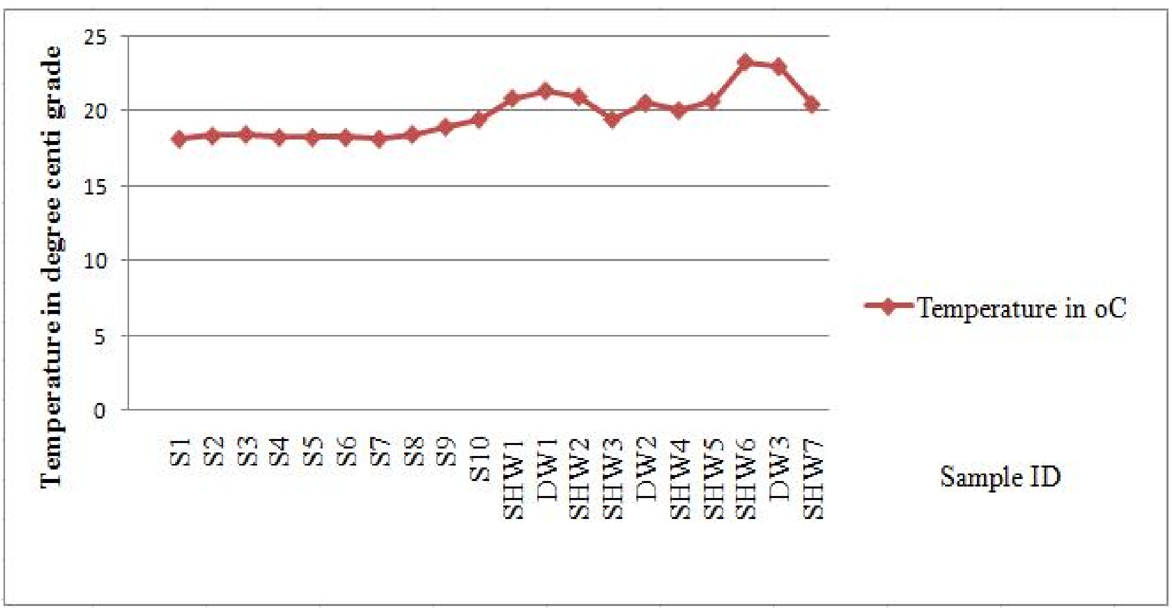

Figure 4.1: Temperature variation in the study area

Where, S1 = Tafki, S2= Dima magno, S3=Tafki golden1, S4= Tafki golden2, S5= Gora harkiso2, S6=Boneya 1, S7= Boneya2, S8=Haro jila, S9=Fulaso, S10= Bole and present samples ID. SHW and DW, while previous samples ID and which are assigned as shallow wells and deep wells respectively.

4.1.2. pH

The pH of water in the study area were minimum 6.58 and maximum 7.79 with an average of 7.09, all of the samples fells with the target range (6.5<7.79<8.5) for the recommended WHO guidelines. The pH of the water in the study area can be classified as being within the target range for domestic use and is indicative of the alkaline nature of the groundwater in the area.

As can observed from figure 4.2 the samples labeled pH is less than seven and therefore acidic, where as samples with pH greater than seven boreholes tend to high alkalinity levels.

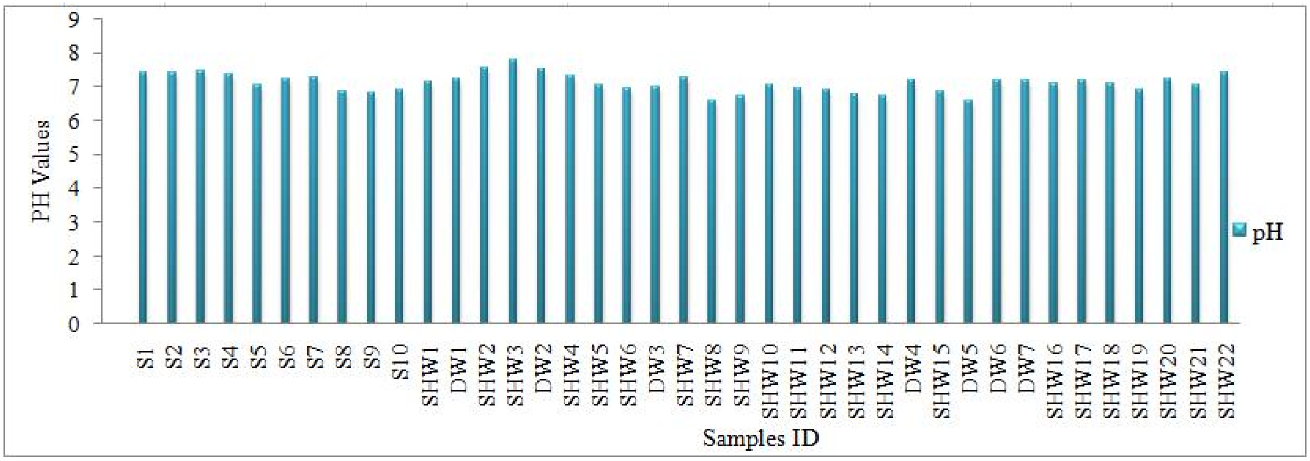

Figure 4.2: pH variation of collected groundwater samples in the study area

Where, S1 = Tafki, S2= Dima magno, S3=Tafki golden1, S4= Tafki golden2, S5= Gora harkiso2, S6=Boneya 1, S7= Boneya2, S8=Haro jila, S9=Fulaso, S10= Bole and present samples ID. SHW and DW, while previous samples ID and which are assigned as shallow wells and deep wells respectively.

4.1.3. Electrical Conductivity (EC)

Electrical conductivity is a measure of water capacity to convey electric current. EC value is manifestation to signify the concentration of soluble salts in water. Electrical Conductivity (EC) is an indicator of total dissolved salts (TDS). It establishes if the water is drinkable and capable of satisfying thirst. The electrical conductivity of the study area was 268 μS/cm minimum and 1327 μS/cm maximum respectively, with an average 570.46 μS/cm. Therefore, the EC of the study area was below the recommended water quality parameter for drinking. Hence, the permissible limit of EC is 1400 μS/cm and it is suitable for drinking water supply.

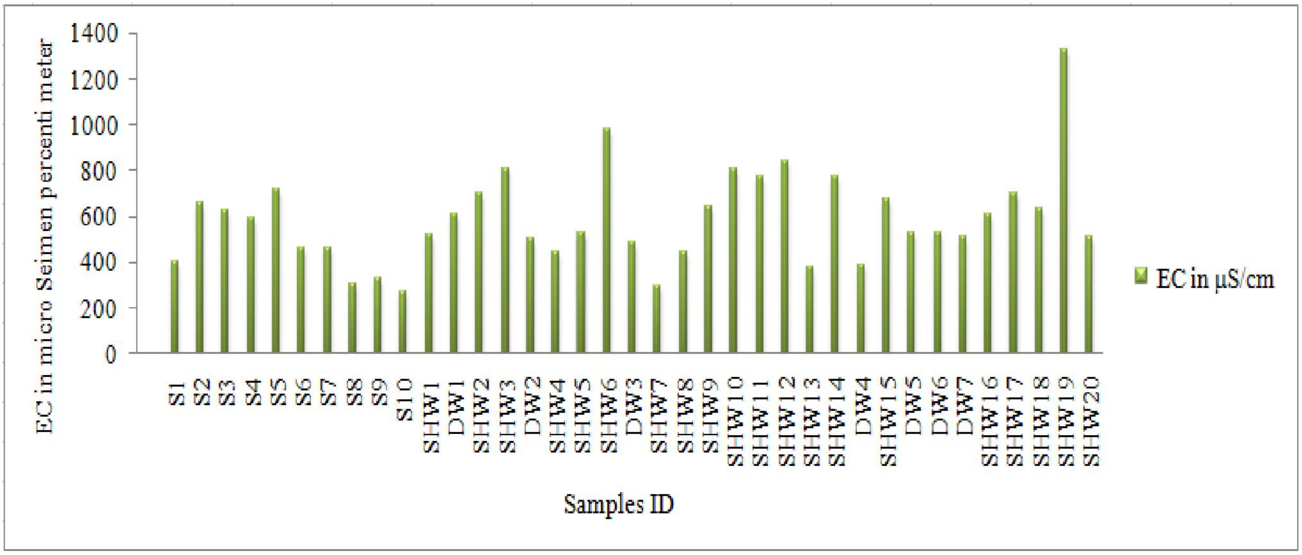

Figure 4.3: Electrical Conductivity of collected water samples in the study area

Where, S1 = Tafki, S2= Dima magno, S3=Tafki golden1, S4= Tafki golden2, S5= Gora harkiso2, S6=Boneya 1, S7= Boneya2, S8=Haro jila, S9=Fulaso, S10= Bole and present samples ID. SHW and DW, while previous samples ID and which are assigned as shallow wells and deep wells respectively. The value of TDS and EC for each sample is showed in figure 4.4 below and it was clearly seen that the value of EC and TDS were directly proportion. Therefore at the high value of total dissolved solid, also the value of electrical conductivity is also high.

