JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

ENVIRONMENTAL ENGINEERING MASTERS PROGRAM

HYDROGEOCHEMICAL AND BACTERIOLOGICAL ANALYSIS OF GROUND WATER QUALITY FOR WATER SUPPLY AND IRRIGATIONAL USES: A CASE OF GUDER TOWN

By

URGESSA GUDDINA LEMMESSA (MSc)

ATHESIS 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

MARCH, 2018

JIMMA, ETHIOPIA

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MARCH, 2018

JIMMA, ETHIOPIA

APPROVAL SHEET

Jimma University Jimma Institute of Technology, Faculty of Civil and Environmental Engineering. Environmental Engineering chair Name of the Student: Urgessa Guddina Lemmessa. Program of Study: M.Sc .in Environmental Engineering.

Title: Hydrogeochemical and Bacteriological Analysis of groundwater quality for water supply and irrigational uses: A case of Guder Town. I declare that the proposed research work has not been done anywhere else before or is not part of any ongoing work. We have agreed to supervise the proposed research work. We have evaluated the contents of the research, found to be satisfactory, complete, and according to the standards and formats of the University. We have also verified that the work has not been done anywhere else before.

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DECLARATION

This thesis entitled "Hydrogeochemical and Bacteriological Analysis of groundwater quality for water supply and irrigational uses: A case of Guder Town." has not been presented for a Masters degree or any other Degree in Jimma Institute of Technology (JiT) or any other university.

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ABSTRACT

Groundwater refers to all the water occupying the voids, pores and fissures within geological formations, which originated from atmospheric precipitation either directly by rainfall infiltration or indirectly from rivers lakes or canals. The current concern of world is the issues of water pollution with chemicals. The study was conducted to analyze 'hydrogeochemical and bacteriological suitability of groundwater for water supply and irrigational uses in Guder town. Here, Ground water quality suitability for domestic purposes, for irrigational uses, and groundwater type were analyzed. Using purposive sampling technique nine samples of water were taken from different sample points. Field and laboratory based measurement were conducted. The following physicochemical and bacteriological parameters were analyzed following standard methods for the analysis of water and wastewater: The average values of groundwater quality parameters of the study area were: Temperature (22.9^oC), turbidity (16.9NTU), pH 7, TS (1326.9mg/L), TDS (741 mg/L), EC ($1164\mu S/cm$),TA (410.9mg/L),Na^+ (306.4 mg/L), K^+(29.5mg/L), Ca^{2+}(106.8mg/L), Mg^{2+}(91.7mg/L), TH(198.5 mg/L), Fe^{2+}(1.3mg/L),SO_4^{2-} (88.95 mg/L), F^-(0.94mg/L),NO_3^-(5.2 mg/L), Mn^{2+}(0.27mg/L), As^{3+} (0.001 mg/L), Cl^- (17.8 mg/L), HCO_3^-(410.9 mg/L), CO_3^{2-} (0 mg/L). The average values of the following physicochemical parameters of were above WHO permissible guideline values such as: EC, TDS, HCO_3^-, TA, Ca^{2+}, Fe^{2+}, Mn^{2+}, Na^+, K^+, TS ,Turbidity, FC, and TC. The rest parameters of: pH, NO_3^-, As^{3+}, CO_3^{2-}, CO_3^{2-}, and Cl^-, average values were below and in (WHO, 2011) guideline values. The maximum values of Mg^{2+}, $SO_4^{2-}$and TH were recorded at BH1 of the source for water supply. Bacteriological analysis results were: FC (9.1MPN/100) and TC (14MPN/100). Water type of the study area was determined by using Aquachem version 4software. The water types of the studies area of BH1, SP6, R8, and R9 were $Na-Mg-Ca-SO_4$ types which is dominant types. The rest sample points of: SP4, and SP5, $Na-Mg-HCO_3$ water types and finally BH2 and HW7 of $Na-HCO_3$ water types were detected. Groundwater suitability for irrigational uses was analyzed by irrigational indices of: SAR (100%) suitable, %Na (55.6%), PI (55.6%) in permissive range. However the values of SSP (77.8%) in doubtful range, and MH (62.34%) were unsuitable. In general the study was concluded that the physicochemical and bacteriological property of groundwater of the study area was unsuitable for domestics and irrigational uses. Therefore Guder town municipal water supply office and concerned body should: design and construct treatment plant; use chlorination treatment; build cascading aerators to remove Iron; construct laboratory center for monitoring the groundwater quality continuously.

Key words: Hydrogeochemical; physicochemical; bacteriological; groundwater; Guder town

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LIST OF ABBREVIATIONS

AAS	Atomic absorption spectrophotometry
APHA	American Public Health Association
AWWA	American Water Works Association
EC	Electrical Conductivity
EMB	Eosin Methylene Blue Agar
EPA	Environmental Protection Agency
FMoWR	Federal Ministry of Water Resource
GPS	Global Positioning System
GV	Guideline Value
GW	Ground Water
HIDE	Hierarchy inside the Definitions of Education
MPP	Multi Parameter Probe
Mg/L	Milligram per litter
MH	Magnesium Hazard
MMT	Methylcyclopentadienyl manganese tricarbonyl
NTU	Nephelolometric Turbidity Units
SAR	Sodium Adsorption Ratio
TA	Total Alkalinity
TDS	Total Dissolved Solids
TH	Total Hardness
UNEP	United Nations Environment Program
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNICEF	United Nations International Children's Emergency Fund
USEPA	United States Environmental Protection Agency
WHO	World Health Organization
WPCF	Water Pollution Control Federation and Water Environment Federation

CHAPTER ONE
INTRODUCTION

1.1 Background

Groundwater refers to all the water occupying the voids, pores and fissures within geological formations, which originated from atmospheric precipitation either directly by rainfall infiltration or indirectly from rivers, lakes or canals. Usually the source of groundwater supply are sands, gravel, sandstones, and limestone formations and some may be drawn from impervious rocks such as granite when they have an over burden of sand or gravel (Oyedotun *et al.,* 2012). The quality of groundwater sources are affected by the characteristics of the media through which the water passes on its way to the groundwater zone of saturation (Adeyemi *et al.,* 2007).

Buchanan (1983) also estimated that groundwater reservoir of the world at about 5×10^{24} L, this volume is more than 2,000 times the volume of waters in the entire world's rivers and more than 30 times the volume contained in the entire world's fresh water (Brindha *et al.,* 2011).

Utilization of groundwater as a source for domestic, municipal, agricultural and industrial activities continue to increase principally because of the heavy capital outlay and maintenance of surface water development through Dams especially in developing countries (Sangodoyin *et al.,* 1992). The increasing water demand has triggered the alteration of water quality by various factors including geological and anthropogenic sources (Saravanan *et al.,* 2015).

1.1.1 Geological perspectives

Groundwater quality is mainly affected by the geological formations that the water passes through its course and by anthropogenic activities (Siegel, 2002). Groundwater pollution occurs when used water is returned to the hydrological cycle. As a result, the naturally existing dynamic equilibrium among the environmental segments get affected leading to the state of polluted rivers.

1.1.2 Plate tectonics and climate change

The horizontal and vertical displacements associated with plate tectonics play a fundamental role in climate change over a wide range of timescales. The solid earth surface is in direct contact with the atmosphere and oceans and its evolving character

affects balances of incoming and outgoing radiation, atmospheric circulation, and ocean currents and the location of elevated terrain suitable for glaciers and ice sheets. Tectonic processes also have important indirect climatic effects through their control on geochemical cycling and the composition of the atmosphere and ocean. This entry provides an introduction to the more direct, physical effects of tectonics on the climate system (Crowley *et al.,* 1998).

Globally, groundwater provides about 50% of the current potable water supplies, 40% of the demand of self supplied industry, and 20% of water use in irrigated agriculture according to UNESCO (2003) estimation. This groundwater resource is however under pollution threats thus undermining its suitability for human consumption with all its contaminants health hazards. These threats may originate from both natural and anthropogenic sources such as geology and geochemistry of the environment, increasing water demand and withdrawal, mineral exploitation, industrialization and agricultural land use, indiscriminate drilling of boreholes and lack of pretesting of groundwater before drilling (Mackey, 1990; Edmund, 1996; MacDonald, 2005; Ocheri, 2010).

Groundwater quality will be analyzed by its physical, chemical and biological properties. These parameters or element interact to define the water resources quality of an area (Caliandro *et al.,* 1995).The classification, modelling and interpretation of water quality data are important steps in assessment and analysis of the water quality (Bayacioglu, 2006).

For many millions more, particularly in sub- Saharan Africa, who do not as yet have any form of improved supply, untreated groundwater supplies from protected wells with hand pumps are likely to be their best solution for many years to come (Chilton, 1996). Sub-Sahara African countries have fusion rich and poor resource but are generally underutilizing their available water resources, including groundwater. Most of the countries in the region have agriculture as their primary source of livelihoods and an entrenched dependence on wells and boreholes for the provision of rural water supplies (Pavelic *et al.,* 2012).

In Sub-Saharan Africa, the Eastern African region, particularly the Horn of Africa, is considered highly geographically exposed to climate change and its impact over water. About 70 million people in this area are located in areas prone to extreme drought leading to water insecurity and food shortages. In this Eastern African region, floods and

droughts can occur in the same area within a very short period. Such events can exacerbate water availability in quality and quantity, sufficient enough to sustain agricultural activities and energy production (Ndaruzaniye, 2011).

Ethiopia a country with complicated hydrogeological environment and complex groundwater regime, has 12 river basins with an annual runoff volume of 122 billion m^3 of water and an estimated 2.6 - 6.5 billion m^3 of groundwater potential, which makes an average of 1575 m^3 of physically available water per person per year, a relatively large volume. However, due to lack of water storage infrastructure and large spatial and temporal variations in rainfall, there is not enough water for most farmers to produce more than one crop per year (Sileshi *et al.,* 2007).

Ethiopia as a second known country in Africa by her population number, most or 85% of the population lives in rural areas where water shortage is more predominating problems. This shortage of water can be solved by proper utilization of groundwater and first attempt to identify the main aquifers in various parts of Ethiopia, identifying geo-graphical environments and variable climate, which will be very important in giving proper solution for water supply problems in arid and semi arid part of the country (Alemayehu and Kebede, 2006).

In Ethiopia several studies on ground water potential assessments indicate the rechargeable or replenishable groundwater potential of the country is in the order of 2.6 billion cubic meters. Estimations of the groundwater require a good understanding of the regional geology, hydrology, hydrogeology, hydraulics of ground water flow (Moges, 2012).

The occurrence of groundwater in Ethiopia is mainly influenced by the geology, geomorphology, tectonics and climate of the country. The geology of a given place provides usable groundwater and provides good transmission of rainfall to recharge aquifers, which produce springs and feed perennial rivers (Tamiru, 2006). Coming to recent occurrences, one of the most important environmental issues today is groundwater contamination and diversity of contaminants that affect water resources (Vadila *et al.,*1997).The most contaminants of groundwater are heavy metals likes Aluminium, Cadmium, Lead, Mercury, Copper, Zinc, Iron, Magnesium, Arsenic and etc. These heavy metals particularly cause strong toxicity even at low concentrations (Marcovecchio *et al.,* 2007).

In Ethiopia, high concentrations of iron were found in the groundwater supplies of Addis Ababa, Afar, Amhara, Benshangul, Gambella, and Western Oromiya. High iron concentrations and water hardness commonly cause unsuitable test that lead to reject groundwater supply. Acceptable water quality shows the safety of drinking water in terms of its physical, chemical, and bacteriological parameters (WHO, 2004). User community's perceptions of quality also carry great weight in their drinking water safety (WHO, 2004).

Guder town community get drinking water supply from ground water. The extracted ground water released to community was unsuitable for drinking and other domestic purposes. The practical observable problems were: unsuitable test; resistance water forming lather with soap; scale forming on heaters; effect of diarrheal on children; potatoes color change; turbidity , settable particles on the bottom can; teas and coffee color and test change were observed.

In general the problems were so severe at Guder towns that iron and hardness removal plants should be installed. However there was no previous detail study conducted on the geological and hydrogeochemical parameters in Guder and around Guder town. Therefore study was attempted to identify and underlying factors that influence the quality of groundwater sources for water supply in Guder town.

Guder is predominantly town with over 17084 of the population living in the areas. This segment of the population is faced with acute water shortage and water supply quality problem, as well as traditional water sources such as streams, rivers, and spring are under stress from climatic variability and intensified agricultural land uses resulting into many of them drying up (Ocheri, 2010; Ocheri et al., 2012).

The current sources for water supply in Guder town were groundwater which was unsuitability for domestic and irrigational use .This indicate that the ground water was polluted by natural and anthropogenic phenomenon (Ocheri, 2010). This has led to some communities abandoning using water from such borehole. As having raised the community expectation and it was dashed (MacDonald et al., 2005).

The concentrations of physical, chemical and bacteriological constituents affect the quality of groundwater for drinking and other domestic purposes (Ocheri, 2010).This study was sought to isolate factors that have a controlling influence on the quality of groundwater in Guder town for different purposes.

1.1.3 Groundwater hardness

The principal natural sources of hardness in water are sedimentary rocks and seepage and runoff from soils. In general, hard waters originate in areas with thick topsoil and limestone formations. Groundwater is generally harder than surface water. Groundwater rich in carbonic acid, usually has a high solvating power; in contacting soil or rocks containing appreciable amounts of minerals, such as calcite, gypsum and dolomite, hardness levels up to several thousand milligrams per litter can result (Mensah *et al.,* 2011)

In areas with hard water, household pipes can clogged with scale; hard waters also cause incrustations on kitchen utensils and increase soap consumption. Hard water is thus both a nuisance and an economic burden to the consumer (Mensah *et al.,* 2011). Public acceptance of hardness varies among communities; it is often related to the hardness to which the consumer has become accustomed, and in many communities hardness tolerance depend up on local conditions. It has been suggested that a hardness level of 80 to 100 mg/L (as $CaCO_3$) provides an acceptable balance between corrosion and incrustation (Bean *et al.,* 1974). However, waters with hardness in excess of 500 mg/L are unacceptable for most domestic purposes (Bean *et al.,* 1974).

Hard water minerals such as calcium, magnesium, iron and manganese result in scaling problems and serious failures in pipelines of boilers and heat transfer equipment. In addition, these divalent ions can react with soap anions decreasing the cleaning efficiency and hence, high consumption of detergents occurred as a result. However, calcium and magnesium are the most common sources of water hardness. It is substantial for intracellular metabolism, bone growth, blood clotting, nerve conduction, muscle contraction and cardiac function (Akyilmaz *et al.,* 2009). However, there is a significant association between high calcium level in drinking water causes: colorectal, gastric and breast cancer (Yang *et al.,* 2000).

Taking too much supplemental magnesium can result in symptoms of toxicity. These symptoms include a fall in blood pressure, confusion, abnormal cardiac rhythm, muscle weakness, difficulty breathing and deterioration of kidney function (Graber *et al.,* 1981). Guder town's groundwater was installed by 67million Ethiopian birr was unsuitable for domestics and irrigational uses. Communities of the town complain about its uses.

Metallic test of the water was another challenge to the community of Guder town and still no measure was taken from the side of concerned bodies.

1.2 Statements of the Problems

The physical, chemical, and biological analysis of groundwater determines its usefulness for various purposes. Chemical analysis of groundwater includes the determination of the concentrations of inorganic constituent such as calcium, sodium, iron; manganese, magnesium, Arsenic, Aluminium, Fluoride and Mercury can have negative impacts on aquatic flora and fauna. The recent concern of world is the issue of quality of water and health of environment focusing on heavy metal contamination which has been seen as a major threat for environmental and human health because of their toxicity   effects   on human being (Schwarzenbach *et al.,* 2010).

Heavy metals can cause damage to practically all the organs in the body and disturbs human health (Bremner *et al.,* 1974). Even though presence of heavy metals in water is at minimal concentration, some of them have given critical attention due to their high toxicity, carcinogenicity and mutagen city (Adepoju-Bello *et al.,* 2012)

But heavy metals, being positively charged ions, exhibit their toxicity by displacing and replacing nutrient minerals of same valance in enzyme binding sites which alter the activity and normal functioning of thousands of enzymes. In general, heavy metals are systemic toxins with neurotoxic, nephrotoxic, phytotoxic and teratogenic effects (Adepoju-Bello *et al.,* 2012).

Groundwater forms the common source of drinking, irrigation, and industrial purposes. However, its quality is getting deteriorated due to low rainfall and high evapotranspiration. Most of the important freshwater bodies are 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 (Deutsch *et al.,* 1997). The geochemical processes are responsible for the seasonal and spatial variation in groundwater chemistry. Hydrogeochemical 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 are dealt with in hydrogeochemistry (Hem *et al.,* 1985). From

hydrogeochemical point of view the deep groundwater is more mineralized due to long time interaction with the host rock (Alemayehu and Kebede, 2006).

Taste and odour problems account for the largest single class of consumer complaints in drinking water supplies, due to the water source, the treatment method, distribution system or a combination of all three (WHO, 1984). Here under the study was focus on hydrogeochemical and bacteriological groundwater quality for domestic and irrigational uses in Guder and around Guder town.

Groundwater sources of water supply for Guder town was found around chancho spring which is locally named as 'Hora chancho' hard mineral water and as already known by community found around the village, it is unsuitable for domestic and irrigational uses. The following considerable problems were detected in the current groundwater for water supply to Guder Town: produces soap scum and consume larger amounts of soap; most noticeable on tubs and showers; produces white mineral deposits on dishes more noticeable on clear glassware; and reduces efficiency of devices that heat water.

The observable effects with groundwater supply of the town: reducing the efficiency of heat transfer; Causes of diarrhea and related water borne disease on children; Kidney problem on most people of the town; resistance of water to form lather with soap; 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; highly concentrated with ash colour; and dissolved substances forming sediment at bottom of a stand still container within an hour. These all effects, lead to increase Guder town community complaint not to use it (Freeze and Cherry, 1979).

Generally it is important to analysis hydrogeochemical and bacteriological ground-water quality for domestic and irrigational uses in Guder and around Guder town to search alternatives treatment. Additionally this study will work, being a scientific information, and data input will help to ascertain for further treatment work and improved management of the water at use (Hem, 1985)

1.3 Objective of the study

1.3.1 General objective

The main objective of the study is to analysis hydrogeochemical and bacteriological properties of groundwater quality and suitability for water supply and irrigational uses.

1.3.2 Specific objectives

1. To evaluate groundwater's physicochemical parameters suitability for drinking and other domestic purposes.
2. To determine bacteriological quality of groundwater for drinking purposes.
3. To identify and describe the major hydrogeochemical facies of groundwater types of the study area.
4. To investigate the suitability of groundwater for irrigational uses.

1.4 Research questions

1. What are the suitability and quality status of groundwater's physicochemical parameters for drinking and other domestic purposes?
2. What is bacteriological quality status of groundwater for water supply?
3. What are major hydrogeochemical facies of groundwater type of the study area?
4. What is the status of chemical composition of groundwater suitability for irrigation?

1.5 Significance of the Study

People to exist on the earth surly needs water priority giving to drinking of potable and palatable water from every source of water supply. It is also fact that basic sanitation and hygiene is crucial need of people. Food which is going to be delivered to children and generally for human being has to be prepared and processed by pure and potable water. WHO (1996) has a guideline permissible limit to the use of water for different activities to keep human health and environment.

This study was focused on hydrogeochemical and bacteriological analysis of ground water quality for water supply and irrigational uses 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 hydrogeochemical and identifying the types of dominant anions and cations is help full for the following purposes; to minimize health side effects due to unsafe water; to design alternative sources of water supply for future; to minimize Guder town's community complaint about water quality problems and search the basic causes of the problems to give remediation.

Generally, this research is important to determine the quality in relation to chemical composition of groundwater for which it is intended to use. It is also important to identify major geochemical processes that cause change in quality of water. Finally the

benefiter of this study will be: Guder town community, hospital, schools, different factory and the owners of the Town University. This research provided baseline information on the profile of geological patterns and water quality deteriorating factors for further study.

1.6 Scope of the study

This thesis work was focused on analysis 'Hydrogeochemical and bacteriological quality of groundwater suitability for water supply and irrigational uses: A case of Guder town.' Under this title four important points were effectively focused and analyzed. The first important point was determinations and analysis of the suitability of groundwater's physicochemical parameters for drinking and other domestic 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^+, K^+, Mn^{2+}, As^{3+}, and Fe^{2+}.

The second important point focused was Bacteriological parameters of: TC and FC were analyzed in detail. The third important focused points were identifying and describing of hydrogeochemical facies groundwater type of the study area. The fourth important point focused were determination of groundwater suitability for irrigation indices which are: SAR, SSP, MH, %Na, and PI

1.7 Limitation of the study

This study did not cover all the area in the district due to resource and time limitations. Material and compiled data access problems in the concerned office such as Guder town municipal water supply offices. The other big challenges faced the researcher was political instability of the study area that prohibited conducting further assessment part. The detail information regarding the groundwater construction was unknown. There may be parameters seasonal variation because study was done during the rainy season. However, the researcher was spent a great deal of time within the study period to collect adequate data to maintain the quality of results.

CHAPTER TWO
LITERATURE REVIEW

2.1 Groundwater 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 are at least three factors that influence groundwater occurrence: hydraulic properties of the geological formations, geological framework, and climate (Freeze and Cherry, 1979).

2.1.1 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 is 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).

2.1.2 Geological framework

The occurrence, distribution, movement, and composition of subsurface waters are intricately linked to the structure and nature of the geological formations (Freeze and Cherry, 1979). One of the primary objectives of hydrogeological investigations is 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).

