JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

ENVIRONMENTAL ENGINEERING CHAIR

DETERMINATION OF GROUND WATER TYPE AND QUALITY FOR DRINKING AND IRRIGATION PURPOSES: A CASE OF NORTH SHOWA ZONE, OROMIYA, ETHIOPIA

BY: GUTU TAYE JIMA

A THESIS SUBMITED TO JIMMA UNIVERSITY, JIMMA INSTITUTE OF TECHNOLOGY, FACULITY OF CIVIL AND ENVIRONMENTAL ENGINEERING, ENVIRONMENTAL   ENGINEERING   CHAIR IN PARTIAL FULFILLMENT FOR THE REQUIREMENTS OF THE DEGREE OF MASTERS OF SCIENCE   IN   ENVIRONMENTAL ENGINEERING

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JIMMA, ETHIOPIA

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DECLARATION

This thesis entitled "**Determination of Ground Water Type and Quality for Drinking and Irrigation Purposes: A Case of North Showa Zone, Oromiya, Ethiopia**" has not been presented for a Master's degree or any other Degree in Jimma Institute of Technology (JiT) or any other university. All source of material used for this thesis has duly acknowledged.

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This thesis has submitted for Examination with my approval as university supervisors.

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ABSTRACT

Groundwater is a vital source of water for domestic and agricultural activities in North showa zone due to non-perennial flow of surface water. Thus the present study aims to evaluate the groundwater quality and assess its suitability for drinking and irrigation purposes. A total of 19 groundwater samples were examined for various physico-chemical parameters to evaluate the quality and suitability of groundwater for the intended purposes and Na^+ and Ca^{2+} were the dominant cations and HCO_3- is the dominant anion in all samples. The suitability of groundwater for drinking purpose was evaluated by comparing the analytical results of different water quality parameters to the Ethiopian standard as well as World Health Organization Standards (WHO, 2006). Hence the study shows that 94.74% and 95.57% of the sample water of the study area meet the WHO and FMoWR (2002) permissible guidelines respectively. Water suitability for irrigation indicates that SAR, %Na and SSP plot, majority of water samples fall under medium saline to low sodium type indicating that water was suitable for irrigation. Based on PI, it was found that ground water was vary from good to moderately suitable for agriculture and there was no much threatening of reduction in permeability of soil. As a whole, the quality of ground water was suitable for agriculture purpose. Piper pilot shows that 26.32% of water samples were $Na-Ca-HCO_3$ water type, 21.05% of water samples were $Ca-Na-HCO_3$ water type, 15.78% of water samples were $Ca-Mg-HCO_3$ water type, and 10.53% of water samples were $Ca-Na-Mg-HCO_3$ water type and finally $Ca-HCO_3-SO_4-Cl$, $Mg-Ca-HCO_3-CL$, $Na-CO_3-HCO_3$, $Ca-HCO_3$, and $Na-HCO_3$ water types are totally 26.32% of water samples. Rock-water interaction and cation exchange along groundwater flow path are responsible for the current characteristics of hydro geochemical facies. Water quality index using quality rating scale to evaluate the suitability of water for drinking purpose shows that 36.84% of samples fall in the class of excellent water type, 26.31% of samples fall in the class of good water type and 36.84% of samples fall in the class of moderate water type for drinking purpose.

Keywords: Drinking Water, Ground Water Quality, Physicochemical Parameters, North Showa.

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ACRONYMS

AAWSA	Addis Ababa Water and Sanitation Authority
ALT	Alaltu
BGS	British Geological Survey
CAWST	Center for Affordable Water and Sanitation Technology
CGWB	Central Ground Water Board
ESRI	Environmental System and Research Institute
FI1	Fiche 1
FMoWR	Federal Ministry of Water Resource
GIS	Geographical Information System
GPS	Global Positioning System
GVM	Groundwater Vulnerability Mapping
GW	Ground Water
MH	Magnesium Hazard
NTU	Nephelolometric Turbidity Units
SAR	Sodium Adsorption Ratio
SUL	Sululta
TA	Total Alkalinity
TDS	Total Dissolved Solids
TH	Total Hardness
UNEP	Nations Environment Program's
UNESCO	United Nation Educational Science and Cultural Organization
UNICEF	United Nations Children's Fund
UTM	Universal Transverse Mercator
WHO	World Health Organization
WQI	Water Quality Index

CHAPTER ONE

1. INTRODUCTION

1.1 Background

Getting to safe drinking water played an important role in human life related to health (Sridhan et al., 2017). Recently, the United Nations (UN) stated that safe and clean drinking water was a human right. Therefore, the UN declared "Water for life" program in the period from 2005-2015 and made one of the targets of the millennium development goals that shall be achieved by 2015 was halving the number of people without proper access to safe water and basic sanitation (WHO, 2011). Water, as a basic necessity to life which was highly demanded. Every living thing wants it at different scales and for different needs. Human beings need water for their domestic, agricultural or industrial purposes (Mitiku, 2011). The major sources of clean water were tap, borehole, hand pumps, open wells, streams and rivers (Tsegaye, 2014). In the absence of available good water, people begin to use unsafe sources and encounter some health problems. The water on the surface was accessible but usually needs extra treatment before use. The subsurface waters were potable in most instances but were not easily accessible (Tsegaye, 2014).

Groundwater provides potable water to an estimated 1.5 billion people worldwide daily and has proved to be the most reliable resource for meeting rural water demand in the sub-Saharan Africa (Gemechu et al., 2019). Most of water supply for domestic purposes in the world comes from underground storages due to its abundance and potability without excessive treatments. There were also places where groundwater is used largely for irrigation and industrial consumptions (Tsegaye, 2014).

Groundwater was also an important part of the water cycle and was used to maintain soil moisture, wetlands, stream flow. Even if it seems pure, groundwater can contain high amount of dissolved chemicals that can affect its quality (Sridhan et al., 2017). Quality refers to chemical, physical, biological and radiological characteristics of water with respect to its suitability for a particular purpose. The quality of ground water can be affected by natural and anthropogenic pollution sources. Naturally occurring contaminants were present in the rocks and sediments. As groundwater flows through the sediments, metals

such as iron and manganese were dissolved and may later be found in high concentrations in the water (Gemechu et al., 2019).

Water quality assessment was based on physicochemical analysis. The required water quality was determined by the purpose for which it was to be used (for domestic, urban, agricultural, or industrial) (Jamil et al., 2011). For each purpose there were different water quality standards to help monitor the quality of water sources. Standards were risk management strategies developed at national and regional level from the scientific basis provided in the guidelines (WHO, 2011). World Health Organization (WHO) provides the guidelines for drinking water the primary purpose of which was the protection of public health. The guidelines describe reasonable minimum requirements of safe practice to protect the health of consumers and derive numerical "guideline values" for constituents of water or indicators of water quality. A guideline value normally represents the concentration of a constituent that does not result in any significant risk to health over a lifetime of consumption (WHO, 2011)

The majority of population in developing countries like sub-Sahara countries have no access to clean water and sanitation services. Consequently, millions of people were suffering from diseases related to water, sanitation, and hygiene, such as diarrhea, skin diseases, and trachoma. Waterborne diseases were caused by the ingestion of water contaminated with human or animal faeces or urine containing pathogenic bacteria or viruses including cholera, typhoid, bacillary dysentery, adenoviruses, retroviruses, and other diseases (Ministry of Water, 2017). In addition, ground water derived from various sources may also contain dissolved inorganic and organic substances which could cause health problems to the community (Gonfa et al., 2019).

Ethiopia expects to have a substantial potential of groundwater resources that can be exploited for the economic development of the country. Currently water supply requirements of towns and rural communities were partially met from groundwater and there was an understanding that this huge resource can be further utilized for the development of irrigated agriculture activities in the country (Gemechu et al., 2019). Cognizant of these resources currently the Ethiopian Government was investing on

groundwater development activities in different groundwater basins in the country. Ethiopia was confronted with poor sanitation and drinking water infrastructure. About 52.1% of the population has been using unimproved sanitation facilities while 36% of them practiced open defecation (Gonfa et al., 2019). It was estimated that more than 60% of the communicable diseases were due to poor environmental health conditions arising from unsafe and inadequate water supply with poor hygienic and sanitation practices. Likewise, most health problems of children in the country were communicable diseases due to polluted water and improper sanitation (Girmay, 2010).

The problems of contamination of urban water distribution system were diverse. The major sources of water contaminants were mostly wastes from improper sanitation and agricultural and other activities that make their way to the water distribution networks (Gonfa et al., 2019). Furthermore, break in the distribution system, age and improper maintenance of the distribution system, and low level of chlorine usually compromise the integrity of the distribution system and quality of potable water.

Physicochemical parameters such as turbidity, pH, temperature, nitrate, and others were widely accepted as other critical water quality parameters for drinking water (Alemayehu, 2006). These parameters either directly influence microbiological quality or affect disinfection efficiencies and human health (WHO, 2011).

Several studies carried out in Ethiopia on the physicochemical and bacteriological quality of drinking water from various sources showed that water sources were contaminated with pollution indicators such as different chemicals, ions, physical, faecal and total coliforms (UNEP, 2003).

The groundwater quality was equally important as that of quantity (Gemechu et al., 2019). Mapping of spatial variability of groundwater quality was of vital importance and it was particularly significant where groundwater was primary source of potable water (Urgessa, 2018).

Ethiopia was one of the participant countries that decided the millennium development announcement with its main impartial of poverty reduction (Ministry of Water, 2017).

This resulted in prioritizing accessibility to improved drinking water quality (Oljira, 2015). Therefore, to achieve these goals, drinking water quality concerns were often the most important component for measuring access to enhanced water supply sources & 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).

Considering the above aspects of groundwater contamination and use of AquaChemin groundwater quality mapping, this study demonstrates to map the groundwater quality in North Showa Zone, Oromiya, Ethiopia. In the study area, the water supply for domestic purposes was mainly from ground water (WSUP, 2017). For example, the urbans water supply were from boreholes of ground water source. Other institutions like resorts, potable drinking water factories and textile factory were using boreholes for their domestic purposes as report of water and energy office of the zone.

1.2. Statement of the Problem

Lack of sufficient potable water access and the risk of water borne diseases were serious problem in the North showa (Ministry of Water, 2017; Gorail et al., 2013). Even though the human right to water specifies that water should be available continuously and in a sufficient quantity to meet the requirements of drinking, getting safe and sufficient water in the study area was unresolved society's problem. Supply needs to be continuous enough to allow for the collection of sufficient amounts to satisfy all needs, without compromising the quality of the water; but it was difficult to practice in the study area because of poor water supply infrastructures. While drinking water should be available in sufficient quantities at all times, it was unlikely that in the short term all residents can attain that level of service. Where services are unreliable or intermittent, households typically store water to ensure that it was available when needed. They may also restrict their consumption when water sources were far away, available only for a few hours a day or at certain times of the year, or out of service. According to North Showa Water, Mineral and Energy Office report; thirteen districts of the zone were used ground water even though its quality and quantity didn't meet the minimum requirement WHO (2011).

According to the resident of North Showa zone towns complaints, groundwater sources of water supply had the following problems: high scarcity of the water supply even though high potential amount of ground water in the study area, produces soap scum and consume larger amounts of soap; produces white mineral deposits on dishes more noticeable on clear glassware; reduces efficiency of devices that heat water, reducing the efficiency of heat transfer; Causes of diarrhea and related water borne disease on children; explosive and distortion of pipe; unsuitable test to drink and cooking; form red color on white objects and cloths; discoloration of tea, coffee and potatoes and dissolved substances forming sediment at bottom of a stand still container within an hour.

Generally it was important to evaluate the suitability of the ground-water quality for domestic and irrigational uses in the North Showa Zone to search alternatives treatment. Access of the potable water and the risk of water borne diseases were serious problem of public health concerns of Ethiopia (UNEP, 2003). Despite being a popular destination for both foreign and domestic investment, many residents in the zone still do not have household access to clean drinking water. This has caused mass protests to arise in Sululta in December 2015 and during the 2016 Ethiopian protests (Wikipedia, 2019). Therefore, north show was one of the area which mainly suffering from scarcity of sufficient water supply and water borne diseases (WSUP, 2017). This was mainly due to lack of proper study and continuous monitoring of water.

1.3. Rationale of the Study

The quality of the ground water was very important for different purposes of water. This study has justified the suitability of the physico-chemical properties of the ground water for domestic and irrigation purposes. Finally the benefiter of this study were North showa zone community, hospital, schools, different factory, college and universities. This research has provided baseline information on the water quality deteriorating factors for further study. It was also help planners and designers who are going to engage in the water and related activities of the zone and give them a clue for their future planning and implementation.

1.4. Objective of the Study

1.4.1 General Objective

The main objective of the study was to analysis hydro-geochemical properties of groundwater and to evaluate the suitability of groundwater for drinking and irrigation purposes in the North Showa Zone, Oromiya, Ethiopia.

1.4.2 Specific Objectives

The specific objectives of the study were:

➢ To determine the physical and chemical characteristics of ground water;

➢ To evaluate groundwater suitability for drinking and irrigation purposes;

➢ To classify water type of the study area using Aquachem 2011.1 and

➢ To check groundwater class using WQI.

1.5 Research Questions

1) What were the physico-chemical properties of the ground water was look like through the Zone?

2) Did the ground water quality fits the guide lines of WHO and Ethiopian for drinking and irrigation purposes?

3) What were the water type in the zone?

4) What were the class of the ground water (using WQI)?

1.6 Significance of the Study

Ground water can be contaminated by different pollutants such as nitrates, phosphates, heavy metals, and thus influencing its physicochemical parameters (Bisrat, 2015). People to exist on the earth surly need water priority giving to drinking of potable and palatable water from every source of water supply (Shiferaw, 2015). According to WHO (2011) guideline permissible limit to the use of water for different activities to keep human health and environment (Wondye, 2017). This study was focus on the hydro-geochemical analysis of ground water quality: to determine the correlation between variables, which types of parameter are dominant over quality of groundwater, to determine suitability of groundwater for domestic and irrigational uses.

Analyzing hydro-geochemical and identifying the types of dominant anions and cations was help full for the following purposes: to minimize health side effects due to unsafe water, to design alternative sources of water supply for future and search the basic causes of the problems to give remediation. Generally, this research was important to determine the quality in relation to chemical composition of groundwater for which it was intended to use. It was also important to identify major geochemical processes that cause change in quality of water.

Finally the benefiters of this study were: North Showa zone community, hospital, schools, different factory, colleges and universities. This research provided baseline information on the water quality deteriorating factors for further study. Therefore this study was very important; to identify the intensity of the water quality parameters and to suggest clue of the possible treatment process of groundwater. And also it may help planners and designers who are engaged on the water and related activities of the zone and give them a clue for their future planning and implementation.

1.7 Scope of the Study

Thesis work was focused on the determination of the groundwater suitability for drinking and irrigation uses of the North Showa zone. In the case of North Showa Zone the study was focus on the three important points. The first point was analysis of the suitability of groundwater's physicochemical parameters for drinking purposes of the following parameters: Temperature, turbidity, pH, EC, TDS, TS, TH, CO_3^{2-}, HCO_3^{-}, Cl^{-}, F^{-}, SO_4^{2-}, NO_3^{-}, Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}. The second important focus points was identifying and describing of hydro-geochemical facies groundwater type of the study area. The third important point was determination of groundwater suitability for irrigation indices which are: SAR, SSP, MH, %Na and PI.

1.8 Limitations of the study

This study was not cover all the area in the zone due to lack of complete data of wells. Lack of relevant material and compiled data access problems in the North Showa Zone water and energy offices. There may be parameters seasonal variation because study has been done during the rainy season. However, the researcher has spent a great deal of time within the study period to collect adequate data to maintain the quality of results.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Ground Water Resource

Ground water was resource found under the land surface in the saturated zone (Alemayehu, 2006). It constitutes about 95 percent of the freshwater on our planet (discounting that locked in the polar ice caps) (Shiferaw, 2015; UNEP, 2003). Most of the Earth's liquid freshwater was found, not in lakes and rivers, but stored underground in aquifers (Sridhan et al., 2017). These aquifers provide a valuable base flow supplying water to rivers during periods of no rainfall. Therefore it was an essential resource that requires protection.

Chemical analysis of groundwater includes the determination of the concentrations of inorganic constituent such as calcium, sodium, iron, and magnesium can have negative impacts on aquatic flora and fauna. Groundwater forms the common source of drinking, irrigation, and industrial purposes (Urgessa, 2018). However, its quality was getting deteriorated due to low rainfall and high evapo-transpiration. Most of the important freshwater bodies were getting polluted by anthropogenic activities and natural processes thus decrease the potability of water. The chemistry of groundwater depends on the number of factors which includes the nature of recharge, hydrologic gradient, residence time of groundwater in the aquifer, pollution by anthropogenic activities and rock–water interactions beneath the surface (Urgessa, 2018). From hydro geochemical point of view the deep groundwater was more mineralized due to long time interaction with the host rock (Alemayehu, 2006). The geochemical processes were responsible for the seasonal and spatial variation in groundwater chemistry. Hydro-geochemical processes such as dissolution, precipitation, absorption and desorption, ion exchange reactions and the residence time along the flow path which controls the chemical composition of groundwater, constitutes the other issues that were dealt with in hydro-geochemistry (Srinivas Rao, 2013).

2.2 Ground Water Occurrence

Groundwater may be found almost anywhere in the world and in almost all types of geological formations. However, its distribution in terms of quality and quantity varies from one place to another and from one geological formation to another (Fetter,

1994). There were at least three factors that influence groundwater occurrence: hydraulic properties of the geological formations, geological framework, and climate (Rubia, 2017).

2.2.1 Hydraulic Properties of the Geological Formations

Geological formations differ considerably in their ability to store and transmit water. Therefore knowledge of typical values of porosity and permeability of different geological formations was a prerequisite for successful groundwater exploration (Fetter, 1994). Virtually all groundwater originates as surface water and in order to reach the saturated zone, water must not only be available at the surface; it must also be able to infiltrate to the saturated zone (Freeze and Cherry, 1979). The availability of water at the surface depends on climate, while the infiltration rate depends on the thickness and permeability of the unsaturated zone as well as topography (Fetter, 1994).

2.2.2 Geological Framework

The occurrence, distribution, movement, and composition of subsurface waters were intricately linked to the structure and nature of the geological formations (Freeze and Cherry, 1979). One of the primary objectives of hydro-geological investigations was to identify geological formations and structures of importance for the occurrence of groundwater and understand the different types of geological formations, as well as the events that produce them and their fundamental properties (Fetter, 1994).

2.2.3 Hydro Geochemical Process

The chemical quality of water results from hydro geochemical processes of solution or precipitation of the solid minerals reduction and oxidation compounds, solution or evolution of gases, sorption or ion exchange, pollution, leaching fertilizes or manure, and mixing of different waters (Appelo and postman, 2005; Hounslow,1995). These processes were dependent on water and rock interaction, atmospheric input of chemicals by human activities, precipitation, geological structure, mineralogy of aquifers. The chemical quality of groundwater can influence the chemical composition of soils and rocks through which the water flows, depending upon the mineral dissolution, mineral solubility, ion exchange, oxidation, reduction (Rao et al., 2011). Chemical analysis of groundwater includes the determination of the concentrations of inorganic substances

including metallic constituents, pH and electrical conductance. The parameter determined under physical analysis methods also includes measurement of temperature, colour, turbidity, odour and taste (Adepoju-Bello et al., 2012). Geological formations provide major, minor and trace elements to the biological system (Klaassen, 2008). Concentrations of many trace elements vary much larger than variations in the concentrations of major components, often by many orders of magnitude (White, 2013). The concentration of trace elements in soil and groundwater are highly controlled by geological processes (Fowler et al., 2011). In rocks, they exist as their ores in different chemical forms. Trace elements were mainly concentrated in mineralized provinces associated with ore grade rocks (White, 2013). Geochemical provinces were part of earth crust in which chemical composition was significantly different from the average earth crust. Some elements can occur as both sulphide and also as oxide ores such as iron, copper and cobalt (Duruibe et al., 2007, White, 2013). The sources of geogenic (apatite, biotitic, and clays) and anthropogenic (chemical fertilizers), with a combination of higher rate of evaporation and longer interaction of water with the aquifer materials under alkaline environment, were the key factors for the concentration of F^-, NO_3^- was a non-lithological source (White, 2013).

In natural conditions, the concentration of NO_3^- does not exceed 10 mg/L in the water so that the higher concentration of NO_3^-, beyond 10 mg/L, was an indication of anthropogenic pollution. The concentration of bicarbonate in groundwater was determined by natural geological formation of an area. Mainly amount of bicarbonate was low in areas where marine clay occurs (Rao et al., 2011).

2.3 Ground Water Quality and Sources of Pollution

Groundwater quality was a hidden issue inside a hidden resource, and as a result far too little attention was given to it (Gemechu et al., 2019). Once groundwater has become polluted, it was usually a very long, complex and expensive task to restore the water quality. For these reasons that monitoring, prevention and remediation of groundwater pollution was a vital management issue (UNEP, 2003). The quality of water either it was surface water or ground water affected by both natural influences and human activities (Wondye, 2017; AWST, 2013). While water contains natural contaminants, it

was becoming more and more polluted by human activities such as, inadequate wastewater management, dumping of garbage, poor agricultural practices, and chemical spills at industrial sites (Girmay, 2010). Even though water may be clear, it does not necessarily mean that it was safe for us to drink. It was important to judge the safety of water by taking the following three types of parameters into consideration. The first parameter was physical-temperature, color, smell, taste and turbidity the second one was Chemical -minerals, metals, chemicals and pH and the last one was microbiological-bacteria, viruses, protozoa and helminths (worms), (Gemechu et al., 2019).