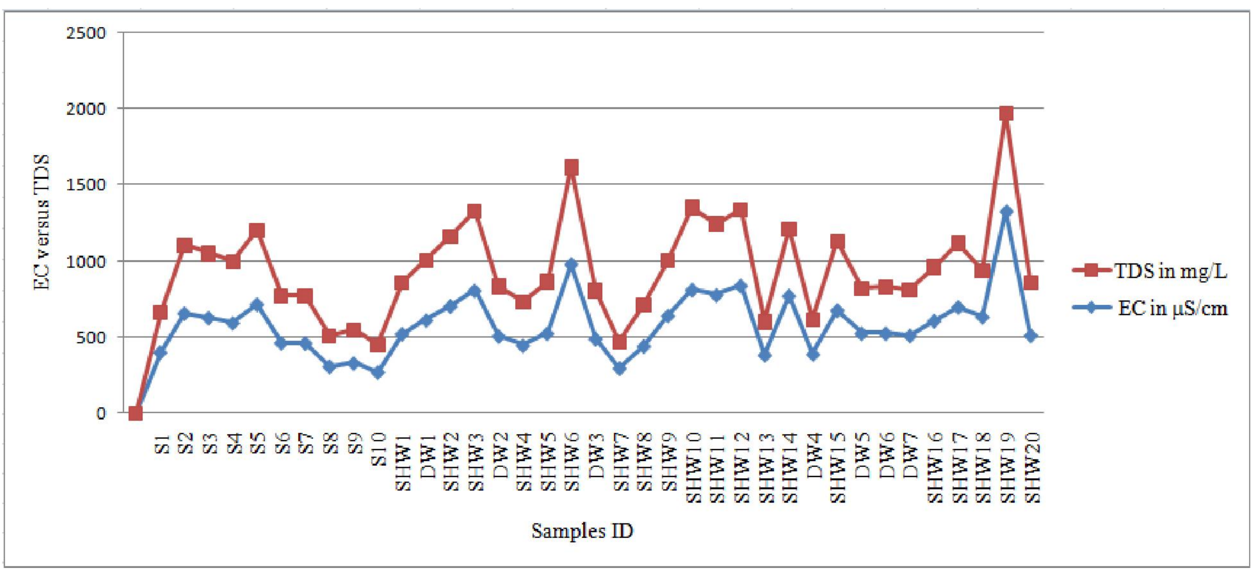

Figure 4.4: The relationship between TDS and EC variations samples collected in the study area

4.1.4. Turbidity

The minimum and maximum values of turbidity in the study area were 0.11 NTU and 10 NTU respectively with an average of 1.46 NTU. From all samples Tafki (5.2 NTU) and Fulaso (10 NTU) were above WHO (2011) and Ethiopia guidelines (2001) recommended and this is due to dissolved materials that found in the wells are high. High turbidity interferes with both the detection and the disinfection of pathogens, by adsorbing them into the particulate matter and thus shielding them. Some turbidity may also promote bacterial growth if they provide a source of nutrients.

4.1.5. Total Dissolved Solid (TDS)

TDS constitute of inorganic salts. It principally contains calcium, magnesium, potassium, sodium, bicarbonate, chlorides and sulfate and small amounts of organic matter that are dissolved in water (WHO, 2008). Total dissolved solids show that the salinity behavior of groundwater in the water sample. TDS is one of the most important parameter used to investigate water suitability for drinking. Davis and Dewiest (1966) and Freeze and Cherry (1979) devised classification methods to classify water suitability according to TDS levels.

The results from the total ground water samples classifications for the groundwater from the study are showed in the table below.

The minimum and maximum values of TDS in the study area were 174 mg/L and 645 mg/L respectively, with an average of 359.68 mg/L. For the classification of water quality based on TDS values Davies and Dewiest (1966) classification is adopted. As per this classification, 87.5% of the water samples in the study area are found to be desirable for drinking and the rest of 12.5% are found to be permissible for drinking water.

Table 4.1: Classification of water quality based on TDS levels Davies and Dewiest (1966)

TDS(mg/L)	Classification	Number of samples	Cumulative %
<500	Desirable water for Drinking	35	87.5%
500-1000	Permissible for drinking water	5	12.5%
1000-3000	Useful for irrigation Water	0	0
>3000	Unfit for irrigation Water	0	0
Total		40	100

Classification based on TDS according to Freeze and Cherry (1979) (table 4.2) showed that 100% of the groundwater samples are considered fresh water.

Table 4.2: Water classification based on TDS Freeze and Cherry (1979)

TDS (mg/L)	Classification	Number of samples	Percentage
< 1000	Fresh water	40	100%
1000-10000	Brackish water type	0	0
10000-100000	Saline water type	0	0
> 100000	Brine water type	0	0
Total		40	100

As showed from the following figure 4.5 the samples labeled SHW19 (Dobi) and SHW6

(Mehal Atebela) were high concentration of TDS and which indicated that high concentration of salinity found in these boreholes. Where, S1 = Tafki, S2= Dima magno, S3=Tafki golden1, S4= Tafki golden 2, S5= Gora harkiso 2, S6=Boneya 1, S7= Boneya 2, S8=Haro jila, S9=Fulaso, S10= Bole and present samples ID. SHW and DW, while previous samples ID and which are assigned as shallow wells and deep wells respectively.

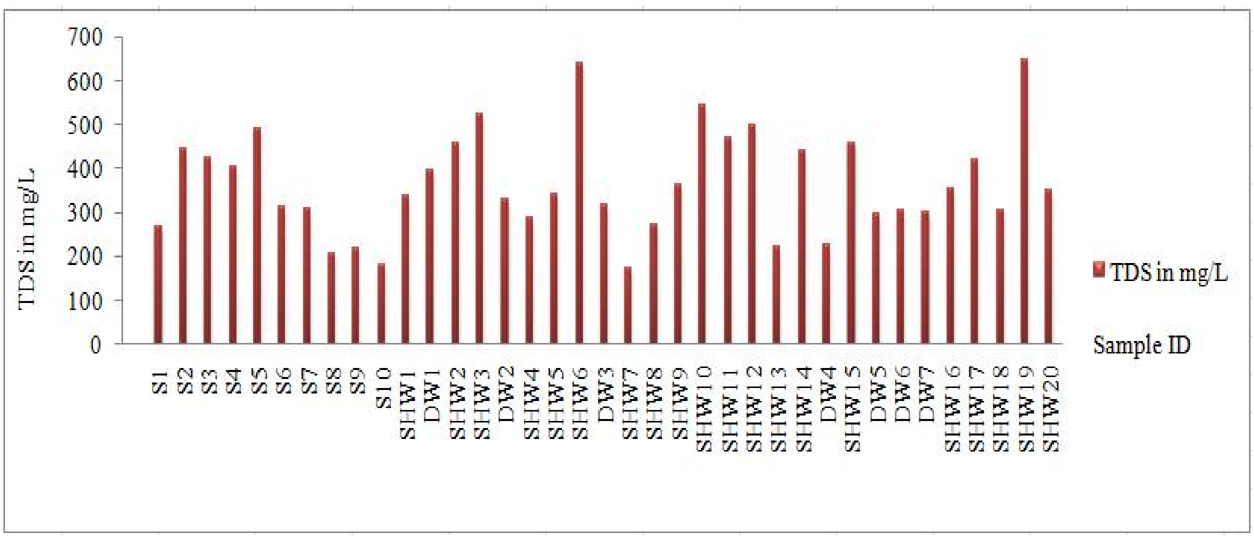

Figure 4.5: TDS variation of collected groundwater samples in the study area

4.1.6. Total hardness

The total hardness represents the total concentration of calcium ion and magnesium ion in water unit's mg/L as equivalent CaCO3. Hardness in drinking water can cause health problems such as kidney failure (WHO, 2008).

There are two types of hardness:-

1. Temporary hardness
2. Permanent hardness

Temporary hardness: is due to the presence of bicarbonates of calcium and magnesium. It can be easily removed by boiling.