2.1.3 Hydrogeochemical process

The chemical quality of water results from hydrogeochemical 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 postma,2005;Hounslow,1995). These processes

are 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 etc. (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 are mainly concentrated in mineralized provinces associated with ore grade rocks (White, 2013). Geochemical provinces are part of earth crust in which chemical composition is 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, are the key factors for the concentration of F^-, NO_3^- is a non-lithological source (White, 2013).

In natural conditions, the concentration of $NO3^-$ does not exceed 10 mg/L in the water so that the higher concentration of $NO3^-$, beyond 10 mg/L, is an indication of anthropogenic pollution. The concentration of bicarbonate in groundwater is determined by natural geological formation of an area. Mainly amount of bicarbonate will be low in areas where marine clay occurs (Rao *et al.,* 2011).

2.2 Physicochemical water quality

It is very important to test the water before it is 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 we are 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.

WHO (1995) describes the meaning of physicochemical as; quality which is 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 (Adepoju-Bello *et al.,* 2012).

2.2.1 pH

The pH value of a water source is a measure of its acidity or alkalinity. The pH level is a measurement of the activity of the hydrogen atom, because the hydrogen activity is a good representation of the acidity or alkalinity of the water. The pH scale, ranges from 0 to 14, with 7.0 being neutral. Water with a low pH is said to be acidic, and water with a high pH is 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 are in the water (WHO, 1985).

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 (Adepoju-Bello *et al.,*2012). Strength of water to react with acidic or alkaline materials present it can be determined by pH (Rao *et al.,* 2011).

No health based guideline value is proposed for pH. Although pH usually has no direct impact on consumers, it is one of the most important operational water quality parameters. Although pH usually has no direct impact on consumers, it is 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).

2.2.2 Temperature

The temperature of water largely determines the extent of microbial activity. Temperature is the measure of hotness or coldness of water measured in either degree Celsius or Fahrenheit by using a thermometer. When temperature of water becomes

above 25°C, it will cause bone disease (pain and tenderness of) children may get (WHO, 1997).

Temperature is 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 are under the influence of high specific heat of water.

2.2.3 Total Dissolved Solids

Total dissolved solid is 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 is generally considered to be good; 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 is usually not a health hazard. In fact, many people buy mineral water, which has naturally elevated levels of dissolved solids. 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 is undesirable (WHO, 1996).

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 is related to other water quality parameters like hardness, which may occur if the high TDS content is due to the presence of carbonates (Adepoju-Bello *et al.,* 2012). Water with TDS value above 1000mg/L can cause stomach discomfort (WHO, 1997).

2.2.4 Turbidity

Turbidity is an optical property of water that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample. It is 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 is the amount of the particulate matter (Sarai, 2006). 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 (Barnes *et al.,* 1989).

Turbidity adversely affects the efficiency of disinfection of water. It is measured to determine what type and level of treatment are needed. It can be carried out with a simple turbidity tube that allows a direct reading in Nephelometric turbidity units NTU (WHO, 2006). It may also be due to the presence of inorganic particulate matter in some groundwater or sloughing of bio film within the distribution system.

The appearance of water with a turbidity of less than 5 NTU is usually acceptable to consumers, although this may vary with local circumstances. No health-based guideline value for turbidity has been proposed; ideally, however, median turbidity should be below 0.1 NTU for effective disinfection, and changes in turbidity are an important process control parameter (WHO, 2006). Water with elevated turbidity will cause nausea, cramps, diarrhea and associated head ache (WHO, 1997).

2.2.5 Total solid

Total solids' is 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. 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 are the residue remaining after ignition for 1 hour at 550°C. The solid portion that is volatilised during ignition is called volatile solids. It will be mostly organic matter. According to (Howard *et al.,* 1933), the difference between the total solids and the total dissolved solids will give the total suspended solids.

2.2.6 Electrical Conductivity

Conductivity is the measure of capacity of a substance to conduct the electric current. Most of the salts in water are present in their ionic forms and capable of conducting current and conductivity is a good indicator to assess groundwater quality. EC is an indication of the concentration of total dissolved solids and major ions in given water body (Richards, 1954). It is temperature dependent and the international unit is Siemens per meter (Hounslow, 1995). When the Electrical Conductivity value of water becomes larger; Anaemia; liver kidney or spleen damage; changes in blood will occur in the body of consumers (WHO, 1997)

Table 2.1: Classification water suitability for irrigation based on EC

Water Class	EC (mhos/cm)	Salinity Significance
Excellent	<250	Water of low salinity is generally composed of higher proportions of calcium, magnesium and bicarbonate ions.
Good	250-750	Moderately saline water, having varying ionic Concentrations
Permissible	750-2250	High saline waters consist mostly of sodium and chloride Ions
Doubtful	>2250	Water containing high concentration of sodium, bicarbonate and carbonate ions have high pH

2.2.7 Iron

Iron is the second most abundant metal in the earth's crust, and it accounts for about 5% of the metal. Iron is most commonly found in nature in the form of its oxides. In anaerobic groundwater iron will be in the form of iron (II). Concentrations of iron in drinking-water are normally less than 0.3 mg/l but may be higher in countries where various iron salts are used as coagulating agents in water treatment plants and where cast iron, steel, and galvanized iron pipes are used for water distribution.

Iron with concentration value greater than 0.3 mg/L can causes rusting and cancer (WHO, 2004).Dissolved iron in groundwater is controlled by pH and redox conditions and is dependent on iron bearing minerals in the aquifer. Dissolution of iron can occur as a result of oxidation and decrease in pH. In drinking water supplies, iron (II) salts are unstable and are precipitated as insoluble iron (III) hydroxide, which settles out as a rust colored silt.

Staining of laundry and plumbing may occur at concentrations above 0.3 mg/L and is maximum contaminant level. Iron also promotes undesirable bacterial growth ("iron bacteria") within a waterworks and distribution system, resulting in the deposition of a slimy coating on the piping. Iron in water can cause yellow, red, or brown stains on laundry, dishes, and plumbing fixtures such as sinks (WHO, 2006).

In addition, iron can clog wells, pumps, sprinklers, and other devices such as dishwashers, which can lead to costly repairs. Iron gives a metallic taste to water, and can affect foods and beverages turning tea, coffee, and potatoes black warn that iron poisoning can affect the central nervous system. Iron stains laundry and plumbing

fixtures at levels above 0.3 mg/L. There is usually no noticeable taste at iron concentrations below 0.3 mg/L (WHO, 2006).

When the iron concentration of the water is above 0.3mg/L, rusting, the probability of occurrence cancer is great (WHO, 1997). Iron is the primary source for discoloration problems in the drinking water distribution system. Iron particles in water supplies cause various aesthetic and operational problems including bad taste. The values of iron shows that the range between 0.111 mg/L to 0.305 mg/L (WHO, 2006).

2.2.8 Manganese

Manganese is a naturally occurring cation that is widely present in groundwater supplies. Manganese can cause an undesirable taste as well as staining laundry when levels exceed 0.1 mg/L. The presence of manganese may also lead to the accumulation of deposits in the piping system (WHO, 2004). There is no health based guideline value set for iron but for manganese it is four times higher than the acceptable threshold of 0.1 mg/L (WHO, 2004).

Geochemically, manganese and iron behave similarly, so high manganese concentration can be expected from wells and springs that produce water with high iron concentrations. There is no EPA primary drinking water standard for manganese in water supplies because there are no identified, serious health threats, There is, however, a secondary standard of 0.05 mg/L for manganese based on the fact that higher concentrations may produce objectionable odour, taste, colour, corrosion, and staining.

Manganese usually occurs in fresh water with typically level range from 1 to 200 mg/L, although levels as high as 10 mg/L in acidic groundwater have been reported; higher levels in aerobic waters usually associated with industrial pollution. The WHO standard guide line value for Manganese is 0.1mg/L (WHO, 2006).

2.2.9 Calcium

Calcium occurs in water naturally. One of the main resources for abundance of calcium in waters its natural occurrence in the earth crusts. Calcium is also a constituent of coral. Calcium is essential to human health. In a watery solution calcium is mainly present as $Ca^{2+,}$ but it may also occur as Ca (OH) $_2$, or as $CaSO_4$ in seawater. Calcium is important determinant of water hardness, and it also functions as a pH stabilizer, because of its buffering qualities.

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Calcium also gives water a better taste. Hard water assists in strengthening bones and teeth because of its high calcium concentration. Chemical softening, reverse osmosis, ion exchange reduce the calcium and the associated hardness to acceptable level (APHA, 1998). Calcium carbonate has a positive effect on lead water pipes, because it forms a protective lead (II) carbonate coating. This prevents lead from dissolving in drinking water, and thereby prevents it from entering the human body. Inadequate intakes of calcium have been associated with increased risks of osteoporosis, nephrolithiasis or kidney stones, colorectal cancer, hypertension and stroke, coronary artery disease, insulin resistance and obesity. Most of these disorders have treatments but no cures (Akpoborie *et al.,* 2012).

Calcium is unique among nutrients, in that the body's reserve is also functional: increasing bone mass is linearly related to reduction in fracture risk (WHO, 2004). The WHO guide line contaminant level of calcium in drinking water is 200 mg/L. Calcium is undesirable because it may be detrimental for household use such as washing, bathing and laundering. It also tends to cause encrustation in kettles, coffee makers and water heaters and may impair treatment processes (Zodape *et al.,* 2014). When the concentration of calcium in drinking water is above 200mg/L, it will cause indigestibility of fat in the body (WHO, 1997).

2.2.10 Sodium

All natural waters contain some sodium since sodium salts are highly water soluble and it is one of the most abundant elements on earth. It is found in the ionic form (Na^+), and in plant and animal matter (it is an essential element for living organisms). The WHO guideline limit for sodium in drinking water is 200 mg/L. Sodium is commonly measured where the water is to be used for drinking or agricultural purposes, particularly irrigation.

Excess sodium in the soil limits the uptake of water due to decreased water potential, which may result in wilting, similar concentrations in the cytoplasm can lead to enzyme inhibition, which in turn causes and chlorosis. Excess sodium may also be stored in old plant tissue, limiting and damage to new growth. No health based guideline value is proposed. However, concentrations in excess of 200 mg/L may give rise to unacceptable taste (WHO, 2006).

Sodium in the human body helps in maintaining the amount of water balance. Human intake of sodium is mainly influenced by the consumption of sodium as chloride or table salt. The treatment for certain heart condition, circulatory or kidney diseases or cirrhosis of liver may include sodium restrictions (Møller *et al.,* 2009).

The recommended maximum level for people suffering from certain medical conditions such as hypertensions, congestive heart failure or heart disease is 20mg/L (Zodape *et al.,* 2014). Water with sodium concentration above 200mg/L increased the risk of cancer (WHO, 1997).

2.2.11 Potassium

Potassium is an essential element in humans and occurs widely in the environment, including all natural waters. Some food additives are also potassium salts like potassium iodide and it is also rarely occur in drinking water a level that could be a concern for healthy humans (Zodape *et al.,* 2014). However the contamination of drinking water by potassium can occur due to the use of excessive potassium permanganate as an oxidant in water treatment and due to the consumption of water obtained from water softeners that uses potassium chloride (Zodape *et al*., 2014).

Potassium occurs widely in the environment, including all natural waters and it can also occur in drinking water as a consequence of the use of potassium permanganate as an oxidant in water treatment. When the concentration of potassium in drinking water is above 50mg/L, there will be effect on blood pressure of consumers (WHO, 1997).

Potassium is found in low concentrations in natural waters since rocks, which contain potassium, are relatively resistant to weathering. However, potassium salts are widely used in industry and in fertilizers for agriculture and enter freshwaters with industrial discharges and run-off from agricultural land (Svetlana *et al.,* 2012).

2.2.12 Chloride

Chloride is minor constituent of the earth's crust. Chloride is present in all natural waters, mostly at low concentrations. Chloride in drinking water originates from natural sources, sewage and industrial effluents, urban runoff containing salt, and saline intrusion (WHO, 2011). High concentration of chloride gives a salty taste to water and beverages and may cause physiological damages (Balakrishnan *et al.,* 2011). It is highly soluble in water and moves freely with water through soil and rock. High concentrations of Chloride can make water unpalatable and, therefore, unfit for drinking or livestock

watering (Yisa *et al.,* 2010). In groundwater, the chloride content is mostly below 250 mg/L except in cases where inland salinity is prevalent and in coastal areas.

Chloride in drinking water originates from natural sources, sewage and industrial effluents, urban runoff containing de-icing salt and saline intrusion. Elevated concentration of chloride in increases the rates of metallic corrosion in water distribution system even though it depends on the alkalinity of the water. No health-based guideline value is proposed for chloride in drinking water. However, chloride concentrations in excess of about 250 mg/L can give rise to detectable taste in water (WHO, 2006).

2.2.13 Alkalinity

The alkalinity of a solution may be defined as the capacity of its solutes to react with and neutralize acid. The alkalinity in most natural waters is primarily due to the presence of dissolved carbon species, particularly bicarbonate and carbonate. Other constituents that may contribute minor amounts of alkalinity to water include silicate, hydroxide, borates, and certain organic compounds (Hem, 1985).

The alkalinity nature of water can be determined by the presence of one or more ions in water including hydroxides, carbonates, and bicarbonates (Lottermoser *et al.,* 2003). The nature and toxicity of water from different sources can be affected by alkalinity, pH and hardness substances found within it. It is usually expressed as the capacity to neutralize acid. To prevent corrosive effect of acidity in drinking water supply system it is anticipated to have moderate concentration of alkalinity. Unbalanced and excessive quantities alkalinity of water may cause a number of damages. The WHO standards express the alkalinity only in terms of total dissolved solids of 500 mg/L (Mohsin *et al.,* 2013).

2.2.14 Nitrate

The main source of nitrate in water is from atmosphere, legumes, plant remains and animal excreta (WHO, 2011). It also originates from sewage effluents, septic tanks and natural drains carrying municipal wastes. NH_4^+ from organic sources is converted to NO_3^- by oxidation. Because of this and its anionic form NO_3^- is very mobile in groundwater. The concentration of nitrate in natural water is less than 10 mg/L. Water containing more than 100 mg/L is bitter to taste and causes physiological distress.
Nitrate and nitrite are naturally occurring ions that are part of the nitrogen cycle.

Nitrate is used mainly in inorganic fertilizers, and sodium nitrite is used as a food preservative, especially in cured meats. The nitrate concentration in groundwater and surface water is normally low but can reach high levels because of leaching or runoff from agricultural land or contamination from human or animal wastes as a consequence of the oxidation of ammonia and similar sources (Follett *et al.,* 1991). Guideline value for nitrate is 50 mg/L to protect against methaemoglobinaemia in bottle-fed nitrate infants (WHO, 2006).

Follett *et al.* (1991) stated that low levels of nitrogen in the form of nitrate are normal in groundwater and surface water. However, elevated nitrate caused by human activity is a pollutant in the water. Nitrate enters ground or spring water from many sources, including nitrogen-rich geologic deposits, wild-animal wastes, precipitation, septic system drainage, feedlot drainage, dairy and poultry production, municipal and industrial waste, and fertilizer (Amanial *et al.,* 2015).

2.2.15 Magnesium

Magnesium and other alkali earth metals are responsible for water hardness. Water containing large amounts of alkali earth ions is called hard water, and water containing low amounts of these ions is called soft water. Large number of minerals contains magnesium, for example dolomite (calcium magnesium carbonate); $CaMg (CO_3)_2$ and magnesite (magnesium carbonate). Magnesium is washed from rocks and subsequently ends up in water.

Chemical softening reverse osmosis, electrodialysis, or ion exchange reduce the magnesium and the associated hardness to acceptable level. Magnesium sulphate is applied in beer breweries, and magnesium hydroxide is applied as a flocculent in wastewater treatment plants. However, due to the role magnesium plays in water hardness, WHO drinking water guideline has maximum contaminant level to be 150mg/L (WHO, 2006).

Magnesium is an essential nutrient in brain development and function, muscle contraction and DNA replication, and is an ingredient of many enzymes. There are no known cases of magnesium poisoning, but large oral doses may cause vomiting and diarrhea. Excess magnesium concentration can lead to changes in mental status, loss of appetite, extremely low blood pressure and irregular heartbeat (Rasheed *et al.* 2014).

2.2.16 Sulphate

Sulphates occur naturally in numerous minerals and are used commercially, principally in the chemical industry. They are discharged into water in industrial wastes and through atmospheric deposition; however, the highest levels usually occur in groundwater and are from natural sources. However, in areas with drinking-water supplies containing high levels of sulphate, drinking water may constitute the principal source of intake (WHO, 2006). In groundwater, most sulphates are generated from the dissolution of minerals, such as gypsum and anhydrite (Friedman *et al.,* 1997). Saltwater intrusion and acid rock drainage are also sources of Sulphates in drinking water. Manmade sources include industrial discharge and deposition from burning of fossil fuels (WHO, 2011). Sulphate concentrations in natural waters are usually between 2 and 80 mg/L.

High concentrations of sulphates greater than 400 mg/L may make water unpleasant to drink (Fetter *et al.,* 2017). When the concentration of sulphate in drinking water is above 400mg/L allergic dermatitis problem can occur on the consumer (WHO, 1997).

2.2.17 Total Hardness

Hardness in water is caused by dissolved calcium and to a lesser extent magnesium. It is usually expressed as the equivalent quantity of calcium carbonate. Depending on pH and alkalinity, hardness above 200 mg/L can result in scale deposition particularly on heating. Soft waters with a hardness of less than 100 mg/L have a low buffering capacity and may be more corrosive to water pipes. A number of ecological and analytical epidemiological studies have shown a statistically significant inverse relationship between hardness of drinking-water and cardiovascular disease (WHO, 2006). The degree of hardness in water may affect its acceptability to the consumer in terms of taste and scale deposition (WHO, 2006).

Public acceptability of the degree of hardness may vary considerably from one community to another, depending on local conditions, and the taste of water with hardness in excess of 500 mg/L is tolerated by consumers in some instances (WHO, 2006). Hardness caused by calcium and magnesium is usually indicated by precipitation of soap scum and the need for excess use of soap to achieve cleaning. Public acceptability of the degree of hardness of water may vary considerably from one community to another, depending on local conditions. In particular, consumers are likely to notice changes in hardness (WHO, 2006).

Depending on the interaction of other factors, such as pH and alkalinity, water with hardness above approximately 200 mg/L may cause scale deposition in the treatment works, distribution system and pipe work and tanks within buildings. It will also result in excessive soap consumption and subsequent "scum" formation. On heating, hard waters form deposits of calcium carbonate scale. Soft water, with a hardness of less than 100 mg/L, may, on the other hand, have a low buffering capacity and so be more corrosive for water pipes. No health-based guideline value is proposed for hardness in drinking-water (WHO, 2006).

Hardness in water is caused primarily by the presence of carbonates and bicarbonates of calcium and magnesium, Sulphate, chlorides and nitrates (Singh *et al.,* 2012). The hardness of natural waters depends mainly on the presence of dissolved calcium and magnesium salts. The total content of these salts is known as total hardness, which can be further divided into carbonate hardness (determined by concentrations of calcium and magnesium bicarbonates), and non-carbonate hardness (determined by calcium and magnesium salts of strong acids).

The total hardness of water classified in to three ranges low, medium and high (Karthikeyan *et al.,* 2013).When the total hardness of drinking water exceed 500mg/L increase in blood pressure of consuming community will occur (WHO, 1997).

Calculating calcium hardness as CaCO₃

The hardness (in mg/L as CaCO₃) for any given metallic ion is calculated using Equation

$$\frac{calcium \ hardness \ mg/L \ as \ CaCO_3}{equivalent \ weight \ of \ CaCO_3} = \frac{calcium \ (mg/L)}{equivalent \ weight \ of \ calcium} \tag{1}$$

Calculating magnesium hardness as CaCO₃

To calculate magnesium harness, we use Equation (2)

$$\frac{magnesium \ hardness \ (m/L) \ as \ CaCO_3}{equivalent \ weight \ of \ CaCO_3} = \frac{magnesium \ (mg/L)}{equivalent \ weight \ of \ magnesium} \tag{2}$$

Calculating total hardness

Calcium and magnesium ions are the primary cause of hardness in water. The total hardness is the sum of calcium concentrations and magnesium ions, expressed in terms of calcium carbonate (CaCO₃) (Tchobanoglous *et al.,* 1985). Total hardness (mg/L) as CaCO₃ = Ca^{2+}hardness (mg/L) as CaCO₃ + Mg^{2+}hardness (mg/L) as CaCO₃. (3)

Table 2.2: classification of water according to hardness

Worded description	Sanitary engineering (mg/l as Caco3)	Water conditioning industry (mg/l as $Caco_3$)
Soft water	0-75	0-50
Moderately hard	76-150	51-100
Hard water	151-300	101-150
Very hard	301 and above	151and above

Groundwater can be classified as soft, moderate, hard water, and very hard (Sawyer and McCarty, 1967)

2.2.18 Fluoride

Fluoride contamination of groundwater is a serious problem in several countries spread throughout the world as ingestion of excess fluoride, most commonly, through drinking contaminated groundwater causes fluorisis. Mainly two factors are responsible for contamination of groundwater with fluoride geological and anthropogenic (Susheela *et al.,* 2007). The anthropogenic factors industrialization, urbanization and improper utilization of water resources are of prime importance, in case of the developing countries.

Long term ingestion of fluoride in high doses can lead to severe skeletal fluorisis (Susheela *et al.,* 2007). Fluoride contamination of groundwater is a serious problem in several countries spread throughout the world as ingestion of excess fluoride, most commonly, through drinking contaminated groundwater causes fluorisis. Physiological conditions of rock, like decomposition, dissociation and subsequent dissolution along with long residence time may be the responsible factors for fluoride leaching (Madhnure, 2007).