2.4 Physical Characteristics of Water Quality

It was very important to test the water before it was used for drinking, domestic, agricultural and industrial purposes. Water must be tested with different physicochemical parameters. Selection of parameters for testing water solely depends upon the purpose for what the study was going to use the water and to what extent we need its quality and purity. Water contains different types of floating, dissolved, suspended and microbiological as well as bacteriological impurities. According to WHO(1995) studies the physicochemical was quality which was used in reference to the characteristics of water which may affect its potability and palatability due to aesthetic considerations. The odour of substance can also influence temperature because of relationship between odour and vapour pressure, therefore odour measurement usually specify temperature (Urgessa, 2018).

2.4.1 Temperature

The temperature of water mainly determines the extent of microbial activity (Rubia, 2017). Temperature was the measure of hotness or coldness of water measured in either degree Celsius or Fahrenheit using a thermometer. When temperature of water becomes above 25°C, it cause bone disease (pain and tenderness of) children may get (WHO, 1997). Temperature was one of the important factors in an aquatic environment for its effects on the chemistry and biological reactions in the organisms. The change in atmospheric temperature with change in season brought corresponding changes in water temperature. The difference in atmospheric temperature and groundwater temperature were under the influence of high specific heat of water.

2.4.2 Total Dissolved Solids

Total dissolved solid was a measure of salinity that can have an important effect on the taste of drinking water. The palatability of water with a TDS level of less than 600 mg/L was generally considered to be good, while drinking water becomes significantly unpalatable at total dissolved solid levels greater than 1000 mg/L. Total dissolved solid comprise of organic matter and inorganic salts, which was originated from sources such as sewage, effluent discharge and urban runoff or from natural bicarbonates, chlorides, sulfate, nitrate, sodium, potassium, calcium and magnesium (WHO, 2006). High concentration of dissolved solids was usually not a health hazard. In fact, many people buy mineral water, which has naturally elevated levels of dissolved solids (Shiferaw, 2015). Most people think of TDS as being an aesthetic factor. However, a very low concentration of TDS has been found to give water a flat taste, which was undesirable (WHO, 2011). However, the presence of high levels of total dissolved solid in drinking water greater than 1200 mg/l may be objectionable to consumers. Water with extremely low concentrations of TDS may also be unacceptable because of its flat, insipid taste (WHO, 2006). TDS was related to other water quality parameters like hardness, which may occur if the high TDS content was due to the presence of carbonates (Urgessa, 2018). Water with TDS value above 1000mg/L can cause stomach discomfort (WHO, 2011).

2.4.3 Turbidity

Turbidity was an optical property of water that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample (Shiferaw, 2015). It was caused by the molecules of water itself, dissolved substances, and organic and inorganic suspended matter. Turbidity particles can be waterborne pathogens or particles harbouring them. The lower the turbidity, the less the amount of the particulate matter (Urgessa, 2018). The ability of a particle to scatter light depends on the size, shape, and relative refractive index of the particle and on the wavelength of the light (Srinivas Rao, 2013). Turbidity adversely affects the efficiency of disinfection of water. It was measured to determine what type and level of treatment were needed. It can be carried out with a simple turbidity tube that allows a direct reading in Nephelometric turbidity units NTU (WHO, 2006). It may also be due to the presence of inorganic particulate matter in some groundwater or sloughing of bio film within the distribution system (WHO, 2011). The

appearance of water with a turbidity of less than 5 NTU was usually acceptable to consumers. No health-based guideline value for turbidity has been proposed; ideally, however, median turbidity should be below 0.1 NTU for effective disinfection (WHO, 2006). Water with elevated turbidity was caused nausea, cramps, diarrhea and associated headache (Urgessa, 2018).

2.4.4 Total solid

Total solids" was the term applied to the material left in the vessel after evaporation of a sample of water/waste water and its subsequent drying in an oven at a definite temperature (Gemechu et al., 2019). Total solids include "total suspended solids" the portion of total solids retained by a filter and "total dissolved solids" the portion that passes through the filter. Fixed solids were the residue remaining after ignition for 1 hour at $550°C$ (APHA, 2005). The solid portion that was volatilized during ignition was called volatile solids. It may be mostly organic matter. According to (Rubia, 2017), the difference between the total solids and the total dissolved solids was give the total suspended solids.

2.4.5 Electrical Conductivity

Conductivity was the measure of capacity of a substance to conduct the electric current (Gemechu et al., 2019). Most of the salts in water were present in their ionic forms and capable of conducting current and conductivity was a good indicator to assess groundwater quality. EC was an indication of the concentration of total dissolved solids and major ions in given water body (Gonfa et al., 2019). It was temperature dependent and the international unit was Siemens per meter (Oljira, 2015). When the EC value of water becomes larger: Anaemia, liver kidney or spleen damage, changes in blood may be occur in the body of consumers (WHO, 2011).

2.5 Chemical Aspects of Drinking Water Quality

2.5.1 Calcium (Ca)

Calcium was one of the alkaline earth elements, fifth in abundance in the earth's crust (3%), reacts with water essential basic of bones and teeth. The most common compounds of calcium were limestone ($CaCO_3$), gypsum ($CaSO_4.2H_2O$), fluorite (CaF_2), hypochlorite ($Ca(ClO)_2$) and nitrate ($Ca(NO_3)_2$) (Abreham, 2016). The high concentration of calcium

ions can cause abdominal ailments and was undesirable for domestic use as it causes encrustation and scaling (Rubia, 2017).

2.5.2 Chloride (Cl)

Sometimes special significance was given to the chloride contents of water, particularly sodium chloride and was mainly obtained from the dissolution of salts of hydrochloric acid as table salt (NaCl), $NaCO_2$ and sources of chlorides were mainly from road salts, wastewater, storm sewers and animal feed (Oljira, 2015).Surface water bodies often have low concentration of Cl and were a home of main physiological processes. High chloride concentration demolition metallic pipes and structure as well as harms growing plants. Permitting to WHO guideline maximum permissible limits of the concentration of chloride should not exceed 250 mg/l. Chloride in excess imparts a salty taste to water, and people who were allergic to high chloride were subjected to laxative effects (Gonfa et al., 2019).

2.5.3 Fluoride (F)

Fluoride in drinking water was mainly due to the geogenic sources (Urgessa, 2018). Fluoride at low concentrations has a beneficial effects on teeth by preventing and reducing the risk of tooth decay (Rubia, 2017), whereas fluoride levels above 1.5 mg/l in drinking water can cause fluorosis (WHO, 2011).

2.5.4 Hardness

Hardness in groundwater was mainly due to the presence of divalent cation of calcium and magnesium (Oljira, 2015). It derived largely from the soil and rock formations. In general, hard waters originate in areas where the top soil was thick and limestone formations were present (Rubia, 2017).

2.5.5 Magnesium (Mg)

Magnesium was an essential element for human being, it was important for normal bone structure in the body (Gonfa et al., 2019). Water with high levels of magnesium or calcium was considered as hard and was undesirable for domestic purposes (Urgessa, 2018).

2.5.6 Nitrate (NO$_3$)

Nitrate concentration above the required limit causes methemoglobinemia (blue baby syndrome), gastric cancer, thyroid disease and diabetes (WHO, 2011; Rubia, 2017). Hence, increasing nitrate contamination seriously threatens public drinking water supply and human health (Urgessa, 2018). The main source of nitrate concentration in drinking water was anthropogenic activity (Gonfa et al., 2019).

2.5.7 Alkalinity

Alkalinity was due to bicarbonate, carbonate and hydroxides ions (Gonfa et al., 2019). The presence of acid substances was indicated by pH below 7.0 and alkaline substances by pH greater than 7.0. Acidic water was corrosive to metallic pipes. Alkalinity was the presence of one or more ions in water including hydroxides, carbonates, and bicarbonates. It can be define as the capacity to neutralize acid (Urgessa, 2018). Moderate concentration of alkalinity was desirable in most drinking water supplies to stable the corrosive effects of acidity. However, excessive quantities may cause a number of damages. The WHO standards express the alkalinity only in terms of total dissolved solids of 500 mg/l (WHO, 2011).

2.5.8 PH

The pH value of a water source was a measure of its acidity or alkalinity (Chilton, 1996). The pH level was a measurement of the activity of the hydrogen atom, because the hydrogen activity was a good representation of the acidity or alkalinity of the water (Oljira, 2015). The pH scale, ranges from 0 to 14, with 7.0 being neutral. Water with a low pH was said to be acidic, and water with a high pH was basic, or alkaline. Pure water would have a pH of 7.0, but water sources and precipitation tends to be slightly acidic, due to contaminants that were in the water (WHO, 2011). PH influences the taste and odour of a substance significantly, especially when it controls the equilibrium concentration of the neutral and ionized forms of a substance in solution (Gemechu et al., 2019). Although pH usually has no direct impact on consumers, it was one of the most important operational water quality parameters, the optimum pH required often being in the range 6.5–8.5 (WHO, 2006). When pH of water exceeds the maximum permissible limit 8.5, it cause rusting and causes cancer (WHO, 1997).

2.6 Bacteriological Aspects of Drinking Water Quality

The type and numbers of microorganisms present in the water determine the microbiological properties of water (Oljira, 2015). A diversity of microorganisms can be present even in very good quality domestic waters. Most of these microorganisms were harmless but if the water was, polluted pathogens may be present (Srinivas Rao, 2013). Pathogens were disease causing microorganisms such as those causing cholera, gastro enteritis, and hepatitis. Pathogen from the Greek words pathos, meaning suffering and gen, meaning to give rise to (WHO, 2011). It was difficult to determine the presence of all the different pathogenic organisms and therefore the presence of certain indicator organisms were used to give an indication of the possible presence of pathogens (Abreham, 2016). There were different types of indicator organisms. The most common indicator organisms used for domestic water quality assessment were total coliforms and fecal coliforms (Gemechu et al., 2019).

2.7 Ground Water Suitability for Irrigation

2.7.1 Sodium Adsorption Ratio

Sodium adsorption ratio (SAR) was a measure of the suitability of water for irrigation use, because sodium concentration can reduce the soil permeability and soil structure. SAR was a measure of alkali/sodium hazard to crops and it was estimated by the following formula (Gemechu et al., 2019).

$$\text{SAR} = \frac{Na^+}{\sqrt{((Ca^{2+}+Mg^{2+})\ x0.5)}}\text{---2.1}$$

Where:- SAR- Sodium Adsorption Ratio, $[Na^+]$- Sodium concentration, $[Ca^{2+}]$- Calcium Concentration and $[Mg^{2+}]$- Magnesium concentration in meq/l.

The SAR value of water for irrigation purposes has a significant relationship with the extent to which sodium was 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 (Urgessa, 2018). This was caused a decrease in the ability of the soil to form stable aggregates and loss of soil structure. This was also lead to decrease in infiltration and permeability of the soil to water leading to problems with crop production (Srinivas Rao, 2013).

2.7.2 Soluble Sodium Percentage

According to Wilcox (1948) percentage of sodium and electrical conductance were used in evaluating the suitability of groundwater for irrigation. The percentage of sodium was computed with respect to the relative proportions of cations present in water, where the concentrations of ions were expressed in meq/l using the formula as shown in equation below (Gemechu et al., 2019).

$$SSP = \frac{(Na^+ + K^+)}{(Ca_2^{2+} + Mg_2^{2+} + Na^+ + K^+)} * 100 \text{---2.2}$$

Where: - SSP- Soluble Sodium Percentage, Na^+- Sodium ion concentration, K^+- potassium ion concentration and Ca^+- Calcium ion concentration in mg/l.

Excess Na^+, combining with carbonate, leads to formation of alkali soils, whereas with 28 chloride, saline soils were formed. Neither soil was support plant growth (Urgessa, 2018). Generally, percent of Na^+ should not exceed 60% in waters intended for irrigation purpose (Rubia, 2017).

2.8 Groundwater Quality of Ethiopia

The groundwater quality of Ethiopia was both anthropogenically and naturally affected (Shiferaw, 2015;Alemayehu, 2006). According to (Gemechu et al., 2019) report the main quality controls were: Geomorphological and geographical conditions, climate, geology (geological structures, rock composition, weathering, magmatism, geothermal activities), physico-chemical factors (temperature, pressure, chemical properties of elements, solubility of chemical compounds, pH, EC), biological factors (effects of micro-organisms, plants and animals) and anthropogenic influences.

According to Girmay (2010) suggestions aquifers in Ethiopia were showing signs of increasing contamination by chemicals of nitrate. For example: the level of nitrate contamination in some areas, particularly the minor aquifers was observed to be above permissible limits as defined by local and international standards and its values were as high as 112mg/L have been observed. This was more than twice the WHO recommended maximum limit of 50 mg/L. At central part of Ethiopia the major aquifers (located in the south of Addis Ababa around Akaki-Kaliti areas) values as high as 24 mg/L

have been observed. This was considered to be lower than the maximum permissible value, but a steady rise has been observed (Girmay, 2010).

There were numerous sources of pollutants that could deteriorate the quality of water resources. In developing countries sources of pollution from domestic, agricultural, industrial activities were unregulated (Tamiru. et al, 2003). Similarly in Addis Ababa, where there was no as such environmental protection practice there were a number of pollutant sources that continuously deteriorate the quality of surface and ground water (Tamiru. et al, 2003). According to (Tamru, 2004) reports in the city of Addis Ababa the impact of human population on the surface and groundwater was increasing. The major sources of pollutants in the city are: industrial establishment, agricultural activities, municipal wastes, fuel stations, garages and health centers (Tamiru. et al, 2003). In the same way the AAWSA (2000) reports shows that the sources of pollution of ground water in Addis Ababa were categorized as: industries & factories, government & private institutions, pit-latrines & septic tanks, poor solid waste management, domestic animals, sewerage lines, wastewater treatment plant effluent and surface run-off.

2.9 Ground Water Vulnerability Mapping

Groundwater was vulnerable to contamination by anthropological activities and it was very difficult to remediate once contaminated. To properly manage and protect the resource, it was important to determine areas with more aspects of vulnerable to contamination (Jamil et al., 2011). Development of the vulnerability maps was useful for many aspects of water management, including prioritizing areas for monitoring, protection, and further investigation and the development of risk assessments, resource characterization, and education.

2.10 AquaChem Water Quality Database

AquaChem was a water quality database software package with functionality for graphical and numerical analysis (Urgessa, 2018); and its feature has a fully customizable database. According to Gemechu, (2019) reports; physical and chemical parameters and provides a comprehensive selection of analytical tools such as calculations and graphs for interpreting water quality data. AquaChem's data analysis capabilities cover a wide

range of functionalities and calculations including unit conversions, charge balances, sample comparison and mixing, statistical summaries, and trend analysis (Tsegaye, 2014).

CHAPTER THREE

3. MATERIAL AND METHODS

3.1 The Study Area

North Showa zone (Fitche) was found in Oromiya regional state located at distance of 115km to the north of Addis Ababa. The zone has a latitude and longitude of 1013070, 1009946 and 474421, 511748 respectively and with a highest elevation of 3012 meters above sea level (Wikipedia, 2019). Based on figures from the central statistical agency of Ethiopia in 1999E.C. the zone has an estimated total population of 1,431,305 of whom 717,552 are male and 713,753 were female. According to the North Showa zone Administration statistical report currently the total population was estimated around 2,100,000.

Figure 3:1 Map of the Study area (produced from GIS 2010.1)

Even though ground water quantity and quality was under question, in the study area it was the most common sources of water for domestic and irrigation in addition to surface water. This study was resolve the problem of the water insufficiency and quality which was not satisfied their need. The zone has surrounded by the chain of Rocky

Mountains that contributed to groundwater quality pollution by erosion and run off infiltration. Groundwater of the study area was almost mineral water because the zone covered by different rock types (MoFWR, 2011).

3.2 Study Period and Design

The study was carried out from the beginning of May, 2019 to end of Jan, 2020 and nineteen samples was taken from thirteen districts and towns sources for water supply. Sample water was transported to Abyssinia water factory and Gift water factory laboratory according to laboratory rule. The research was laboratory experiment based and all necessary laboratory experiments conducted in laboratory and field. Thus, the experimental research strictly adopted the scientific method in its investigation.

3.3 Sample Technique and Sampling Size

A total of 19 groundwater samples were collected from various locations of the study area as per the standard protocol prescribed by APHA (1995). The groundwater sample location point were delineated using Global Positioning System (GPS) model 60.
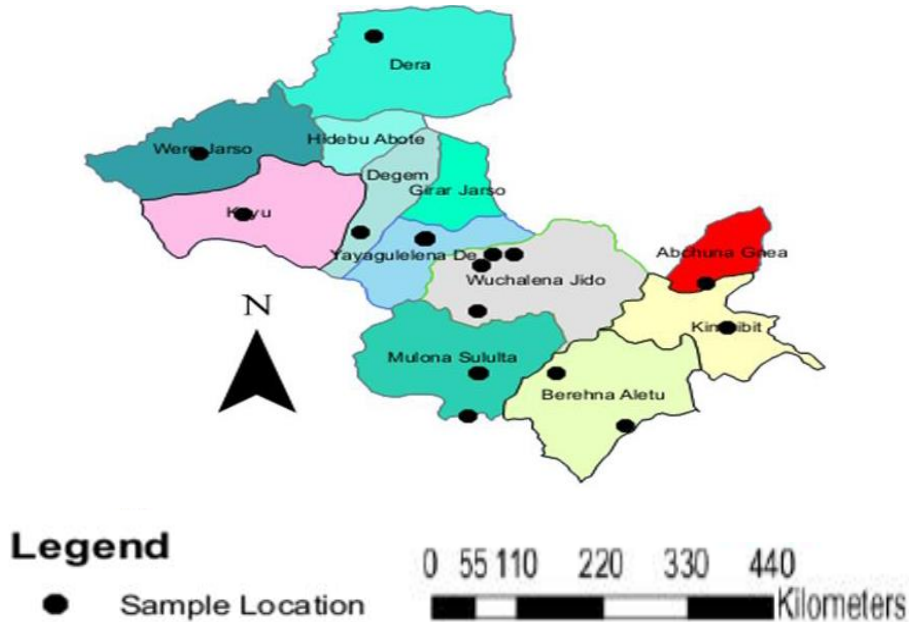
Figure 3:2 Sample Location Size

The sampling size was almost all cover the all districts as the result of community complaint due to unknown causes of groundwater quantity and quality problems.

Table 3.1 Global Positioning System (GPS) data of the samples

Station ID	Location	X	Y	Elevation	Sample Depth
SUL	Sululta	474421	1013070	2610	274
DT1	Tsige1	478945	1067822	2615	134.2
DT2	Tsige2	478624	1067342	2613	189.6
DLB	Libanos	479406	1065700	2627	162
MTR	Muka Xuri	479958	1066485	2657	141
FI1	Fiche1	479297	1067111	2617	135.65
FI2	Fiche2	478945	1067822	2745	145
FI3	Fiche3	478531	1067748	2622	155
JID	Jidda	504315	1055059	2640	170
DAG	Dagem	448582	1074022	2604	173
DAR	Dara	451628	1138627	2263	150
KIM	Qimbibit	535713	1042455	3012	147
YGL	Gulalle	477112	1062827	2574	120
KUY	Kuyyu	414526	1083262	2575	57.8
GJR	Girarjarso	463904	1071691	2726	65
WUC	Wucale	476321	1048046	2625	52.4
ABC	Abichu	532586	10725131	2685	114
WJR	Wara jarso	410272	1099803	2413	198.3
ALT	Alaltu	511748	1009946	2537	180

3.4 Geology of the Study Area

The major geology of the wells can be seen from the lithological log data of wells reports were: scoria, scoriaceous basalt, and basalt (WSUP, 2017). The geology and the Hydro geological setting of the area led to the genesis of void spaces, fractures and weathered zones of the aquifer systems for the main aquifers (Chapman, 1996). Fracture systems were secondary fractures related mainly to weathering and some tectonic fracturing. However, the primary porosity of the scoria and some pyroclastic has some contribution for the water storage and movement for this well. The well was stratified and confined aquifer though it has some leaky layers and thin layer of unconfined layer from top.

3.5 Soil Type of the Study Area

There were four types of soils in the study area on which crops grows annually. Theses soils were koticha (black vertisol soil), dalecha (grey soil), gembore (light soil) and key (red soil), Bathymetric Survey (2002). The dominant soil on this sub watershed according to woody biomass coding was again pellic vertisols and it covers 93% of the total sub watershed area. The remaining 7% was covered by orthic solonchakes (Gessese, 2008).

3.6 Human Activity of the Study Area

3.6.1. Farming

There were two farming system areas identified, lowland and highland. Lowland farming system was characterized by smaller land-labor ratio, livestock unit, share of pulse area, and higher share of large cereals. The majority of farmers in the lowland area cultivate sorghum, teff, millet and field pea. On the other hand, highland farming system was characterized by higher land-labor ratio, relatively higher number of livestock units, comparatively smaller share of large cereals and higher share of small cereals and pulses. Farmers in this farming system have grown wheat, teff, rough pea, horse bean and barley in that order of importance (Sulaiman, 2015).

Livestock activities in the farming systems were the production of cattle, small ruminants (sheep and/or goat) and pack animals. There were various interactions between crop and livestock activities, and they were closely integrated. Animals provide draft power for cropping activities. In turn, the crop sub-system provides feed to animals from crop by-product and residuals. Poor soils, unfavorable and often unpredictable climatic conditions, lack of improved technologies, poor management practices and low resource endowments were among the major constraints. Moreover, lack of suitable infrastructure, credit, input distribution and farmers' training and skill formation program have also contributed for the poor performance and low level of productivity.

3.7 Precipitation Trends

The climate condition of the study area was bounded between two seasons. According to metrological record the main rainy season ranges from May to the beginning of September and the dry season ranges from December to April. The weather was cold during rainy season at highland and medium at low land, where as hot during dry season. The tempera

was hot in winter season during day and cold during night time. The study area was found semi humid climate zone.

3.8 Ground Water Extraction Extents

In the study area the use of ground water highly monopole by private industries for bottled water marketing. Especially Sululta town was known as "boomtown" that welcomes water firms while local society remains thirsty. In the zone there has been investment in boreholes and pumps, but mostly by the private sectors such as Abyssinia Springs in which Nestle, Classy water company, Arki water company, Gift water company, Selam RMY water, Today water were owned by private investors.