Permanent hardness: is due to the presence of chlorides and sulphates of calcium and magnesium. This type of hardness cannot be removed by boiling. Classification of water based on TH by Sawyer and McCarthy (1967) (Table 4.3) indicate that 0% (none) of the groundwater samples fells into the soft category, 10% moderately hard classification, 70% hard and 20% fells within the very hard classification.

Table 4.3: Water classification based on TH (Sawyer and McCarthy, 1967)

TH (mg/L)	Classification	Number of samples	Percentage
<75	Soft	0	0 %
75-150	Moderately hard	1	10%
150-300	Hard	7	70%
> 300	Very hard	2	20%

Concentration between 150 mg/L and 300 mg/L (hard category are found in boreholes Tafki, Dima magno 1, Tafki golden1 , Tafki golden 2, Gora harkiso 2, Boneya1 and Boneya2 and concentration of > 300 mg/L which belong to very hard category are found in boreholes Gora harkiso 2 and Fulaso. The reason for high total hardness in these boreholes especially Gora harkiso 2 and Fulaso is due to the high concentration of Ca^{2+} and Mg^{2+}, which could be due to silicate weathering, carbonate weathering and gypsum dissolution in the groundwater of the area.

Table 4.4: Summary of hardness and softness categorize range (Dezuane, 1996)

No	Range of the concentration (mg/L)	Categorized of hardness	Number of samples	Percentage (%)
1	0-50	Soft water	0	0%
2	50-150	Moderately hardness	0	0%
3	150-300	Hardness	8	80%
4	>300	Very hardness	2	20%

According to Dezuane, 1996 water classification based on hardness and softness categorized 80% of ground water of the study area were categorized under hard water and the rest of 20% categorized as very hard water ,therefore ground water of the study area have high concentration of calcium and magnesium ions.

4.1.7. Major ions

4.1.7.1. Potassium (K) and Sodium (Na)

The concentration of potassium in the study area ranged from 1.6 mg/L (minimum) to 9.9 mg/L (maximum) with an average of 4.21 mg/L. According to the WHO, the maximum permissible value for potassium is limited to 1.5 mg/L. The laboratory resulted of potassium concentration at all samples points of the location of the study area were found out of the expected range as described above and greater than the maximum permissible limit value set by WHO (2011), this may be origin from silicate weathering, potassium is also an indicator of pollution from human activities. Potassium is a major constituent from fertilizers which is widely used in agricultural activities (Dinka, *et al*., 2015).

As the chemical analyzed of the samples showed, sodium is the least dominant cation in study area that is followed by potassium, calcium and magnesium respectively based on the set of water quality standard. The concentration of sodium in the study area varies from 9.4 mg/L to 116 mg/L minimum and maximum respectively with an average 32.59 mg/L. The WHO and national drinking water standard for sodium is 200 mg/L all collected water samples were below the maximum permissible level.

4.1.7.2. Calcium (Ca) and Magnesium (Mg)

The concentration of Ca^{2+} found in the samples of the study area ranges between 41.68 mg/L (minimum) to of 117.03 mg/ L (maximum) with an average value 66.372 mg/L. Most of the calcium concentration fells with the WHO (2011) standard or <75 mg/L, only two samples (Tafki golden 2 and Gora harkiso 2) fells out of the target range. Magnesium in the study area was measured 3.89 mg/L minimum value and 83 mg/L maximum value with the mean value of 16.55 mg/L. Therefore only one sample (Debel kejima) in the study area fells out of target based on the basis of magnesium concentration.

4.1.7.3. Iron (Fe) and Manganese (Mn)

Iron is the fourth most abundant element in the earth's crust. Iron is a very common problem in drinking water and has a strong relationship with water hardness typically with both hardness and iron increasing at the same time. Iron can cause discoloration (laundry and plumbing), unpleasant taste, color and promotion of growth iron bacteria. Iron can also precipitate in distribution systems and household plumbing thereby causing additional problems. Iron in study area was measured 0.01 mg/L minimum value and 1.18 mg/L maximum value with an average of 0.206 mg/L.

Based on aesthetic reasons the WHO (2011) guidelines drinking water quality recommended that the iron levels should be kept below 0.3 mg/L and only one sample above the recommended value. There should be no direct health effects with iron in drinking water, but iron can be linked to excessive bacterial activity. The end-result of this action is water that is not pleasant to drink (smell and taste). Manganese is a grayish hard white metal similar to iron. Drinking water guidelines for manganese are set for aesthetic reasons as manganese can stain plumbing and laundry as well as telling taste and odor to the water. The laboratory resulted for manganese the minimum value 0.01 mg/L and 2.2 mg/L maximum value and with mean value of 0.193 mg/L. According to WHO (2011) guideline the maximum permissible limit for manganese concentration in drinking water quality should not exceed 0.1 mg/L and according to ES (2001) 0.5 mg/L and 29.6 % above the permissible WHO (2011) and as well as 3.7% above the recommended value by national standard.

The major anions include bicarbonate, nitrate, chloride and sulphate ions. Of these parameters, the dominant anion is bicarbonate. Bicarbonate is commonly the primary anion in groundwater. It is derived from the carbon dioxide released by the organic decomposition in the soils, where CO2 is generated by root respiration and decay of humus that in turn combines with rainwater to form bicarbonates (Drever, 1988, and Todd, 1980). The concentration of bicarbonate in the study area ranges between 146.4 mg/L to 483.1 mg/L with an average of 265.19 mg/L. The present study there is high concentration of bicarbonate in entire samples consequently the dominant water type is bicarbonate type. This anion is the most dominant constitute of all the other constituents. There is no specification on the maximum acceptable limits of bicarbonate either by WHO or national standard for drinking water supply.

4.1.7.4. Ammonia (NH3) and Ammonium (NH4+)

The maximum and minimum value of NH_4^+ collected from different bore holes of the study area were 10.45 mg/L and 0.02 mg/L with the mean value 1.12 mg/L respectively.

The result of NH3 found to be 9.8 mg/L to 0.1 mg/L. The permissible limit for NH3 and NH_4^+ 1.5 mg/L therefore, 15% of NH_4^+ and NH3 above the recommended value and hence no known toxic effects in concentrations that can be expected to be found in drinking water supply.

4.1.7.5. Fluoride (F) and Chloride ions (Cl)

The permissible level of chloride in drinking water is 250 mg/L based on WHO and Ethiopian standards. In the present study, the result of chloride in all sampling sites were between 1.92 mg/L and 146 mg/L accordingly, the chloride levels measured in all sampling points were below the permissible level for drinking water supply.

The concentration of fluoride in the study area varied from 0.25 mg/L (Haro jila) to 3.6 mg/L (Tafki) which indicated that the concentration of fluoride 93.1% below the recommended standard and the rest of 6.9% (Tafki and Boneya1) above the permissible limit so that, the higher concentration of fluoride leads to the discoloration of teeth known as dental fluorosis. The more dangerous is the deformation of the skeleton and hence important to treat before use the wells that had high concentration of fluoride in order to keep the health of the users.

4.1.7.6. Nitrate (NO3-) and Sulfate (SO_4^{2-})

The nitrate concentration of the study area ranges from Melima 0.26 mg/L to Gora harkiso2 131.42 mg/L. These values were within the acceptable limits of both WHO (2011) and Ethiopian Standards (2001), which is 50 mg/L except Gora harkiso 2 and Boneya2. According to Shayaq Ali *et al.* (2015), high concentration of nitrate is associated with agricultural activities, which are a major problem in some shallow aquifers. For instance, the high nitrate concentrations in samples labeled Gora harkiso 2 and Boneya 2 indicates that the area is affected by anthropologic source in related to agriculture fertilizers and animal manures. On the other hand high concentration of nitrate is one of the extreme significant disease causing parameters of drinking water quality, particularly blue baby syndrome in babies.

The main sources of sulphate in groundwater are oxidation of sulphides from igneous rocks, fertilizers, rainwater, industrial discharge, and deposition from burning of fossil fuel.

The sulphate concentrations from collected samples were low. It was measured between 0.53 mg/L (minimum) at sample labeled (SHW23) and 47 mg/L (maximum) at sample labeled (SHW1) and with mean value of 17.16 mg/L. The acceptable limit for sulphate as given in Ethiopian standard is 250 mg/L.

4.1.7.7. Phosphate ($PO4^{3-}$)

Drinking water supplies may contain phosphate derived from natural contact with minerals or through pollution from application of fertilizers, sewage and industrial wastes. The minimum and maximum values of phosphate in the study area were 0.09 mg/L and 3.7 mg/L with an average of 1.23 mg/L. There is no specification on the maximum acceptable limits of phosphate either by WHO or national standard for drinking water supply.