2.2.19 Arsenic

Arsenic is a naturally occurring element that is found in rocks and soil, and is usually combined with other elements to form mineral compounds. Arsenic can be found at high levels in areas with volcanic or geothermal activity. Arsenic can enter water supplies and waterways via the erosion of rock formations, volcanic activity, agricultural runoff, mining activities, or certain types of industrial waste runoff (Carpenter *et al.,* 1998).

Elevated levels of arsenic affect groundwater in various regions throughout the world. The species, or types, in which arsenic commonly occurs in groundwater, are: arsenite As (III), and arsenate As (V) and hazardous to human health (Ng *et al.,* 2003).

Arsenic is a prevalent element in the environment. Its sources in the environment can be natural or anthropogenic (Ng et al., 2003). Numerous methods are described in the literature, for the analysis of total arsenic in water. Many analytical methods essentially employ the same principles, but apply different reagents or concentrations.

The possibilities for total arsenic determination include: Atomic absorption spectrometry method by (Hydride Generation System or Graphite furnace), inductively coupled plasma method (With atomic emission or mass spectrometry), Atomic fluorescence spectrometry method, Anodic stripping voltammeter, and Spectrophotometry method (Srogi *et al.,* 2008; Lamble *et al.,* 1997).

2.3 Bacteriological Water Quality Analysis

The presence of certain microorganisms in water is used as an indicator of possible contamination and an index of water quality (Hurst *et al.,* 2002). Indicator organisms' are selected to demonstrate the presence of human and animal wastes and hence the potential presence of pathogens in drinking water. Indicator organisms are usually of intestinal origin from humans and animals (Hurst *et al.,* 2002; Brian, 2002). Therefore, the presence of indicator organisms in water indicates contamination of water by faecal matter, which could probably contain pathogens such as Salmonella and Shigella (Ekhaise *et al.,* 2011).

According to USEPA regulations three main groups of bacteria are suggested to serve as indicators to monitor water quality. These are total coliforms, faecal coliforms, and E.*coli*. The criteria set to identify indicator organisms for water quality analyses are: the organisms must be exclusively of faecal origin and consistently present in fresh faecal waste; they must occur in greater numbers than the associated pathogens; they must be more resistant to environmental stresses and persist for a greater length of time than the pathogen; they must not proliferate to any greater extent in the environment or they should not grow in natural waters; and they have to be detected on the basis of simple: reliable, and inexpensive methods(Hurst *et al.,* 2002;WHO, 2004).

2.3.1 Coliform Bacteria

Total coliforms are the ones that are commonly measured as indicator bacteria for drinking water quality (Brian, 2002; Hurst *et al.,* 2002). They are defined as aerobic and facultative anaerobic non spore forming bacteria that ferment lactose at 35 to 37^0C with the production of acid and gas within 24-48 hours (WHO, 1985; Hurst *et al.,* 2002).

Coliform bacteria belong to the family enterobacteriace and include Escherichia coli as well as various members of the genera Nitrobacteria, Klebsiella and Citrobacter (Hurst *et al.,* 2002).These bacteria originate in the intestinal tract of warm blooded animals and can be found in their wastes. They can also be found in soil and on vegetation (Brian, 2002; Nold, 2008).

2.3.2 Faecal coliform bacteria

Faecal coliform bacteria are differentiated in the laboratory by their ability to ferment lactose; with production of acid and gas at 44.5ºC within 24 h. Faecal coliforms pose some of the same limitations as those posed by coliforms regrowth in distribution system; less resistance to water treatment than viruses and protozoa etc. Faecal coliforms are detected by most probable number (MPN) method and also used for total coliforms counting.

The persistence of total coliform bacteria in aquatic systems is comparable to that of some of the waterborne bacterial pathogens (Hurst *et al.,* 2002). Furthermore, coliform bacteria are relatively simple to identify and are present in much larger numbers than more dangerous pathogens (Brain, 2002; Hurst *et al.,* 2002). For this reason the degree of faecal pollution and the presumed existence of pathogens can be estimated by monitoring coliform bacteria.

Coliform group comprises of all the aerobic, facultative and anaerobic gram-negative non-spore forming rod shaped bacteria that ferment lactose with gas formation within 48h at 35°C. The standard test for this group may be carried out either by multiple tube fermentation technique or by membrane filter technique.

The *E.coli* test by multiple tube fermentation technique consists of three phases presumptive, confirmed and completed. Escherichia for the purpose of sanitary examination of water, is defined as a gram-negative, non spore forming rod which is capable of fermenting lactose with the production of acid and gas at 35°C in less than 48 hours, which produces indole peptone water containing tryptophan, which is incapable of

utilising sodium citrate as its sole source of carbon, which is incapable of producing acetyl methyl carbinol, and which gives a positive methyl red test. The results are expressed in terms of MPN (Most Probable Number), which is based on certain probability formulae.

$$\text{MPN/100ml} = \frac{\text{Table MPN} * 10}{\text{Largest volume used (ml)}} \tag{4}$$

The estimate may give a value greater than the actual number of coliform present. The accuracy of any single test depends on the number of tubes fermented. This method helps in describing the sanitary quality of water. The safety of the water is generally judged from the knowledge of sanitary condition and mentioned by the number of samples yielding positive or negative results. If more than 95% should yield negative results, the safety is usually assured.

2.3.3 Multiple tube fermentation technique for coliform bacteria

In the multiple-tube method, a series of tubes containing a suitable selective broth culture medium (lactose-containing broth, such as MacConkey broth) is inoculated with test portions of a water sample. After a specified incubation time at a given temperature, each tube showing gas formation is regarded as "presumptive positive" since the gas indicates the possible presence of coliforms (MacConkey *et al*., 1905).

However, gas may also be produced by other organisms, and so a subsequent confirmatory test is essential. The two tests are known respectively as the presumptive test and the confirmatory test. For the confirmatory test, a more selective culture medium (brilliant green bile broth) is inoculated with material taken from the positive tubes. After an appropriate incubation time, the tubes are examined for gas formation as before. The most probable number (MPN) of bacteria present can then be estimated from the number of tubes inoculated and the number of positive tubes obtained in the confirmatory test(Zimbro *et al*., 2003).

2.4 Hydrogeochemical facies

The chemical constituents of groundwater tend to increase with the length of its flow paths. Due to ion exchange and precipitation of least soluble salts first, the chemistry of water at an outcrop is modified as it flows through the ground. Groundwater evolves chemically towards the composition of seawater (Freeze and Cherry, 1979).

The main geological and hydrogeological factors which generally affect the groundwater geochemistry include rainfall, recharge, climate, soil, air, aquifer lithology, saline water

and flow pattern. However, the present study under this topic was limited to the analysis and interpretation of piper plot, Wilcox plot, Durov plots, Radial diagram in hydrogeochemical facies (Piper, 1944)

2.5 Ground water suitability for irrigation

2.5.1 Sodium Adsorption Ratio

Sodium adsorption ratio (SAR) is a measure of the suitability of water for irrigation use, because sodium concentration can reduce the soil permeability and soil structure. SAR is a measure of alkali/sodium hazard to crops and it was estimated by the following formula (Richards, 1954).

$$SAR = \frac{Na^+}{\sqrt{(Ca^{2+}+Mg^{2+})x.5}} \tag{5}$$

Where $[Na^+]$, $[Ca^{2+}]$ and $[Mg^{2+}]$ are concentration of sodium, calcium and magnesium in meq/l. The SAR value of water for irrigation purposes has a significant relationship with the extent to which sodium is absorbed by the soils. Irrigation using water with high SAR values may require soil amendments to prevent long-term damage to the soil, because the sodium in the water can displace the calcium and magnesium in the soil. This will cause a decrease in the ability of the soil to form stable aggregates and loss of soil structure. This will also lead to a decrease in infiltration and permeability of the soil to water leading to problems with crop production (Richards, 1954).

Table 2.3: Classification of irrigation water based on SAR

SAR	Water class
Less than 10	Excellent
10 to 18	Good
18 to 26	Permissible
More than 26	Unsuitable

2.5.2 Soluble sodium percentage

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

$$SSP = \frac{[Na^++K^+]X100}{[Ca^{2+}+Mg^{2+}+Na^++K^+]} \tag{6}$$

Excess Na^+, combining with carbonate, leads to formation of alkali soils, whereas with

chloride, saline soils are formed. Neither soil will support plant growth (Rao, 2006). Generally, percent of Na^+ should not exceed 60 % in waters intended for irrigation purpose (Wilcox, 1955).

Table 2.4: Classification of irrigation water based on SSP

SSP	Water class
< 20	Excellent
20 – 40	Good
40 – 60	Permissible
60 – 80	Doubtful
>80	Unsuitable

2.5.3 Magnesium Hazard

Magnesium is essential for plant growth; however at high content it may associate with soil aggregation and friability (Khodapanah *et al.,* 2009). More Mg^{2+} present in waters affects the soil quality converting it to alkaline and decreases crop yield (Joshi *et al.,* 2009). Szabolcs *et al.* (1964) proposed MH value for irrigation water as given by the formula expressed in equation.

$$MH = \frac{[Mg^{2+}] \times 100}{[Ca^{2+} + Mg^{2+}]} \tag{7}$$

Where, all the ionic concentrations of the elements are expressed in meq/l.

MH values >50 are considered harmful and unsuitable for irrigation purposes.

2.5.4 Permeability index

The Permeability Index (PI) values also indicate the suitability of groundwater for irrigation, as the soil permeability is 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. Permeability Index (PI) can be written as follows.

$$PI = \frac{Na^+ + \sqrt{HCO_3^-}}{(Ca^{2+} + Mg^{2+} + Na^+ + K^+)} \tag{8}$$

Where, the concentrations are reported in meq/L.

2.5.5 Percent sodium (%Na)

Sodium concentration is important parameter in classifying irrigation water because sodium reduces the permeability of soil. Excess Sodium in water is responsible in changing soil properties and reducing soil permeability (Kelley *et al.,* 1951). In all natural waters percent of Sodium content is 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).

$$\%Na = \frac{Na^+}{Na^+ + K^+ + Ca^{2+} + Mg^{2+}} \, X100 \tag{9}$$

Where, the quantities of Ca^{2+}, Mg^{2+}, Na^+, and K^+ are expressed in mill equivalents per litre (meq/L). When the concentrations of sodium are 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 is restricted under wet conditions and such soils will become usually hard when dry.

2.6 Aquachem water quality database

Aquachem is a water quality database software package with functionality for graphical and numerical analysis (Abreha *et al.,* 2014). Its feature has a fully customizable database. Physical and chemical parameters and provides a comprehensive selection of analytical tools such as calculations and graphs for interpreting water quality data (Hounslow, 1995; Tyagi *et al.,* 2015). 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.

CHAPTER THREE
MATERIALS AND METHODS

3.1 The study area

Guder town is found in Oromia regional state west showa zone, Tokke kutaye district which was located 12km to the west Ambo town and 126km apart from Addis Ababa. The town has a latitude and longitude of $8^o58'N$ $37^o46E'$ with an elevation of 2101 meters above sea level. Based on figures from the central statistical agency of Ethiopia in 1999EC, Guder Town has an estimated total population of 17,084 of whom 8,272 are male and 8,812 are female.

In the study area, groundwater is the most common sources of water for domestic and irrigation in addition to surfacewater. The town surrounded by the chain of Rocky Mountains that contributed to groundwater quality pollution by erosion and run off infiltration.

Groundwater of the study area is almost mineral water because the areas were covered by different rock types. However some selected areas had less contents of mineral water that is suitable to drinking and irrigational uses. Actually the two groundwater used for water supply to Guder town were unsuitable for domestic and irrigational uses. Therefore community complaint was increased from time to time about not to use such boreholes.
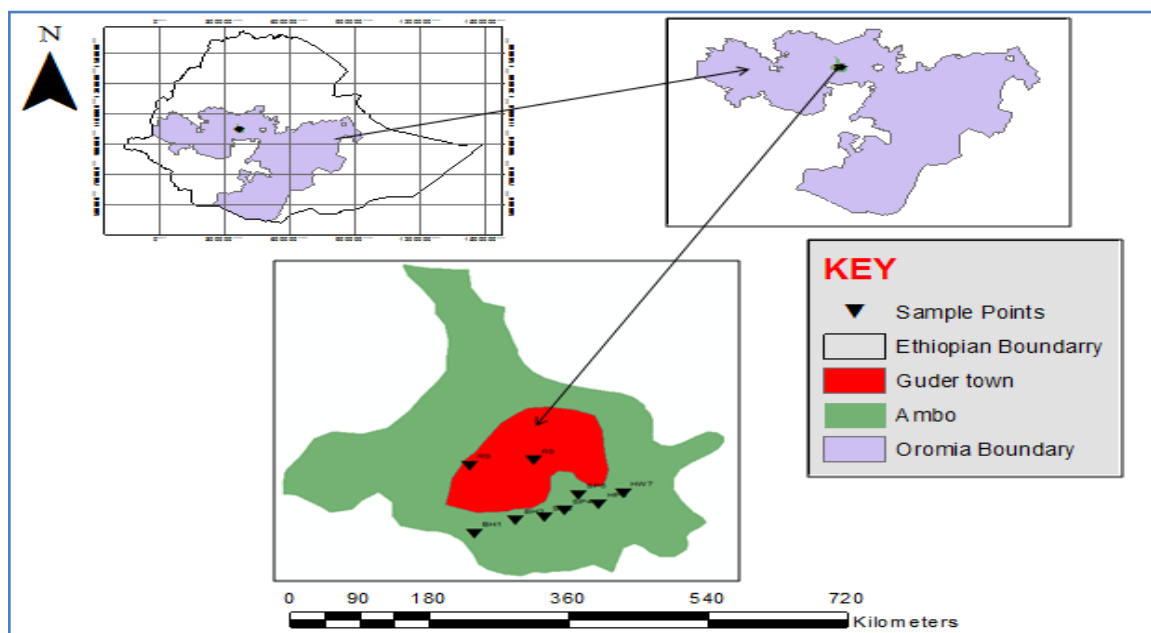

Figure 3.1: Guder town's and sample area

3.2 Study period and design

The study was carried out from the beginning of July, 2017 to end of November, 2017 and nine samples were taken from sub-areas around Guder town's sources for water supply such as Kogne, Dawwe, Chancho1, Chancho2, Kogne, Odokela1, Odokela2, Ajo reservoir R8, and Gorfo reservoir R9. Sampled water was transported to laboratory according to laboratory rule. The research was laboratory experiment based and all necessary laboratory experiments were conducted in laboratory and field. Thus, the experimental research strictly adopts the Scientific method in its investigation.

3.3 Sample size

Samples were collected by purposive sampling technique from nine groundwater sources (2 /3borehole, 1/2 hand dug well, 1/1 hand pump well, 3/3 protected springs and 2/2 town's water reservoir) sampled. A purposive sampling technique was chosen because of groundwater quality sources for water supply problem was informally known and no pre study was conducted. The sampling size was considered as the result of community complaint due to unknown causes of groundwater quality problems. The two boreholes BH1 and BH2 sources for water supply were found around spring SP3 and SP4 which are hard mineral water locally named as "Hora chancho". Therefore the study is important at a location to dig out the relation between geochemical variables that dominated water quality of the area; to understand more if the influence of hard mineral water pollutes water supply sources by geochemical process.

For the sample selection important criteria were considered: Wells closer to polluting sources like improper waste disposal sites, natural deposits minerals, municipal effluents, leakage of gasoil from fuel oil storage tank, road construction, Garages, etc were considered.; Elevations, Longitude, and altitudes of selected sample sites were determined on the field using a GPS model 60.

3.4 Sampling procedures

Water samples were collected early hours in the morning. This was to ensure that the water had not been disturbed much through pumping which can affect the temperature and content of total dissolved solids. All plastic bottles were cleaned with warm water and soap then rinsed 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 boreholes, the mouth of the metal pipe was cleaned before taking samples. Sample bottles for physicochemical, metal and microbial analysis were rinsed with some of the borehole water and then completely filled to capacity leaving no air space and immediately covered. 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.

Considering the hand-dug wells, plastic container with rope was used to fetch water from wells. The plastic container was cleaned with warm water and soap and completely rinsed with distilled water three times. Sample bottles for physicochemical, metal and microbial analysis were rinsed with some of the hand-dug well water and then completely filled to capacity leaving no air space and immediately covered. Water quality parameters such as temperature, pH and electrical conductivity, and TDS were analyzed immediately by using portable multi parameter probe (HQ40d Model). Each sample of groundwater were collected and filtered with 0.45 μm filter membrane into an individual clean 1000ml plastic water bottle.

For metal Fe^{2+}, Mn^{2+}, Ca^{2+}, Mg^{2+}, Na^+ and K^+ 10% nitric acid solution was 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 analyzed within 6hours. Samples meant for metal analysis were stored in a refrigerator at 4^0C.

3.5 Study variables

3.5.1 Independent variables

Physical parameters:-Temperature, pH, Electrical conductivity, TDS, TS and Turbidity
Chemical parameters:-Total alkalinity, Total hardness (Calcium and Magnesium), and Sodium, Potassium, Iron, Manganese, Fluoride, Bicarbonate, Carbonate, Nitrate, Chlorine, Arsenic, and Sulfate ions.
Bacteriological analysis: - total coliform, Faecal coliform, and E.coli bacteria.

3.5.2 Dependent variables

Groundwater is suitable.

Table 3.1: Study area sample location GPS Reading

Samples cod	Name of the location	Water sources	GPS60 Reading			
			Easting	Northing	Elevation	accuracy
BH1	Kogne1	Bore hole	0363498	0986851	2102	±8
BH2	Dawwe	Bore hole	0363794	0986191	2115	±8
SP3	Chancho1	Spring	0364549	0983379	2180	±7
SP4	Chancho2	Spring	0364558	0983350	2180	±6
SP5	Kogne2	Spring	0362906	0986840	2067	±7
HP6	Odokela1	Hand pump	0364125	0988166	2062	±6
Hw7	Odokela2	Hand dug well	0364065	0988183	2067	±6
R8	Ajo	reservoir	0364375	0990978	2048	±7
R9	Gorfo	reservoir	0362699	0991456	2071	±7

3.6 Instruments and apparatus

The apparatus used for the experiments are: 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.

3.7 Sample Analysis

Physicochemical and bacteriological analyses were conducted at laboratories of Ambo University; Oromia water works design and supervision enterprise, and Bless Agri food laboratory P.L.C. in Addis Ababa. The laboratory analyses were undertaken according to procedures outlined in the Standard methods for the examination of water and wastewater (APHA, 1998).

3.8 Method of data analysis

Samples were collected from borehole, spring, hand pump and hand well town reservoirs to analyze physicochemical and bacteriological quality of Guder Town groundwater for domestic and irrigational uses. Method of data analysis was explained.

Different methods of data analysis were used for different parameters: EDTA titration method; Gravimetric method; Colorimetric, potentiometer; SPADNS spectrophotometric ; Flame Photometric Method; Gravimetric Method; Extraction/Air-Acetylene Flame method; and Graphite furnace atomic absorption Spectrophotometric methods.

Table 3.2: Instruments and methods of data analysis

No	Parameter	Instrument used	Method of analysis
1	Temperature	MPP(HQ40dModel	Direct reading
2	pH	MPP(HQ40dModel)	Direct reading
3	Turbidity,NTU	MPP(HQ40dModel)	Direct reading
4	EC(μS/cm)	MPP(HQ40dModel)	Direct reading
5	TDS(mg/L)	-	Gravimetric method
6	TS at 105^0c. mg/L	-	Dry oven
7	CO_3^-Alk mg/L. Ca CO_3	-	Potentiometric titration
8	HCO_3Alk. mg/Las $CaCO_3$	-	Potentiometric titration
9	TA, mg/L as Ca CO_3	-	titration method
10	Ca H. mg/L as Ca CO_3	-	EDTA titration method
11	Mg H. , mg/L as Ca CO_3	-	EDTA titration method
12	TH , mg/L as Ca CO_3	-	Sum of Ca^{2+} and Mg^{2+} H.
13	nitrate(NO_3^-), mg/L	Spectrophotometer	potentiometer
14	chloride(Cl^-), mg/L	-	Potentiometric $AgNO_3$
15	Fluoride(F^-), mg/L	Spectrophotometer	SPADNS spectrophotometer
16	sulphate (SO_4^{2-}), mg/L	Spectrophotometer	Turbidimetric method
17	Sodium(Na^+) , mg/L	AAS	Flame Photometric
18	Potassium (K^+) mg/L	AAS	Flame Photometric
19	Manganese(Mn^{2+}) mg/L	AAS	Extraction/Air-Acetylene Flame method
21	Iron(Fe^{2+}),mg/L	AAS	Extraction/Air-Acetylene Flame method
23	Arsenic (As^{3+}) mg/L	AAS	Graphite furnace AAS

3.9 Analysis method and laboratory procedures

All the physicochemical parameters namely: pH, Temp., TDS, EC,TS ,Turbidity, Na^+, K^+, Ca^{2+}, Mg^{2+}, HCO_3^-, Cl^-, SO_4^{2-} , NO_3^-, F^-, As^{3+}, TH, TA, CO_3^{2-},Mn^{2+}, Fe^{2+} , and bacteriological parameters TC and FC were analyzed in the laboratory and field following internationally accepted procedures and standards, APHA (1998).Some selected cations and anions laboratory procedures were explained) see Annex1.

3.10 Data analysis

Analysis and interpretation of all water chemistry data were carried out using Aqua-Chem 4.0 version package software and Microsoft excel software. Aqua-Chem is a fully-integrated software package developed specifically for graphical and numerical analyses

and interpretation of aqueous geochemical data sets. The analyzed data were presented by using table, graphs and piper diagram.