3.9 Sampling Procedures

Water samples were collected early hours in the morning. This was to ensure that the water would not been disturbed much through pumping which can affect the temperature and content of total dissolved solids. All plastic bottles were cleansed with warm water and soap then rinse with distilled water three times. Water samples for microbial analysis were collected with 1000mL plastic bottles and holding in black box to prevent bacterial contamination. For wells, the mouth of the metal pipe was cleaned before taking samples. Sample bottles for physicochemical, metal analysis were rinsed with some of the borehole water and then completely fill to capacity leaving no air space and immediately cover. The cover of the container was sealed with masking tape. Water samples were collected from pumping wells after minimum of several minutes of purging prior to sampling. This was done to remove groundwater stored in the well. Water quality parameters such as temperature, pH, electrical conductivity, TS and TDS were analyzed immediately by using portable multi parameter probe (HQ40d Model). Each sample of groundwater was collected and was filtered with 0.45 μm filter membrane into an individual clean 1000mL plastic water bottle.

For metal Ca^{2+}, Mg^{2+}, Na^+ and K^+ 10% of nitric acid solution has immediately added to the water samples for heavy metal analysis reducing the pH to less than 2. This is to dissolve the metals in the water samples and prevent it from adhering to the inner surface of the bottles. Water samples were taken to the laboratory in cool box with ice and was

analyzed within 6hours. Samples meant for metal analysis were stored in a refrigerator at 4^0C.

3.10 Study Variables

3.10.1 Independent Variables

Physical parameters:-Temperature, Electrical conductivity, TDS, TS and Turbidity

Chemical parameters:-Total alkalinity, pH, Total hardness, Sodium, Potassium, Fluoride, Bicarbonate, Carbonate, Nitrate, Chlorine, and Sulfate ions.

3.10.2 Dependent Variables

Groundwater was suitable.

3.11 Instruments and Apparatus

The apparatus used for the experiments were: evaporating dishes, analytical balance, beaker, graduated cylinder, standard flasks, funnel, wash bottle, forceps, burette, pipette, pipette bulb, dish tongs, gooch crucibles, filter, vacuum pumps, crucible tongs, measuring cylinders, conical flasks, drying oven, desiccators, pH meter with a combination of pH electrode and temperature compensation probe, Spectrophotometer, AAS, conductivity meter, burettes and stand, autoclave, fume hook, Petri dish, filter unit, incubator and photo cameras instruments were precisely used.

3.12 Data Quality Assurance and Quality Control

Proper quality assurance procedures and precautions were have been taken to ensure the reliability of the results to (APHA, 1995). Data quality assurances were has been analyzed carefully and triple measurements had performed per one task using calibrated instruments to assure quality of the data. In order to minimize error, samples were taken three times, measurement was also perform three times alone, mean value ± standard deviation (x± SD)was taken both for field based, and laboratory based measurements. While analysis data quality was assured by replicating data and taking the average of all results. For the sake of data quality assurance Ion Balance Error (IBE) was calculated and samples whose IBE > 5% was discard.

$$IBE = \frac{\sum Cation - \sum Anion}{\sum Cation + \sum Anion} * 100 \text{---3.1}$$

Where: - IBE- Ion Balance Error

3.13 Assessment of Salt Water

Salt water contamination may be identified by the relative concentration of some of the characteristic ions of sea water such as chlorides, sodium and magnesium (Gemechu et al., 2019). The second parameter suggested for identification of salt water contamination was total alkalinity/total hardness ratio (TA/TH) (Srinivas Rao, 2013). An excess of TA over TH indicated the presence of sodium bicarbonate. In case water show the existence of free sodium bicarbonate (TA/TH = 1), it may be presumed that the waters might not have been contaminated with sea water since the sea water are full of sodium chloride and sulphate of calcium and magnesium. The third parameter that recommended for identification of salt water contamination was Ca^{2+}/Mg^{2+} ratio, since magnesium was present in seawater in much greater concentration than calcium. Ca^{2+}/Mg^{2+} value of seawater was 0.18 (Srinivas Rao, 2013). The fourth parameter was Cl^-/Na^+ ratio. However, these parameters were to be adjudged carefully in the light of variable country rocks which also contribute to the anomalies in the ratios (Gemechu et al., 2019).

3.14 Data Processing and Analysis

The groundwater suitability was evaluated on the bases of the physicochemical characteristics. Water quality for drinking purpose was analyzed comparing the physicochemical parameters of the water sample with Federal Ministry of Water Resources (FMoWR) of Ethiopia (Federal Ministry of Water Resources, 2002) and WHO (World Health Organization, 2006) guideline values (Sridhan et al., 2017).

Most of the irrigation activities in the study area depended on the groundwater. The concentration and composition of dissolved substances in the water determines the suitability of the water for agricultural uses (Matheus, 2008). Salinity, Sodicity and related parameters were considered to evaluate the suitability of the groundwater for irrigation use (Gebrerufael et al., 2019). Water salinity was assessed using electric conductivity whereas water sodicity of the area was assessed by sodium percent (Na %) and Sodium absorption ratio (SAR). Salinity and sodium hazards of the study area were also assessed based on the salinity classification standard of the US Department of Agriculture diagram or Wilcox plots (Wilcox, 1955). The characteristics of water most important in determining its quality for irrigation purpose were: total concentration of

soluble salts; relative proportion of Na^+ to other cations; and other elements that may be toxic (Ali, 2017).

The characteristic ratios of North Showa zone hydrogeochemical irrigational indices were (Table 4.4). These ratios like Sodium Absorption Ratio (SAR), Soluble Sodium Percentage (SSP), Percent Sodium (%Na), Permeability Index (PI), Magnesium Hazard (MH), salinity index and Sodicity index were help to evaluate the groundwater quality for the irrigation purposes (Ali, 2017); and water type were identified by using Aquachem 2011.1 (Waterloo hydrologic - Canada), ArcGIS 10.3 (Esri, Redlands, California, US) and Microsoft Excel 2010 software were used as tools to analyze and present the data. The results of the study were presented in numerical values, tables and figures.

3.14.1. Sodicity Index

Groundwater with a high Na^+ concentration was not suitable for irrigation (Gebrerufael et al., 2019). High Na^+ deposition deteriorates soil characteristics. The SAR was commonly used to assess irrigation water suitability (Singh et al., 2012). It determines the degree to which Na^+ has been absorbed by the soil. Sodicity indices were calculated using SAR, computed using equation below. The Na^+, Ca^{2+} and Mg^{2+} concentrations were expressed in meq/L. The SAR predicts the Na^+ hazard of high carbonate waters, especially if they contain no residual alkali (Rao, 2006). Concentration were also very important in classifying irrigation water.

$$SAR = \frac{Na^+}{\sqrt{0.5(Ca^{2+}+Mg^{2+})}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.3.2$$

Where:- SAR- Sodium Adsorption Ratio, [Na+]- Sodium concentration, [Ca2+]- Calcium concentration and [Mg2+]- Magnesium concentration in meq/l.

Table 3.2 Classification of Ground water using SAR

No.	SAR	Class	Conditions
1	<3	I	No Na^+ problem
2	3 to 6	II	Few problems except with Na^+ sensitive crops
3	6 to 8	III	Medium Na^+, increasing problems
4	8 to 14	IV	Not generally recommended
5	>14	V	Disregard, very high Na^+, unsuitable

3.14.2 Soluble Sodium Percentage (SSP)

According to Wilcox (1948) percentage of sodium and electrical conductance were used in evaluating the suitability of groundwater for irrigation. The percentage of sodium was computed with respect to the relative proportions of cations present in water, where the concentrations of ions were expressed in meq/l using the formula as shown in equation below(Gemechu et al., 2019).

$$SSP = \frac{(Na^+ + K^+)}{(Ca_2^{2+} + Mg_2^{2+} + Na^+ + K^+)} * 100 \text{--3.3}$$

Where:- SSP- Soluble Sodium Percentage, Na^+- Sodium ion concentration, K^+- potassium ion concentration and Ca^+- Calcium ion concentration in mg/l.

The SSP values of < 50 indicate good quality and if it was more than 50% it indicates the unsuitable water quality for irrigation purpose (Gemechu et al., 2019).

3.14.3 Percent sodium (%Na)

Sodium concentration was important parameter in classifying irrigation water because sodium reduces the permeability of soil. Excess Sodium in water was responsible in changing soil properties and reducing soil permeability (Kelley et al., 1951). In all natural waters percent of Sodium content was a parameter to evaluate its suitability for agricultural purposes. Wilcox (1948), Sodium combining with carbonate can lead to the formation of alkaline soils, while sodium combining with chloride forms saline soils. Alkaline as well as saline soils do not help the plants for their growth (Richards et al., 1969).

$$\%Na = \frac{(Na^+)}{(Ca_2^{2+}+Mg_2^{2+}+Na^++K^+)} * 100 \text{---3.4}$$

Where, the quantities of Ca^{2+}, Mg^{2+}, Na^+, and K^+ are expressed in mill equivalents per liter (meq/L). When the concentrations of sodium were high in irrigation water, sodium ions tend to be absorbed by clay particles, displacing Mg^{2+} and Ca^{2+}, ions. This exchange process of Na^+ in water for Ca^{2+} and Mg^{2+} in soil would reduce the permeability and eventually give rise to soil with poor internal drainage. Hence, air and water circulation was restricted under wet conditions and such soils was become usually hard when dry. According to (Wilcox et al., 1955) percent sodium <20 were excellent, 20-40 were good, 40- 60 were permissive, 60-80 were doubtful, >80 were unsuitable.

3.14.4 Permeability Index

The Permeability Index (PI) values also indicate the suitability of groundwater for irrigation, as the soil permeability was affected by long term use of irrigation water, as influenced by Na^+, Ca^{2+}, Mg^{2+} and HCO_3^- contents of the soil. Doneen (1964) evolved a criterion for assessing the suitability of water for irrigation based on a Permeability Index (PI) and waters can be classified as class I, class II, and class III. Class I water was categorized as good for irrigation with 75% or more maximum permeability class II which are 25-75 good permeability , and class III water was unsuitable with less than or equal 25% of maximum permeability (Doneen,1964). Permeability Index (PI) can be written as follows.

$$PI = \frac{(Na^++\sqrt{HCO3^-})}{(Ca^{2+}+Mg^{2+}+Na^++K^+)} * 100 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots3.5$$

Where: - PI – permeability index, Na^+- Sodium ion concentration; K^+-, potassium ion concentration and Ca^+- Calcium ion concentration in mg/l.

3.14.5. Magnesium Hazard (MH)

Mg^{2+} was an important parameter in determining the water quality for agricultural uses. All the sample Lab. results were compared with the acceptable limit of the Mg^{2+} ratio limit of 50% (US Salinity Laboratory Staff, 1954). High Mg^{2+} content in water unfavorably affects crop productivity as the soil becomes more saline. In general, Ca^{2+} and Mg^{2+} maintain a state of equilibrium in most waters. MH value was proposed to evaluate water for irrigation

(Rao, 2006), which can be calculated as a percentage using Eq. (3.4), where all the ions were expressed in meq/L.

$$MH = \frac{Mg^{2+}}{Ca^{2+}+Mg^{2+}} * 100 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.3.6$$

Where: - MH was magnesium hazard, Mg^{2+}- magnesium ion concentration and Ca^{2+}- calcium ion concentration in mg/l.

3.15 Water Quality Index (WQI)

Water quality index (WQI) was an exceptionally valuable tool for evaluating the overall quality of water (Ashiyani, 2012). It reduces the large number of data into single value and facilitates easy understanding of the information. WQI was utilized to determine the suitability of the groundwater for drinking purposes (Nafyad, 2018). The following steps were involved in WQI determination.

Weightage factor (Wi) in first step weight (wi) was assigned to each parameter as per its relative significance in the water for drinking purposes. The weightage factor was calculated by following equation:

$$Wi = \frac{wi}{\sum_{i=1}^{n} wi} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots..\dots\dots\dots\dots3.7$$

Where: - Wi was the relative weight, wi was the weight of each parameter and n was the number of parameter.

To compute WQI, assigning of a weight for each groundwater meters (w_i), computing of relative weight (W_i) and quality rating scale (q_i) were needed. Thus, w_i were assigned for pH, TDS, EC, Ca^{2+}, Mg^{2+}, Na^+, K^+, HCO_3^-, Cl^-, SO_4^{2-}, PO_4^{3-}, NO_3^- and F^-. The assigned w_i values for each groundwater parameters were shown (Table 3.3). Weighted values were assigned according to relative significance of groundwater parameter in drinking water quality (Bisrat, 2015). The highest weight of 5 was assigned to parameters which have the major effects on water quality. Total dissolved solids, NO_3^- and F^- were assigned the highest weight because of their importance in the water quality assessment (Ashiyani, 2012). Chloride was given the minimum weight of 1 as it plays an insignificant role in the water quality assessment. Other parameters like pH, total dissolved solids, calcium, magnesium, total hardness and sulphate were assigned weight between 1 and 5 depending on their importance in water quality determination. Thirteen physico-chemical parameters

in mg/l (n =13) were used in this calculation. Computed W_i values for groundwater parameter were presented in Table 3.3.

Table 3.3: The assigned weight and relative weight for each parameter

Parameters	Min	Max	Average	STD	WHO(2011)	Weight (wi)	Relative Weight(Wi)
PH	7.17	8.85	7.69	0.453499	7.5	4	0.10
EC	145.7	507	333.82	97.99176	1000	4	0.10
TDS	103.9	290	200.97	59.89011	500	5	0.13
Ca2+	5.32	153	40.38	31.46169	75	2	0.05
Mg2+	0.91	37	8.7	7.66481	50	2	0.05
Na+	8	50.5	31.32	14.8174	200	3	0.07
K+	0.6	8.2	3.16	2.062204	12	1	0.03
Cl-	1.95	59	14.68	12.09251	250	1	0.03
HCO3-	51.24	248.51	169.49	59.56733	120	3	0.07
SO42-	0.01	45.21	14.44	12.80722	250	3	0.07
NO3-	0.01	19	3.41	5.182295	50	5	0.13
F-	0.03	1.6	0.46	0.340933	1.5	5	0.13
PO42-	0.002	1.15	0.2	0.253377	10	1	0.03
						$\sum wi=39$	$\sum Wi=1$

For calculating the WQI, sub-index was first calculated for each parameter by using the following equation.

$$SIi = Wi * qi \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.3.8$$

Where SI_i was the sub index of ith parameter, q_i was the rating based on concentration of $_i$th parameter and n was the number of parameters. The overall water quality index (WQI) was figured by adding together each sub index value of each groundwater sample as follows (Ramakrishnaiah et al. 2009; Sadat-Noori et al. 2014).

Quality rating (qi)

The quality rating is calculated by following equation:

$$qi = \frac{ci}{Si} * 100 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.3.9$$

Where: - Ci was the concentration of each chemical parameter in each water sample in mg/l, C_i was the ideal value of the parameter in pure water and, Si was the standard value. After all this calculation WQI was calculated by substituting all parameters as the following formula.

$$WQI = \sum SIi \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.10$$

Computed WQI values were classified into six categories excellent, good, moderate, poor, very poor and unsuitable for human consumption.

Table 3.4. Classification of Groundwater quality according to WQI range

WQI Range	Type of water
< 35	Excellent
35 – 45	Good
45 – 55	Moderate
55 - 65	Poor
65 - 75	Very poor
> 75	Not suitable for drinking water

General procedure of data analysis methodology was described here.

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┌─────────────────────────────┐
│       Data collection       │
└─────────────────────────────┘
              │
┌─────────────────────────────┐
│    Collecting Ground water  │
│  sample from each well and GPS │
│           location          │
└─────────────────────────────┘
              │
┌─────────────────────────────┐
│ Physico chemical determination of Ground water │
│           sample            │
└─────────────────────────────┘
              │
┌─────────────────────────────┐
│        Data Analysis        │
└─────────────────────────────┘
              │
┌─────────────────────────────┐
│ Suitabilty Of Ground Water Quality │
│  For Drinking And Irrigation │
│          Purposes           │
└─────────────────────────────┘
┌─────────────────────────────┐
│       Using AquaChem        │
└─────────────────────────────┘
┌─────────────────────────────┐
│      Water clasify and      │
│ Generation of Spatial distribution │
│            Maps             │
└─────────────────────────────┘
┌─────────────────────────────┐
│    Result and Discussion    │
└─────────────────────────────┘
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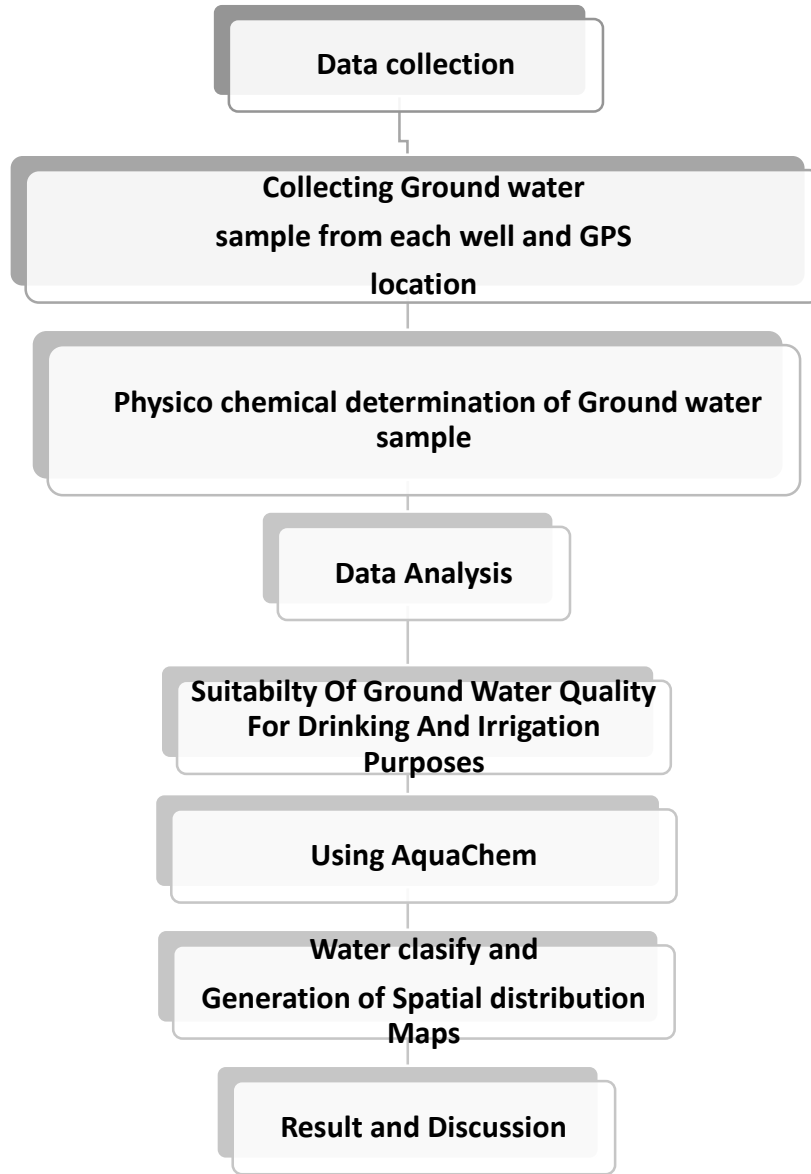Fig 3.3 Flow chart of data processing and analysis procedure

3.16 Aquachem 2011.1

AquaChem was a software package developed specifically for graphical and numerical analysis and modeling of water quality data (Wilox, 2011). It features a fully customizable database of physical and chemical parameters and provides a comprehensive selection of analysis tools, calculations, and graphs for interpreting water quality data.

AquaChem's data analysis capabilities cover a wide range of functionalities and calculations including unit conversions, charge balances, sample comparison and mixing, statistical summaries, trend analyses, and much more. AquaChem also comprises a customizable database of water quality standards with up to three different action levels for each parameter. Any samples exceeding the selected standard are automatically highlighted with the appropriate action level color for easily identifying and qualifying potential problems.

These powerful analytical capabilities were complemented by a comprehensive selection of commonly used plotting techniques to represent the chemical characteristics of water quality data. The plot types available in AquaChem include: Wilcox, Depth Profile, Summary plots, Box and Whisker, Single sample plots and Modeling program PHREEQC for calculating equilibrium concentrations (or activities) of chemical species in solution and saturation indices of solid phases in equilibrium with a solution.

Each of these plots provides a specific interpretation of the many complex interactions between the groundwater and aquifer materials, and identifies important data trends and groupings.

3.17 Plan for Dissemination

The result of this study will be presented to Jimma Institute of Technology Faculty of Civil and Environmental Engineering, Environmental Engineering chair and will be disseminated to North Showa zone and other governmental and non-governmental organizations, which are concerned with the study findings. Publication in national and international journals will also be considered.