Table 4.5: Summary of the suitability of groundwater quality for drinking purpose

Parameters	Min.	Max.	Avg.	St. dev.	WHO(2011) standard sand Ethiopian standard (2001)	Number of samples exceeding recommended limit
Tub.	0.11	10	1.463	3.03	5	2
TDS	179	488	324.7	109.66	1000	0
EC	268	715	480.9	52.86	1400	1400
PH	6.78	7.47	7.17	0.25	6.5-8.5	0
TA	120	260	178	43.41	200	1
TH	124	800	278.2	186.14	300	2
Na^{+}	12.1	75	33.19	23.83	200	0
K^{+}	1.6	9.9	3.5	2.6	1.5	28
Ca^{2+}	41.68	117.03	66.37	21.88	75	2
Mg^{2+}	3.89	48.64	15.45	13.05	50	0
Cl^{-}	10	57.98	25.69	19.42	250	0
F^{-}	0.25	1.06	0.65	0.29	1.5	0
$HCO3^{2-}$	146.4	317.2	217.16	57.30	-	-
$NO3^{-}$	0.53	131.42	20.08	13.156	50	2
$SO4^{2-}$	0.78	43.07	14.406	2.663	250	0

Where, Max= Maximum, Min= Minimum, Av. = Average and St.dev = Standard deviation.

4.2. Groundwater quality for irrigation purpose

The quality of water for irrigation is determined by how the long term use of the water affects soil and plant health, the use of water with inferior quality for irrigation could lead to reduced crop yield (Ramesh and Elango, 2010). Parameters used to assess the quality of water for irrigation included total salt concentration measured by EC (salinity hazard), the relative proportion of sodium which indicate the sodium hazard, which are: the sodium percent, sodium adsorption ratio, residual sodium carbonate and Kelley's ratio, permeability index and magnesium ratio.

4.2.1. Salinity Hazard

The salinity hazard increases the osmotic pressure of the soil water and restricts the plant roots from absorbing water; these results in a physiological drought condition. Table 4.6 below showed that the result according to USSL, 1954 classification of EC. According to this classification 82.5% the groundwater samples have medium salinity hazard and 17.5% high salinity hazard; this is due to the high TDS in the groundwater.

This showed that, with respect to salinity hazard the groundwater in the study area with medium salinity hazard is suitable for irrigation, while the groundwater with high salinity hazard is not suitable since high salt concentrations influence osmotic pressure of the soil solution and affects the ability of plants to absorb water through their roots.

Table 4.6: Classification of water based on EC (US Salinity Laboratory, 1954)

Salinity Hazards	EC (mS/m)	No. of samples	Percent (%)
Low	< 250	0	0
Medium	250- 750	33	82.5
High	750- 2250	7	17.5
Very high	> 2250	0	0
Total		40	100

4.2.2. Sodium Hazard

The sodium hazard results from accumulation of sodium in an excessive amount which causes the physical structure of the soil to break down. When calcium and magnesium are replaced by sodium adsorbed on clays, the result is dispersal of soil practices. Consequently, the soil becomes hard and compact when dry and increasingly impervious to water resulting in plant roots not getting enough water. For this reason, the sodium in water is an important parameter when determining suitability of the water for irrigation. Therefore, based on the concentration of sodium ground water in the study area is suitable for irrigation purpose.

4.2.3. Sodium adsorption ratio (SAR)

SAR is measure of suitability of water for irrigation, because sodium concentration can reduces the soil permeability and soil structure.

The sodium adsorption ratio (SAR) is an index of the potential of a given irrigation water to induce sodic soil conditions. Sodicity in irrigation water is due to high concentration of Na^+ relative to Ca^{2+} and Mg^{2+}. SAR is computed from the relative measures of these cat ions (DWAFF, 1996). Water with SAR ≤ 6 is more desirable for irrigation while water with SAR ≥ 9 may cause the soil structure to deteriorate resulting in slower water infiltration and residual soil reduced air movement (Peacock and Christensen, 2000).

The maximum and minimum values of SAR for groundwater samples in the area were 2.21 and 0.3 respectively with an average value of 0.97 and standard dev. value is 0.66. 100% of the ground water samples have SAR less than 6 therefore all samples of the study area where can be classified under more desirable for irrigation. All the samples have low SAR meaning they have more Ca^{2+} and Mg^{2+} relative to Na^+, which indicate that the capacity of the water to induce sodic conditions in the soil is low and are suitable for irrigation. Hence ground water in the study area is suitable for irrigation according to (Peacock and Christensen, 2000).

As described in USSL (US Salinity Laboratory, 1954), water having SAR values <10 is considered excellent, 10 to 18 good, 18 to26 as fair, and > 26 unsuitable for irrigation use.
The calculated SAR of the Sabata Hawas district ranges from 0.3 to 2.21 with mean value of 0.97. Based on USSL (US Salinity Laboratory, 1954) SAR classification, 100% of the analyzed ground water samples in the study area were classified as excellent and hence suitable for irrigation.

4.2.4. Sodicity and Salinity Hazards

Wilcox diagram relating sodium percent and total concentration of the analyzed water samples from the study area is showed in figure.4.6. Concerning to sodium hazard, 99% of the groundwater samples of the study area fells in the low hazard range while, the remaining 1% fells under medium range.

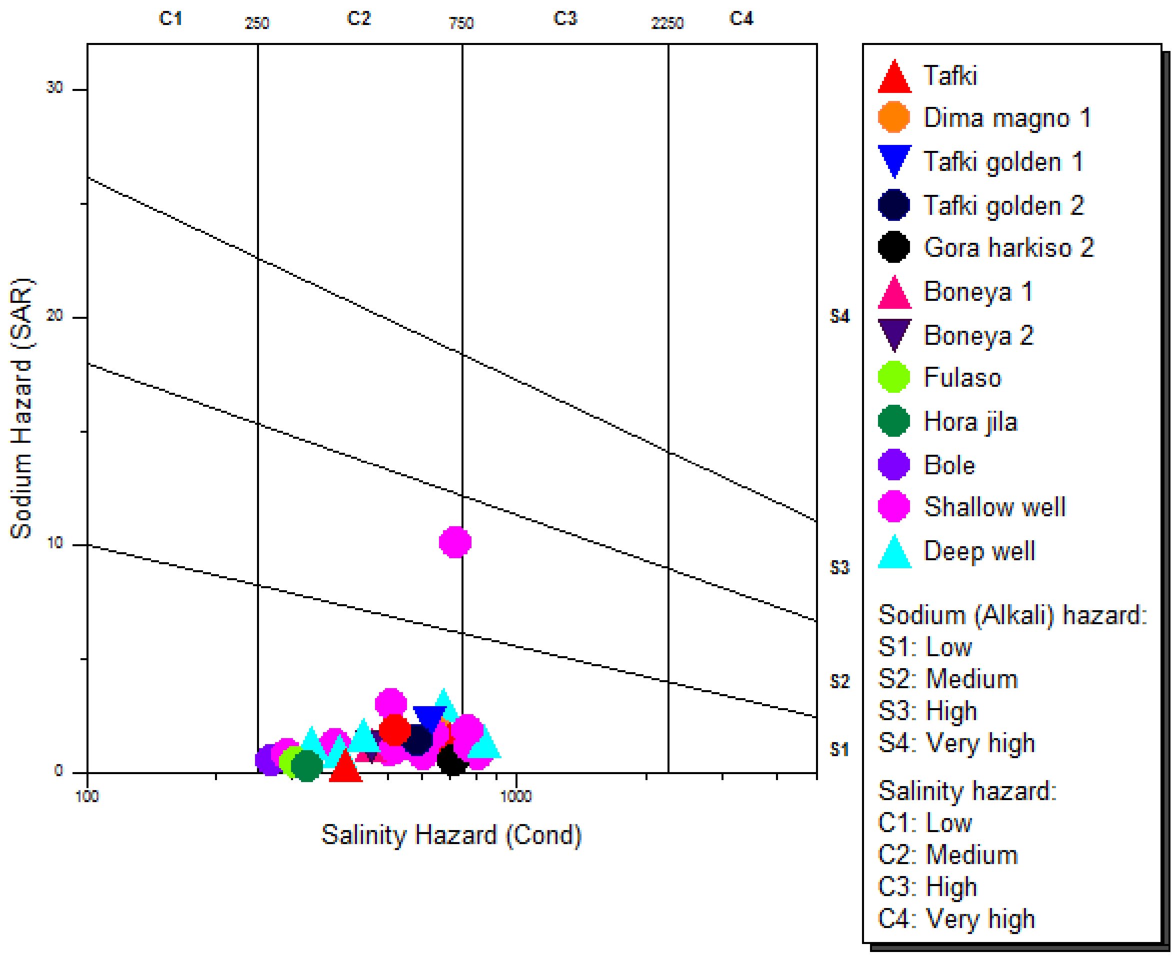

Figure 4.6: Wilcox diagram of sodium hazard versus salinity hazard in the study area.