3.11 Data quality assurance and quality control

Proper quality assurance procedures and precautions were taken to ensure the reliability of the results to (APHA, 1995). Data quality assurances were analysed carefully and triple measurements were performed to assure quality of data.

In order to minimize error, Samples were taken three times, measurement was also performed three times alone, average value 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% were discarded.

$$IBE = \frac{\sum Cation - \sum Anon}{\sum Cation + \sum Anion} X100 \tag{10}$$

3.12 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 Tokke Kuttaye district and other governmental and non-governmental organizations, which are concerned with the study findings. Publication in national and international journals will also be considered

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Physical Parameters

4.1.1Temperature

The temperature of groundwater samples ranges from 15 to 28°C with a mean value of 22.9°C see Table 4.1. The highest temperature 28℃ was observed at sample point of SP3 and the lowest temperature 15℃ was observed at HW7 see fig. 4.1. The standard value recommended by (Temitope *et al*., 2012) referring the (WHO 1997) for groundwater temperature should not be exceeds 25°C.

However, the temperature at sample points BH2, SP3, and SP4 of groundwater were above the standard value recommended by WHO and national standard. This may be due to variations in solar energy received at the earth's surface create periodicities, both diurnal and annual, in temperature below ground surface. Season and topography influences the temperature. Moreover, calcium carbonate ($CaCO_3$) precipitation also increases temperature of groundwater (Jensen *et al.,* 2003).
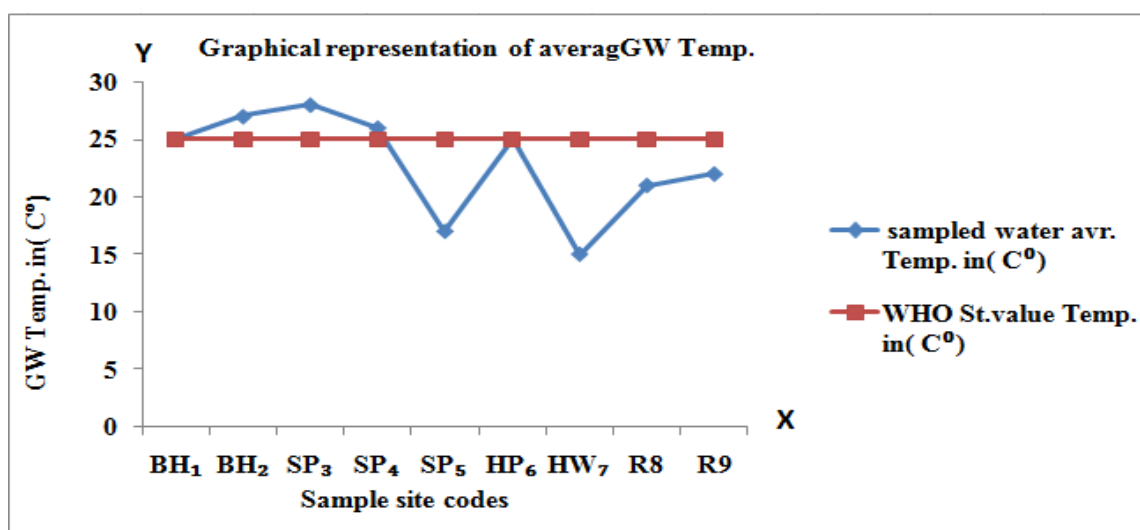

Figure 4.1: Variation of groundwater temperature in study area

4.1.2 pH

The pH of groundwater samples ranges from 6.2 to 7.4 with a mean value of 7 as indicated in Table 4.1. The highest pH 7.40 was observed at samples BH2, HW7, and R9. The lowest pH 6.2 was observed at SP3 and SP4 see fig. 4.2. The limit of pH value for drinking water is specified as 6.5 to 8.5 (WHO, 2004).

The result clearly shows that the groundwater in the study area is in the intervals of (WHO, 2004) recommended. The minimum values pH of samples SP3 and SP4 were below the standard limited. The lowered of pH of these water samples may be due to the acidic nature of the rock that contain elevated concentration of dissolved iron in the strata from which water originates and presence of organic acids and dissolved carbon dioxide. Adjustment of pH to neutralize acidic nature water should be performed. The ground water of study area has high concentration of Iron 0.57 and 1.9 mg/l which may acidify the water and reduce the pH. Therefore effective aeration will reduce Iron concentration and raise the pH. However, when water has a pH that is too low, it will lead to corrosion and pitting of pipes in plumbing in distribution systems. It was concluded that the pH value at SP3 and SP4 was 6.2 which was lowest observed and not suitable for drinking purpose.
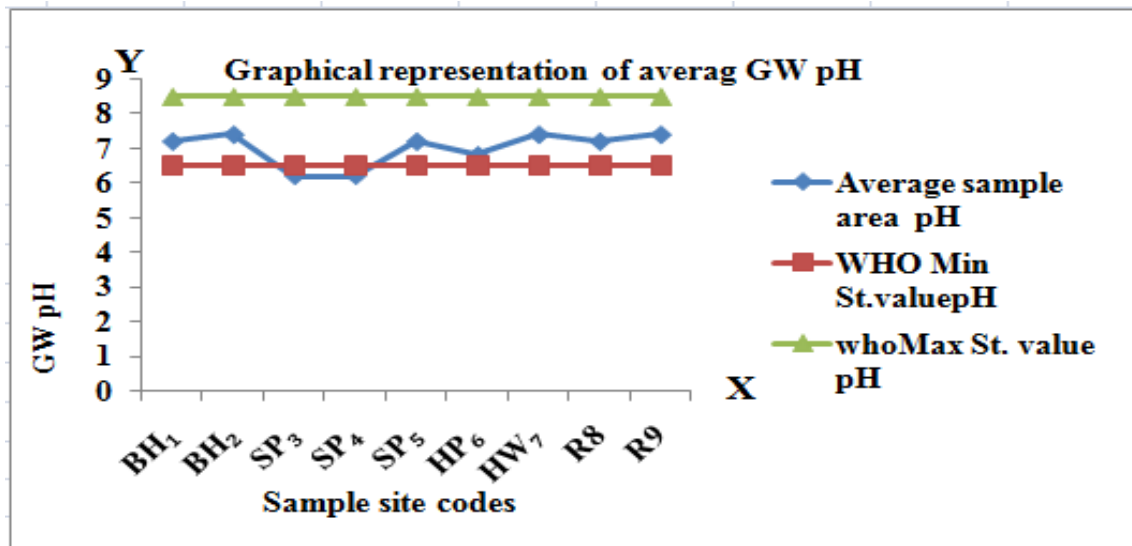
Figure 4.2: Variations of Study area's ground water pH

4.1.3 Electrical Conductivity

Electrical conductivity is the measure of ground water ability to carry an electric current, the more dissolved ionic solute in water the greater its electrical conductivity. The electrical conductivity of groundwater samples ranges from 476 μS /cm to 2586μS /cm with a mean value 1164μS/cm see Table 4.1. The highest EC (2586μS /cm) was observed at sample R8 and the lowest EC (476μS /cm) was observed at SP5 see fig. 4.3. The most desirable limit of EC in drinking water is prescribed 1000μs/cm (WHO, 2011).

The conductivity of clean water is lower but as it moves down the earth it leaches and dissolves ions from the soil and also picks up organic from biota and detritus. Lower EC

in the study area indicates the low enrichment of salts in the groundwater. As observed from figure 4.3 water of the study area unsuitable for drinking and irrigation because of high conductivity recorded at sample sites BH1 and R8 which exceed 1000μS/cm standard. The average value of the samples EC was above recommended (WHO, 2011) GV. This indicates that EC value increases as the results of variations in dissolved solids, mostly mineral salts.

Electrical conductivity in groundwater is 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 aluminium cations(ions that carry a positive charge). So those in the study area BH1, and R8 high sulphate concentration were observed. At BH1, SP3, SP4, HP6, R8 and R9 high sodium concentration were observed.

In general, high conductivity is an indication of TDS total dissolved salts and salinity result in soils poorly drained and allow for excessive surface evaporation (APHA 1998). As soluble salt levels increase, plant utilization of soil water often declines. Ground water of the area is not suitable for drinking and needs optimal treatment of steam distillation, ion exchange (H^+ and OH^- saturated resin only) and reverse osmosis for reducing TDS and conductivity levels (Camberato *et al.,* 2001).
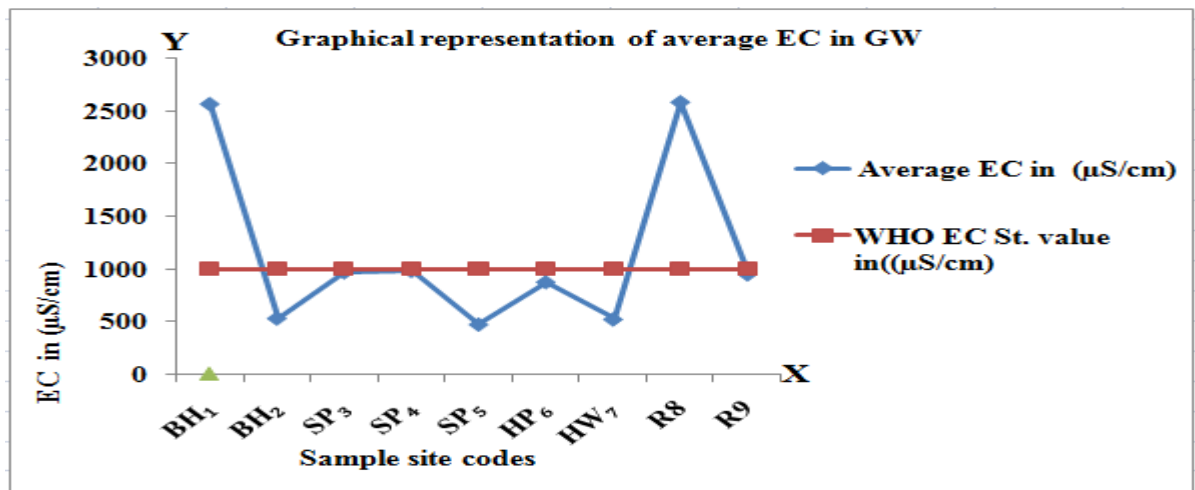
Figure 4.3: EC variation of the study area

4.1.4 Total Dissolved Solids

The total dissolved solid values of the samples were varied between a minimum 238.0 mg/L and a maximum of 1450mg/l with a mean value of 629.9 mg/L see Table 4.1. The

highest TDS (1450.0 mg/l) was recorded at sample R8 and the lowest (238.0 mg/L) was observed at SP5 see figure 4.4.

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 extremely exceeded the limiting guide line of (WHO, 2011). This factors cause water test metallic test, which was not suitable for drinking and domestic, purposes (Dietrich *et al.,* 2013).

In general, Guder town ground water for water supply has unfavourable test and aesthetic for drinking and other domestic purposes. Drinking water aesthetics is one of the top ten issues facing drinking water providers that use desalination (Duranceau *et al.,* 2012). The causes of aesthetics water problems were derived from natural sources which includes inorganic salts, principally calcium, magnesium, potassium, sodium, bicarbonate, chlorides, sulphates, and small amounts of organic matter that are dissolved in water (WHO, 1996).

TDS also originate from sewage and urban run-off. Groundwater samples in study area contain greater than 500 mg/L of dissolved solids in average. Therefore it needs: steam distillation; ion exchange; and reverse osmosis to reduce it. Actually locally available treatment methods are a mandatory.

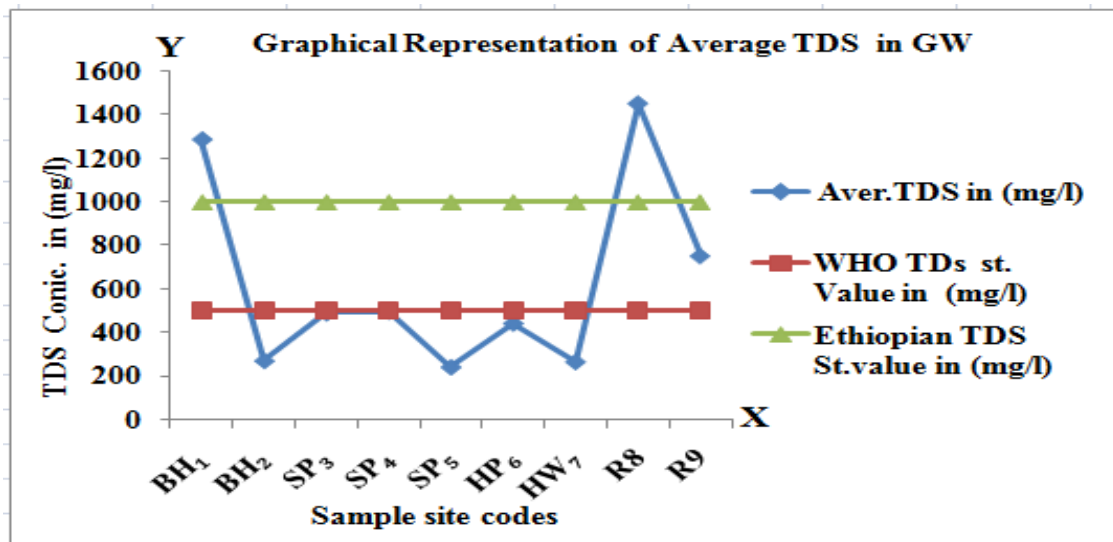

Figure 4.4: Variation of TDS concentration area.

4.1.5 Turbidity

Turbidity is a measure of the relative clarity of water. Turbidity values above 5 NTU become perceptible to the eye, especially in large volumes such as a white sink or bath.

This effect might be increased if the water also contains coloured materials such as humic acid or inorganic colored products such as iron compounds (APHA, 2005)

In this study area, the turbidity values of groundwater samples ranged from 3.23 NTU to 76 NTU and with a mean value of 16.9 NTU see Table 4.1. The maximum value that recorded at sample site SP3 and the minimum value recorded at site SP5. As illustrated on fig. 4.5 the turbidity of the study area above (WHO, 2004) guide line of 5NTU. Turbidity in these samples water 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).

Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria. Turbidity of water affects other water quality parameters such as color, when it is imparted by colloidal particles. It also promotes the microbial proliferation, thus affecting negatively the microbiological quality of water. Locally available treatment method of slow sand filtration and settlement tank is needed.

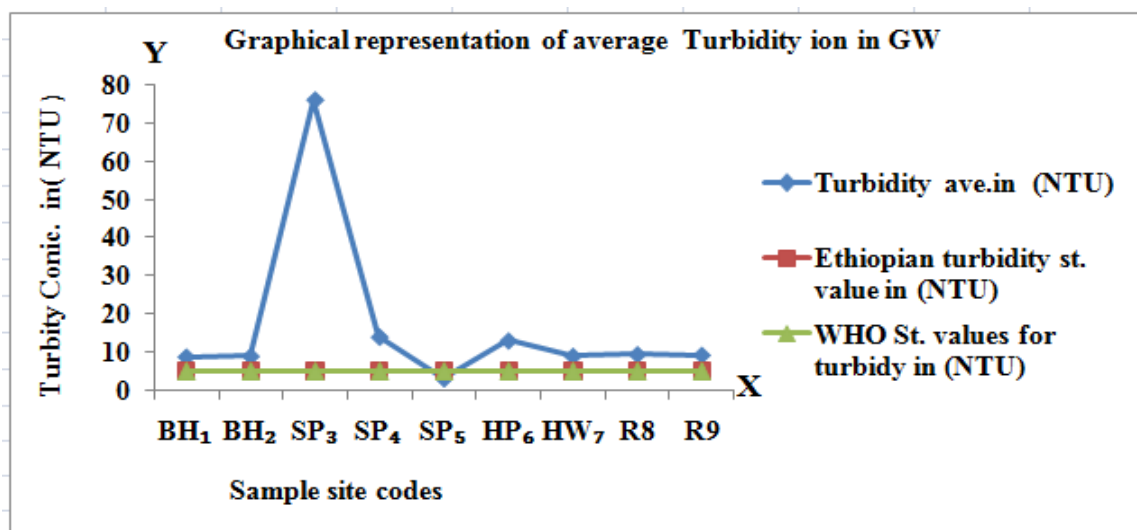Figure 4.5: Variation of turbidity on samples areas

4.1.6 Total solid (TS)

Residue left after the evaporation and subsequent drying in oven at specific temperature 103-105°C of a known volume of sample are total solids. Total solids include "Total suspends solids" (TSS) and "Total dissolved solids" (TDS). Whereas loss in weight on ignition of the same sample at 550°C in which organic matter is converted to CO_2

volatilisation of inorganic matter as much as consistent with complete oxidation of organic matter, are volatile solids according to (WHO, 1996).

The minimum value of TS recorded was 270 mg/L at sample location of SP5 and maximum value recorded was 2400 mg/L at sample site R8 with average value of 926.9 mg/L. Total solid result at BH1 and R8 were above WHO guide line of 2290 mg/L and 2400 mg/L respectively as shown on table 4.1. Generally the water from these two area were not suitable for drinking and domestic purpose because, of high concentrations of inorganic minerals and organic compounds. The effects of high concentration of TS were; reduce water clarity, decrease photosynthetic rate, aesthetically unpleasing, and increase water temperature.
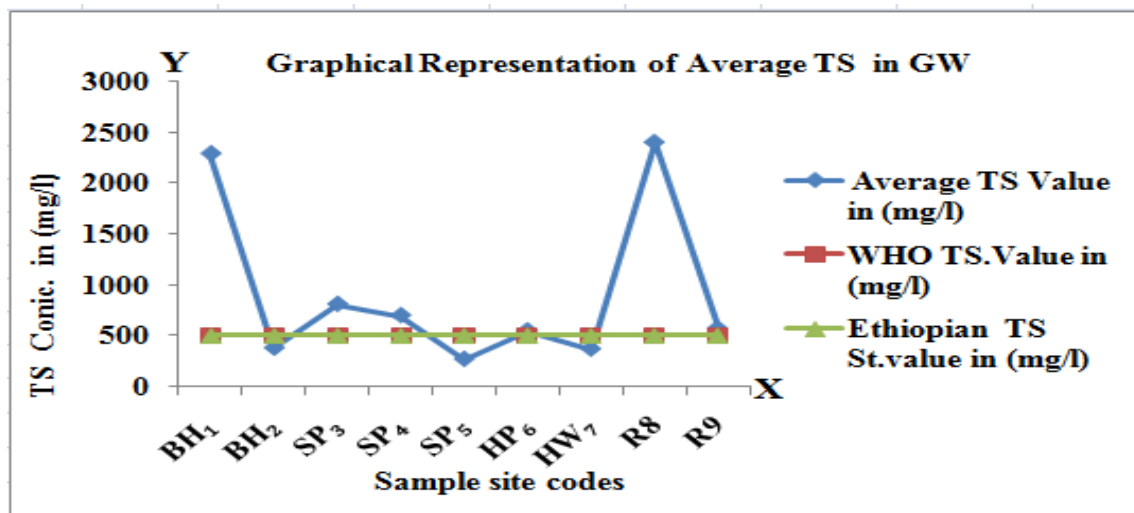
Figure 4.6: Graphical analyses of TS along sample site

4.2 Chemical parameters

4.2.1 Total Hardness

Hardness, which occurs naturally in water, is an aggregate parameter that is the sum of aqueous divalent cations. Calcium and magnesium are the major divalent cations in natural fresh waters, and hence the major ions in hardness. Total hardness is the sum of calcium hardness and magnesium hardness as calcium carbonate. The total hardness values of groundwater samples area were varied from 27.1 mg/L to 667.9 mg/L with a mean value of 198.6 mg/L see Table 4.1.

According to the portability 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$_3$ are acknowledged to cause scale formation, and thus the WHO (2011) established aesthetic guidelines at 200 mg/L CaCO$_3$.

The TH value of study area may be due to presence of calcium and magnesium. As it was known Guder groundwater sources of water supply have high concentrations of: turbidity, TDS, EC, and TS as observed in the laboratory results. These indicate that, ground water of the study area is unsuitable for domestic and irrigational uses. Specially from borehole one (BH1) and reservoir (R8) which were sources of water supply for the town, total hardness were above WHO (2011) guideline value as shown in figure 4.7. However, the mean value was in standard value. The challenges were, aesthetic problem, consumption of large soap, and resistance of water forming lather with soap were the drawback detected. In order to recover the water, softening by lime-soda ash processes will be a mandatory.
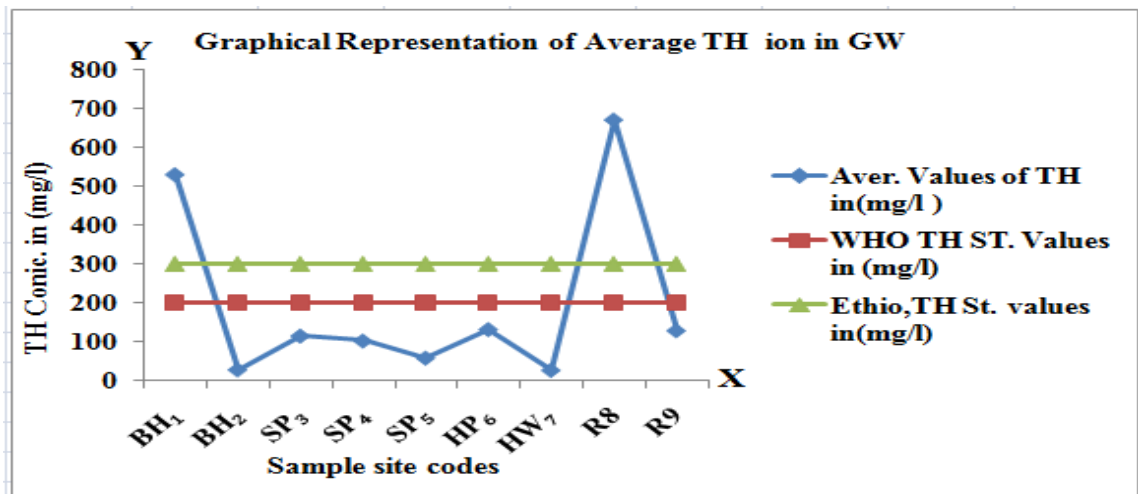
Figure 4.7: Graphical analysis of total Hardness of sample area

4.2.2 Total Alkalinity

Alkalinity is a measure of the capacity of water to neutralize acids. Alkalinity measures the concentrations of bicarbonate, carbonate, and hydroxide ions and is expressed as an equivalent concentration of calcium carbonate (CaCO$_3$). The total alkalinity of the study area measured was varied from 150 mg/L at BH1 to 600.0 mg/L at SP3 and SP4 with mean value of 410.9 mg/L see 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 CaCO$_3$. These results show that at all points of sample taken, the values of total alkalinity lay above the (WHO, 2011) maximum permissible limit except sample on BH1 see figure 4.8.