4. RESULTS AND DISCUSSION

4.1 Physical Parameters

4.1.1 Turbidity

In this study area, the turbidity values of groundwater samples ranged from 0 to 9.07 NTU and with a mean value of 1.433 NTU (Table 4.1). The maximum value that recorded at sample site of Dagem district and the minimum values were recorded at site SUL, DT1, DT2, DLB, MKT, FI1, FI2, FI3,JID, KIM and YGL. The turbidity (Figure 4.1) of the study area were nearly below (WHO, 2004) guide line of 5NTU. Turbidity in the Dagem districts water samples was caused by suspended and colloidal matter, such as clay, silt, finely divided organic and inorganic matter, plankton and other microscopic organisms according to (APHA, 2005). Generally the turbidity of the ground water in the study area was below the WHO 2006 and FMoWR guidelines and it was suitable for water supply usage.
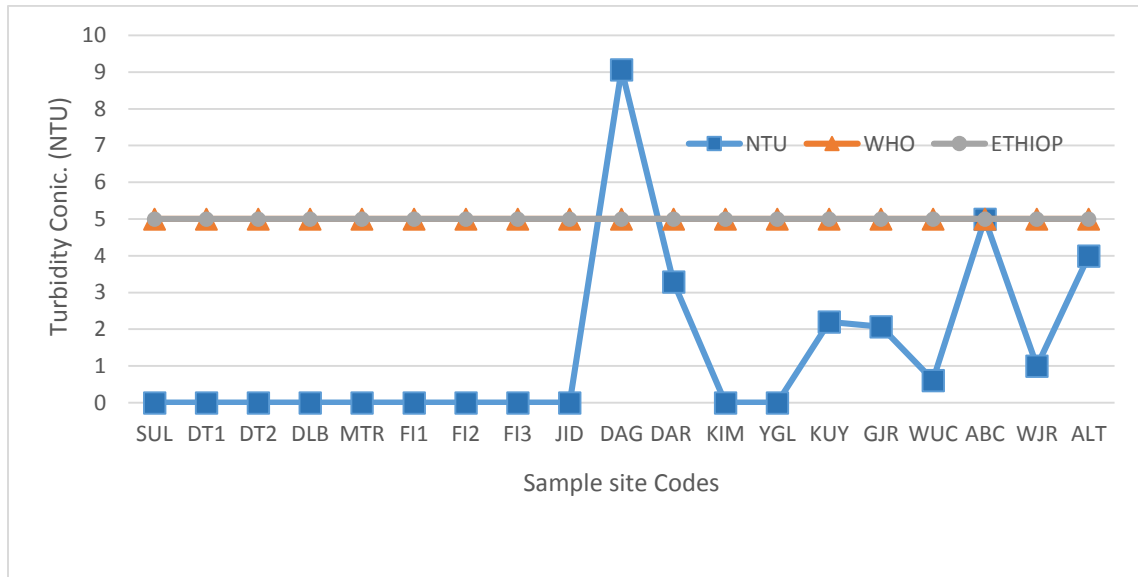
Figure 4.1: Variation of turbidity on samples area

4.1.2 Total solid (TS)

The minimum value of TS recorded was 132 mg/L for a sample location of MTR and maximum value recorded was 298 mg/L for a sample site FI2 with average value of 215 mg/L. TS result at all location samples were below WHO and FMoWR guide lines (Table

4.1). Generally the water from the study area is suitable for drinking and domestic purpose in case of total solid tests because, of low concentrations of inorganic minerals and organic compounds.
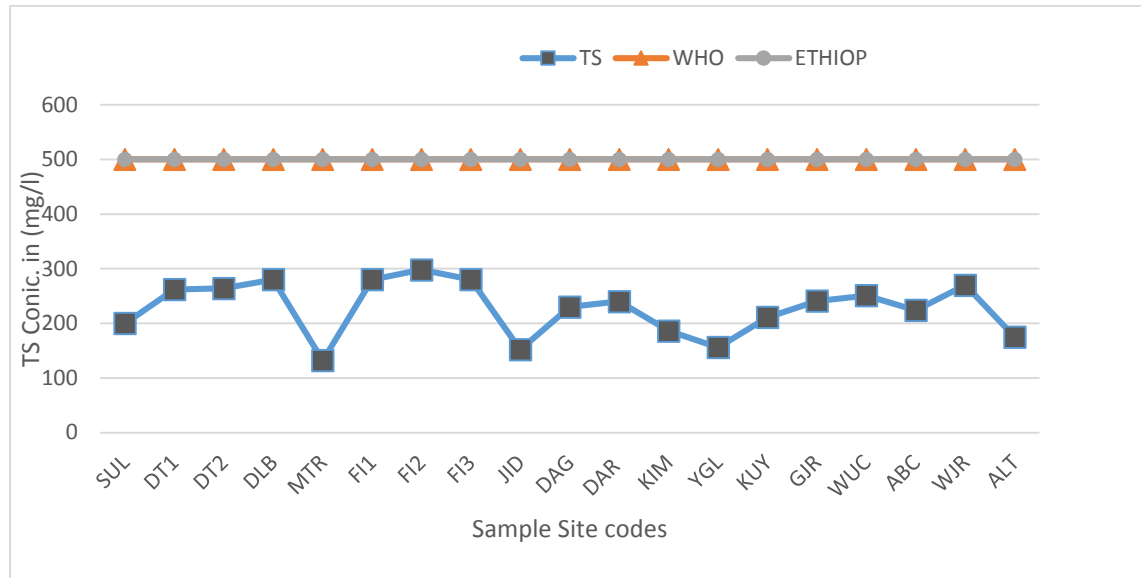
Figure 4.2: TS of the study area

4.1.3 Total Dissolved Solids

The total dissolved solid values of the samples were varied between a minimum 103.9mg/L and a maximum of 290mg/L with a mean value of 201 mg/L (Table 4.1). The highest TDS (290 mg/L) was recorded for a sample FI2 and the lowest (103.9 mg/L) was observed for a sample KUY (Figure 4.3).

The magnitude and direction of the total dissolved solid difference between two waters, affects the ability to discriminate based on taste. TDS of the study area were below the limiting guide line of (WHO, 2011). Based on this factors ground water samples of the study area were suitable for drinking and domestic, purposes (Dietrich et al., 2013).
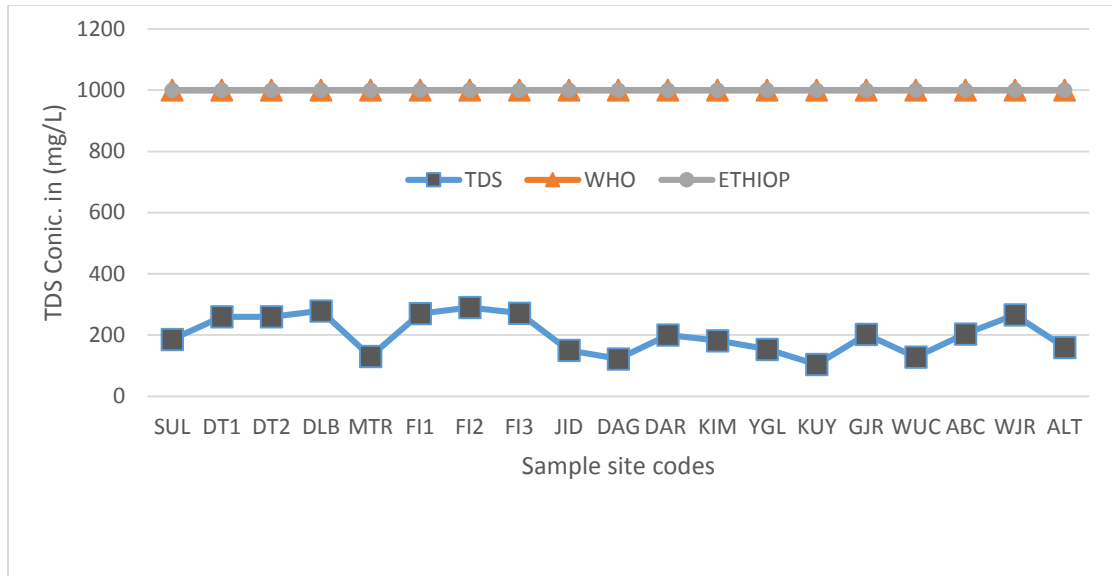
Figure 4.3: TDS of the study area

4.1.4 Electrical Conductivity

The electrical conductivity of groundwater samples ranges from 145.7μS/cm to 507 μS/cm with a mean value 334μS/cm (Table 4.1). The highest EC (507μS/cm) was observed for a sample DLB and the lowest EC (145.7μS/cm) was observed for a sample KUY (Figure 4.4). Lower EC in the study area indicates the low enrichment of salts in the groundwater. Water samples of the study area were suitable for drinking and irrigation because of low conductivity recorded for all sample sites which were not exceed 1000μS/cm standard. The average value of the samples EC was below recommended (WHO, 2011).

Electrical conductivity in groundwater was affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). As soluble salt levels decrease, plant utilization of soil water often inclines. Ground water of the area was suitable for drinking and no needs optimal treatment of steam distillation, ion exchange and reverse osmosis for reducing TDS and conductivity levels (Camberato et al., 2001).
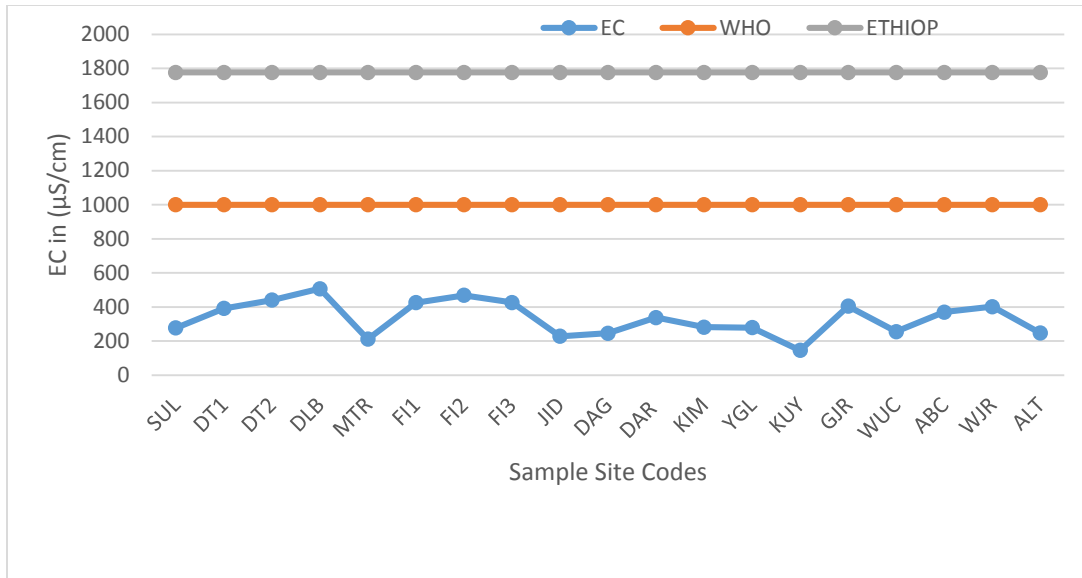
Figure 4.4: EC of the study area

4.1.5 PH

In present study pH concentration was ranges from 7.17 to 8.85 which shows that it was within the permissible limit except for a samples location of JID and ALT. The pH of the groundwater was within permissible value of 6.5–8.5 (Federal Ministry of Water Resources, 2002; World Health Organization, 2006). The pH of most of the groundwater samples were nearly neutral and about 89.47% of the samples have pH less than 8.5 which indicates the absence of carbonate in the water and this could indicate that the area was discharge area. The result clearly shows that the groundwater in the study area was nearly in the recommended intervals of (WHO, 2004).
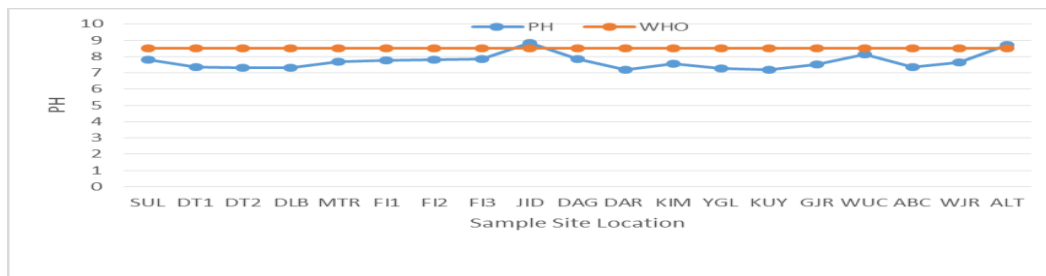
Figure 4.5: PH of sample area

The minimum values pH of samples DAR 7.17 which was within the standard limit. The elevated value of pH of these water samples may be due to the alkalinity nature of the

rock that contain elevated concentration of dissolved iron in the strata from which water originates.

4.2 Chemical Parameters

4.2.1 Total Hardness

The total hardness values of groundwater samples area were varied from 17.1 mg/L for a sample location MTR to 200 mg/L for a sample location DT2 and with a mean value of 108.55 mg/L(Figure 4.6). This result indicate that ground water of the study area was suitable for domestic purposes. Hardness, which occurs naturally in water, is an aggregate parameter that was the sum of aqueous divalent cations. Calcium and magnesium were the major divalent cations in natural fresh waters, and hence the major ions in hardness. Total hardness was the sum of calcium hardness and magnesium hardness as calcium carbonate.
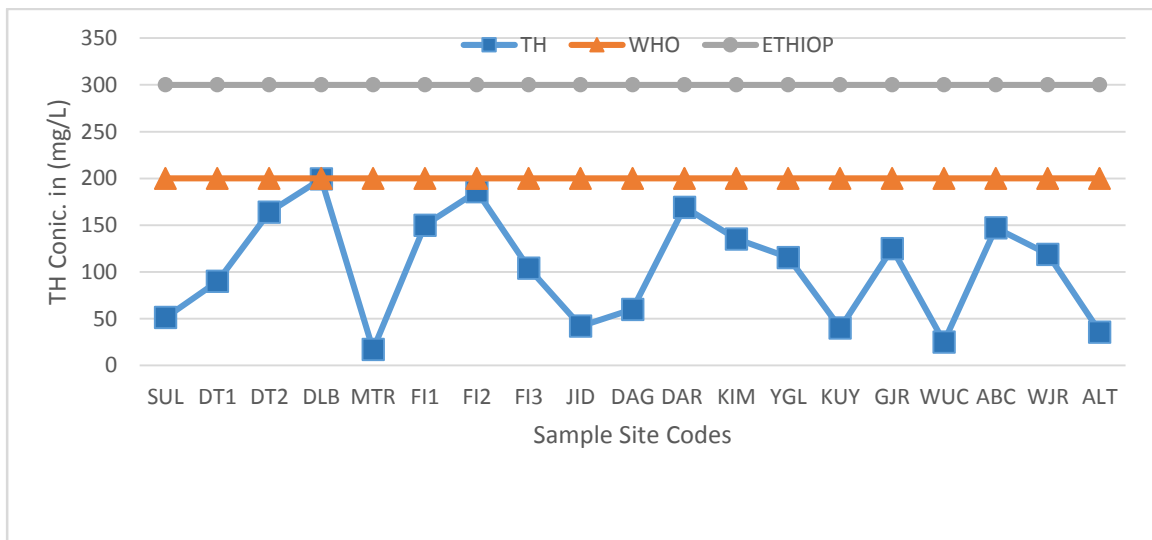
Figure 4.6: Total hardness of sample area

According to the potability of drinking water set by WHO standard, the maximum permissible limit should not be exceeded 200 mg/L and hardness values >200 mg/L of $CaCO_3$ were acknowledged to cause scale formation, and thus the WHO (2011) established aesthetic guidelines at 200 mg/L $CaCO_3$. As it was groundwater sources of water supply have low concentrations of: turbidity, TDS, EC, and TS as observed in the laboratory results. These indicate that, ground water of the study area was suitable for domestic and irrigational uses.

4.2.2 Total Alkalinity

The total alkalinity of the study area was varied from 70 mg/L for a sample of WUC to 203.7 mg/L for a sample of DLB and with mean value of 136.85mg/L (Figure 4.7; Table 4.1). Alkalinity was a measure of the capacity of water to neutralize acids. Alkalinity measures the concentrations of bicarbonate, carbonate, and hydroxide ions and was expressed as an equivalent concentration of $CaCO_3$. According to the potability of drinking water set by WHO (2011) standard, the maximum permissible limit should not be exceeded 200 mg/L of $CaCO_3$. These results show that at all points of sample taken, the values of total alkalinity lay below the limit of the (WHO, 2011) maximum permissible limit except at points DLB and FI2 which were little above the limit.

High alkalinity above 200 mg/L was usually associated with high pH values, hardness and high dissolved solids and has adverse effects on plumbing systems, especially on hot water systems (water heaters, boilers, heat exchangers) where excessive scale reduces the transfer of heat to the water, thereby resulting in greater power consumption and increased costs (Khawaji et al.,2008). The sources of alkalinity were: pipes, hazardous waste landfills. Generally 89.45% of the ground water samples of the study area was below the permissible limit of the WHO and FMoWR guidelines. Hence it was suitable for drinking and domestic usages.
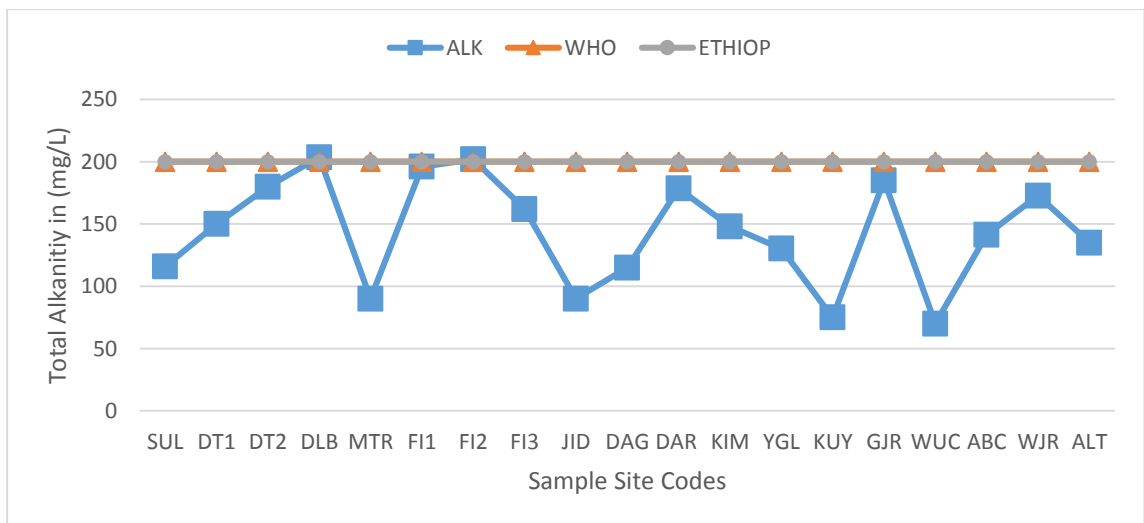
Figure 4.7: Total Alkalinity of study area

4.2.3 Calcium (Ca^{2+})

Calcium concentration of study area varied from 5.32mg/L for a sample of MTR to 153mg/L for a sample of GJR with a mean of 40.38mg/L (Figure 4.8). Calcium concentration for a sample point of GJR which was sources of water supply for the town was 153mg/L above (WHO, 2004) guide line value (Figure 4.8). The high concentration of calcium ions can cause abdominal ailments and was undesirable for domestic use as it causes encrustation and scaling (Kumar et al. 2014). The desirable limit of calcium concentration for drinking water was specified as 75mg/L (WHO, 2004). The high deficiency of calcium in humans may cause rickets, poor blood clotting, bones fracture etc. and the exceeding limit of calcium produced cardiovascular diseases (Magesh et al., 2012). The result shows that, 5.26% of the total sample study area were above the permissible limiting values and almost the ground water was suitable for drinking and domestic purposes.
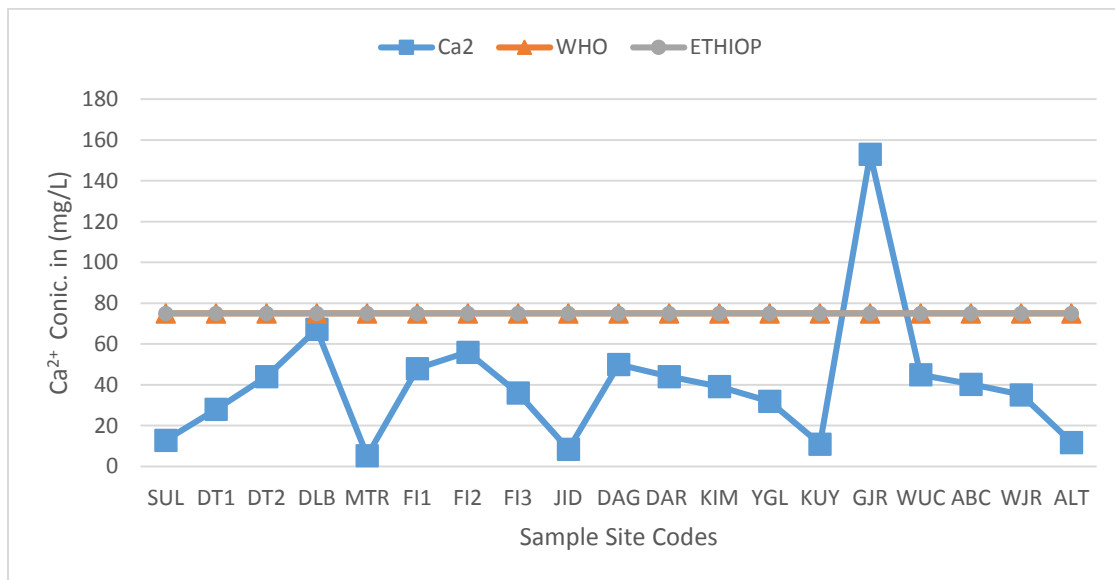
Figure 4.8: Calcium concentration of the study area

4.2.4 Magnesium (Mg^{2+})

Magnesium concentration of study area ranged from 0.91 mg/L for a sample MTR to 37 mg/L for a sample DAG with a mean of 8.7 mg/L (Figure 4.9). The permissible values of magnesium in water should be below 30 mg/L (WHO, 2004). The quantity of magnesium hardness as CaCO3 was significantly low in study area of except at sample sits of DAG