Where, present site locations samples were called their original name and while the previous site location samples were assigned as shallow wells and deep wells based on their types of bore holes. Based on Wilcox plot 82.5% of the groundwater samples of the study area fells in the medium salinity range while the remaining 17.5% fells under high salinity range. Based on the Wilcox diagram classification, groundwater quality in major part of the study area can be considered suitable for irrigation purposes. However, groundwater from the south eastern part of the study area is characterized by high salinity and significant Sodicity which limits irrigation.

4.2.5. Percentage of sodium

Sodium percent is an important factor for studying sodium hazard. It is also used for adjusting the quality of water for agricultural purposes. High percentage sodium water for irrigation purpose may affect the plant growth and reduces soil permeability (Joshi *et al.*, 2009).

Percentage of Na^+ is widely used for assessing the suitability of water for irrigation purposes. The sodium percentage (Na %) is computed with respect to relative proportion of cat ions Present in water. The result computed for sodium percentage tabulated below based on United State salinity laboratory.

Table 4.7: Classification of water based on percentage of Na^+ (US salinity laboratory, 1954).

Sodium ,%	Class	Number of samples	Percentage of samples
<20	Excellent	5	50%
20-40	Good	4	40%
40-60	Permissible	1	10%
60-80	Doubtful	0	0
>80	Unsuitable	0	0

According to the table above 50% of the samples can be classified as excellent for irrigation while, 40% of the groundwater samples categorized into the good class, and 10% fell under permissible class. Therefore based on, the classification of (US Salinity laboratory, 1954), the ground water of the study area suitable for irrigation use.

4.2.6. Residual Sodium Carbonate (RSC)

RSC had been calculated to determine the hazardous effect of carbonate and bicarbonate on the quality of water for agricultural purpose (Aghazadeh and Mogaddam, 2010). Residual sodium carbonate (RSC) exists in irrigation water when the bicarbonate (HCO3) content exceeds the calcium (Ca) content of the water. Where the water residual sodium carbonate is high (>2.5 meq/l), extended use of that water for irrigation will lead to an accumulation of sodium (Na) in the soil. This may results in (1) direct toxicity to crops, (2) excess soil salinity (EC) and associated poor plant performance and (3) where appreciable clay or silt is present in the soil, loss of soil structure occur through clogging of pore spaces thereby hindering air and water movement. High RSC in irrigation water indirectly results in an increase in Na^+ levels in the water which increases sodium hazard potential of irrigation water.

Table 4.8: Classification based on Residual Sodium Chloride for the study area.

RSC	class	No. of samples	percentage of samples
<1.25	Safe	all	100%
1.25-2.5	Marginally suitable	0	0
>2.5	Not suitable	0	0

Table above showed that based on the RSC values for the samples in the study area 100% of the samples are safe for irrigation purposes, this showed that all the samples have higher Ca^{2+} and Mg^{2+} relative to bicarbonate ($HCO3^-$).

4.2.7. Permeability Index (PI)

The quality of irrigation water can affect the permeability of the soil after long term use; this can be measured by computing the permeability index (PI). PI is influenced by sodium, calcium, magnesium and bicarbonate contents of the soil. It can be classified into three classes; class I and class II can be categorized as good for irrigation with ≥ 75% and 75-25 % respectively permeability while class III water is classified as unsuitable with < 25% of permeability (Doneen, 1964). PI values computed for the groundwater samples for the study area ranged from minimum 29.76 % to maximum 69.27%, with mean value of 56.79%. According to the classification by Doneen, 1964 the samples fells under class II; this indicates that groundwater of the study area suitable for irrigation purpose based on permeability index.

4.2.8. Magnesium hazard

The use of water with high magnesium content for irrigation may pose a threat to crop yield as it may cause alkaline condition in the soil. Paliwal (1972) developed an index for calculating the magnesium hazard. The computed MR values for the study area range from 5.2 % to 62. 76 % with mean value of 23.08%. A value of MR less than 50% is considered suitable for irrigation while more than 50% MR is considered unsuitable for irrigation practice. The results showed that 90% of the samples from the study area suitable for irrigation and 10% is unsuitable with respect to magnesium hazard. This indicates that 10% of the groundwater samples have a potential to cause alkaline soil which is known to have low infiltration capacity.

4.2.9. Kelly's Ratio

Kelly's ratio assess irrigation water quality based on the level of Na^+ against Ca^{2+} and Mg^{2+}. Kelly's ratio more than 1 indicates an excess level of Na^+ in the water and therefore the water can be considered unsuitable for irrigation. The calculated value for KR of the study are range from 0.1 (minimum) to 0.75 (maximum) with an average value of 0.33 and in detail expressed in the following table.

Table 4.9: Kelley's Ratio classification (Concentrations are in meq/l)

KR	Classification	No. of samples	Percentages of samples
<1	Suitable	all	100%
>1	Unsuitable	0	0

The results from the computed Kelley's ratio (table 4.9) showed that 100 % of the samples were within the recommended Kelley's ratio. Therefore the ground water of the study area is suitable for irrigation purpose. The trilinear Durov plot is based on the percentage of major ion mill equivalents. The cat ions and anions values are plotted on two separate triangular plots and the data points are projected onto a square grid at the base of each triangle. In addition, the Durov plot allows for the direct comparison of two other groundwater parameters, typically pH and the total dissolved solids.

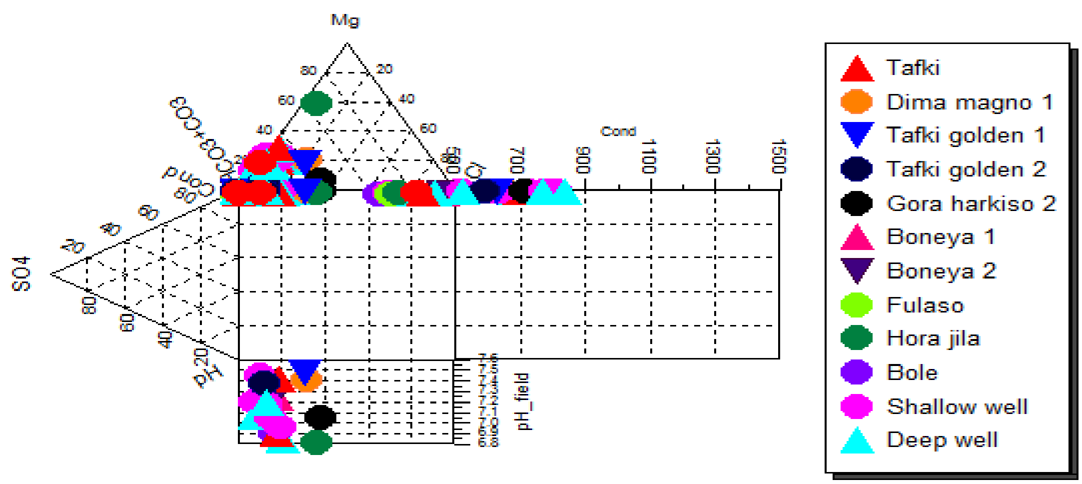

Figure 4.7: Durov's diagram

Where, present site locations samples were called their original name and while the previous site location samples were assigned as shallow wells and deep wells based on their types of bore holes.

4.3. Water types

The hydro chemical analysis results indicate that, the origin and geochemical composition of the groundwater in the area is spatially variable because the geologic variations caused spatial variability of the hydro chemical parameters.

This classification with the samples from the study area produced five hydro-chemical facies, (water types) which are: Ca-Mg-HCO_3, Ca-Na-HCO_3-SO_4, Ca- HCO_3, Na-Ca-HCO_3 and Ca-Na-Mg-HCO_3-Cl. This variation in the chemical facies can be attributed to cation exchange process with prolonged water-rock interaction following the groundwater flow direction.

The Ca-Mg-HCO_3 water type characterizes more than 50% of the groundwater samples and has the lowest concentrations of total dissolved solids. This water type also had the highest level of total hardness in this type of water is temporary and is mainly caused by calcium carbonates.