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High alkalinity above 500 mg/L is 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, etc.) 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 are: pipes, hazardous waste landfills.
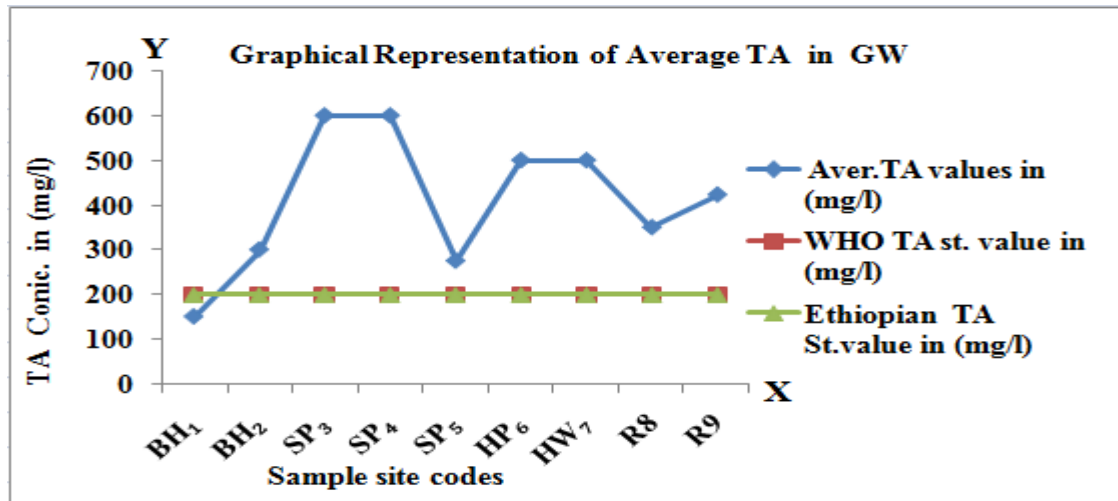
Figure 4.8: Graphical analysis of Total Alkalinity of sample area

4.2.3 Bicarbonate

The bicarbonate of the study area measured was ranged from 150mg/L at BH1 to 600.0 mg/L at SP3 and SP4 respectively with mean value of 410.9 mg/L see 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 $CaCO_3$. However, except BH1 of sample area the rest were above the Guideline value see figure 4.9. 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 etc. is the main causes of hardness of water.

The concentration of bicarbonate in study area was above the standard guideline. 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 exceeded WHO limiting value, it is mandatory to treat Carbonate and bicarbonates by lowering the pH of water through acid injection.
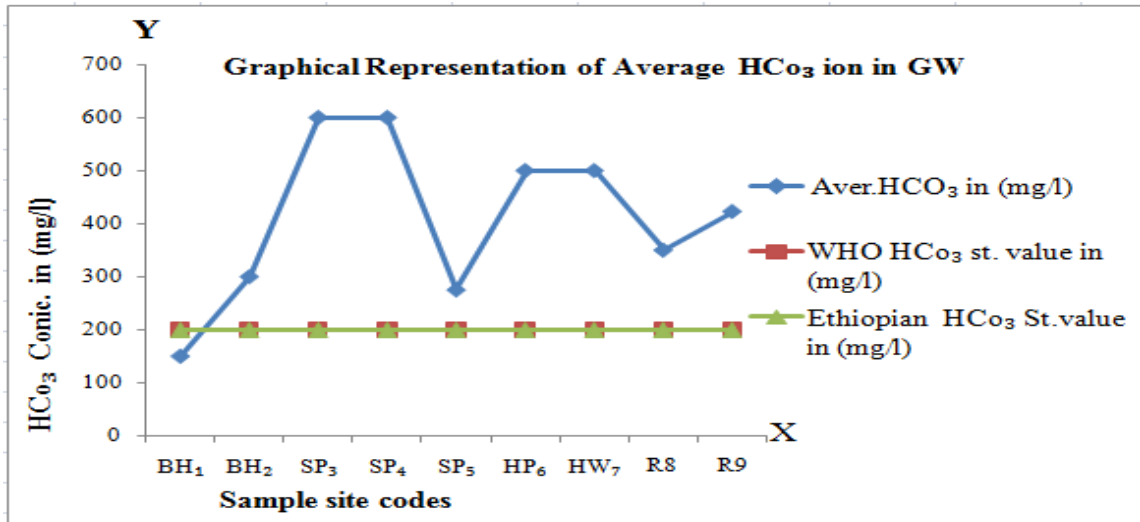
Figure 4.9: Graphical representation of bicarbonates concentration

4.2.4 Chloride

In study area the chloride value ranges from minimum value of 12.1mg/L at BH2 and maximum value of 33.8mg/L at HP6 with a mean value of 17.8 mg/L see Table 4.1. According to (WHO, 2004) standards concentration of chloride should not exceed 250 mg/L. All groundwater samples have lower concentration of chloride and below the maximum permissible limit value set by WHO standard as shown on figure 4.10. 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 interms of chloride concentration.
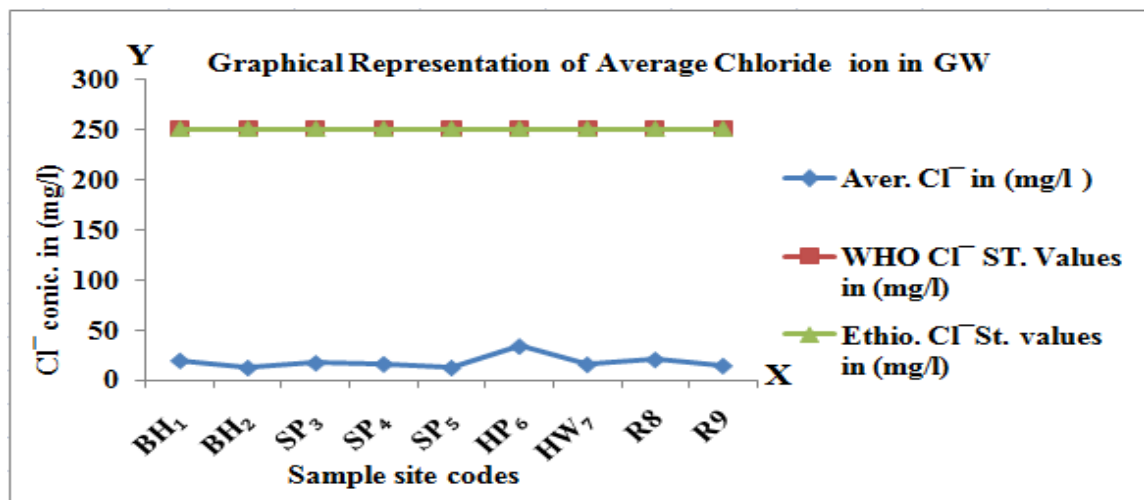
Figure 4.10: Graphical representation of chloride concentration

4.2.5 Nitrate

Nitrate in study area ranged from 0mg/l at SP4 to 16.4mg/l at HP6 with a mean value of 5.2 mg/L see Table 4.1. The permissible limit of nitrate in drinking water was 10 mg/L (WHO, 2004). The concentration of nitrate in the sample points of HP6 and R8 was above the WHO standard see figure 4.11.

Elevation of nitrate concentration in water causes the diseases blue baby syndrome in infants. Since the average concentration of nitrate of the study area below the maximum 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 purpose except at sample points of HP6 and R8. Low levels of nitrogen (in the form of nitrate) are normal in groundwater and surface water (Follett *et al.,* 1991).
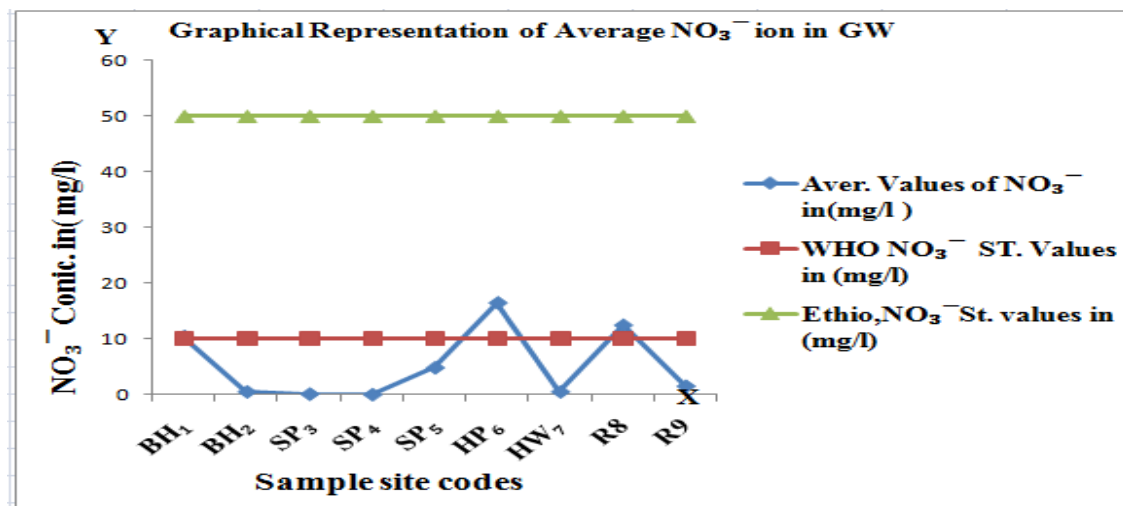
Figure 4.11: Graphical representation of Nitrate concentration

4.2.6 Sulphate

Sulphate in study area ranged from 0.0 to 388.7 mg/L with a mean value of 88.96 mg/L see Table 4.1. WHO (2011) has established 250 mg/L as the highest desirable limit of sulfate in drinking water. The minimum values of sulphate observed at sample site: SP3, SP4, and HW7. The maximum value of sulphate concentration was observed at sample site of R8. From the analysis, the source of water supply for the town, which was BH1, is the next maxim concentration values recorded of 368.7 mg/L.

High sulfate concentration was detected in sampled water. The result of the elevation of sulphate at the site cause aesthetic problem like unsuitable tests and diarrhea on most

children at first utilization of water supply. Sulphate at high concentrations can cause diarrhea when first encountered, although eventually individuals acclimate to high sulfate levels (Lajçi *et al.,* 2017). Sulfate mainly derived from the dissolution of salts of sulphuric acid and abundantly found in almost all water bodies in nature.

According to, laboratory results of study area sulfate concentration were high at BH1 and R8. The rest samples result were below (WHO, 2011) standard guideline as observed on figure 4.12. Sources of sulfate are: animal sewage, septic system, sewage, by-product of coal mining, industrial waste and natural deposits or salt. Sulphate treatment method should be: ion exchange and, distillation methods are mandatory.
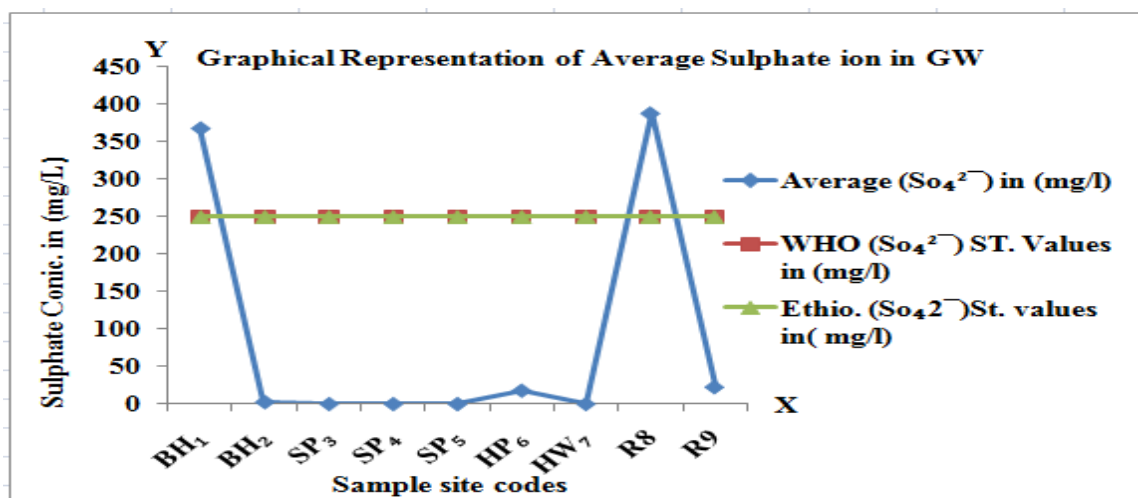
Figure 4.12: Graphical representation of Sulphate concentration

4.2.7 Calcium ($Ca^{2+}H$)

Calcium concentration of study area varied from 15.8mg/L at HW7 to 377.1mg/L at R8 with a mean of 106.8mg/L. Calcium concentration at sample point BH1 which was sources of water supply for the town was 317.1mg/L above (WHO, 2004) guide line value see figure 4.13. The desirable limit of calcium concentration for drinking water is specified as 75mg/L (WHO, 2004).

The high deficiency of calcium in humans may caused rickets, poor blood clotting, bones fracture etc. and the exceeding limit of calcium produced cardiovascular diseases (Magesh *et al.,* 2012). The result shows, the values were above the maximum permissible limit set by WHO standard at sample site BH1 and R8. This implies that the source of water is almost hard water .Therefore, soda ash softening process and Water Softener Ion exchange treatment will be needed.
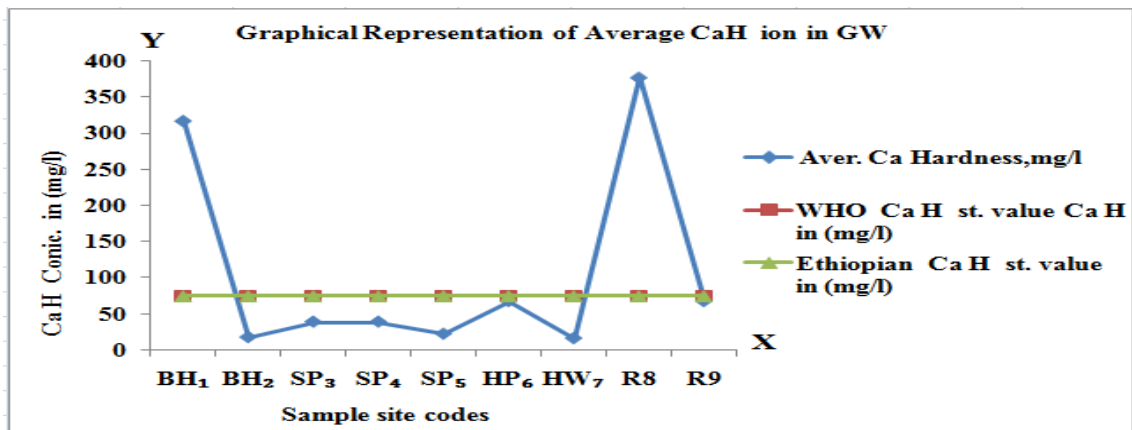
Figure 4.13: Graphical representation of Calcium concentration

4.2.8 Magnesium (Mg^{2+} H)

Magnesium concentration of study area ranged from 11.1 mg/L at BH2 to 290.8 mg/L at BH1 with a mean of 91.7mg/L. The standards the permissible values of magnesium in water should be 30 mg/L (WHO, 2004)

The quantity of magnesium hardness as CaCO$_3$ is significantly high in study area of except at sample sits of BH2 and HW6 see figure 4.14. The study will concluded that the concentration of magnesium in groundwater samples of study area was high and not suitable for drinking The Ethiopian permissible range for magnesium in water should be 50 mg/L
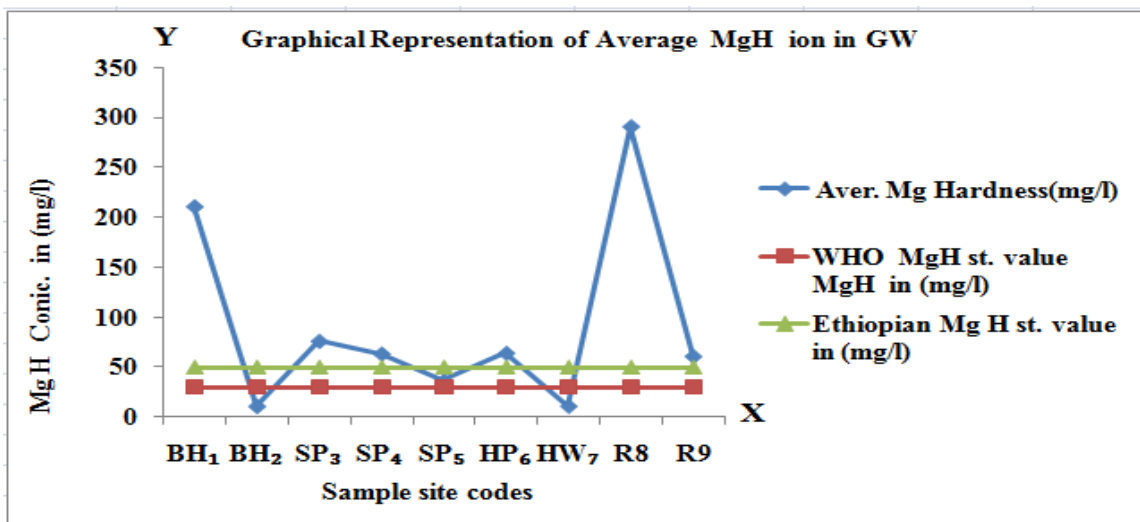
Figure 4.14: Graphical representation of Magnesium concentration

4.2.9 Sodium

The concentration of Na$^+$ was varied from 123.4 mg/L at SP5 to 616.9 mg/L at R8 with a mean value of 306.34 mg/L see Table 4.1. The WHO (2004) Standards value for sodium

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is 200 mg/l. Sodium concentration of study area was so high that could be harmful for the health of local inhabitants and irrigation figure 4.15. The Na^+ concentration of samples at: BH1, SP3, SP4, HP6, R8, and R9 above WHO guideline. The sodium ion is primarily responsible for the salty taste. Taste testing indicated that both chloride and sodium in drinking waters are negatively associated with preference, indicating that consumers do not like these ions in water (Platikanov *et al.,* 2013).
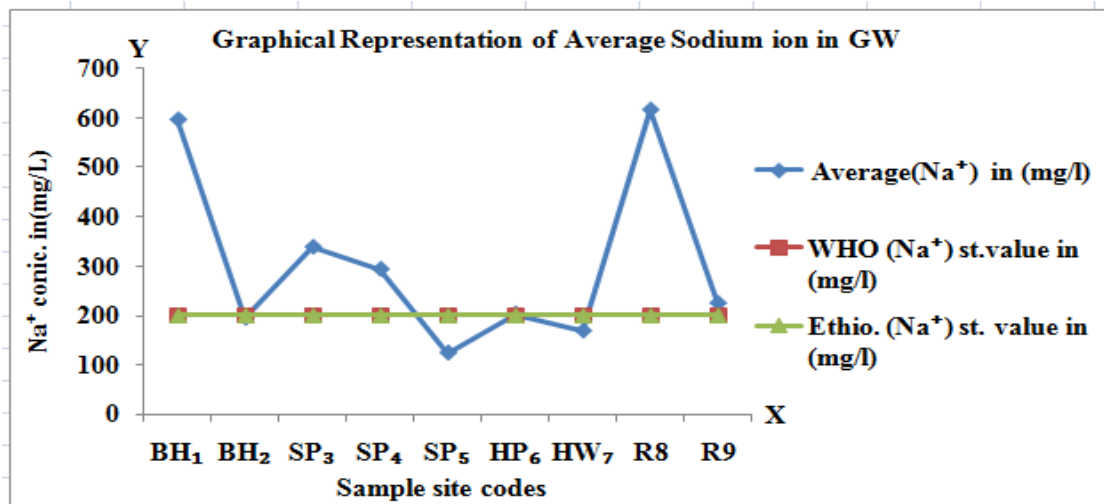
Figure 4.15: Graphical representation of sodium concentration

4.2.10 Potassium

The concentration of K^+ in study area is varied from 16.8 mg/L at HP6 to 53.4mg/L at SP4 with a mean value of 29.5 mg/L see Table 4.1.

According to WHO standards the permissible limit of potassium is 10 mg/L. The laboratory result of potassium concentration at all groundwater sample points of the study area was found above the maximum permissible limit value set by WHO see figure 4.16. Potassium more than 50 mg/L in the presence of suspended solids causes foaming which accelerates scale formation and corrosion in boilers.