(Figure 4.9). The study was concluded that the concentration of magnesium in groundwater samples of study area was shows that, 5.26% of the total sample study area were above the permissible limiting values and almost the ground water was suitable for drinking and domestic purposes. The Ethiopian permissible range for magnesium in water should be less than 50 mg/L.
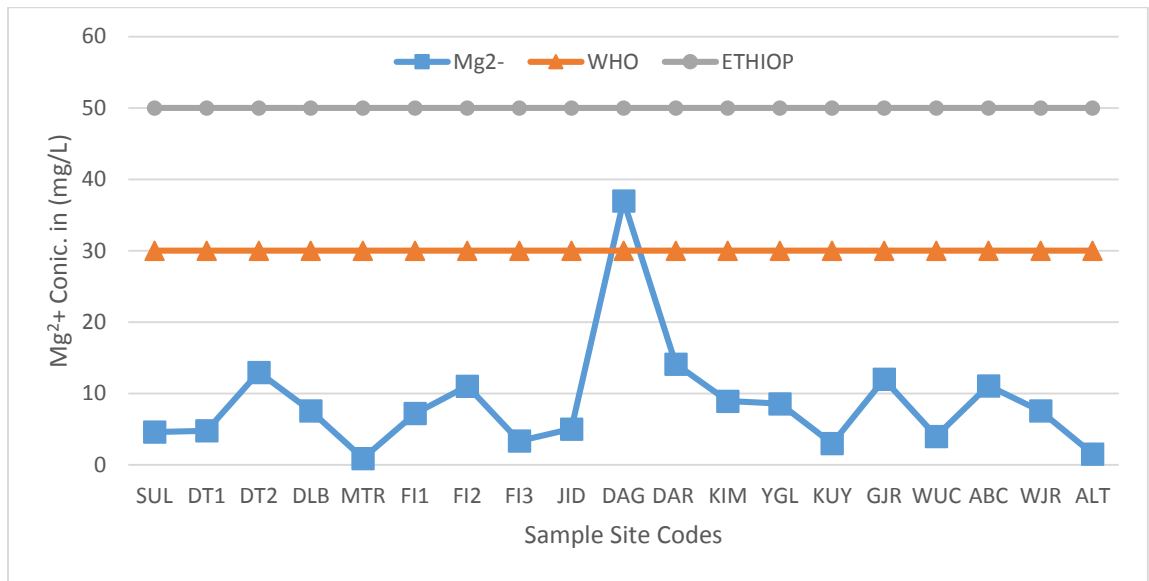
Figure 4.9: Graphical representation of Magnesium concentration

4.2.5 Sodium

The concentration of Na^+ was varied from 8.0 mg/L for a sample KUY to 48.5mg/L for a sample ALT with a mean value of 31.32mg/L (Figure 4.10; Table 4.1). The WHO (2004) Standards value for sodium was 200 mg/l. Sodium concentration of study area was so low that could not be harmful for the health of local inhabitants and irrigation (Figure 4.10). The Na^+concentration of samples at all samples were below WHO guideline. Generally the sodium concentrations of the study area was totally suitable for drinking and domestic purposes.
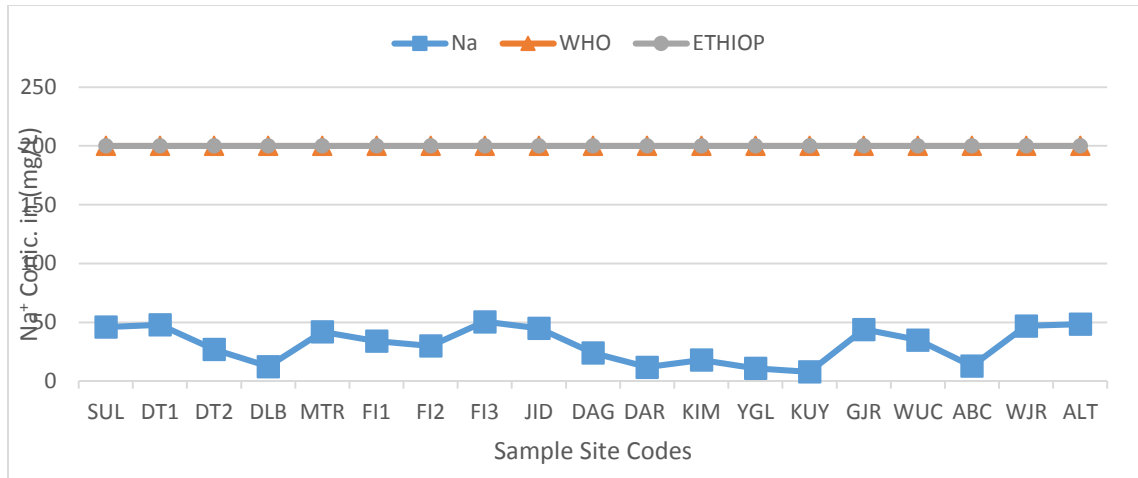
Figure 4.10: Graphical representation of sodium concentration

4.2.6 Potassium

The concentration of K^+ in study area was varied from 0.6 mg/L for as sample KIM to 8.2mg/L for a sample DT1 with a mean value of 3.17mg/L (Table 4.1). According to WHO and Ethiopian standards the permissible limit of potassium was 10 mg/L and 1.5mg/L respectively. The laboratory result of potassium concentration at all groundwater sample points of the study area was found below the maximum permissible limit value set by WHO, but it was found above the maximum permissible limit of Ethiopian standards except at sample points of SUL, DLB, KIM, KUY and ALT which were below the maximum permissible limit of Ethiopia (Figure 4.11). Sodium and potassium carbonate in re-circulating cooling water can cause deterioration of wood cooling towers. Here under it was important to make limited treatment practices for reducing K^+ levels by consider distillation, reverse osmosis or ion exchange methods to meets Ethiopian standards.
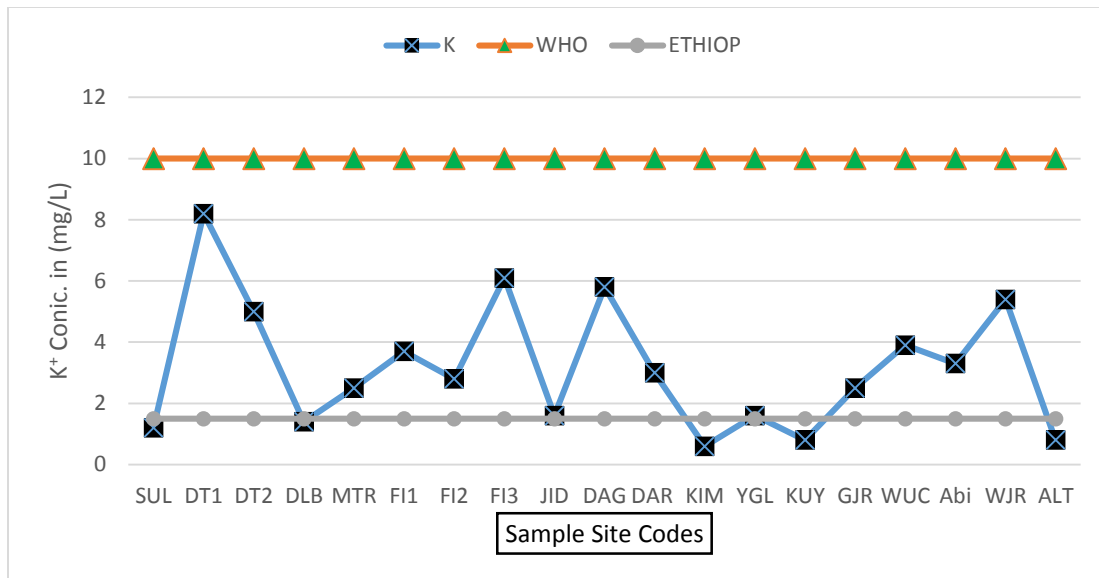
Figure 4.11: Graphical representation of potassium concentration

4.2.7 Iron

The concentration of Fe^{2+} was varied from 0.00 for a sample area of GJR to 0.35 mg/L for a sample site of DAG with a mean value of 0.09 mg/L (Figure 4.12; Table 4.1). Iron concentration from DAG (0.35 mg/L) and YGL (0.34 mg/L) were above (WHO, 2011) guide line value recommended. The desirable concentration iron set by WHO (2011) was 0.3 mg/L. Rock and mineral dissolution are causes of high iron levels in groundwater. The elevation of Iron concentration above 0.3 mg/L in the area may be due to the result of the weathering of rocks and minerals. Long term consumption of drinking water with high concentration of iron may leads to liver diseases (WHO, 2004).

Iron may be present in groundwater as a result of mineral deposits and chemically reducing underground conditions. The concentrations of iron in the study areas were almost all below the WHO (2011) maximum permissive level except at sample points DAG and YGL (Figure 4.12). It can be concluded that 89.46 of the concentration of iron in study area were suitable for drinking purpose.

The groundwater sources for water supplied from DAG and YGL as observed, a brownish color to laundered goods, plumbing fixtures, produce a bitter, a stringent taste in water and beverages, were detected. So that it needs optimal treatment for removal of iron

by ion exchange (Water Softener), filtration method, and aeration method (Sarin et al., 2004).
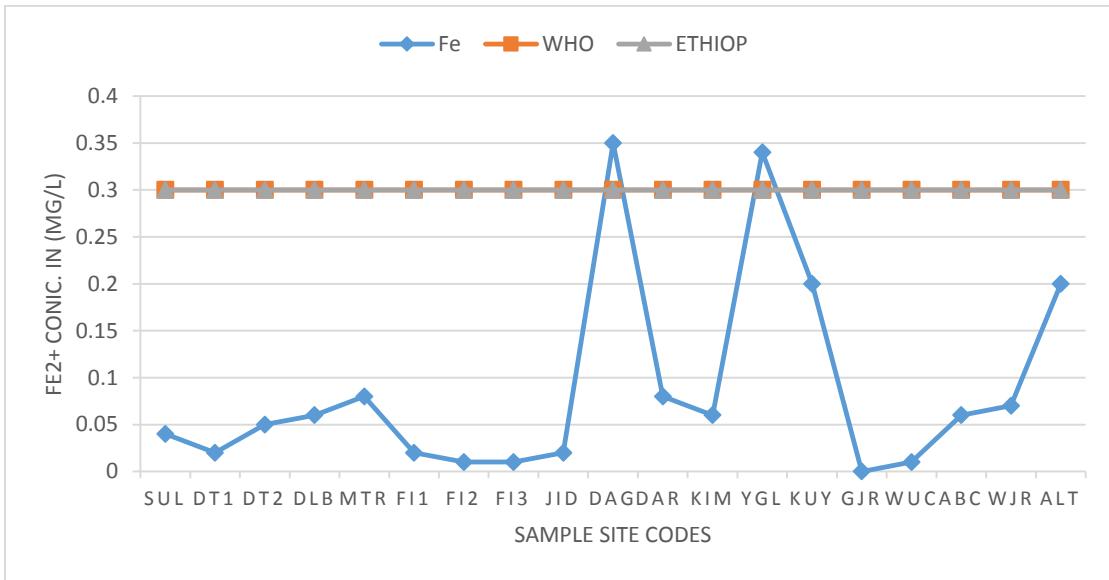
Figure 4.12: Graphical representation of iron concentration

4.2.8 Fluoride

The fluoride concentration of ground water quality of the study area, Varied between 0.03 mg/L for a sample of KUY to 1.6 mg/L for a sample area of WUC with mean value of0.46mg/L (Figure 4:13). The concentration of fluoride of the study area was suitable for water supply. The maximum allowable limit of fluoride is 1.5 mg/L (WHO, 1993). The concentration level for a sample point of WUC was above 1.5 mg/L and it was unsuitable to drink in case of fluoride concentration. Generally 94.74% of fluoride in the study areas were below the WHO (2011) maximum permissive level and it can be concluded that fluoride in study area were suitable for drinking and domestic purpose.
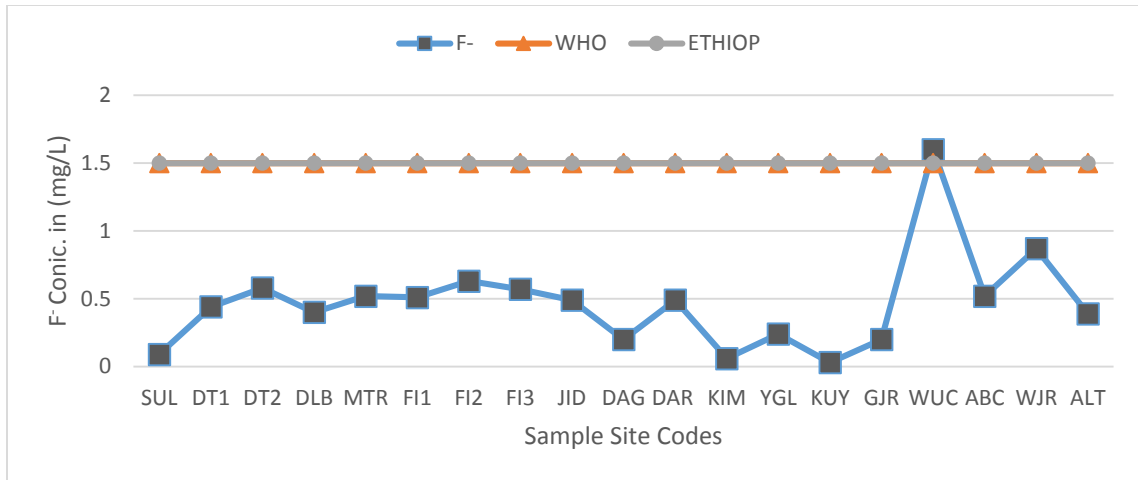
Figure 4.13: Graphical representation of fluoride concentration

4.2.9 Chloride (Cl)

In the study area chloride concentration ranges from 1.95 mg/l to 59 mg/l. According to (WHO, 2004) standards concentration of chloride shall not exceed 250 mg/L. All groundwater samples have lower concentration of chloride and below the maximum permissible limit value set by WHO standard (Figure 4.14). Thus, the water from all study area considered as fresh water because they were containing low levels of chloride. Therefore, it can be concluded that the concentration of chloride in groundwater samples was suitable for drinking purposes in terms of chloride concentration.
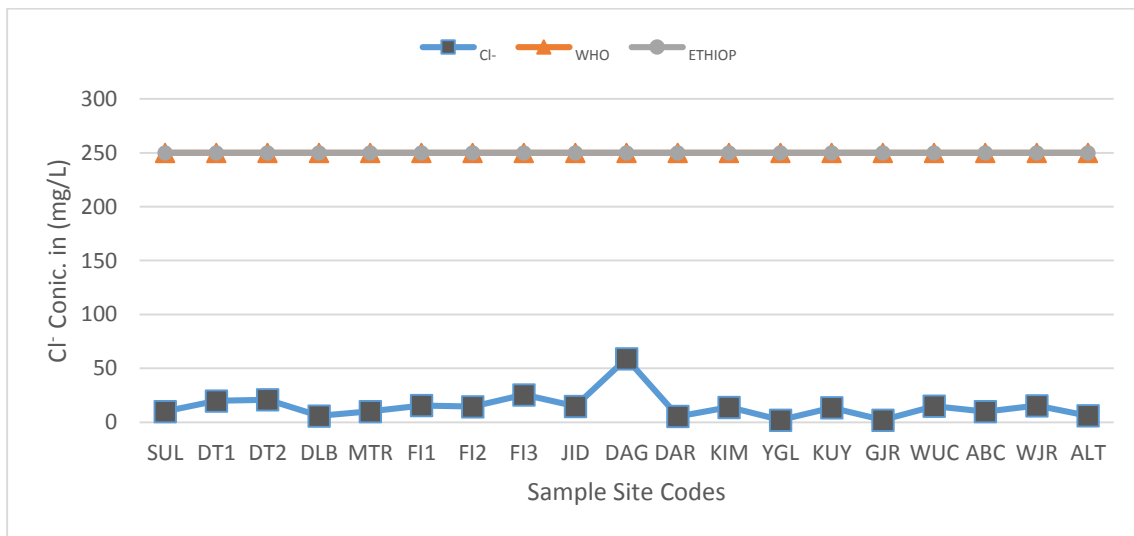
Figure 4.14: Graphical representation of chloride concentration

4.2.10 Bicarbonate

Bicarbonate of the study area was ranged from 51.24mg/L for a sample JID to 248.1mg/L for a sample of DLB and with mean value of 149.67 mg/L (Table 4.1). According to the potability of drinking Water set by (WHO, 2011) standard, the maximum permissible limit should not be exceeded 200 mg/L of as $CaCO_3$. Except DT2, DLB, FI1, FI2, DAR, GJR and WJR of samples area the rest were below the guideline value (Figure 4.15). Source of carbonate and bicarbonate were: dissolution of limestone, dolomite, and atmospheric carbon dioxide. Weathering of rocks adds bicarbonate content in water. Mostly bicarbonates are soluble in water i.e. bicarbonate of magnesium and calcium is the main causes of hardness of water.

Generally 63.16% of the study area ground water samples were below the permissible limit of the standard guideline in the case of bicarbonate. High bicarbonate and carbonate levels in the presence of calcium and magnesium may lead to formation of lime deposits in plumbing and irrigation systems. Since the concentration of bicarbonate in some sample area exceeded WHO limiting value, it is mandatory to treat carbonate and bicarbonates by lowering the pH of water through acid injection.
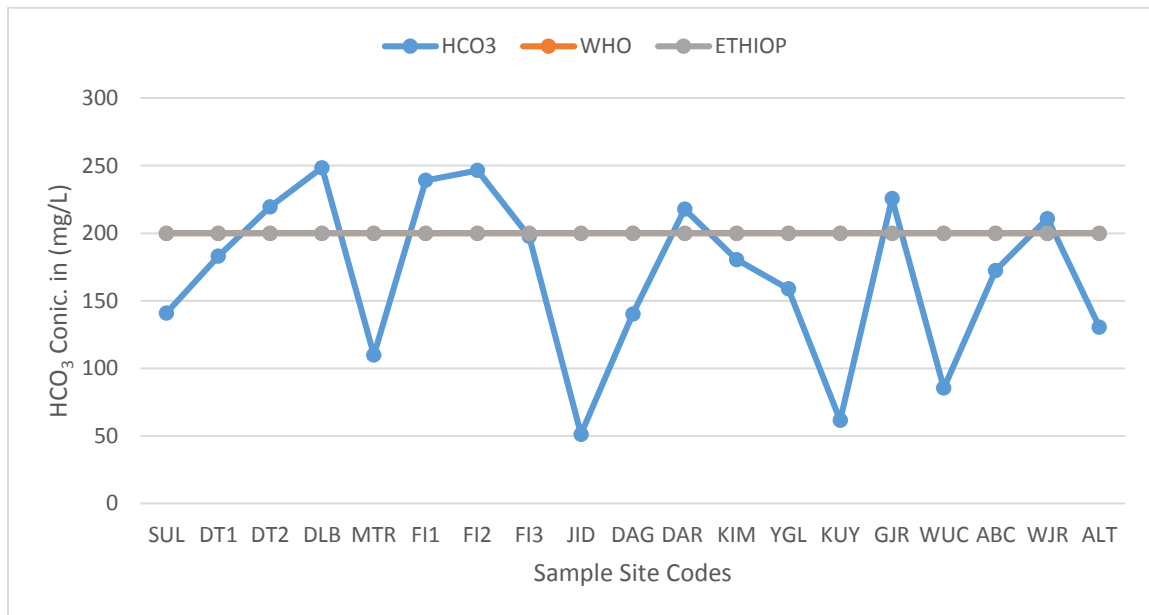
Figure 4.15: Graphical representation of bicarbonates concentration

4.2.11 Nitrate

Nitrate in study area ranged from 0.00 for a samples area SUL, DLB, FI1, FI3, JID, YGL, WUC and ABC to 0.42mg/L for a sample of FI2 with a mean value of 0.068mg/L (Table 4.1). The permissible limit of nitrate in drinking water was 10mg/L (WHO, 2004). The concentration of nitrate in the sample points of FI2 was above the WHO standard (Figure 4.16). Elevation of nitrate concentration in water causes the diseases blue baby syndrome in infants. Since 89.47% of the study area ground water samples were below the permissible limit, it was concluded that the water in the study area have no effect with regarding nitrate concentration that could lead to health problems. Therefore the results indicate that the concentration of nitrate in study area was suitable for drinking and irrigation purposes. Low levels of nitrogen (in the form of nitrate) are normal in groundwater and surface water (Follett et al., 1991).
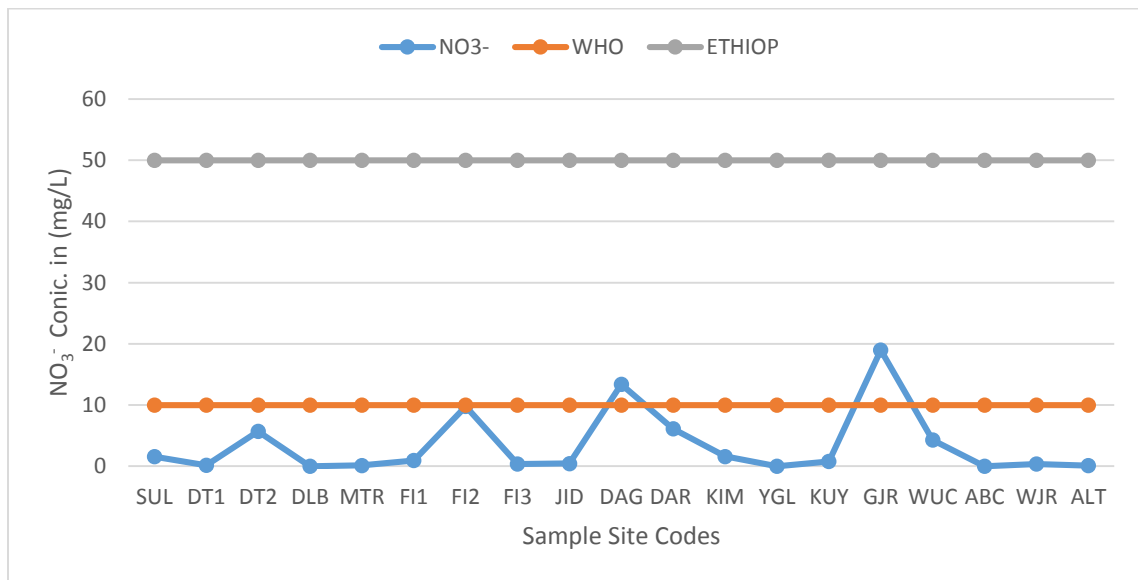
Figure 4.16: Graphical representation of Nitrate concentration