The Ca-Na- HCO_3-SO_4 to Ca-Mg-HCO_3-SO_4 water type is a product of mixing types characterized boreholes. Which comprises 20% of the groundwater samples has high levels of Ca^{2+}, Mg^{2+}, Na^{+}, SO_4^{2-} and HCO_3- ions in this water type could be attributed to the combined influence of silicate weathering, calcite dissolution, ion exchange processes and gypsum dissolution. This type of water can be characterized as hard water and high levels of TDS. The most of water type in the study area change from Ca-Mg-HCO_3 to Ca-Na-HCO_3 which is formed due to ion exchange.

The rest of 30% water type is Ca-HCO_3 to Mg-HCO_3 and Ca-Na-Mg-HCO_3- Cl. The Ca-Na-Mg-HCO3- Cl water type the presence of high concentration of chloride and sodium showed a complex process of rock-water interaction and ion exchange (GSE, 2010). The piper trilinear diagram is the widely used diagram to represent the hydrochemical facies of water (piper, 1944). This piper plot helps us to classify water based on chemistry and compare the chemical trend between different water samples. The primary and secondary data chemical analyzed result are plotted on piper diagram (figure.4.8) below.

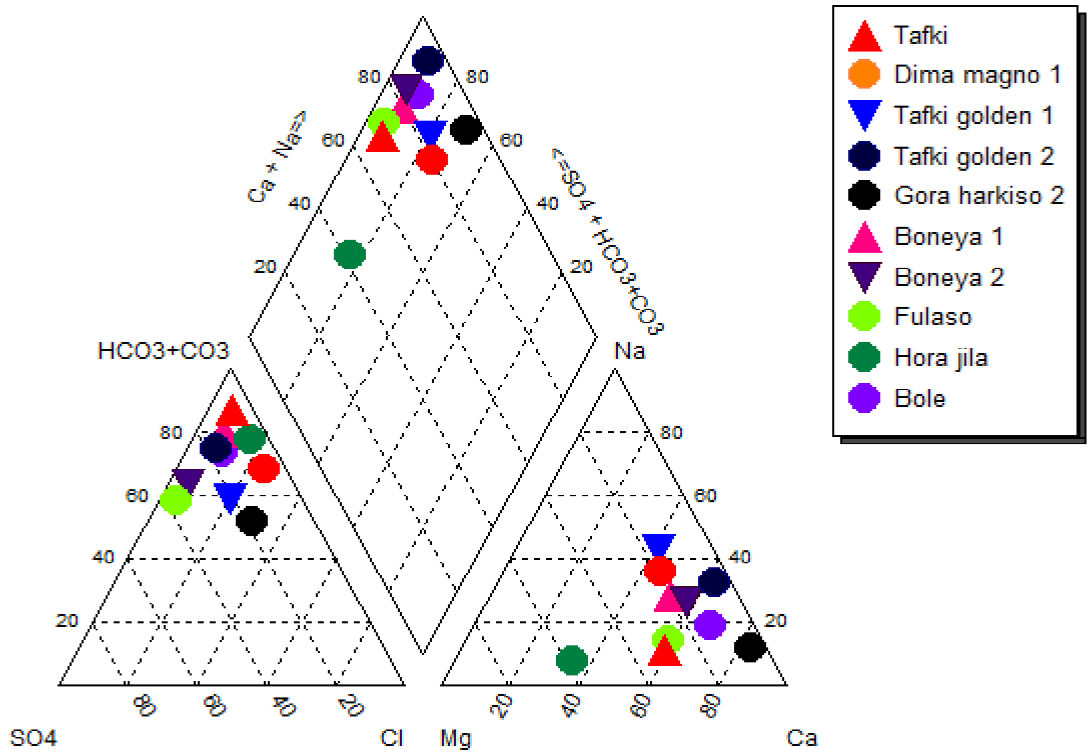

Figure 4.8: Piper plots of the hydro chemical data showing groundwater type

The hydro chemical analysis results indicated that, the origin and geochemical composition of the groundwater in the area is spatially variable because the geologic variations caused spatial variability of the hydro chemical parameters. The identified water types are Ca-Mg-HCO_3, Ca-Na-HCO_3-SO_4, Ca- HCO_3, Na-Ca-HCO_3, and Ca-Na-Mg-HCO_3-Cl.

CHAPTER FIVE

5. Conclusions and Recommendations

5.1. Conclusions

The study area, Sabata Hawas district located in Oromiya Special Zone surrounding Finfinne, Oromiya Regional State, Ethiopia. The absolute geographical location of the study area is between 8º 37'-9^0 1'30" N latitude and 38^0 24' 30" - 38^0 45' 30"E longitude with an area of 87,572 hectare. The rock formation of the study area is volcanic rocks such as Ignimbrite, Trachytes, Tarmaber Basalt, Rhyolite, Alluvial deposit and Basalts. The main objective of this study is to examine the water quality in terms of physiochemical and determining its criteria for drinking and irrigation purposes.

The results revealed that most of the samples were within the permissible range for both Ethiopian Standard (2001) and WHO (2011) water guidelines, except turbidity of Tafki bore hole and Fulaso bore hole. In addition ground water of the study area fells under hard to very hard classes. Also at all sampling points of the study area, the concentration of K^+ were higher than WHO and national standards , 15% of NH_4^+ and NH3 concentrations were above 1.5 mg/L permissible limited that recommended water supply for drinking purpose. The concentration of F^- in Tafki (2.3 mg/L) and Boneya1 (3.6 mg/L) above 1.5 mg/L recommended WHO and national standard for drinking water supply. The concentration of NO_3^- in Gora harkiso2 (131.14 mg/L) and Boneya 2 (131.02 mg/L) were also above the recommended of domestic water supply for drinking. The dominant of major ions in the area is as $Ca^{2+} > Na^+ > Mg^{2+} > K^+$ and $HCO_3^- > Cl^- > NO_3^- > SO_4^{2-} > F^-$.

Based on ground water for irrigation the concentrations of SAR, Na%, KR, RSC, and PI all the samples were found suitable for irrigation except 10% of magnesium hazard and 17.5% of salinity hazard were found to be unsuitable for irrigation because of its potential to cause alkaline soil which is known to have low infiltration capacity and salinity hazard increases the osmotic pressure of the soil water and restricts the plant roots from absorbing water. The hydro-chemical data was further analyzed using AquaChem. Soft ware (V2014.2). Classical hydro-chemical methods showed the existence of five hydro-chemical facies/water types in the area, were Ca-

Mg-HCO_3, Ca-Na-HCO_3, Ca-HCO_3 and mixed water Ca-Na-HCO_3-SO_4 and Ca-Na-Mg-HCO_3-Cl water type. The facies showed the evolution of ground from Ca-Mg-HCO_3 to Na-Ca-HCO_3 through silicate weathering and reverse ion exchange processes and the Ca-Na-SO4-HCO3 water type is a result of mixing of different water type. The analyzed of the major ion chemistry and their spatial distribution indicated the dominance of rock-water interaction as the main process controlling groundwater chemistry in the area. Further, the ionic concentration is due to silicate weathering, carbonate weathering and ion exchange processes. In conclusion, it also indicated the influence of anthropogenic activities in the area. The role of anthropogenic activities is also evident by the association of ions such as NO_3^- , NH_4^+, NH_3 and K^+ which are caused groundwater pollution because of uncontrolled agriculture.

5.2. Recommendations

- ✓ In view of the findings of the study, it is recommended that the water in bore holes that exceeded the WHO (2011) and (2001) national guidelines for drinking water supply and in the boreholes that showed high magnesium and salinity hazard potential and should be treated before use.
- ✓ In future studies, more parameters and more bore holes should be analyzed and observed, such as heavy metals and trace metals and organics (pesticides and pharmaceuticals) and effects of seasonal changes on the groundwater.
- ✓ Programs should also implemented on how to better protected groundwater anthropogenic impact.
- ✓ The recommendation drawn on the suitability of groundwater for irrigation in the present study is based on water quality parameters which are empirical.
- ✓ It would be better for future studies to consider other factors like soil type, crop type, crop pattern, frequency and recharge (rainfall), climate in evaluating the suitability of groundwater for irrigation.