Sodium and potassium carbonate in re-circulating cooling water can cause deterioration of wood cooling towers. Here under it is important to make limited treatment practices for reducing K^+ levels by consider distillation, reverse osmosis or ion exchange methods.
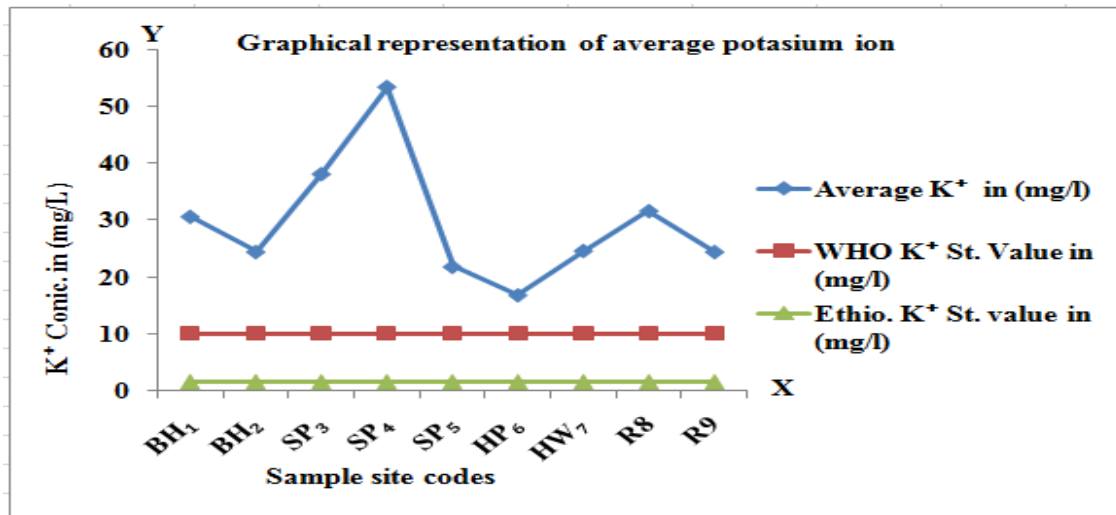
Figure 4.16: Graphical representation of potassium concentration

4.2.11 Iron

The concentration of Fe^{2+} is varied from 0.57 mg/L at sample area of HP6 to 2.72 mg/L at sample site of R8 with a mean value of 1.33 mg/L see Table 4.1. Iron concentration from BH1 (2.54 mg/L) and R8 (2.72 mg/L) were above (WHO, 2011) guide line value recommended.

Iron concentration from BH1 (2.54 mg/L) and R8 (2.72 mg/L) were above (WHO, 2011) guide line value recommended. The desirable concentration iron set by WHO (2011) is 0.3 mg/l for iron. 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 and cast iron pipes during water distribution. 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 all study areas were definitely above the WHO (2011) maximum permissive level see figure 4.17. It can be concluded that all of the concentration of iron in study area were not suitable for drinking purpose. Excessive levels of iron in drinking water supplies may impart a brownish colour to laundered goods, plumbing fixtures and the water itself; it may produce a bitter; astringent taste in water and beverages; and the precipitation of iron can also promote the growth of iron bacteria (Sarin *et al.,* 2004).

The groundwater sources for water supplied from BH1, BH2 and R8 as observed, a brownish colour to laundered goods, plumbing fixtures, produce a bitter, astringent 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.
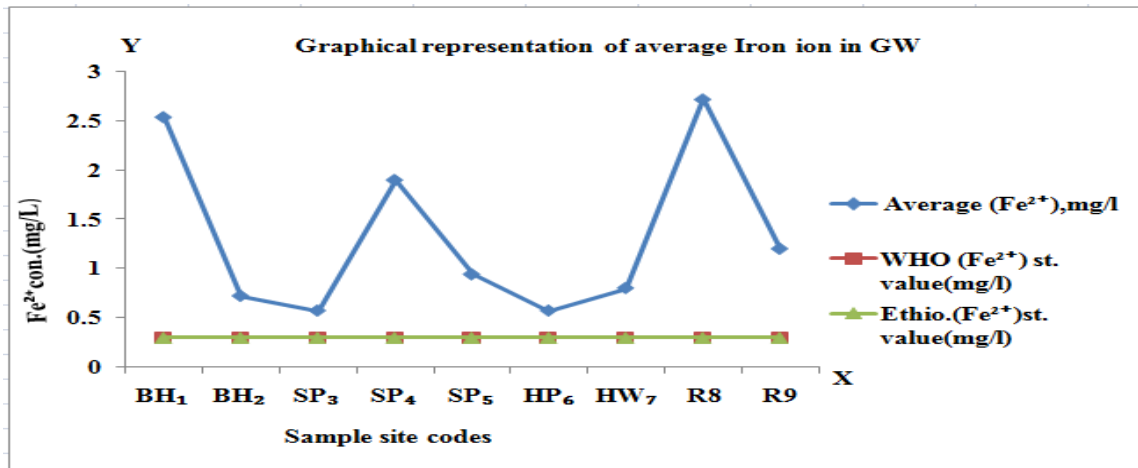
Figure 4.17: Graphical representation of Iron concentration

4.2.12 Manganese

The concentration of Mn^{2+} in study area is varied from 0.0 mg/L to 1.22 mg/L with a mean value of 0.27 mg/L see Table 4.1. The desirable limit of manganese concentration for drinking water is specified as 0.1 mg/L (WHO, 2004). The result shows that all groundwater samples below the permissible limit except HB2 and HP6 as shown on figure 4.18. The highest value of 1.22 mg/L was recorded at BH2 and HP6 the lowest value of 0.0 mg/L was recorded at the rest samples points.

A high dose of manganese causes apathy, headaches, insomnia and weakness of legs (Amankona, 2010). It can be concluded that most of the concentration of manganese in study area were suitable for drinking purpose except HB2 and HP6 which were above the permissive guidelines value. Since BH2 was the sources of water supply for the town, that different problems were detected while the costumers used this borehole's water. These problems were stains laundry, fixtures black, and cause undesirable tastes in beverages. The same treatment as with iron Ion exchange (Water Softener), filtration, and aeration method will be needed.
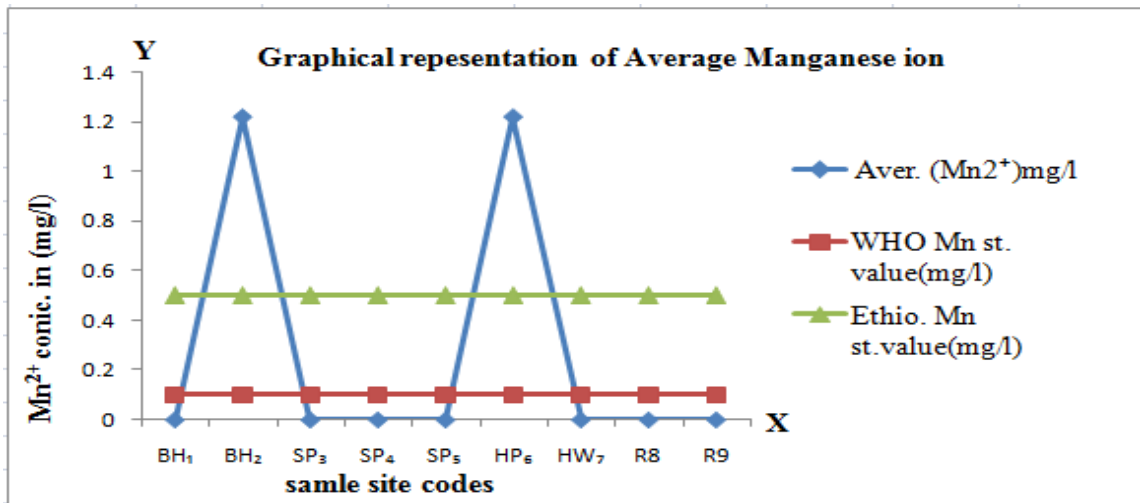
Figure 4.18: Graphical representation of Manganese concentration

4.2.13 Fluoride

The fluoride concentration ground water quality of the study area, Varied between 0.67 mg/L at sample area of SP4 to 1.38 mg/L at sample area of BH1 with mean value of 0.94 mg/L as shown in table 4.1.

The ground water of the study area was suitable concentration contents of fluoride in water. The maximum allowable limit of fluoride is 1.5 mg/L (WHO, 1993). The concentration level was below 1.5 mg/L in all sampled area and suitable to drink in case of fluoride concentration.
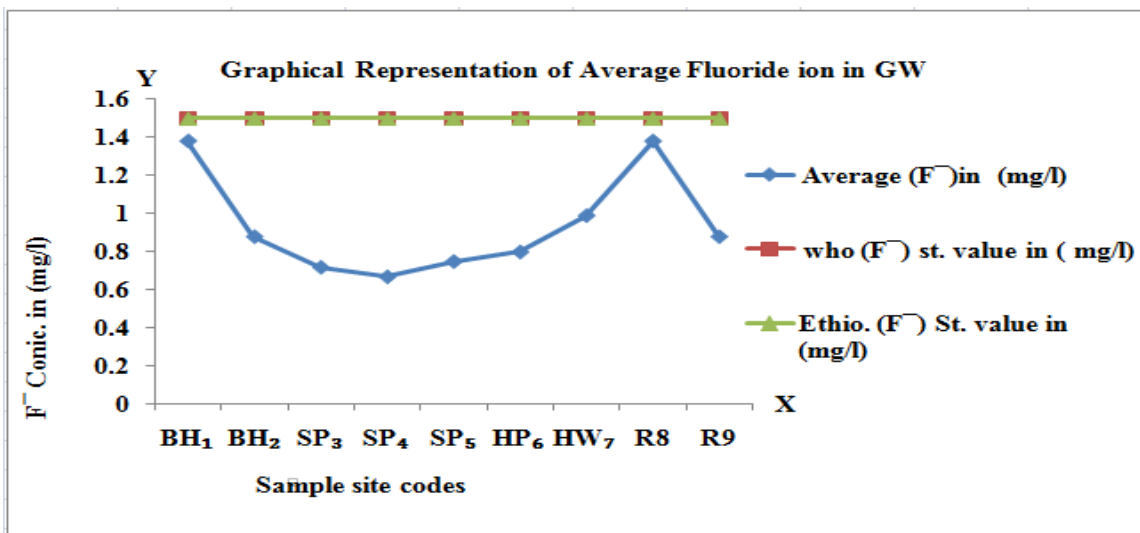
Figure 4.19: Variation of Fluoride concentration

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4.2.14 Arsenic

The arsenic concentration across the study area were, minimum concentration at sample point PH6 was 1E-05 mg/L (10^{-5}) mg/L and the maximum concentration value at sample site SP3 which was 0.01 mg/L with mean value of 0.00159 mg/L

The USEPA has set the arsenic standard for drinking water at 0.010 mg/L to protect consumers from chronic exposure. Excessive intake of arsenic can include stomach pain, nausea, vomiting, diarrhea, and blindness, numbness in hands and feet and partial paralysis. Arsenic has been connected to cancer of the lungs, bladder, kidney, and skin, liver and prostate (Kusi *et al.,* 2015). From these results the values of Arsenic concentration on all sample area were below (WHO, 2011) standard guide line value see figure 4.20. Water from these sample area was safe to drink in case of Arsenic content.
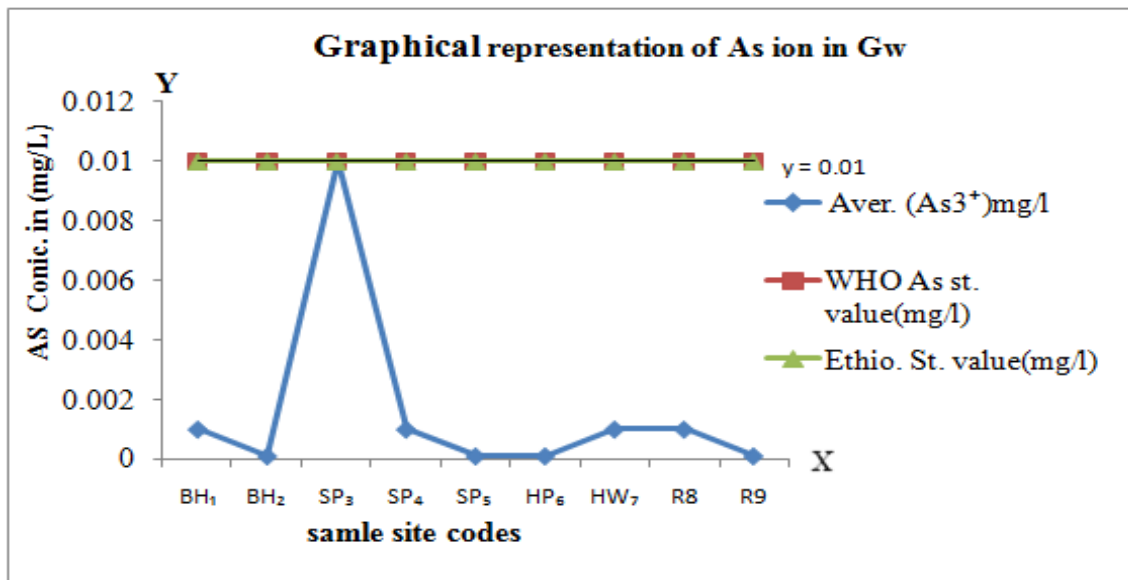
Figure 4.20: Variation of average Arsenic concentration

Table 4.1: Study area physicochemical parameters results

parameters	BH1	BH2	SP3	SP4	SP5	HP6	HW7	R8	R9	sum	Average	Min	Max	WHO GV
Temp.	25	27	28	26	17	25	15	21	22	206	22.9	15	28	25^0c
PH	7.2	7.4	6.2	6.2	7.2	6.8	7.4	7.2	7.4	63	7	6.2	7.4	6.5-8.5
Turbidity,NTU	8.9	9.06	76	14.06	3.23	13.09	9.06	9.5	9.36	152.26	16.9	3.23	76	5
EC(µS/cm)	2569	534	972	985	476	878	524	2586	953	10477	1164.1	476	2586	1000
TDS(mg/l)	1285	267	486	493	238	439	262	1450	749	5669	629.9	238	1450	500
TS at 105^0c.mg/l	2290	380	810	700	270	550	370	3900	2672	11942	1326.9	270	3900	1000
CO_3 Alk(mg/l) as $CaCO_3$	0	0	0	0	0	0	0	0	0	0	0	0	0	
HCO_3^- Alk (mg/l)as$CaCO_3$	150	300	600	600	275	500	500	350	423	3698	410.9	150	600	200
TA,mg/l as $CaCO_3$	150	300	600	600	275	500	500	350	423	3698	410.9	150	600	200
Ca H(mg/l) as $CaCO_3$	317.1	17.3	38.7	38.7	21.9	67.4	15.8	377.1	67.3	961.3	106.8	15.8	377.1	75
MgH (mg/l)as $CaCO_3$	210.8	11.1	76.2	63.5	36.7	64.2	11.3	290.8	61.1	825.7	91.7	11.1	290.8	30
TH (mg/l)as $CaCO_3$	528	28.4	114.9	102.2	58.5	131.6	27.1	667.9	128.4	1787	198.6	27.1	667.9	200
Nitrate(NO_3^-),mg/l	10.4	0.5	0.1	0	4.8	16.4	0.5	12.4	1.5	46.6	5.2	0	16.4	10
Chloride(Cl^-),mg/l	19.3	12.1	16.9	15.9	12.1	33.8	15.4	20.3	14.1	159.9	17.8	12.1	33.8	250
Fluoride(F^-)	1.38	0.88	0.72	0.67	0.75	0.8	0.99	1.38	0.88	8.45	0.94	0.67	1.38	1.5
Sulfate(SO_4^{2-}),mg/l	368.7	2.6	0	0	0	18	0	388.7	22.6	800.6	88.96	0	388.7	250
Sodium(Na^+) ,mg/l	596.9	194.1	338.2	293	123.4	202.8	168.1	616.9	224.1	2757.5	306.4	123.4	616.9	200
potassium(K^+)mg/l	30.6	24.4	38.1	53.4	21.8	16.8	24.6	31.6	24.4	265.7	29.5	16.8	53.4	12
Iron(Fe^{2+}),mg/l	2.54	0.72	0.57	1.9	0.94	0.57	0.8	2.72	1.2	11.96	1.33	0.57	2.72	0.3
Manganese(Mn^{2+})mg/l	0	1.22	0	0	0	1.22	0	0	0	2.44	0.27	0	1.22	0.1
Arsenic (As^{3+})mg/l	0.001	0.0001	0.01	0.001	0.0001	0.00001	0.001	0.001	0.0001	0.01431	0.0016	1E-05	0.01	0.01

Table 4.2: Comparison of physicochemical parameters with WHO standard

Samples area parameters	Ranges of parameters	Average values	WHO St. value	Ethiopian St. values(2013)
Temp.	15-28	22.9	15C	25C
pH	6.2-7.4	7	6.5-8.5	6.5-8.5
Turbidity	3.23-76	16.9	5NTU	5NTU
EC	476-2586	1164.0	1000(μS/cm)	-
TDS	238-1450	629.9	500mg/L	1000mg/L
TS	270-3900	1326.9	500mg/L	500mg/L
CO_3^{2-}	0	0	NA	NA
HCO_3^-	150-600	410.9	200mg/L	200mg/L
TA	150-600	410.9	200mg/L	200mg/L
Ca H as $CaCO_3$	15.8-377.1	106.8	75mg/L	75mg/L
Mg H as $CaCO_3$	11.1-290.8	91.7	30mg/L	50mg/L
TH	27.1-667.9	198.6	200mg/L	300mg/L
NO_3^-	0-16	5.2	10mg/L	50mg/L
Cl^-	12.1-33.8	17.8	250mg/L	250mg/L
F^-	0.67-1.38	0.9	1.5mg/L	1.5mg/L
SO_4^{2-}	0-388.7	88.95	250mg/L	250mg/L
Na^+	123.4-616.9	306.4	200mg/L	200mg/L
K^+	16.8-53.4	29.5	10mg/L	1.5mg/L
Fe^{2+}	0.57-2.72	1.3	0.3mg/L	0.3mg/L
Mn^{2+}	0-1.22	0.27	0.2mg/L	0.5mg/l
As^{3+}	0.0001-0.01	0.0016	0.01 mg/L	0.01 mg/L

4.3 Biological Parameters results

4.3.1 Fecal Coli form

The results of analysis indicated that the values of fecal coliform counted were varied from 4 MPN/100ml atBH2 to14 MPN/100ml atHW7 with a mean value of 9.1 MPN/100 ml see Table 4.4. The FC in drinking water should be 0MPN/100ml (WHO, 2004).

As indicated in figure 4.21, all sampled water was polluted by FC and above WHO guide line. The danger of coliform presence can rest on the health .The concentration of FC obtained from the groundwater samples exceeds the acceptable limits 0MPN /100ml in all the investigated well, bore holes, reservoirs, and protected springs. From the result, the study concluded that drinking water samples collected from all water sources are not safe for human consumption. Especially BH1, BH2, R8, and R9 which were sources of water supply for the town have been highly polluted by FC because there is no treatment plant and chlorination process.
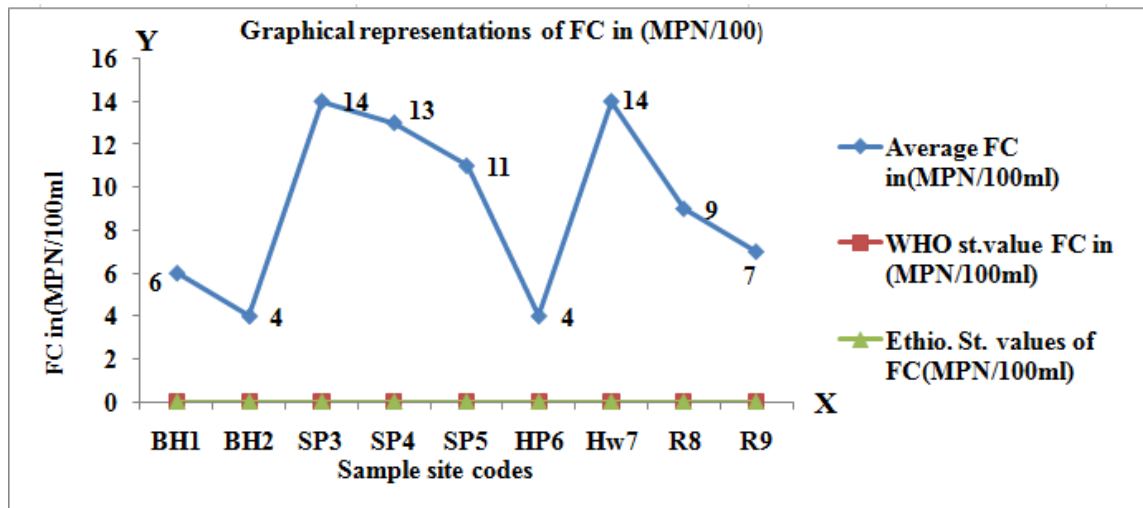
Figure 4.21: Graphical representation of faecal coliform density.

4.3.2 Total Coli form

The results of analysis indicated that the values of TC varied from 7 MPN/100ml to 21 MPN/100ml with a mean value of 14 MPN /100 ml see Table 4.4. In drinking water, TC and FC should be absent (WHO, 2004).

The presence of bacteria in water not only can cause objectionable odours but also may indicate a breakdown in the disinfection system (Bourne *et al.,* 2001). Total coliforms do not positively indicate contamination of fecal origin (Amundson *et al.,* 1988). Only fecal bacteria can positively indicate contamination by faeces of humans or other warm-blooded animals (Leeming *et al.,* 1996).