4.2.12 Sulphate

Sulphate in study area ranged from 0.01 to 45.21mg/L with a mean value of 14.40mg/L (Table 4.1). WHO (2011) has established 250 mg/L as the highest desirable limit of sulphate in drinking water. The minimum values of Sulphate observed for a sample site of YGL which is 0.01. The maximum value of Sulphate concentration was observed for a sample site of KUY which is 45.21mg/L (Figure 4.17). From the analysis; low sulfate

concentration was detected in sampled ground water. According to, data analysis results of study area sulfate concentration were laid below the standard guideline (Figure 4.17). Sources of sulfate were: animal sewage, septic system, sewage, by-product of coal mining, industrial waste and natural deposits or salt. No need of Sulphate treatment method.
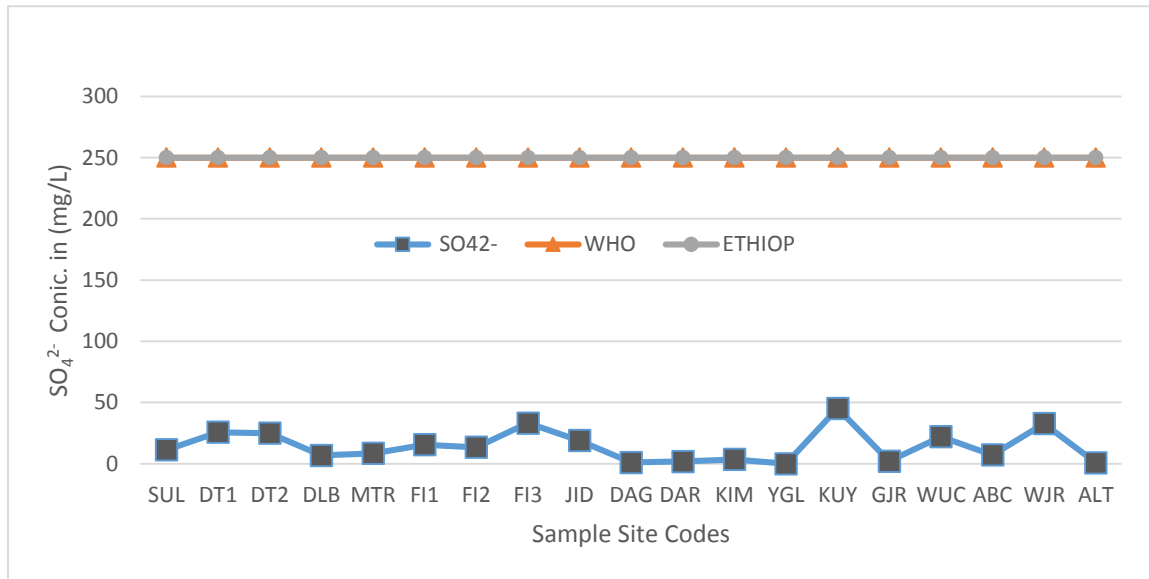
Figure 4.17: Graphical representation of Sulphate concentration

Generally physico chemical characteristics of the study area of the ground water samples were seem (Table 4.1). The major dissolved cations in the groundwater are Ca^{2+} and Na^+ and Mg^{2+}, with lower levels of K^+ and the major dissolved anions include HCO_3^-, SO_4^{2-} and Cl^-. Na^+ and Ca^{2+} are the dominant cations in the water from western part of the study area.

Table 4.1 Study area physicochemical parameters results

Station	NTU	TS	TDS	EC	T	PH	NH3	Na	K	TH
SUL	0.0	200.0	186.0	277.0	12.0	7.8	0.1	46.0	1.2	51.3
DT1	0.0	262.0	260.0	391.0	15.0	7.4	0.3	48.0	8.2	90.0
DT2	0.0	264.0	260.0	440.0	15.0	7.3	0.2	27.0	5.0	164.0
DLB	0.0	280.0	279.0	507.0	17.0	7.3	0.4	12.4	1.4	199.5
MTR	0.0	132.0	130.0	211.0	18.0	7.7	0.5	42.0	2.5	17.1
FI1	0.0	280.0	270.0	425.0	14.0	7.8	0.2	34.0	3.7	150.0
FI2	0.0	298.0	290.0	468.0	13.0	7.8	0.3	30.0	2.8	186.0
FI3	0.0	280.0	272.0	426.0	14.0	7.8	0.1	50.5	6.1	104.0
JID	0.0	152.0	150.0	228.0	19.0	8.9	0.2	45.0	1.6	42.0
DAG	9.1	230.0	122.0	246.0	21.0	7.9	11.6	24.0	5.8	60.0
DAR	3.3	240.0	200.0	338.0	27.0	7.2	0.2	11.9	3.0	169.1
KIM	0.0	186.0	182.0	282.0	20.0	7.6	0.4	18.0	0.6	135.2
YGL	0.0	156.0	153.7	279.0	21.0	7.3	0.4	11.0	1.6	115.5
KUY	2.2	211.0	103.9	145.7	17.0	7.2	0.0	8.0	0.8	40.0
GJR	2.1	241.0	202.0	405.0	16.0	7.5	0.0	44.0	2.5	125.0
WUC	0.6	251.0	128.0	255.0	18.0	8.2	0.0	35.0	3.9	25.0
ABC	5.0	224.0	204.0	370.0	19.0	7.4	0.0	12.8	3.3	147.0
WJR	1.0	270.0	266.0	402.0	23.0	7.6	0.3	47.0	5.4	118.8
ALT	4.0	175.0	160.0	247.0	11.0	8.7	0.1	48.5	0.8	35.7

	Ca_2	Mg^{2+}	Fe	F^-	Cl^-	NO_3^-	ALK	CO_3^{2-}	HCO_3	SO_4^{2-}	PO_4^{3-}
SUL	12.9	4.6	0.0	0.1	10.0	1.6	116	0.0	141.0	11.3	0.3
DT1	28.0	4.8	0.0	0.4	19.9	0.2	150	0.0	183.0	25.6	0.2
DT2	44.0	13.0	0.1	0.6	20.9	5.7	180	0.0	219.6	25.0	0.1
DLB	67.2	7.6	0.1	0.4	5.8	0.0	204	0.0	248.5	6.8	0.1
MTR	5.3	0.9	0.1	0.5	10.0	0.1	90.0	0.0	109.8	8.5	0.5
FI1	48.0	7.2	0.0	0.5	15.5	1.0	196	0.0	239.1	15.5	0.1
FI2	56.0	11.0	0.0	0.6	14.6	9.8	202	0.0	246.4	13.4	0.2
FI3	36.0	3.4	0.0	0.6	25.5	0.4	162	0.0	197.6	33.1	0.3

JID	8.4	5.0	0.0	0.5	14.8	0.5	90.0	28.8	51.2	19.0	0.1
DAG	50.0	37.0	0.4	0.2	59.0	13.4	115	0.0	140.3	1.0	0.3
DAR	44.1	14.1	0.1	0.5	5.5	6.1	178	0.0	217.9	1.8	0.2
KIM	39.2	8.9	0.1	0.1	13.9	1.6	148	0.0	180.6	3.6	0.1
YGL	31.9	8.6	0.3	0.2	2.0	0.0	130	0.0	158.8	0.0	0.1
KUY	11.0	3.0	0.2	0.0	13.5	0.8	75.0	0.1	61.5	45.2	0.0
GJR	153.	12.0	0.0	0.2	2.0	19.0	185.	0.0	225.7	2.0	1.2
WUC	45.0	4.0	0.0	1.6	15.0	4.3	70.0	0.0	85.4	22.0	0.1
ABC	40.3	11.1	0.1	0.5	9.9	0.0	141.	0.0	172.5	7.2	0.1
WJR	35.2	7.6	0.1	0.9	15.4	0.4	172.	0.0	210.8	32.8	0.0
ALT	11.8	1.5	0.2	0.4	6.0	0.1	135.	16.8	130.5	0.7	0.0

4.3 Groundwater Variables Correlation Matrix

The significance of conducting correlation amid groundwater variables is to discern the relationships existing among them. The result of correlation performed on the 19 ground water variables is shown in Table 4.2. Except for Na^+, Ca^{2+}, K^+ and HCO_3, TDS and EC have a significant and positive correlation with all the major ions and correlated positively and negatively. The correlation of TH with Ca^{2+} and Mg^{2+} explains relevantly their roles in influencing the total hardness of groundwater. TH has a strong correlation with ALK, which may impose the property of permanent hardness of water. The very low concentration of TH, which is substantially lower than the maximum requirement, weakens the above claim.

Table 4:2 Correlation matrix of 19 groundwater variables.

	Na	K	Ca2	Mg	Cl-	HCO3	CO3	SO4	NTU	TS	TDS	EC	PH	NH3	TH	Fe	F-	NO2	NO3	ALK	PO4
Na	1																				
K	0.31	1.00																			
Ca2	-0.28	0.28	1.00																		
Mg	-0.46	0.23	0.67	1.00																	
Cl-	0.37	0.68	0.01	-0.04	1.00																
HCO3	-0.08	0.25	0.71	0.51	-0.03	1.00															
CO3	0.11	-0.47	-0.55	-0.43	-0.10	-0.58	1.00														
SO4	0.31	0.39	-0.24	-0.39	0.62	-0.04	0.09	1.00													
NTU	-0.18	0.06	0.14	0.25	-0.16	-0.24	0.21	-0.29	1.00												
TS	0.10	0.56	0.68	0.25	0.41	0.77	-0.46	0.41	-0.15	1.00											
TDS	0.22	0.33	0.46	0.23	0.12	0.88	-0.44	0.22	-0.38	0.79	1.00										
EC	0.06	0.36	0.66	0.40	0.11	0.94	-0.55	0.14	-0.34	0.84	0.94	1.00									
PH	0.66	0.09	-0.12	-0.35	0.41	-0.36	0.28	0.05	-0.02	-0.07	-0.14	-0.24	1.00								
NH3	-0.23	0.09	0.03	0.25	0.14	0.19	-0.33	-0.30	-0.32	-0.03	0.08	0.08	-0.13	1.00							
TH	-0.39	0.11	0.68	0.70	-0.12	0.89	-0.47	-0.14	-0.15	0.61	0.75	0.83	-0.49	0.22	1.00						
Fe	-0.46	-0.28	-0.34	0.04	-0.24	-0.35	0.21	-0.43	0.41	-0.51	-0.49	-0.50	-0.30	0.45	-0.18	1.00					
F-	0.28	0.61	0.16	-0.02	0.38	0.23	-0.28	0.42	-0.14	0.48	0.42	0.39	0.22	-0.02	0.15	-0.39	1.00				
NO2	-0.03	0.00	0.22	0.36	0.01	0.22	0.07	-0.16	0.34	0.10	-0.01	0.07	-0.12	0.10	0.15	0.11	-0.09	1.00			
NO3	-0.05	0.16	0.49	0.49	0.26	0.18	-0.19	0.00	0.16	0.24	-0.08	0.07	0.13	-0.13	0.16	-0.32	-0.04	0.56	1.00		
ALK	-0.01	0.19	0.65	0.47	-0.05	0.98	-0.43	-0.06	-0.23	0.73	0.89	0.92	-0.31	0.17	0.88	-0.34	0.21	0.25	0.13	1.00	
PO4	0.23	0.24	0.22	0.16	0.01	0.14	-0.54	-0.20	-0.12	0.01	0.08	0.07	0.17	0.10	-0.01	-0.35	-0.06	0.07	0.36	0.07	1.00

NB: Values in bold are different from 0 with a significance level alpha=0.05

4.4 Principal Component Analysis

In order to identify the dominant variables, which have a significant effect on the quality of groundwater, 21 standardized variables were subjected to principal component analysis (PCA). The use of PCA involves the reduction of correlated variables into smaller uncorrelated variables called principal components (PCs). The correlation matrix shown in Table 4.2 depicted vital correlations among the various groundwater variables. They reflect association and relationship between one groundwater variable and another. This relationship can be used to decipher the basic factors controlling groundwater quality. Eigen values of 1 and higher are considered appropriate for the extraction of relevant factors modifying groundwater quality. Consequently, 10 PCs were extracted, which accounts for the 97.3% of the total variance in the initial groundwater variables (Table4.3). In PCA, the first sets of PCs displayed explain the most significant processes responsible for the variations existing in the initial variables. The first two sets of PCs accounted for the most variance at 34.1% and 18.3%, respectively, while the others 8 PCs accounted for

variance, which ranged from 1.8 to 11.1% (Table3). PC1 explained 36% of the total variance and substantially correlated with Na, K and Ca_2. This suggests that these variables have significant relationships with organic matter.

Table 4:3 Principal Component Analysis

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13
Eigenvalue	7.2	3.8	2.3	1.7	1.6	1.1	1.0	0.8	0.5	0.4	0.2	0.2	0.1
Variability (%)	34.1	18.3	11.1	8.0	7.7	5.3	4.8	3.6	2.5	1.8	0.9	0.8	0.5
Cumulative %	34.1	52.4	63.6	71.5	79.3	84.6	89.4	93.0	95.5	97.3	98.2	98.9	99.4

The association of NO_3 and PO_4 implies point source contamination, which is related to dumpsites, sewage and organic matter decomposition. The presence of Cl and TDS suggests waste from dumping site or sewage. This may be connected to their degree of association in having a common source of origin. K^+ and Na^+ are usually found in sediments rich in feldspars and clay minerals or may be the product of their weathering. The aquifers in the sediment water bearing formation of the Niger Delta basin contain some feldspars and clay minerals, and these are the probable source of K^+ and Na^+. Clay minerals are known to absorb metals in their surfaces. The low acidity of groundwater from the study area may enhance their leaching into the unsaturated and saturated zones, while HCO_3 promotes their removal from these zones.
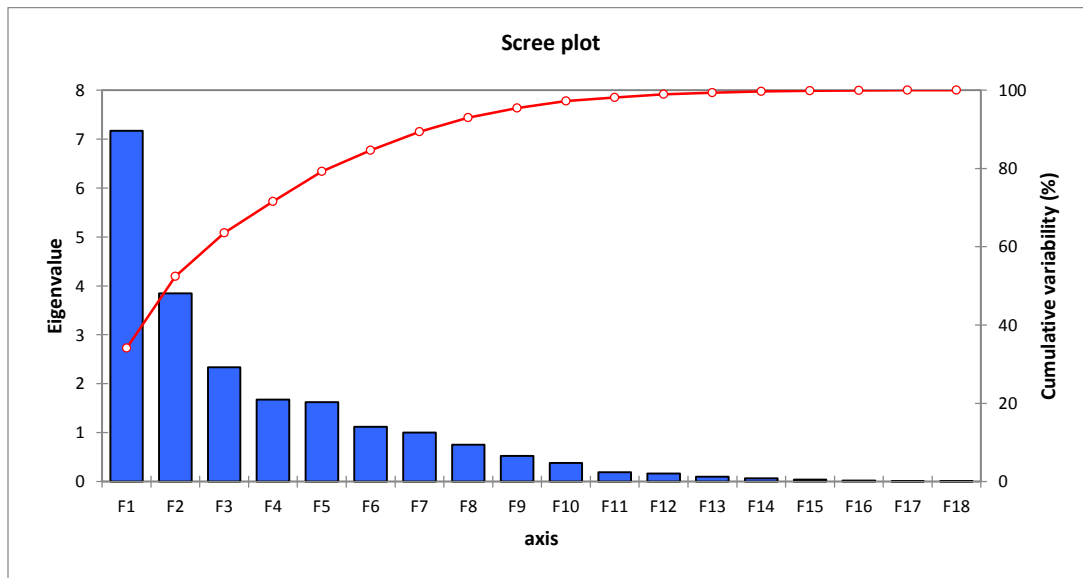

Figure 4.18 Principal Component Analysis

4.5 Suitability for Drinking and Domestic Purposes

The suitability of groundwater for drinking purpose was evaluated by comparing the analytical results of different water quality parameters to the Ethiopian standard (ES 261:2001) as well as World Health Organization Standards (WHO, 2006) guidelines.

Water quality varies depending on soil types, geological formations, natural and anthropogenic processes (Tamiru. et al, 2003). The types and concentrations of different elements present in the groundwater depend on the associated rock bodies and the time it has been in contact with geological materials (Ali, 2017). Parameters, such as Na^+, K^+, Ca_2^+, Mg_2^+, HCO_3^-, Cl^-, SO_4^{2-}, F^-, pH, EC, TDS and TH are regarded as critical determinants for most development studies of water quality (Bisrat, 2015).

Na^+ was an essential macro mineral for our body. But excess consumption of Na^+ was related with hypertension. The concentration of Na^+ in nineteen groundwater (100%), within the permissible value according to WHO (200 mg/L) and FMoWR.

Fluoride was identified as the minor problem for the suitability of the groundwater in the study area. According to WHO guideline, about 5.26% of the groundwater had excess F^-, > 1.5 mg/L, which can be a public health concern. Higher F^- intake can cause potential health hazards such as, dental and skeletal fluorosis (Gebrerufael et al., 2019). Excess F^- can come from leaching of acid volcanic rocks containing alkaline minerals. The interaction of F^- bearing rock minerals with water and agricultural practices are considered to be the main sources for F^- in groundwater.

Percentage of the analytical results of the water samples in the study area falling beyond the permissible limits for drinking as compared to Ethiopian standard and WHO are given in (Table 4.4). From this table, it can be observed that the groundwater quality was exceeding the guidelines permissible limits of Ethiopian standard by Ca^{2+} in 5.26%, total iron in 10.52%, bicarbonate in 36.84%, fluoride in 5.26% and alkalinity in 10.52%; While, ground water quality was exceeding the guidelines of WHO standard by Ca^{2+} in 5.26%, Total iron in 10.52%, bicarbonate in 36.84%, fluoride in 5.26%, nitrate in 10.52% and alkalinity in 10.52%.

Physical parameters of the ground water samples of the study area such as total hardness , pH, electrical conductivity, total dissolved solids were used to assess the suitability of the groundwater for drinking purpose. TDS and TH were important parameter of water quality (WHO, 2011). For the classification of water quality based on TDS values 100 % of the water samples in the study area were found to be permissible for drinking. While, for classifying the water quality suitability based on total hardness 100% of the water samples in North Showa zone fall in the permissible class. The pH of most of the groundwater samples were nearly neutral and about 89.47% of the samples have pH less than 8.5 which indicates the absence of carbonate in the water and this could indicate that the area is discharge area (Chapman, 1996).

Generally the study concluded that 94.74% and 95.57% of the sample water of the study area meet the WHO and FMoWR (2002) permissible guidelines. Hence the ground water of the study area can be used for domestic purposes with little treatments of some parameters like bicarbonate, alkalinity, total iron, fluoride, calcium, pH and turbidity which were exceed the maximum permissible of both guidelines.

Table 4.4: Comparison of selected water quality parameters with water quality standards

Parameter	Unit	Min	Max	Max. Permissible Limit		Samples exceeding the limit			
				WHO	FMoWR	WHO (2006		FMoWR (2002)	
						No.	%	No.	%
Turbidity	NTU	0	9.07	5	5	1	5.26	1	5.26
TDS	Mg/L	103.9	290	1000	1000	0	0	0	0
EC	μs/cm	145.7	507	1000	1776	0	0	0	0
PH		7.17	8.85	6.5-8.5	6.5-8.5	2	10.52	2	10.52
Sodium	mg/L	8	50.5	200	200	0	0	0	0
Potassium	mg/L	0.6	8.2	10	1.5	0	0	0	0
TH	mg/L	17.1	199.5	200	300	0	0	0	0
Calcium	mg/L	5.32	153	75	75	1	5.26	1	5.26
Mg2+	mg/L	0.91	37	30	50	1	5.26	0	0
Total Iron	mg/L	0	0.35	0.3	0.3	2	10.52	2	10.52
Fluoride	mg/L	0.03	1.6	1.5	1.5	1	5.26	1	5.26
Chloride	mg/L	1.95	59	250	250	0	0	0	0
Nitrate	mg/L	0.01	19	10	50	2	10.52	0	0
Alkalinity	mg/L	70.0	203.7	200	200	2	10.52	2	10.52
Bicarbonate	mg/L	51.24	248.5	200	200	7	36.84	7	36.84
						∑=19	5.26%	∑=16	4.43%

4.6 Suitability for Irrigation Purpose.

For a plant growth apart from soil type and quality, water was also an essential component. Poor quality water when used for agriculture purposes may affect the crop productivity (Gebrerufael et al., 2019). Intense agricultural practices and application of chemical fertilizers, pesticides and insecticides have significant effect on ground water quality. Sodium adsorption ratio (SAR), soluble sodium percentage (Na %), permeability index (PI), and salinity hazard were some of the factors to understand the ground water suitability for agriculture.