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Appendixes

Appendix 1: Table test method and parameters were tested

S.No	Parameters	Unit	Test method (APHA20thEdition)
1	Turbidity	NTU	2130B
2	Total Dissolved Solid (TDS)	mg/L	2540C
3	Electrical Conductivity at 25C (EC)	µS/cm	2520B
4	pH at 25 C	-	4500-H^+B
5	Total alkalinity as CaCO3	mg/L	2320B
6	Total hardness as CaCO3	mg/L	2340C
7	Sodium ion, Na^+	mg/L	3500-Na^+B
8	Potassium ion, K^+	mg/L	3500-K^+B
9	Calcium ion, Ca^{2+}	mg/L	3500-Ca-B
10	Magnesium ion, Mg^{2+}	mg/L	3500-MgB
11	Chloride ion, Cl^-	mg/L	4500-Cl^-B
12	Fluoride ion , F^-	mg/L	4500-F^-D
13	Bicarbonate ion, HCO_3^-	mg/L	2320B
14	Carbonate ion, CO_3^{2-}	mg/L	2320B
15	Nitrate ion, NO_3^-	mg/L	4500-$NO3^+$ B
16	Sulfate ion, SO_4^{2-}	mg/L	4500-$SO4^{2-}$ E

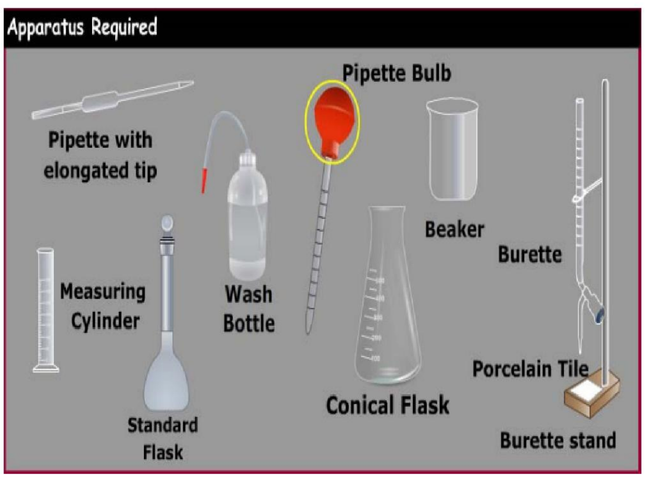
Appendix 2. Total Alkalinity test procedure

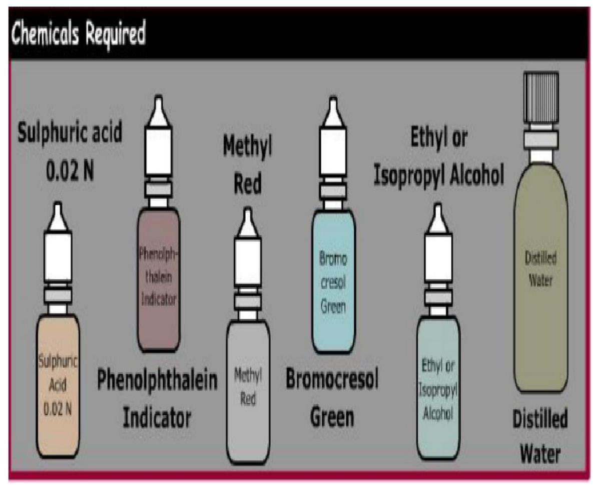
Test procedure is in accordance to IS: 3025 (part 23) reaffirmed 2003.

APHA standard method for the examination of water and waste water- 20th Edition.

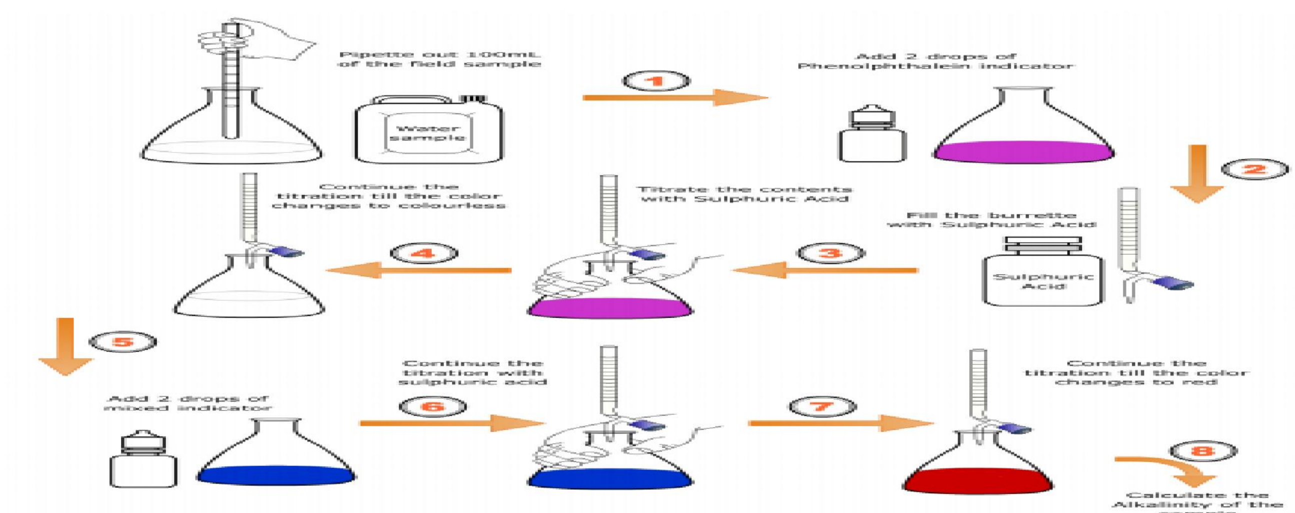
Method 2320-B.

Materials required	Chemical required
Burette with burette stand and porcelain title Pipettes with elongated tips, Pipette bulb Conical flask (Erlenmeyer flask) 250 ml graduated cylinder, Standard flask, Standard bottle and Beaker	Standard sulphuric acid ,Phenolphthalein Mixed indicator, Bromocresol green Methyl red, Ethyl alcohol and Distilled water





Procedure chart



Appendix 3. Figure 1 water quality sampling and analysis

Appendix 4: Table2 ground water chemistry result from the study area and laboratory analyzed

Sample ID	Site Name	Location		Groundwater quality parameters															
		X_UTM	Y_UTM	TH	TA	Tub.	TDS	EC	PH	Na	K	Ca	Mg	Cl	F	HCO3	CO3	NO3	SO4
S1	Tafki	444624	978143	240	190	5.2	266	399	7.42	13.6	2	64.13	19.46	10	0.82	231.8	0	5.26	12.62
S2	Dima magno 1	451518	985340	232	200	0.69	445	656	7.4	60	3.6	65.73	16.54	51.98	1.03	244	0	1.8	19.56
S3	Tafki golden 1	442842	977555	216	200	0.18	425	626	7.47	75	3.3	62.52	14.59	49.98	2.33	244	0	2.52	14.53
S4	Tafki golden2	442811	977625	224	260	0.32	402	592	7.37	49	3.8	83.37	3.89	19.99	0.92	317.2	0	1.85	8.76
S5	Gora Harkiso 2	452466	976970	308	140	0.23	488	715	7.05	19	1.7	117.03	3.89	57.98	0.50	170.8		131.42	0.78
S6	Boneya 1	460464	974637	236	200	0.17	311	461	7.24	40	9.9	64.13	18.48	14	1.6	244		13.24	23.42
S7	Boneya2	460454	974629	228	190	0.11	309	460	7.26	38	5.6	72.14	11.67	13	0.54	231.8	0	131.12	2.67
S8	Fulaso	451518	985340	264	160	0.64	204	305	6.78	12.1	1.6	44.89	12.65	10	0.38	195.2	0	2.15	13.06
S9	Haro jila	449434	980645	800	120	10	218	327	6.81	12.1	1.6	48.1	48.64	17.99	0.25	146.4	0	18.39	5.59
S10	Bole	450080	985388	124	120	0.77	179	268	6.9	13.1	1.9	41.86	4.86	12	0.42	146.4	0	11.42	43.07

Where S stands for samples ID, NTU= Nephelometric turbidity units, Tub. = turbidity, TA= Total alkalinity, TH= Total hardness, EC= Electrical Conductivity, TDS =Total Dissolved Solid and all values are in mg/L except PH (untiless), Turbidity in NTU and EC in µS/cm.