The highest TC may be as a result of the refuse dump, human faeces scattered nearby the spring in the forest, dog excrement, decomposition of plant material by the action of microbial washed down into the soil and domestic animals that normally visit the site to drink and defecate around the water source (Cintron *et al.,* 2016).

Bacterial growth commonly occurs on walls of pipes, valves, pipe fittings, and aerator and surface of media in point-of-use products (Regunathan *et al.,* 1987). All sample area water was polluted by total coliform See figure 4.22. Therefore series chlorination treatment will be mandatory to make water safe to drink.
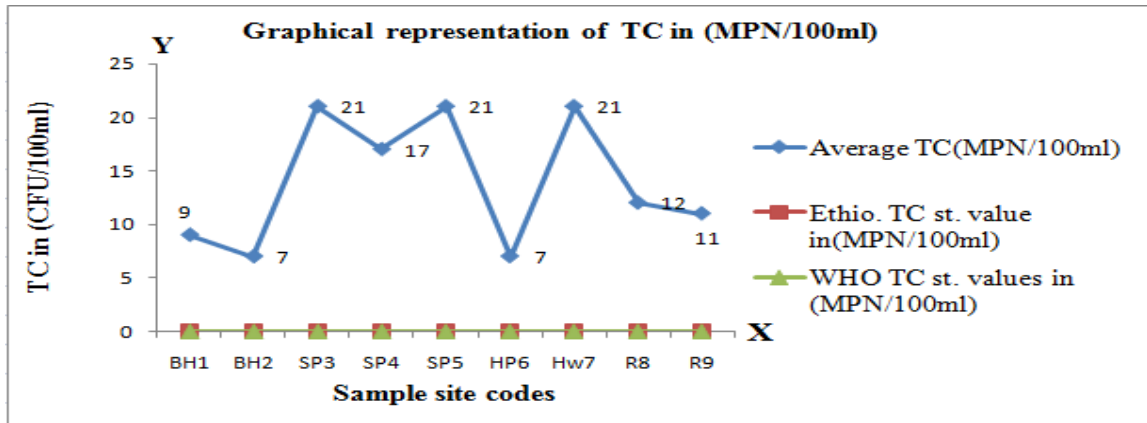
Figure 4.22: Graphical representation of TC density

4.3.3 Comparison of total coliform with fecal coliform

Total coliform is the combination of faecal coliform and E.coli that is E.coli is subset of Faecal coliform and Faecal coliform is also subset of Total coliform. So that, the numbers of TC $>$ FC $>$ E.coli.
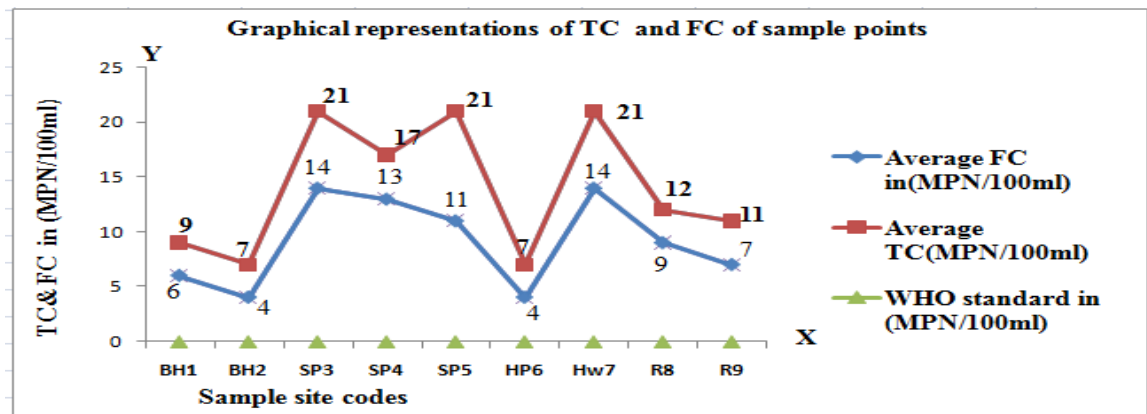
Figure 4.23: Graphical analysis and comparison of FC and TC

Table 4.3: Groundwater bacteriological quality statistical data

Faecal coliform					Total coliform				
Sample site	Tr-1	Tr-2	Tr-3	Aver.	Tr-1	Tr-2	Tr-3	Aver.	WHO GV MPN/100ml
BH1	4	8	6	6	7	9	11	9	0
BH2	2	4	6	4	5	6	10	7	0
SP3	12	13	17	14	10	26	27	21	0
SP4	11	14	14	13	9	14	28	17	0
SP5	9	12	12	11	11	25	27	21	0
HP6	3	4	5	4	4	7	10	7	0
HW7	12	15	15	14	16	23	24	21	0
R8	9	11	7	9	12	14	10	12	0
R9	4	6	11	7	9	10	14	11	0

Table 4.4: Groundwater total coliform and faecal coliform statistical data

sample points	Average FC in(MPN/100ml)	Average TC(MPN/100ml)	WHO standard in (MPN/100ml)
BH1	6	9	0
BH2	4	7	0
SP3	14	21	0
SP4	13	17	0
SP5	11	21	0
HP6	4	7	0
Hw7	14	21	0
R8	9	12	0
R9	7	11	0
sum	82	126	0
Average	9.1	14	0
min.	4	7	0
Max.	14	21	0

4.4 Hydrogeochemical fancies

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 4.0 was used to plot these diagrams. Piper diagram is a multifaceted plot where in milli equivalents percentage concentrations of major cations (Ca^{2+}, Mg^{2+}, Na^+ and K^+) and anions (HCO_3^-, SO_4^{2-}, and Cl^-) were plotted in two triangular fields, which were then projected further into the central diamond field.

Table 4.5: Summary of Hydrogeochemical Data Groundwater

Samples area parameters	Ranges of parameters	Average values	WHO St. value	Ethiopian St. values
EC	476-2586	1164.0	1000(μS/cm)	1000(μS/cm)
TDS	238-1450	629.9	500mg/L	1000mg/L
CO_3^{2-}	0	0	NA	NA
HCO_3^{-}	150-600	410.9	200mg/L	200mg/L
TA	150-600	410.9	200mg/L	200mg/L
TH	27.1-667.9	198.6	200mg/L	300mg/L
NO_3^{-}	0-16	5.2	10mg/L	50mg/L
Cl^{-}	12.1-33.8	17.8	250mg/L	250mg/L
SO_4^{2-}	0-388.7	88.95	250mg/L	250mg/L
Na^{+}	123.4-616.9	306.4	200mg/L	200mg/L
K^{+}	16.8-53.4	29.5	10mg/L	1.5mg/L
Ca H as $CaCO_3$	15.8-377.1	106.8	75mg/L	75mg/L
Mg H as $CaCO_3$	11.1-290.8	91.7	30mg/L	50mg/L
Fe^{2+}	0.57-2.72	1.3	0.3mg/L	0.3mg/L

4.4.1 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.
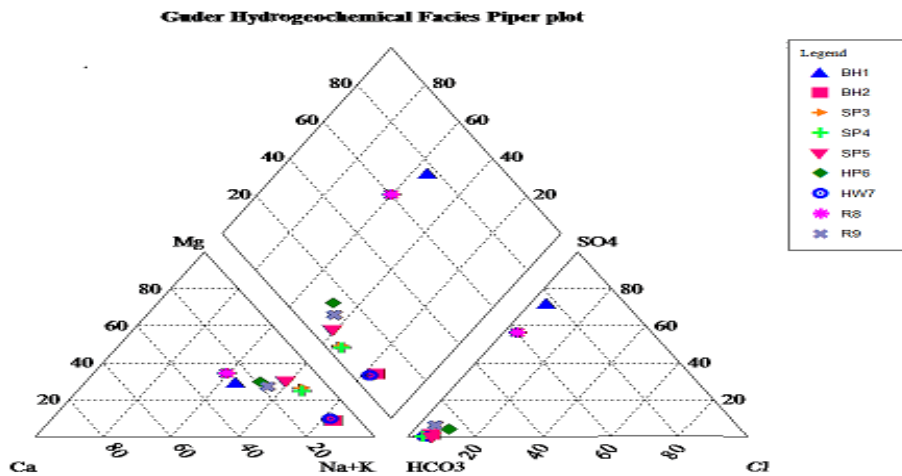
Figure 4.24: Guder hydrogeochemical facies analysis piper plot

Piper divided waters into four basic types according to their placement near the four corners of the diamond as shown in the 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 Na^+ and the anion is HCO_3^- , and the order of dominance ions is $Na^+>Ca^{2+}>Mg^{2+}>K^+$: $HCO_3^- > SO_4^{2-} > Cl^-$. From the result of piper plotted, the water types of the studies area of: BH1, SP6, R8, and R9 were Na-Mg-Ca-SO₄ types, which is dominant types and the other sample points water type which are, SP3, SP4, and SP5 of Na-Mg-HCO₃water types and finally BH2 and HW7 were Na-HCO₃ water types observed.

Table 4.6: Guder town hydrogeochemical groundwater type

| Samples codes | Name of the location | Water sources | GPS60 Reading | | | | Water Type |
			Easting	Northing	Elevation	accuracy	
BH1	Kogne1	Bore hole1	0363498	0986851	2102	±8	Na-Mg-Ca-SO4
BH2	Dawwe	Bore hole2	0363794	0986191	2115	±8	Na-HCO3
SP3	Chancho1	Spring	0364549	0983379	2180	±7	Na-Mg-HCO3
SP4	Chancho2	Spring	0364558	0983350	2180	±6	Na-Mg-HCO3
SP5	Kogne2	Spring	0362906	0986840	2067	±7	Na-Mg-HCO3
HP6	Odokela1	Hand pump	0364125	0988166	2062	±6	Na-Mg-Ca-HCO3
Hw7	Odokela2	Hand dug well	0364065	0988183	2067	±6	Na-HCO3
R8	Ajo	Reservior1	0364375	0990978	2048	±7	Na-Mg-Ca-HCO3
R9	Gorfo	Reservior2	0362699	0991456	2071	±7	Na-Mg-Ca-HCO3

4.4.3 Guder Hydrogeochemical facies Wilcox plot

As illustrated in fig. 4.25 the Wilcox plot was used to identify groundwater sodium and salinity hazards to assure the groundwater suitability for irrigation and for other domestic purpose. In the study area, the salinity and alkalinity hazard classes of sampled water were C2–S2, C3–S2, C4-S2, C3-S1, and C2–S1.
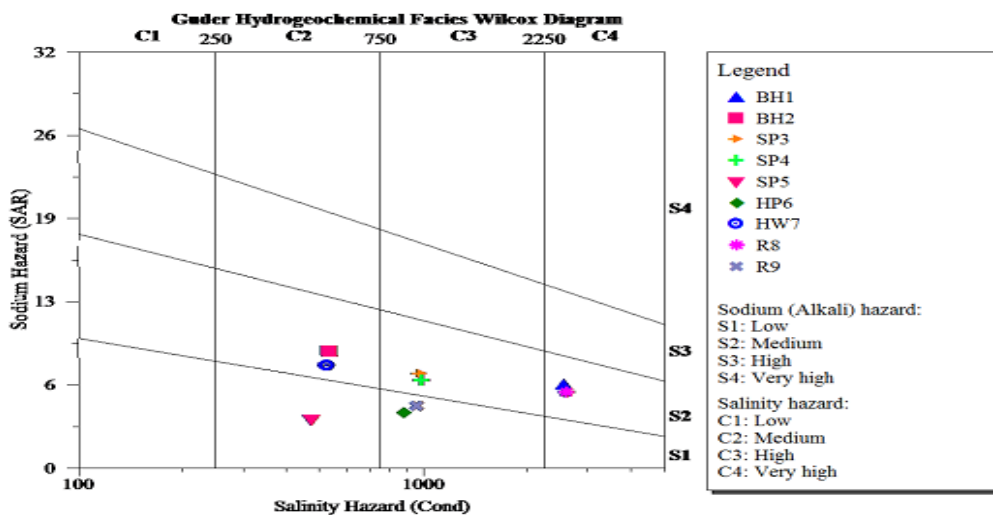

Figure 4.25: Guder hydrogeochemical facies Wilcox plot

The result shows that the groundwater possessed medium to very high salinity hazards with low to medium sodium hazards see fig.4.25 (Richards 1954). The excessive amount of salts can be one of the major problems in water used for irrigation in the study

area. The waters cannot be used for irrigation of most crops. So that it needs for the future special circumstances for salinity control such as leaching requirement or cropping of salt tolerant plants (Richards 1954).

4.4.4 Guder Hydrogeochemical facies Durov plot

As illustrated on fig. 4.26 the Durov plot was used to categorize the hydrogeochemical 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 are set equal to 100% and the data points in the two triangles are projected onto a square grid which lies perpendicular to the third axis in each triangle. From these points of view the hydrogeochemical facies of the study area that identified by Piper and Durov were Na-Mg-Ca-SO$_4$ types, Na-Mg-HCO$_3$, and Na-HCO$_3$.
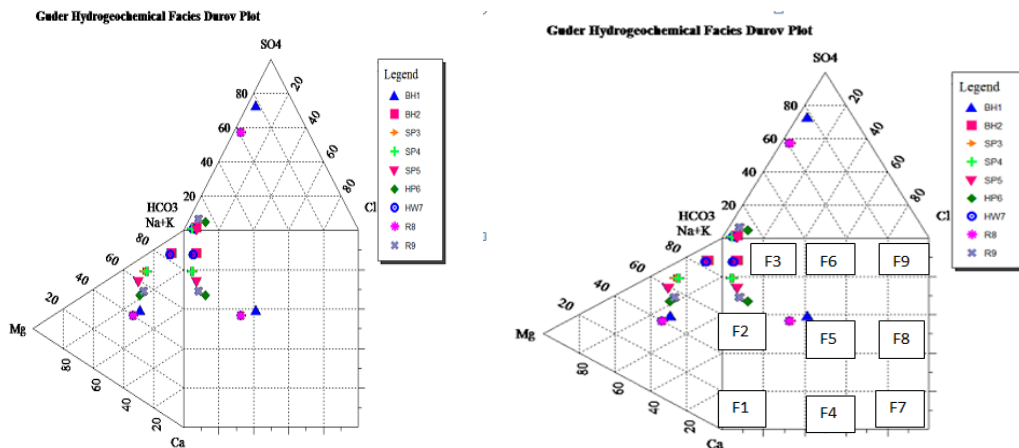
Figure 4.26: Graphical representation of Durov plot

The advantage of Durov diagram over Piper diagram is that this diagram displayed some possible geochemical processes that could affected the water genesis. Most of the groundwater samples of Guder Town's were plotted in field (3) HCO$_3^-$ and Na$^+$ 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).

Other small parts of the samples area were plotted in the field (5) which indicated no domination of cation or anion they are 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 sulphate and chloride (Lloyd *et al.,* 1985).

4.4.7 Guder Hydrogeochemical facies by radial diagram

Radial diagrams are plotted for individual samples as a method of graphically comparing the concentrations of measured parameters for several individual samples. The shape formed by the Radial diagrams will quickly identify samples that have similar compositions.

From figure 4.27 shown the major cation average concentration of Guder town hydrogeochemical facies of $Na^+ > Ca^{2+} > Mg^{2+} > K^+$ and average concentration of anion of the study area was $HCO_3^- > SO_4^{2-} > Cl^- > NO_3^-$ become observed (Lloyd *et al.*, 1985).
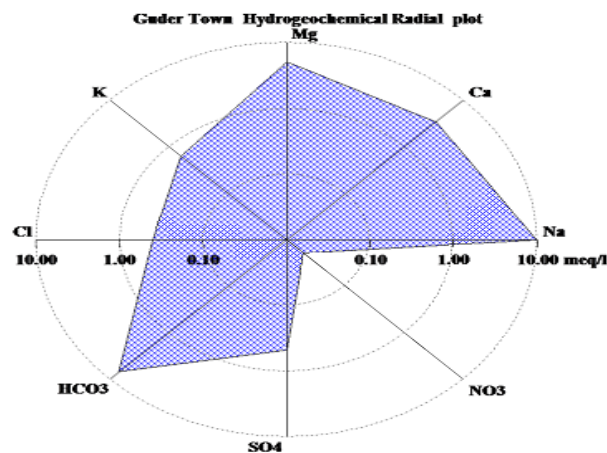
Figure 4.27: Graphical representation of Radial diagram

4.5 Irrigation Indices

The characteristic ratios of Guder town Hydrogeochemical irrigational indices were shown in the Table 4.7. These ratios like Sodium Absorption Ratio (SAR), Soluble Sodium Percentage (SSP, Percent Sodium (%Na), Permeability Index (PI), and Magnesium Hazard (MH) evaluate the groundwater quality for the irrigation purposes (Panaskar *et al.,* 2007).

4.5.1 Sodium Absorption Ratio

The SAR is an important parameter for determination of suitability of irrigation water because it is responsible for the sodium hazard according to (Panaskar *et al.,* 2007).

The SAR values of the groundwater samples range from 2.44 at sample point HP6 to 8.97 at sample point BH2 with a mean value of 5.99 as shown in table 4.4.

According to Richards (1954), the water having SAR < 10 are excellent quality, 10 to 18 are good, 18 to 26 are fair and above 26 are unsuitable for irrigation purpose. The SAR

values of most of the groundwater samples 100% of the study area were less than 10, which indicate excellent quality for irrigation purpose as shown in fig. 4.28.
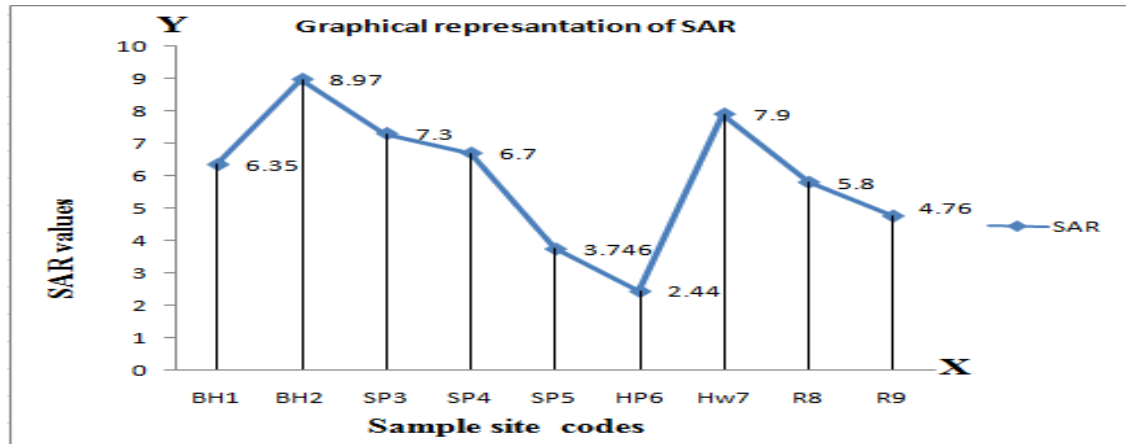
Figure 4.28: Graphical illustration of Sodium Absorption Ratio

4.5.2 Percent Sodium

The percent Na content of the groundwater samples range from 39.3 at sample site of R8 to 86.7% at sample site BH2 with mean value of 60.23% in table 4.7.

Sodium concentration is important parameter in classifying irrigation water because sodium reduces the permeability of soil. Excess Sodium in water is responsible in changing soil properties and reducing soil permeability (Kelley *et al.*, 1951). In all natural waters percent of Sodium content is a parameter to evaluate its suitability for agricultural purposes (Wilcox *et al.*, 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).

According to (Wilcox *et al.*, 1955) percent sodium <20 are excellent, 20-40 are good, 40-60 are permissive, 60-80 are doubtful, >80 are unsuitable. As indicated in table 4.7 maximum value recorded at R8 was unsuitable for irrigation. The rest value were below the 60% categorized 55.6% sampled area were suitable water for irrigation purposes and above 60 classifications, 44.4% samples area water fair to recommended for agricultural purposes.
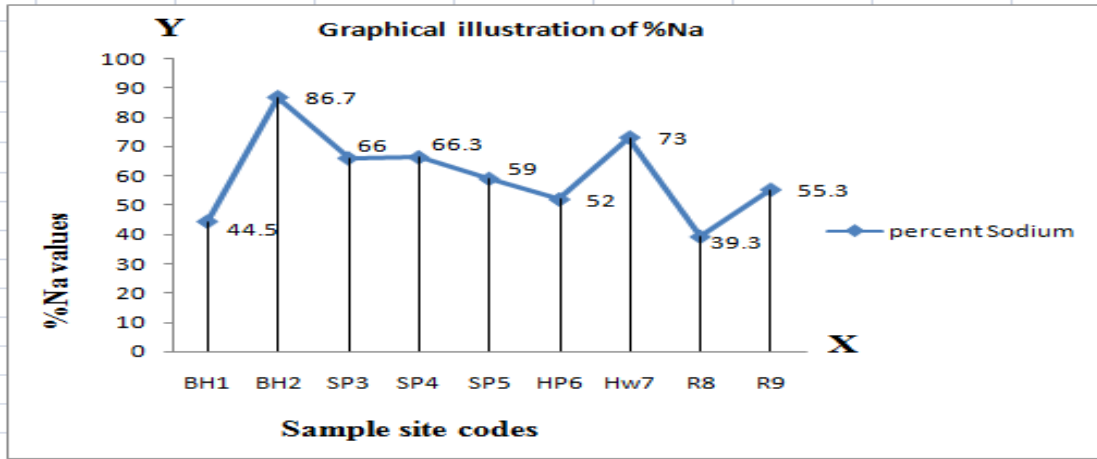
Figure 4.29: Graphical illustrations of percent Sodium

4.5.3 Soluble Sodium Percentage

The SSP values of < 50 indicate good quality and if it is more than 50% it indicates the unsuitable water quality for irrigation purpose (HIDE, 1954). The SSP values for the study area were varied from 39% at sample site of R8 to 80.95% at sample site of Hw7 with mean value of 59.1% as shown in table 4.8.The sample site BH1 and R8 which were 22.2% of the total sample site were less than 50 and therefore indicated excellent quality for irrigation purpose.