4.6.1. Sodium Adsorption Ratio (SAR)

Groundwater samples were classified based on SAR values. Class I and II waters were generally considered suitable for irrigation. More than 1/5th of the samples were categorized under class I (21.05%) and class II (31.57 %) which have no Na^+ problem. About 47.368% of samples exceeded class II, 10.53% in class III, 15.79% in class IV and class V, 21.05%, indicating poor quality for irrigation (Figure 4:19). The samples which were categorized under class IV and V are SUL, DT1, MTR, FI3, JID, WJR and ALT which were not generally recommended for irrigation (Table 4.5). Generally the ground water in the study area were good by some treatments of sodium removal for irrigation.
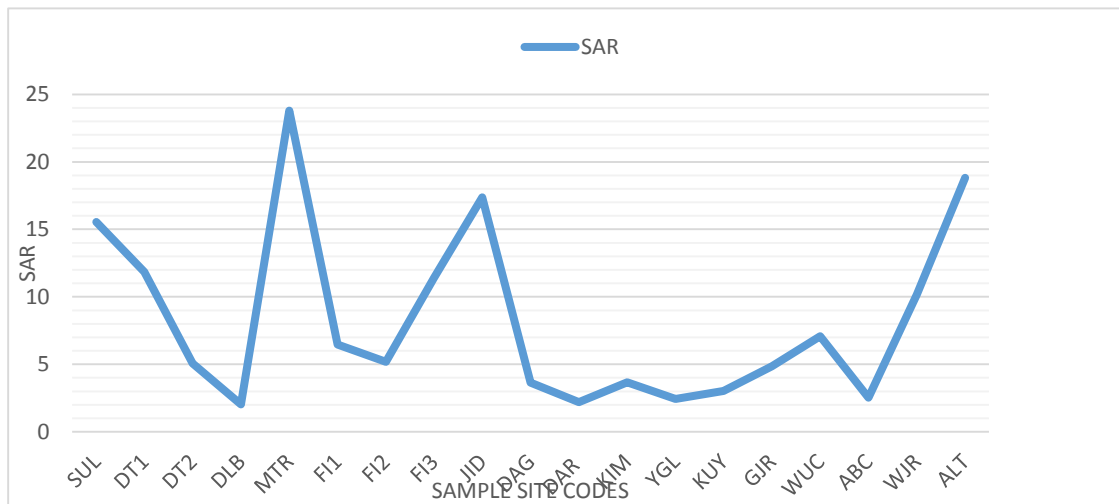

Fig 4.19 Sodium Adsorption Ratio (SAR)

4.6.2. Soluble Sodium Percentage (SSP)

The SSP values for the study area were varied from 15.58% at sample site of DLB to 87.72% at sample site of MTR with mean value of 44.49 % (Table 4.5). The SSP sample which are 63.15% of the total sample site were less than 50 and therefore indicated excellent quality for irrigation purpose. The SSP values of 36.85% groundwater samples were above 50% indicated that unsuitable quality for irrigation purpose (Figure.4.20). Here it needs optimal adjustment for utilization purpose.
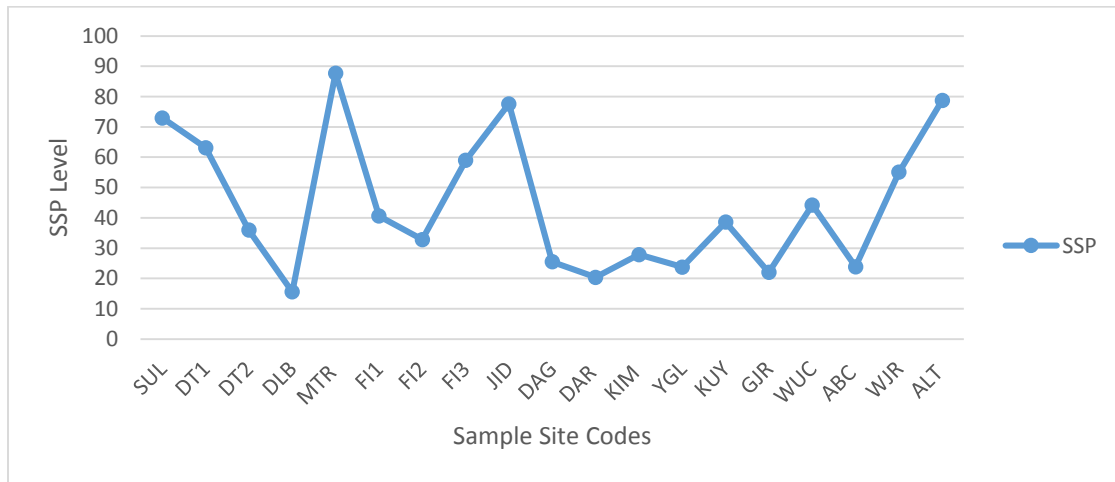
Figure 4.20: Graphical illustrations of soluble sodium percentage

4.6.3 %Na Percent

The %Na values for the study area were varied from 14 at sample site of DLB to 82.79 at sample site of MTR with mean value of 40.49 (Table 4.5). According to (Wilcox et al., 1955) percent sodium 15.78% were excellent, 47.36% were good, 15.78% were permissive, 15.78% were doubtful, and 5.26% were unsuitable. Generally as indicated in (Table 4.5) the ground water samples (78.92%) of the study area were suitable for irrigation and the rest few water sample (5.26%) were not suitable for irrigation purposes.
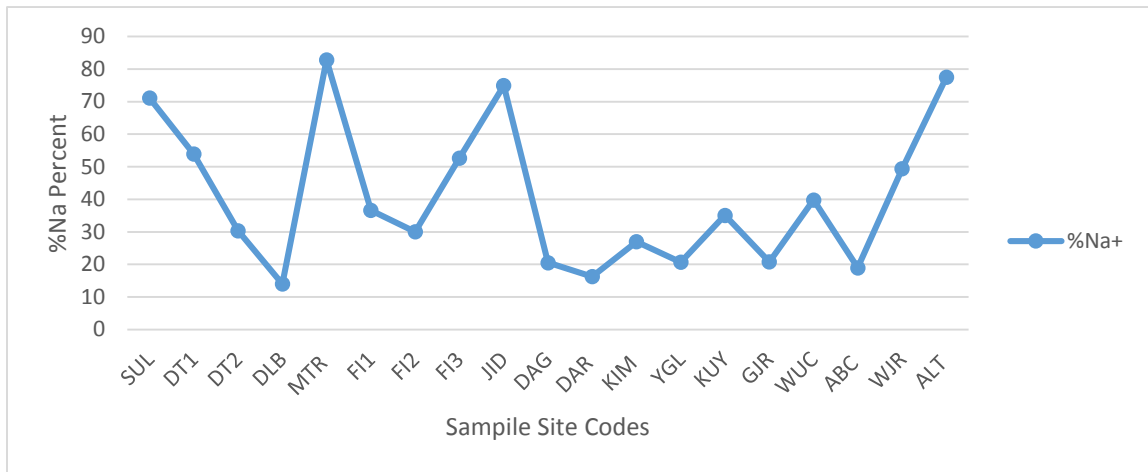
Figure 4.21: Graphical illustrations of sodium percentage

4.6.4 Permeability Index

In present study area, (Table 4.5) showed that the minimum value recorded was 27.90% at sample site of GJR and maximum permeability recorded was 103.44% at sample site of MTR with mean value of 74.4%. From these results, all sources of water in the study area sources of water supply were suitable for irrigation. Some of the sample site sources 21.05% of the sample site were excellent permeability and suitable for irrigation and the rest of 78.95% were laid in good permeability interval (Figure 4.22).

Figure 4.22: Graphical illustrations of Permeability index

4.6.5. Magnesium Hazard (MH)

The calculated Mg_2^+ ratio ranged from 7.27% to 42.52% (mean 18.85%) for groundwater samples in the study area (Figure 2:23; Table 4.5).

Figure 4.23: Graphical illustrations of Magnesium Hardness (MH)

All the sample Lab. results were below the acceptable limit of the Mg^{2+} ratio limit of 50% (US Salinity Laboratory Staff, 1954). High Mg^{2+} content in water unfavorably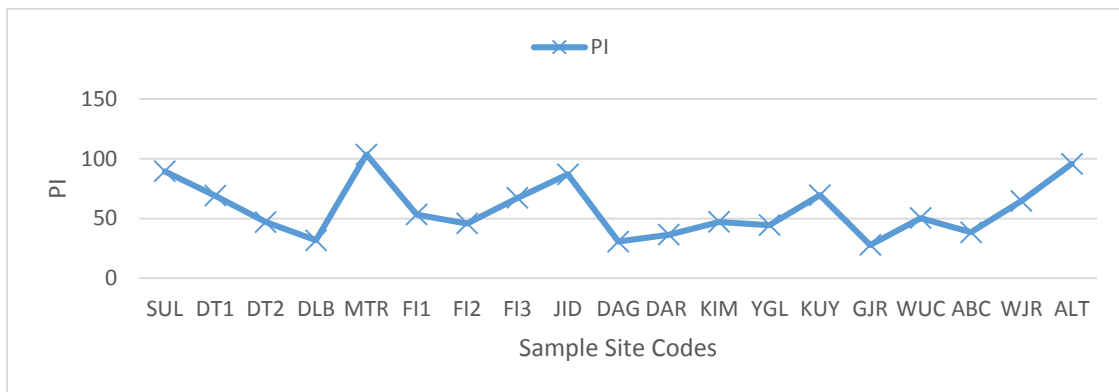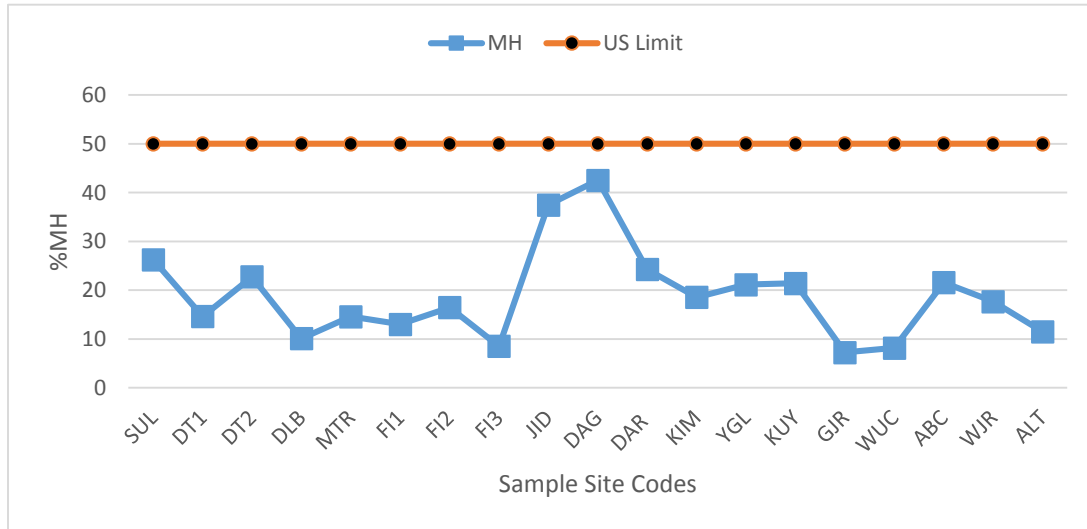 affects crop productivity as the soil becomes more saline. Therefore, the ground water of the study area were therefore, considered suitable for irrigation.

Table 4.5 Suitability of ground water samples for irrigation

	SUL	DT1	DT2	DLB	MTR	FI1	FI2	FI3	JID	DAG
SAR	15.6	11.9	5.1	2.0	23.8	6.5	5.2	11.4	17.4	3.6
%Na	73.0	63.1	36.0	15.6	87.7	40.6	32.9	58.9	77.6	25.5
SSP	72.9	63.1	35.9	15.5	87.7	40.5	32.8	58.9	77.6	25.5
MH	26.3	14.6	22.8	10.1	14.6	13.0	16.5	8.5	37.5	42.5
TH	51.2	89.7	163.2	198.9	17.0	149.5	185.2	103.7	41.7	277.2
PI	89.5	69.1	47.0	31.8	103.4	53.2	45.8	67.3	86.9	30.7
	DAR	KIM	YGL	KUY	GJR	WUC		ABC	WJR	ALT
SAR	2.2	3.7	2.4	3.0	4.8	7.1		2.5	10.2	18.8
%Na	20.4	27.9	23.7	38.6	21.9	44.3		23.8	55.1	78.8

SSP	20.4	27.87	23.7	39	22	44.25	23.8	55.1	78.8
MH	24.3	18.6	21.2	21.4	7.3	8.2	21.6	17.7	11.5
TH	168.2	134.6	114.9	39.8	431.4	128.0	146.3	119.0	35.7
PI	36.5	47.1	44.5	69.5	27.9	50.3	38.4	64.6	95.7

The quality of ground water for irrigation was analyzed by calculating parameters such as SAR, SSP, Na%, PI, MH which were indicate that the majority of water samples were very good to moderately suitable for agriculture. In SAR, %Na and SSP plot, majority of water samples fall under medium saline to low sodium type indicating that water was suitable for irrigation. Based on PI, it was found that ground water is good to moderately suitable for agriculture and there was no much threatening of reduction in permeability of soil. As a whole, the quality of ground water was suitable for agriculture purpose. The temporal variation of ground water quality depicts that there was a significant increase in EC, TDS and ions like Mg, K, Ca and Cl chiefly due to anthropogenic activities with little geogenic impact. Hence, the present study recommends that regular monitoring of ground water was essential to avoid major environmental threat.

4.7 Aquachem 2011.1 Results

The geochemical evolution of water in general (groundwater in particular) can be understood by constructing Piper (1944) tri-linear diagram and Durov (1948) plot. In the present study, Aquachem Scientific software version 2011.1 was used to plot these diagrams.

4.7.1 Piper Diagram

A piper diagram is a graphical representation of the chemistry of ground water sample or samples. These tri-linear diagrams are useful in bringing out chemical relationships among groundwater samples in terms that are more definite rather than with other possible plotting methods. Piper diagrams according to (Piper, 1944), are a combination of anion and cation triangles that lie on a common baseline. Diamond shape between them can be used to make a tentative conclusion as to the origin of the water represented by the analysis and to characterize different water types .The major cations (Ca^{2+}, Mg^{2+}, $Na^+ + K^+$) are plotted on the left triangle, while the major anions (SO_4^{2-}, Cl^-. and alkalinity or

HCO_3^-) are plotted on the right triangle. Piper divided waters into four basic types according to their placement near the four corners of the diamond (Figure 4.24). Water that plots at the top of the diamond is high in $Ca^{2+} + Mg^{2+}$ and $Cl^- + SO_4^{2-}$ which results in an area of permanent hardness. The water that plots near the left corner is rich in $Ca^{2+} + Mg^{2+}$ and HCO_3^- is the region of water of temporary hardness (Figure 4.24). Water plotted at the lower corner of the diamond is primarily composed of alkali carbonates ($Na^+ + K^+$ and $HCO_3^- + CO_3^{2-}$). Water lying nears the right hand side of the diamond may be considered saline ($Na^+ + K^+$ and $Cl^- + SO_4^{2-}$) (Piper, 1944). The cations and anions were shown by separate ternary plots. The apexes of the cation plot are calcium, magnesium and sodium plus potassium cations. The apexes of the anion plot are sulfate, chloride and carbonate plus bicarbonate anions. The two ternary plots are then projected up onto a diamond. The diamond is a matrix transformation of a graph of the anions and cations which are its concentration in (%meq/L) (Piper, 1944).

The values obtained from the physicochemical analysis of groundwater samples indicate that the dominant cation in the area is Ca^+ and the anion is HCO_3^-, and the order of dominance ions is $Ca^{2+} > Na^+ > Mg^{2+} > K^+$: $HCO_3^- > Cl^- > SO_4^{2-}$. From the result of piper plotted, the water types of the studies area of: SUL, DT1, FI3, WJR and ALT were Na-Ca-HCO_3 types, which is dominant types and the other sample points water type which are FI1, FI2, GJR and WUC were Ca-Na-HCO_3; ABC, YGL and DAR were Ca-Mg-HCO_3; DT2 and KIM were Ca-Na-Mg-HCO_3; DLB was Ca-HCO_3; MTR was Na-HCO_3; JID was Na-CO_3-HCO_3; DAG was Mg-Ca-HCO_3-CL; and finally KUY was Ca-HCO_3-SO_4-Cl.

Most water samples were plotted at the top of the diamond are high in $Ca^{2+} + Na^+$ and $HCO_3^- + SO_4^{2-}$ which results in an area of permanent hardness.
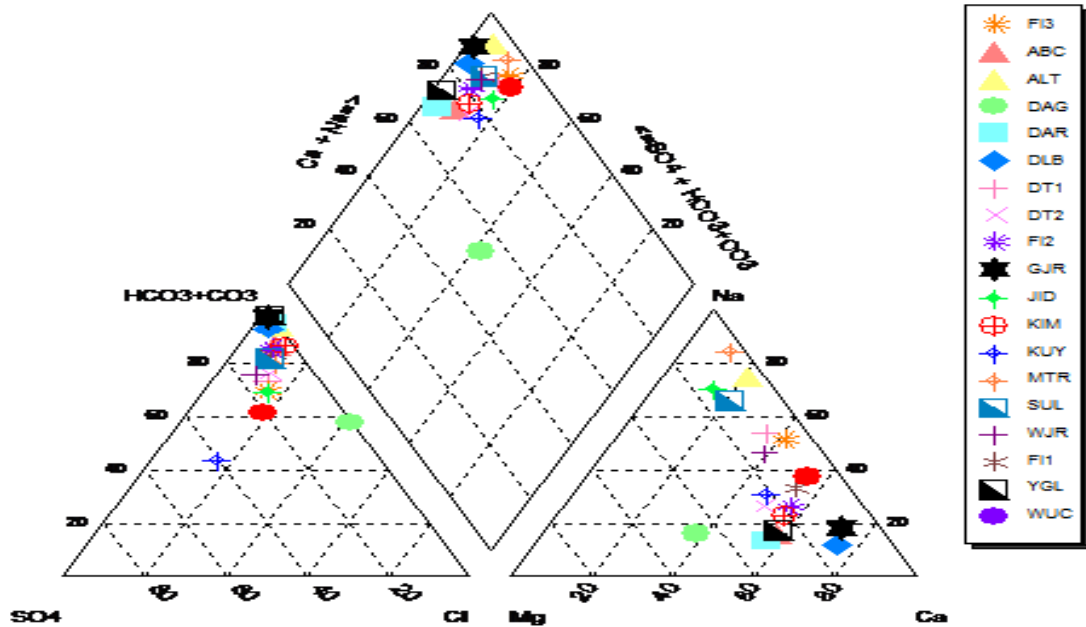
Figure 4.24: North Showa hydro geochemical facies analysis piper plot.

4.7.2 Hydro Geochemical Facies Wilcox Plot

The Wilcox plot (Figure 4.25) was used to identify groundwater sodium and salinity hazards to assure the groundwater suitability for irrigation and for other domestic purpose. In study area, the salinity and alkalinity hazard classes of sampled water were C1–S1, and C2–S1.The result shows that the groundwater possessed low to medium salinity hazards with low sodium hazards (Figure 4.25) (Richards 1954). The waters can be used for irrigation of most crops. So that it needs for the future special circumstances for salinity preventions such as leaching requirement or cropping of salt tolerant plants (Richards 1954).
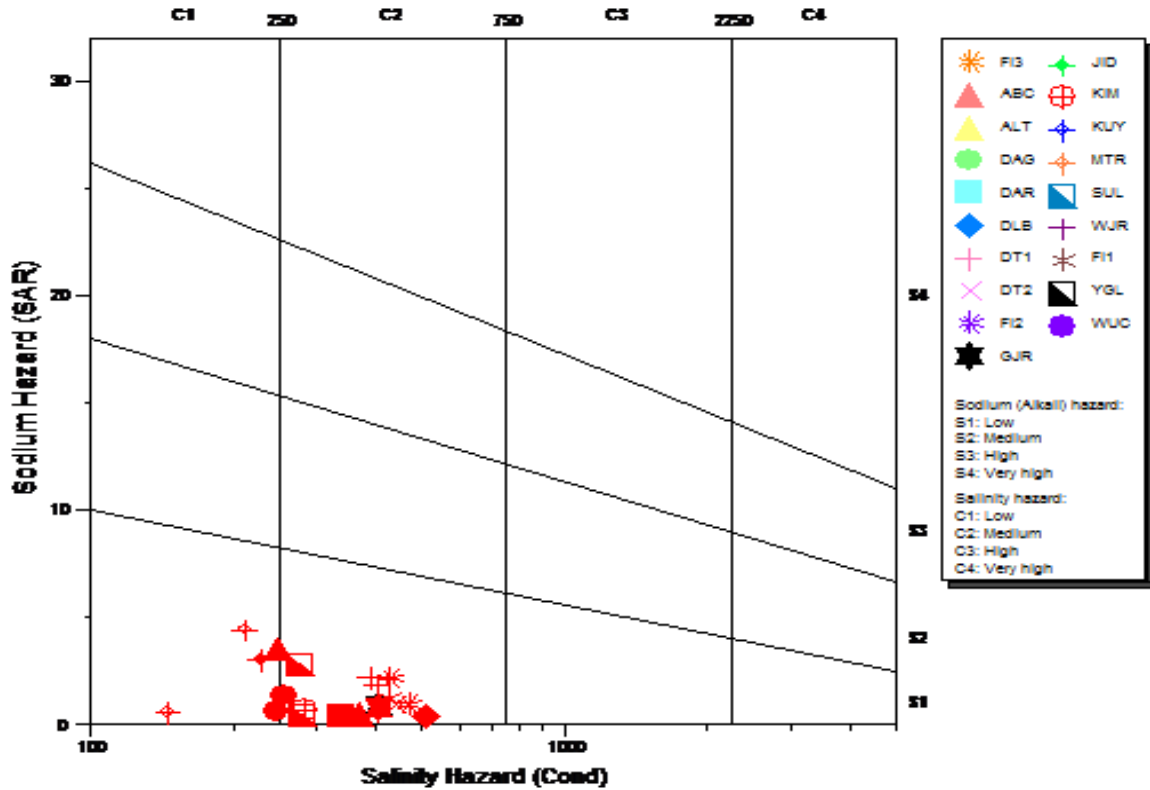
Figure 4.25: Hydro geochemical facies Wilcox plot

4.7.3 Hydro Geochemical Facies Durov Plot

The Durov plot (Figure 4.26) was used to categorize the hydro geochemical facies of both surface and groundwater. The Durov diagram plots the major ions as percentages of milli-equivalents in two base triangles. The total cations and the total anions were set equal to 100% and the data points in the two triangles were projected onto a square grid which lies perpendicular to the third axis in each triangle. From these points of view the hydro geochemical facies of the study area that identified by Piper and Durov were Na-Ca-HCO_3, Ca-Na-HCO_3, Ca-Mg-HCO_3; DT2, Ca-Na-Mg-HCO_3, Ca-HCO_3, Na-HCO_3, Na-CO_3-HCO_3, Mg-Ca-HCO_3-CL and Ca-HCO_3-SO_4-Cl. The advantage of Durov diagram over Piper diagram was that this diagram displayed some possible geochemical processes that could affected the water genesis. Most of the groundwater samples of the study areas were plotted in field (3) HCO_3^- and Ca^{2+} are dominant, indicates ion exchanged water, although the generation of CO_2 at depth can produce HCO_3^- where Na^+ is dominant under certain circumstance (Lloyd et al.,1985).