Appendix 5: Table 3 Summary of the suitability of groundwater quality for drinking purpose

Parameters	Min.	Max.	Avg.	St. dev.	WHO (2011) standards	Ethiopian Standard (2001)	No of samples exceeding recommended limit
Tub.	0.11	10	1.463	1.03	5	5	2
TDS	174	645	359.68	113.13	1000	1000	0
EC	268	1327	570.46	213.56	1400	1400	0
PH	6.58	7.79	7.09	0.46	6.5- 8.5	6.5- 8.5	0
TA	120	396	228.4	76.52	200	200	13
TH	124	800	278.2	186.14	300	300	2
Na^{+}	12.1	75	33.19	23.83	200	200	0
K^{+}	1.6	9.9	3.5	2.6	1.5	1.5	10
Ca^{2+}	41.68	117.03	66.37	21.88	75	75	2
Mg^{2+}	3.89	83	19.88	10.97	50	50	1
Cl^{-}	1.92	146	26.06	23.04	250	250	0
F^{-}	0.25	3.6	0.65	0.67	1.5	1.5	2
$HCO3^{2-}$	146.4	483.1	265.19	154.78	-	-	-
$NO3^{-}$	0.31	131.42	11.01	5.48	50	50	2
$SO4^{2-}$	0.53	47	17.16	12.8	250		0
Fe	0.01	1.18	0.206	0.13	0.5	0.5	1
PO4	0.09	3.7	1.23	1.08	-	-	
Mn	0.01	2.2	0.193	0.107	0.1	0.5	1
NH4	0.02	10.45	1.12	0.53			
NH3	0.1	9.8	1.012	1.003			

Appendix 6: Table 4 irrigation water quality parameters

Well ID	PH	TDS	EC	SAR	Na (%)	MH	KR	PI	RSC
S1	7.42	266	399	0.41	13.29	23.26	0.14	53.21	-0.38
S2	7.4	445	656	1.71	36.66	29.52	0.52	63.34	-0.67
S3	7.47	425	626	2.21	43.52	28	0.75	69.19	-0.5
S4	7.37	402	592	1.42	33.14	7.2	0.48	66.59	-0.34
S5	7.05	488	715	0.47	12.4	5.2	0.13	35.76	0.71
S6	7.24	311	461	1.13	29.57	34.42	0.37	57.63	-0.33
S7	7.26	309	460	1.09	28.15	24.1	0.36	65.49	-0.78
S8	6.78	204	305	0.4	14.0	29.98	0.15	57.56	-0.3
S9	6.81	218	327	0.3	8.11	62.76	0.1	29.75	-3.26
S10	6.9	179	268	0.51	19.92	16.27	0.23	69.27	-0.09
Average	7.11		399	0.97	23.88	23.08	0.33	56.79	-0.59

Where, EC = Electrical Conductivity, SAR= Sodium Adsorption Ratio, KR= Kelley's Ratio

Na % = Soluble sodium percentage, MH = Magnesium hazard, PI = Permeability Index, HDWs = Hand dung wells, except EC (µS/cm) and all the rest are unit less.

Appendix 7: Table 5 secondary data sources of ground water chemistry data for boreholes and HDWs

Site Name	Location X_UTM	Y_UTM	Elev (m)	Temp ^0C	PH	EC	TDS	TA	Na	K	Mg	HCO_3	SO_4	Cl	NO_3	NH_4	NH_3	PO_4	F	Mn	Fe
Fulaso	451518	985340	2141	21.2	7.3	296	192.4	130				158.6	13		13.6	10.4490	9.8	1.75		0.45	1.18
Bole	450080	985388	2132	21.8	6.94	634	236.6														
Makalo	448899	985053	2116	20.9	7.11	520	338	160				195.2	47		7.04	0.2064	0.9	2.8		0.1	0.03
Hordofi	449558	986067	2149	21.4	7.22	610	396.50	260				195.2	19		2.64	0.5160	0.5	2.8		2.2	0.01
Haro Jila (HDW)	449434	980645	2075	21	7.33	681	442.65														
Haro Jila (HDW)	449407	980765	2071	19.8	7.55	703	456.95														
Tefki Dairy	447020	978672	2067	19.5	7.79	805	523.25	316				385.5	25		1.32	0.129	0.1	0.56		0.1	0.02
Tefki (HDW)	445254	978171	2066	19.7	7.46	599	389.35														
Gora 1	452891	980250	2071	20.6	7.49	505	328.25														
Gora 2	452924	980195	2069	20.1	7.32	444	288.60	162				197.6	12		7.04	2.0640	1.9	1.71		0.01	0.08
Mango Gora	453268	980729	2076	20.2	7.03	429	278.85														
Matali	451276	979174	2077	20.7	6.94	523	339.95														
Gora Harkiso 2	452466	976970	2067	20.6	7.48	733	476.45														

Mehal Atebela	455035	981813	2090	23.3	6.98	980	637.00														
Andode Sp-HDW	461003	977106	2110	23	7.26	488	317.20	192				234.2	18		3.52	0.0645	0.6	0.84		0.1	0.06
Cholo	441773	968943	2062		6.6	294	174.00	144	9.4	2.8	7.02	175.7	8.99	1.92	13.2		0.5	0.16	0.7	0.05	
Lilu	441578	967182	2079		6.7	440	270.00	187	22.5	4.2	8.64	228.4	17.9	17.3	1.5		0.3	0.33	0.3	0.05	
Gila	454714	978831	2062		7.05	640	364.00	312	36	7.1	22.7	380.6	12.4	15.4	2.6		0.4	0.12	1.4	0.17	
gombore	454683	975426	2064		6.96	810	542.00	336	20	4.9	28.1	409.9	28.9	31.7	14.2		0.6	0.26	1	0.13	
Mehal Sefera	455784	977521	2059		6.89	776	468.00	362	25	6.4	24.3	442.1	33.6	15.4	9.1		0.6	0.45	0.3	0.1	
Melima & Deti	455988	979556	2072		6.75	837	500.00	286	34	5.7	28.1	348.4	18..6	81.6	0.62		1.1	0.12	0.9	0.07	
Bebeli	457439	978436	2077		6.7	381	220.00	197	18	2.4	10.8	240.1	2	2.9	5.94		0.3	0.27	0	0.02	
TiliquSefer Adea)	457922	974666	2073		7.19	771	442.00	396	42	3.2	24.3	483.1	11.9	10.6	0.74		0.2	0.09	1	0.15	
Berga #1	455502	980145	2073		6.84	386	226.00	149	16	4.2	11.9	181.5	15.1	12.5	11		0	0.41	0.6	0.02	
Berga #2	458390	976091	2075		6.58	676	458.00	152	48	1.2	11.9	185.5	38.3	146	28		0.3	0.25		0.02	
Turo	457253	973055	2075		7.2	523	294.00	295	30	3	12.4	304.5	10.5	6.72	4.09		0.4	0.35	1.2	0.02	
Koticha	456773	980613	2072		7.18	523	302.00	269	22	5	19.4	327.9	2.2	3.84	4.78		0.6	0.19	1	0.1	
Balchi Mediane lem	458457	970573	2113		7.08	509	304.00	254	19	2.7	17.3	310.4	7	2.9	14.2		0.4	0.5	0.4		
Gichichi	458061	971737	2080		7.1	606	354.0	31	18	3.	23.	380.6	4.65	4.8	8.3		0.5	0.3		0.0	

					8		0	2		5	8				1			3		2	
Dima Mango_1	454809	981251	2083		6.86	338	214.00														
Dima Mango _2	454323	981723	2085		6.9	697	420.00	331	32	3.6	21.1	404.1	25.8	11.5	4.03		0.3	0.12	0.6	0.15	
Kontoma	453850	973096	2060		7.23	632	303						15.9	21	8.5	0.27		0.18	0.9		
Dobi	451420	971692	2063			1327	645						46.2	103	10.5	0.23		0.19	0.6	0.12	
Boneya	460464	974637			7.1	376	236		15.5	1.8	13.8	226.5	0.55	5.8	11.5	0.4		0.16	2.6	0	
Boneya (BH)	460464	974637		22.5			337.35	224				273.3	2		131	Nill	Nill	3.7		0.1	0.06
Awash Melka	456740	962388			7.19	510	350		42	9.8	9.4	333.1	2.64	6.7	7.5	0.06		0.18	1.3	0	
Awash Sheba F1	454852	962780																			
Tefki	444624	978143			7.44	726	455		116	6.6	6.1	345.9	15.6	56.6	4.8	0.113		0.29	3.6	0	
Tefki Golden 2	442811	977625	2066		7.94	653	313				44		4.7	5	0.26	0.0017		0.39	1.1	0.18	
Tefki Golden 1	442842	977555																			
Debele Yohanes	445643	973409			7.06	333	219		17	4.2	8.3	235.7	0.53	2.9	7.5	0.025		0.31	0.8	0	
Debela Kajima	443843	969974																			