The SSP values of most of the groundwater samples 77.8% of the total sample site of the study area were above 50% indicated that   unsuitable quality for irrigation purpose and drinking as illustrated in fig.4.30.   Here it needs optimal adjustment for utilization purpose.
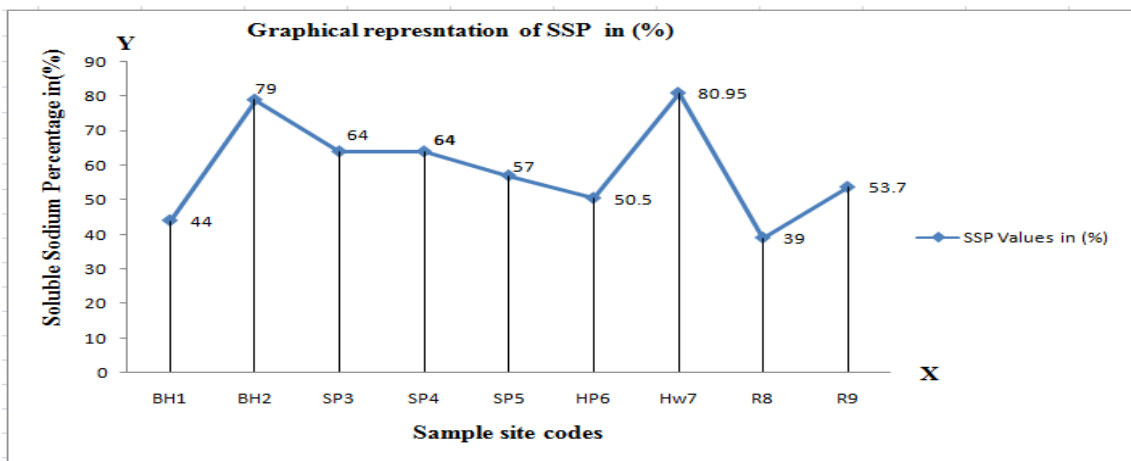
Figure 4.30: Graphical illustrations of soluble sodium percentage

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4.5.4 Permeability index

In present study area, Table 4.7 showed that the minimum value recorded was 42% at sample site of R8 and maximum permeability recorded was 105% at sample site of HW7 with mean value of 74.4%.

Permeability index (PI) for the water samples was determined using the formula developed by Doneen (1964). The soil permeability is affected by long term use of irrigation water. A criterion for assessing the suitability of water for irrigation was based on PI water and can be classified as class I, Class II and Class III orders. 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).

From these results, all sources of water in Guder town's sources of water supply   were suitable for irrigation. Most of the sample site sources 55.6% of the sample site were excellent permeability and suitable for irrigation and the rest of 44.4% were laid in good permeability interval as illustrated in figure 4.31.
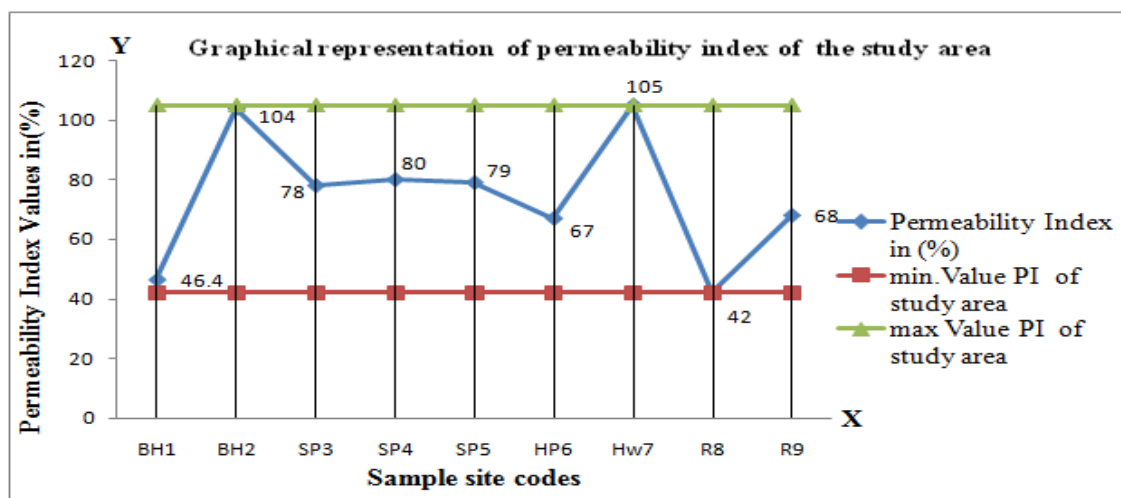
Figure 4.31: Graphical illustrations of Permeability index

4.5.5 Magnesium Hazard

.The calculated values of MH of the study area were ranged from 53 at sample site of BH1to 76.5 at sample site of SP3 with mean value 62.34 as shown in table 4.7.

Calcium and magnesium ions are essential for the plant growth but they may be associated with soil aggregation and friability (Khodapanah *et al.,* 2009). Excess of magnesium affects the quality of soils which is the cause of poor yield of crops (Pandian

et al., 2007). According to (Szabolcs *et al.,* 1964) proposed formula to specify the magnesium hazard (MH) for the irrigation water. The water having magnesium hazard < 50 are safe and suitable for irrigation. All the MH value is higher than 50 and can be classified as unsuitable for irrigation purposes and drinking purposes see figure 4.38
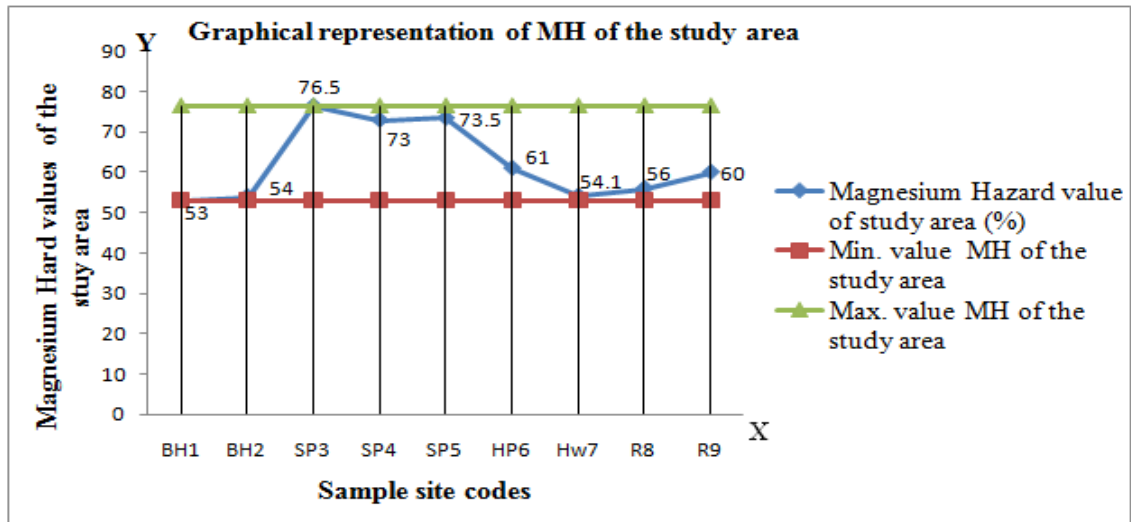
Figure 4.32: Graphical illustrations of Magnesium

Graphical summery of SAR, SSP, PI, %Na, and MH
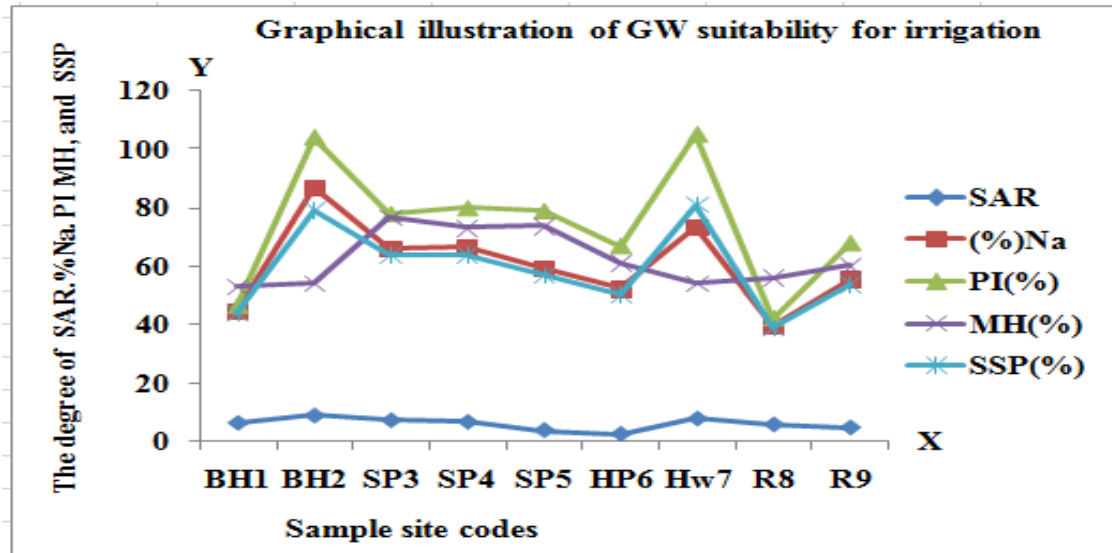
Figure 4.33: Summary of Graphical representation of irrigational indices.

Table 4.7: The statistical values of irrigational indices

sample points	SAR	Na (%)	PI (%)	MH (%)	SSP (%)
BH1	6.35	44.5	46.4	53	44
BH2	8.97	86.7	104	54	79
SP3	7.3	66	78	76.5	64
SP4	6.7	66.3	80	73	64
SP5	3.746	59	79	73.5	57
HP6	2.44	52	67	61	50.5
Hw7	7.9	73	105	54.1	80.95
R8	5.8	39.3	42	56	39
R9	4.76	55.3	68	60	53.7
sum	53.966	542.1	669.4	561.1	532.15
Average	5.99	60.23	74.4	62.34	59.1
Min.	2.44	39.3	42	53	39
Max.	8.97	86.7	105	76.5	80.95

CHAPTER FIVE
CONCUSSIONS AND RECOMMENDATIONS

5.1. Conclusions

The major water supply source for most of the communities of Guder town was ground water. As an optional few communities of the town were used surface water and irrigation water resources as the result of insufficient coverage water supply for all communities. There was no well treatment plant, lack of continuous monitoring techniques; chlorination treatment method; and the laboratory for checking up water quality regularly. The community complaint increased from time to time due to less attention taken to groundwater monitoring. Therefore, it is important to conduct analysis of hydrogeochemical and bacteriological groundwater quality of the area for water supply and irrigational uses.

1. The physicochemical parameters of groundwater samples were measured in laboratory and field. Chemical anion and cations of the water samples were analyzed in laboratory. The important parameters analyzed were: groundwater temperature, Turbidity, pH, TDS, TS, EC, Ca^{2+}, Mg^{2+}, Fe^{2+}, Mn^{2+}, CO_3^{2-}, SO_4^{2-}, NO^-, HCO_3^-, TA, TH, F^-, Cl^-, As^{3+}, Na^+, and K^+. From the analysis done high level of TDS, TS, EC, Na^+, Ca^{2+}, Mg^{2+}, Fe^{2+}, SO_4^{2-}, TA, and TH were recorded at different sample points of the area.

Among the analyzed parameters the maximum average values of the parameters that recorded in the study area were: Turbidity, TDS, TS, EC, Ca^{2+}, HCO_3^-, TA, Fe^{2+}, Na^+, and K^+. The average values of these parameters were above WHO permissive guideline. From these result the study was concluded that most of the sources of water supply will unsuitable for drinking and other domestic purposes.

2. The second important parameter analyzed were bacteriological water quality which are, TC,FC and , *E.coli* .From the analyzed data the values of all sampled water were polluted by total coliform and faecal coliform which were exceeded the (WHO, 2004) GV of 0MPN/100ml.

3. The third important parameter analyzed were determination of the study area hydrogeochemical facies water types. The water types of the study area of BH1, SP6, R8, and R9 were a Na-Mg-Ca-SO4 type which is dominant water type; and sample points

of SP3, SP4, and SP5 of Na-Mg-HCO$_3$ water type and lastly BH2 and HW7 were Na-HCO$_3$ water type observed.

4. The fourth important analysis done was determination the suitability of groundwater for irrigational uses. The average values of irrigational indices such as: %Na, PI, SAR, MH and SSP of the study area were analyzed. The groundwater was unsuitable for irrigation interms of MH and SSP. However, suitable interms Na, PI, and SAR From these results the study concluded that the suitability of groundwater for irrigation depend up on samples points and irrigational indices type and partly unsuitable.

Generally the groundwater for water supply of Guder town physically, chemically and bacteriologic ally were analyzed. Result of the analysis indicated that the water is not safe for domestics and irrigational uses depend up on sources.

5.2. Recommendations

Based on laboratory analytical result the study will recommend the following important point to be considered and applied by Guder municipal water supply, any concerned body, government authority, and users of Guder town groundwater

❖ The chlorination treatment should be mandatory to remove bacteriological density of total coliform, faecal coliform and E.coli with in the water..

❖ 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)

❖ Design and construct Cascade aerator to remove high concentration of Iron content of the water.

❖ Search funds to construct new sources of water supply for the town as optional.

❖ The district should employ qualified expertise and laboratory technician for municipal water treatment.

❖ Construct laboratory centre 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

1A. 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)

$$\text{Total hardness (mg/L)} = \frac{T x N x 50 x 1000}{V} \quad \text{.. (1)}$$

Where; T = volume of EDTA, N = Normality, V = volume of sample

1B. 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).

$$\text{Chloride (mg/l)} = \frac{(Vs - Vb) x N x 1000 x 35.45}{S} \quad \text{.................................. (2)}$$

Where; Vs = volume of $AgNO_3$ for sample, Vb = volume of $AgNO_3$ for blank, S = volume of sample (ml)

1C. Procedures for analysis Sulphate

Sulphate was determined by Spectrophotometer instrument and analysised 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)

1D. Material and method for Calcium and Magnesium hardness analysis

Samples of 50mLwere taken in a porcelain dish and 1ml of NaOH was added to raised 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)

$$\frac{calcium\ \ hardness\ \ mg\,/\,L\ as\ CaCO\ 3}{equivalent\ \ weight\ \ of\ CaCO\ 3} = \frac{calcium\ \ (\,mg\,/\,L\,)}{equivalent\ \ weight\ \ of\ calcium} \quad ..\!\cdots\cdots\ (3)$$

To calculate magnesium harness, we use Equation (2)

$$\frac{magnesium\ \ hardness\ \ (\,m\,/L)\ as\ CaCO\ 3}{equivalent\ \ weight\ \ of\ CaCO\ 3} = \frac{magnesium\ \ (\,mg\,/L)}{equivalent\ \ weight\ \ of\ magnesium} \quad \cdots\cdots..\!\cdots\ (4)$$

1E. 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 analysed on (novAA 400) flame atomic spectrometer set at 248.3nm and was employed a 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 atomised. 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 pyrrolidine dithiocarbamate 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

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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).

1F. 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).

Na (mg/ l) = Na (mg/ l from the calibration curve × Dilution ………………..……... .. (5)

Where: $Dilution = \dfrac{ml\ sampl\ e + ml\ distilled\ water}{ml\ sample}$ ……….……….…................. …..... (6)

1G. Procedures for analysis 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 deionised 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)

K (mg/l) = mg K/l from the calibration curve × Dilution……………….....…….. …... (7)

Where; $Dilution = \dfrac{ml\ sample + ml\ distilled\ water}{ml\ sample}$ ……..……………..……….....… (8)

1H. Bacterial analysis of water samples

1I. Total and faecal coliforms

The three tube Most Probable Number MPN method was used to determine the total and faecal coliform counts in the samples. Serial dilutions of 10^{-1} to 10^{-5} were prepared. 1 ml aliquots from each of the dilutions were inoculated into 5 ml of MacConkey Broth with inverted Durham tubes. The tubes were then incubated at 35 ^{0}C for total coliforms and 44 ^{0}C for faecal coliforms for 18-24 hours. Tubes showing colour change from purple to yellow with gas collected in the Durham tube after 24 hours were identified as positive for both total and faecal coliforms count per 100ml were calculated from the three tubes most probable number MPN Tables(Bremner *et al.,* 1974).

1J. Coli (Thermo tolerant Coliforms)

From each of the positive tubes identified for total and faecal coliforms, a drop was transferred into a 5 ml test tube of Tryptophan Broth and incubated at 44 ˚C for 24 hours. A drop of Kovacs reagent was then added to the tube of Tryptophan Broth. All tubes showing a red ring colour development after gentle agitation denoted the presence of indole and recorded as presumptive for thermo tolerant coliforms (*E.coli*). Counts per 100 ml were calculated from Most Probable Numbers (MPN) table) (Bremner *et al.,* 1974).

1K.Table 4.9 Ground water physicochemical Statistical data expression

parameters	BH$_1$	BH$_2$	SP$_3$	SP$_4$	SP$_5$	HP$_6$	HW$_7$	R8	R9
	Average±SD	Average±SD	Average±SD	Average±SD	Average±SD	Average±SD	Average±SD	Average±SD	Average±SD
Temp.	25±0.255	27± 0.223	28±0.77	26±0.99	17±0.09	25±0.82	15±0.77	21±1	22±2
PH	7.2±0.37	7.4± 0.32	6.2±0.66	6.2±0.76	7.2±0.81	6.8±0.93	7.4±0.63	7.2±0.4	7.4±0.5
Turbidity,NTU	8.9±0.63	9.06± 0.451	76±0.44	14.06±0.7	3.23±0.09	13.09±0.8	9.06±0.51	9.5±0.8	9.36±0.3
EC(μS/cm)	2569±0.52	534±0	972±0.82	985±0.93	476±0.99	878±0.53	524±0.72	2586±0.2	953±0.6
TDS(mg/l)	1285±0.75	267±0.06	486±0.53	493±0.33	238±0.22	439±0.87	262±0.96	1450±0.1	749±0.5
TS at 105^{0}c.mg/l	2290±0.45	380± 0.66	810±0.61	700±0.55	270±0.321	550±0.02	370±0.441	2400±.7	2672±0.5
CO$_3$ Alk as CaCO$_3$	0±0	0±0	0±0	0±0	0±0	0±0	0±0	0	0
HCO$_3$ Alk as CaCO$_3$	150±0.62	300±0.81	600±0.87	600±0.99	275±0.822	500±0.99	500±0.542	350±0.2	423±0.02
TA,mg/l as CaCO$_3$	150±0.84	300±0.34	600±0.72	600±0.85	275±0.911	500±0.87	500±0.091	350±0.06	423±0.75
Ca H as CaCO$_3$	317.1±0.65	17.3±0.75	38.7±0.22	38.7±0.81	21.9±0.22	67.4±0.54	15.8±0.67	377.1±0.02	67.3±0.53
Mg H as CaCO$_3$	210.8±0.32	11.1±0.85	76.2±0.99	63.5±0.32	36.7±0.09	64.2±0.54	11.3±0.82	290.8±0.06	61.1±0.99
Total H as CaCO$_3$	528±0.452	28.4±0.91	114.9±0.56	102.2±0.7	58.5±0.67	131.6±0.9	27.1±0.73	667.9±0.53	128.4±0.6
nitrate(No$_3$),mg/l	10.4±0.56	0.5±0.46	0.1±0.06	0±0	4.8±0.225	16.4±0.98	0.5±0.81	12.4±0.12	1.5±0.12
chloride(Cl$^-$),mg/l	19.3±0.91	12.1±0.55	16.9±0.99	15.9±0.90	12.1±0.09	33.8±0.89	15.4±0.63	20.3±0.61	14.1±0.75
Fluoride(F$^-$)	1.38±0.12	0.88±0.22	0.72±0.12	0.67±0.52	0.75±0.42	0.8±0.71	0.99±0.9	1.38±0.06	0.88±0.52
sulphate(So$_4$$^{2-}$),mg/l	368.7±0.77	2.6±0.98	0±0	0±0	0±0	0±0	0±0	388.7±0.8	22.6±0.22
Sodium(Na$^+$) ,mg/l	596.9±0.66	194.1±0.81	338.2±0.11	293±0.95	123.4±0.9	202.8±0.5	168.1±0.83	616.9±0.51	224.1.4±0
potassium(K$^+$)mg/l	30.6±0.88	24.4±0.221	38.1±0.44	53.4±0.83	21.8±0.93	16.8±0.76	24.6±0.72	31.6±0.52	24.4±0.67
Iron(Fe^{2+}),mg/l	2.54±0.99	0.72±0.62	0.57±0.88	1.9±0.08	0.94±0.54	0.57±0.93	0.8±0.62	2.72±0.67	1.2±0.22
Manganesemg/l	0±0	1.22±0.61	0±0	0±0	0±0	1.22±0.5	0±0	0	0
Arsenic (As3$^+$)mg/l	0.001±0.0001	0.0001±0.0	0.01±0.001	0.001±0	0.0001±0	0.00001±0	0.001±0.0	0.001±0	0.0001±0

Annex 2. Different field and laboratory activities done

2A. Field activities sampling data

2B. Determination of cations and anion by AAS

Annex 3 bacteriological analysis
3A.Preparation reagents and culture media for bacterial growth

3B Bacteriological laboratory results