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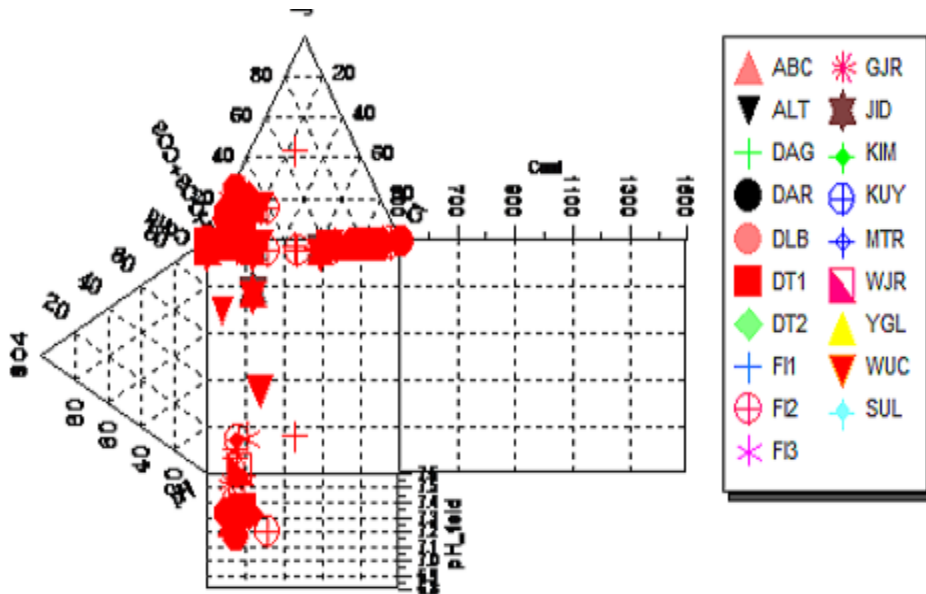
Figure 4.26: Graphical representation of Durov plot

Other small parts of the samples area were plotted in the field (5) which indicated no domination of cation or anion they were located along the mixing line which indicates mixing the recharge groundwater with sewage and this agree with piper plot results which put them in the area of earth alkaline water with increased portion of alkalis and with prevailing sulphates and chloride (Lloyd et al., 1985).

Table 4.6: Water type of the study area.

LOCATION	Station ID	Water Type	Sample Depth
Sululta	SUL	Na-Ca-HCO$_3$	274
DebreTsige1	DT1	Na-Ca-HCO$_3$	134.2
DebreTsige2	DT2	Ca-Na-Mg-HCO$_3$	189.6
DebreLibanos	DLB	Ca-HCO$_3$	162
Mukaxuri	MTR	Na-HCO$_3$	141
Fiche1	FI1	Ca-Na-HCO$_3$	135.65
Fiche2	FI2	Ca-Na-HCO$_3$	145
Fiche3	FI3	Na-Ca-HCO$_3$	155
Jidda	JID	Na-CO$_3$-HCO$_3$	170
Dagem	DAG	Mg-Ca-HCO$_3$-CL	173
Dara	DAR	Ca-Mg-HCO$_3$	150
Qimbibit	KIM	Ca-Na-Mg-HCO$_3$	147
Yaya Gulale	YGL	Ca-Mg-HCO$_3$	120
Kuyyu	KUY	Ca-HCO$_3$-SO$_4$-Cl	57.8
Girarjarso	GJR	Ca-Na-HCO$_3$	65
Wuchale	WUC	Ca-Na-HCO$_3$	52.4
Abichu	ABC	Ca-Mg-HCO$_3$	114
Warajarso	WJR	Na-Ca-HCO$_3$	198.3
Alaltu	ALT	Na-Ca-HCO$_3$	180

Generally the study concluded that 26.32% of water samples were Na-Ca-HCO$_3$ water type, 21.05% of water samples were Ca-Na-HCO$_3$ water type, 15.78% of water samples were Ca-Mg-HCO$_3$ water type, and 10.53% of water samples were Ca-Na-Mg-HCO$_3$ water type and finally Ca-HCO$_3$-SO$_4$-Cl, Mg-Ca-HCO$_3$-CL, Na-CO$_3$-HCO$_3$, Ca-HCO$_3$, and Na-HCO$_3$ water types were totally 26.32% of water samples.

4.8 WQI Calculation

The various classes of water quality index for drinking purpose was shown in (Table 4.7). Computed water quality index shows that 36.84% of samples fall in the class of excellent

water type, 26.31% of samples fall in the class of good water type and 36.84% of samples fall in the class of moderate water type for drinking purpose.

Table 4.7. Computed WQI for each groundwater samples

LOCATION	Station ID	Water Type	WQI	Water Type
Sululta	SUL	Na-Ca-HCO$_3$	32.32	Excellent
DebreTsige1	DT1	Na-Ca-HCO$_3$	43.12	Good
DebreTsige2	DT2	Ca-Na-Mg-HCO$_3$	48.92	Moderate
DebreLibanos	DLB	Ca-HCO$_3$	47.95	Moderate
MukaTuri	MTR	Na-HCO$_3$	30.56	Excellent
Fiche1	FI1	Ca-Na-HCO$_3$	48.40	Moderate
Fiche2	FI2	Ca-Na-HCO$_3$	53.73	Moderate
Fiche3	FI3	Na-Ca-HCO$_3$	46.90	Moderate
Jidda	JID	Na-CO$_3$-HCO$_3$	29.75	Excellent
Dagem	DAG	Mg-Ca-HCO$_3$-CL	40.44	Good
Dara	DAR	Ca-Mg-HCO$_3$	43.66	Good
Kimbibit	KIM	Ca-Na-Mg-HCO$_3$	34.99	Excellent
Yaya Gulale	YGL	Ca-Mg-HCO$_3$	32.75	Excellent
Kuyyu	KUY	Ca-HCO$_3$-SO$_4$-Cl	21.43	Excellent
Girarjarso	GJR	Ca-Na-HCO$_3$	54.72	Moderate
Wuchale	WUC	Ca-Na-HCO$_3$	43.72	Good
Abichu	ABC	Ca-Mg-HCO$_3$	39.90	Good
Warajarso	WJR	Na-Ca-HCO$_3$	49.53	Moderate
Alaltu	ALT	Na-Ca-HCO$_3$	33.27	Excellent

The highest influencing parameters of WQI were determined to be closely related with the excessive values of pH, TDS, Ca^{2+}, HCO$_3^-$ and Na$^+$. None of the samples was fall in the class of unsuitable water type (Table 4.7).

Generally the computed WQI values range from 21.43 to 54.72. Therefore, out of the 19 studied locations, seven locations were classified in the "Excellent water" class, five locations were classified as a "Good water" class, and seven studied locations were

classified as a "moderate for drinking purpose" class. The spatial variation of WQI shows that, larger parts of study have WQI less 45mg/l and it is suitable for drinking purpose.
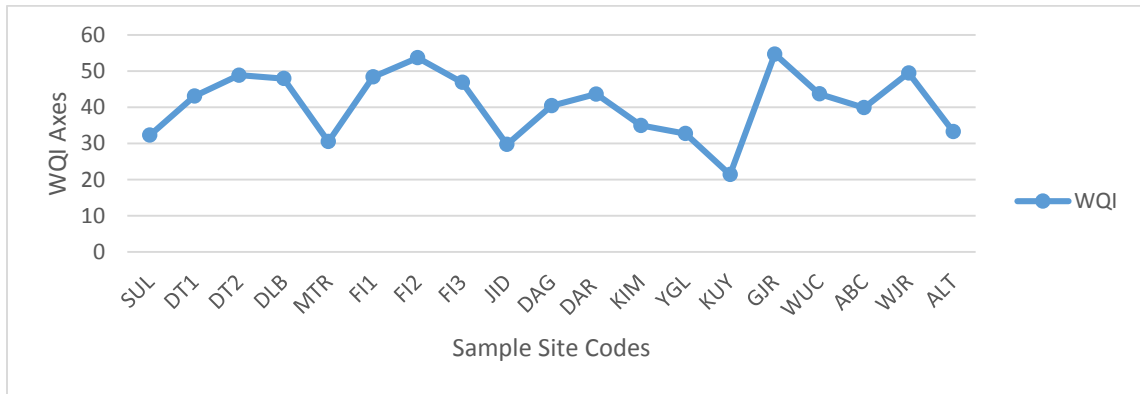

Figure 4.27: Graphical illustrations of WQI

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CHAPTER FIVE

5. CONCUSSIONS AND RECOMMENDATIONS

</div>

5.1. Conclusions

The major water supply source for most of the communities of the zone was ground water. As an optional few communities of the town were used surface water and water resources as the result of insufficient coverage water supply for all communities. There was no well treatment plant, lack of continuous monitoring techniques and the laboratory for checking up water quality regularly. The community complaint increased from time to time due to less attention taken to scarcity of suitable water access for domestic and agricultural usage. Therefore, it is important to conduct more research analysis of hydro geochemical of the area for water supply and irrigational uses.

Physicochemical characteristics of the study area of the ground water samples were presented in (Table 4.1). The important parameters analyzed were: groundwater temperature, Turbidity, pH, TDS, TS, EC, Ca^{2+}, Mg^{2+}, Fe^{2+}, SO_4^{2-}, HCO_3^-, TA, TH, F^-, Cl^-, Na^+, and K^+. The major dissolved cations in the groundwater were Ca^{2+} and Na^+ and Mg^{2+}, with lower levels of K^+ and the major dissolved anions include HCO_3^-, SO_4^{2-} and Cl^-. Na^+ and Ca^{2+} were the dominant cations in the study area.

The second important analysis was determination the suitability of groundwater for drinking and irrigational uses. For the classification of water quality based on TDS and TH values were 100% of the water samples in the study area were found to be permissible for drinking. The pH of most of the groundwater samples were nearly neutral and about 89.47% of the samples have pH less than 8.5 which indicates the absence of carbonate in the water and this could indicate that the area is discharge area. From (Table 4.2), it can be observed that the groundwater quality was exceeding the guidelines permissible limits of Ethiopian standard by Ca^{2+} in 5.26%, total iron in 10.52%, bicarbonate in 36.84%, fluoride in 5.26% and alkalinity in 10.52% While, ground water quality was exceeding the guidelines of WHO standard by Ca^{2+} in 5.26%, total iron in 10.52%, bicarbonate in 36.84%, fluoride in 5.26%, nitrate in 10.52% and alkalinity in 10.52%. Generally the study concluded that 94.74% and 95.57% of the sample water of the study area meet the WHO and FMoWR (2002) permissible guidelines respectively.

The quality of ground water for irrigation was analyzed by calculating parameters such as SAR, SSP, Na%, PI, MH which were indicate that the majority of water samples were very good to moderately suitable for agriculture. In SAR, %Na and SSP plot, majority of water samples fall under medium saline to low sodium type indicating that water was suitable for irrigation. Based on PI, it was found that ground water was vary from good to moderately suitable for agriculture and there was no much threatening of reduction in permeability of soil. As a whole, the quality of ground water was suitable for agriculture purpose. Hence the ground water of the study area can be used for domestic purposes with little treatments of some parameters like bicarbonate, alkalinity, total iron, fluoride, calcium, pH and turbidity which were exceed the maximum permissible of both guidelines.

The study concluded that 26.32% of water samples were $Na-Ca-HCO_3$ water type, 21.05% of water samples were $Ca-Na-HCO_3$ water type, 15.78% of water samples were $Ca-Mg-HCO_3$ water type, and 10.53% of water samples were $Ca-Na-Mg-HCO_3$ water type and finally $Ca-HCO_3-SO_4-Cl$, $Mg-Ca-HCO_3-CL$, $Na-CO_3-HCO_3$, $Ca-HCO_3$, and $Na-HCO_3$ water types are totally 26.32% of water samples.

The computed WQI values range from 21.43 to 54.72. Therefore, out of the 19 studied locations, seven locations were classified in the "Excellent water" class, five locations were classified as a "Good water" class, and seven studied locations were classified as a "moderate for drinking purpose" class. The spatial variation of WQI shows that, larger parts of study have WQI less 45mg/l and it was suitable for drinking purpose. The various classes of water quality index for drinking purpose is shown in (Table 4.5). Generally computed water quality index shows that 36.84% of samples fall in the class of excellent water type, 26.31% of samples fall in the class of good water type and 36.84% of samples fall in the class of moderate water type for drinking purpose.

5.2. Recommendations

Based on laboratory analytical result the study will recommend the following important point to be considered and applied by North Showa Zone water and energy office, any concerned body, government authority, and users of groundwater.

➢ Since the study area was rich with ground water potential; the concerned body should extract the ground water and treat the water and finally distribute it to the society.

➢ With little treatment the ground water is going to use for irrigational purposes. Hence develop the utility of ground water in the area for agricultural purposes.

➢ Design treatment plant to recover the extracted groundwater for water supply.

➢ Continuous monitoring and evaluation of the source water will be a mandatory.

➢ Design to construct filter tank to remove suspended and colloidal particles that increase water turbidity and use alum salt (sodium Sulphate) with convenient dose.

➢ To removing hardness use softening water, lime soda process sodium carbonate soda ash (Na_2CO_3).

➢ Search funds to construct new sources of water supply for the towns as optional.

➢ The Zone should employ qualified expertise and laboratory technician for municipal water treatment.

➢ Construct laboratory center for water treatment plant.

➢ Apply neutralizing agent for irrigational uses of groundwater.

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ANNEXES

Annex 1 Materials and Method of Data Analysis

1.1. Procedure for Analysis Total Hardness

Total hardness was determined by the EDTA method and Apparatus used were; Conical flasks 100mL, Burette, Pipette, and Spatula. Reagents used for hardness determination were; Buffer solution, hydroxylamine hydrochloride100mL, 95% ethyl alcohol, NaCN, Eriochrome black T indicator, Murexide indicator, Sodium hydroxide 2N, Standard EDTA solution 0.01 M, Standard calcium solution and Procedures during total hardness analysis were 50mL well mixed sample in porcelain dish or conical flask was added and buffer solution of 1-2ml was added by followed 1mL inhibitor (hydroxylamine hydrochloride). Pinch of Eriochrome black T and titrate with standard EDTA (0.01M) were added till wine red colour changes to blue, note down the volume of EDTA required. Run a reagent blank, volume of EDTA required were calculated depend on the samples amount. According to (Goetz et al., 1959).

1.2. Materials and Method for Chloride Analysis

Chloride was determined by Potentiometric titration silver nitrate solution with a glass and silver-silver chloride electrode system. During titration an electronic voltmeter used to detect the change in potential between the two electrodes. The end point of the titration is that instrument reading at which the greatest change in voltage has occurred for a small and constant increment of silver nitrate added. Reagent used during chloride analysis were, Standard Sodium chloride solution, 0.0141M (0.0141N): Dissolve 824.0 mg NaCl (dried at 140°C) in distilled water and dilute to 100 ml: 1.00 ml of 500 μg Cl-, Nitric acid, HNO_3, concentration, and Standard silver nitrate titrant, (0.0141 N): Dissolve 2.395 g $AgNO_3$ in distilled water and dilute to 1000 ml (Kolthoff et al., 1951).

1.3. Procedures for Analysis Sulphate

Sulphate was determined by Spectrophotometer instrument and analysis using Turbidimetric method. Apparatus and equipment used during the analysis were; Magnetic stirrer. Colorimeter for use at 420mm or turbidimeter/nephelometer, Stopwatch, Nessler tubes, 100mL, and measuring spoon 0.2 to 0.3mL and reagent used were Buffer solution of different reagents of $MgCl_2.6H_2O$, Sodium acetate ($CH_3COONa.3H_2O$), Barium

chloride and Standard sulphate solution: dissolve. (APHA et al., 1998), and (Sawyer et al., 2000)

1.4. Material and Method for Calcium and Magnesium Hardness Analysis

Samples of 50mLwere taken in a porcelain dish and 1ml of NaOH was added to raise the pH to 12.0 and a pinch of Murexide indicator to 12.0 and a pinch of Murexide indicator. Immediately titrated with EDTA till pink colour changed to purple and run a reagent blank and the mL of EDTA required and kept it asided to compare end points of sample titrations. The volume of EDTA required by sample was calculated according to (Goetz et al., 1959; Babko et al., 1976)

1.5. Procedures for Manganese and Iron Analysis

Atomic absorption spectrophotometry instrument were used to analysis iron depending on the level of iron in the sample. Since the iron level was higher than 0.1ppm, the analyses were held by direct air-acetylene flam method. High level iron were analyzed on (nova 400) flame atomic spectrometer set at 248.3nm and was employed an air-acetylene flame. Samples were aspirated into a laminar flow burner head which support a flame fuelled by a mixture of air and acetylene. Iron present in the samples were atomized. A monochromatic light source (a hollow cathode lamp) emitting light at248.3nm was directed through the flame. Iron atom in the flame was selectively absorbed at 248.3nm.Three concentrations of standard metal solutions in the optimum concentration range were selected. The 100 ml of standard and metal free water for blank were adjusted to pH 3 by adding 1N of HNO_3. PH was adjusted for Iron extraction to obtain optimum extraction.

The standard solution and blank were transferred into in 200ml volumetric flask and 1ml of ammonium pyrrolidinedithiocarbamate solution was added and shaken.10ml of Methyl Isobutyl Ketone was added and shaken vigorously for 30 seconds. When the contents of organic and aqueous were separated, water was added carefully down to the side of each flask where it is accessible to the aspirating tube. Then the organic extract was aspirated directly into the flame and the absorbance was recorded.

A calibration graph was prepared from the obtained absorbance of standard solutions against their concentrations before extraction. The samples were prepared as standard samples and the organic extracts were aspirated directly into the flame and the absorbencies were recorded. The concentration of the iron was determined from the calibration curves using measured absorbance according to (APHA, 1998).

1.6. Material and Method for Sodium Analysis

Flame photometer either direct-reading or internal-standard type, atomic absorption spectrometer in the flame emission mode. Photo electrically the intensity of color imparted to the flame of a Meker type burner where the samples was introduced into the flame under carefully standardized conditions. The intensity of color was proportional to the sodium content in the samples. Sodium was determined at a wavelength of 589 nm.

Apparatus used during sodium analysis in sampled water were, Flame photometer, and Glassware.   Reagents used were; deionized distilled water, Stock sodium solution, and Standard lithium Solution. procedures followed during the analysis were; polluted water and wastewater samples firstly were treated and filter the samples were passed through 0.45μm membrane filter. Instrument perfections and adjustment properly according to manufacturer's recommendation for selecting proper photocell and wavelength, adjusting slit width and sensitivity, appropriate fuel and air or oxygen pressures and the steps for warm-up, correcting for interferences and flame background, rinsing of burner, igniting sample and measuring emission intensity were properly checked. Direct-intensity measurement: Prepared a blank and sodium calibration standards in stepped amounts in any of the following applicable ranges: 0 to 1.0, 0 to 10, or 0 to 100 mg/L were followed. Started with the highest calibration standard and worked toward the most dilute, measure emission at 589 nm and repeated the operation with both calibration standards and samples enough times to secured a reliable average reading for each solution was held.

Finally constructed a calibration curve from the sodium standards and sodium concentration of sample from the calibration curve were determined. Where a large number of samples were run routinely, the calibration curve provided sufficient accuracy. Internal-standard measurement: To a carefully measured volume of sample (or

diluted portion), each sodium calibration standard and a blank, added with a volumetric pipette, an appropriate volume of standard lithium solution. Finally was Measured the intensity directly. Bracketing approach: From the calibration curve, selected and prepared sodium standards that immediately bracketed the emission intensity of the sample and the emission intensities of the bracked standards (one sodium standard slightly less and the other slightly greater than the sample) and the sample as nearly simultaneously as possible were determined and repeatedly determined bracketing standards and sample. Finally the sodium concentration was calculated using standard calibration curve equation according to (Collins et al., 1952).

1.7. Procedures for Analysis of Potassium

Potassium was determined by (AAS) instrument using Flame Emission Photometric method by determined in either a direct-reading of internal standard type of flame photometer at a wavelength of 766.5 nm and apparatus and equipment used during the analysis were; atomic absorption spectrometer in the flame emission mode. Reagent and standard used were, Reagent water deionized distilled water, Stock potassium solution (KCl), and intermediate potassium solution, procedure done during analysis were, waste water samples were treated first and by following manufacturer's recommendation for selecting proper photocell and wavelength, adjusting slit width and sensitivity, appropriate fuel and oxidant gas pressures and the steps for warm-up, correcting for interference and flame background, rinsing of burner, igniting flame and measuring emission intensity procedures were carefully done kept. The Direct-intensity measurement procedures were, Prepared a blank and potassium calibration standards in stepped amount in any of the following applicable ranges: 0 to 1.0, 0 to 10, and 0 to 100 mg /L and was used the last range of 0-100mg/l.

The emission intensity at 766.5 nm were determined by aspirated calibration standards and samples enough time to secured a reliable average reading for each. Finally were Constructed a calibration curve from the potassium standards and determined potassium concentration of sample from the calibration curve by the order of large number of samples were run routinely and the calibration curve provide sufficient accuracy as stated by (Mehlich et al.,1952)