ADDIS ABABA UNIVERSITY

AFRICA CENTER OF EXCELLENCE FOR WATER MANAGEMENT

Assessment of drinking water quality from source to point use (The case of Mojo town, Oromia regional state of Ethiopia)

MSc Thesis

BY

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In partial fulfillment of the requirements for the Degree of Master of Science in water management specialization of water supply and sanitation

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Thesis Approval Form

The undersigned have examined the thesis entitled Assessment of drinking water quality from source to point use (The case of Mojo town, Oromia regional state of Ethiopia) by Fedila Mohammed, a candidate for the degree of Master of Science in water management specialization of water supply and sanitation and hereby certify that it is worthy of acceptance.

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DECLARATION

I hereby declare that this submission is my original thesis work with all sources of material used duly acknowledged and the work has not been presented for a degree in this or any other university.

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ACKNOWLEDGEMENTS

Above all I praise Allah for giving me his helping hands in all of my moves from the beginning up to the end. I would like to thank my advisor Dr. Besha Mogess and my Co- Advisor Dr. Feleke Zewge for his indispensable prompt help and invaluable effort in guiding and supervising during the progress of this thesis. I treasure his advice which has contributed a great deal to the success of this work. I have benefited a lot from AWSSA central laboratory and water, irrigation and energy minister laboratory; Therefore, it gives me great pleasure to express my great gratitude to the personnel for their willingness to use all the equipment's, reagents and to laboratory technicians. It is difficult to express in words my special gratitude to my families, for their unlimited financial and moral support, and also all of my friends.

ABSTRACT

The quality of drinking water has deteriorated due to insufficient treatment plant, direct discharge of untreated wastewater, and ineffective management of piped water distribution systems. The study was conducted on assessing drinking water quality from source to point of use in Mojo town in Oromia region. To achieve the goal of this study, fourteen water samples were collected from different sources and from a household tap, using the purposive sampling method. The pH, turbidity, total dissolved solids (TDS), iron, ammonia, residual free chlorine, fluoride, nitrates, sulfates, total hardness, and Microbiological (total coliforms and faecal coliform bacteria) parameters were determined using laboratory analysis. Laboratory results of bacteriological analysis indicated 66.67% of household tap water samples in kebele two and 60% of water samples in kebele one indicating the presence of total coliforms. On average, 25% of the total household tap shows the presence of faecal coliforms. This is due to a poorly maintained distribution network, improper waste management and broken piping materials. Based on the laboratory results, a large proportion of the community gets the ammonia concentration. 75% of household and 60% of borehole water samples were exceeding the recommended value by the World Health Organization and the national standard. The highest temperature was recorded at BH1, BH2 and BH3 (25,31,29) respectively which is 60% of the total borehole water samples. Turbidity measurements taken from tap water samples especially around kebele one namely HH4, HH5 and HH6 were found to be higher than the recommended value. In addition, a relatively high level of fluoride was observed in BH5. 21.43% of the water sample of the total Iron above WHO recommended level (0.3 mg/l). In addition, a high amount of nitrate concentration was observed in most of the household and borehole samples. All remaining physical and chemical parameters were safe and within acceptable drinking water quality range. In conclusion, poor sanitation, low level of hygiene, and uncontrolled disposal of solid and liquid waste were among the causes of water pollution in the study area. In addition, it is also recommended that the current state of the Mojo water quality system be improved, the proper management of both liquid and solid wastes, the promotion of improved sanitation practices and the constant inspection of water quality.

Key words: -Water quality parameters, WHO standard, sanitation and hygiene, Mojo, Ethiopia

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LIST OF ABBREVIATION

WHO	World Health Organization
MT	Multiple tube method
MPM	Most probability method
(NGOs)	Non-governmental organizations
AWSSA	Addis Ababa water and sewerage authority
MWSEE	Mojo water supply and sewerage enterprise
TC	Total coliform
FC	Feacal coliform
NGL	National guide line
MF	Membrane filtration
TH	Total hardness
TDS	Total dissolved solid
TSS	Total suspended solid
FRC	Free residual chlorine
NTU	Nephelometric turbidity units

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1.INTRODUCTION

Water is one of the basic important abiotic components to the environment. Approximately 97% of water on earth exists in an ocean that is not suitable and only 3% is freshwater while at 2.97% is made up of glaciers and ice cover. The remaining little portion of only 0.3% is available as surface and groundwater for human use (Sani Nahannu, 2017). Harmless drinking water is a basic need for good health and is a basic human right. In addition, it is impossible to imagine a clean and healthy environment without water (Napacho & Manyele, 2010).

Water quality is a measure of how good water is in terms of supporting beneficial uses or meeting its environmental standards. Potable water is a water suitable for drinking and cooking purposes. This is assessed using water quality indicators (parameters or classes) which can be classified into three broad categories: physical, chemical and biological. Within each category, a number of quality variables are considered. The acceptability of the water quality for its intended use depends on the magnitude of these indicators and is often governed by regulations (Yasin et al., 2015). Drinking water quality has deteriorated due to insufficient treatment plant, direct discharge of untreated sewage into rivers, and ineffective management of piped water distribution systems (Damtie et al., 2014).

Most developing countries including Ethiopia, the main water sources are surface water bodies such as rivers and lakes, aquifers and pore spaces below the water table (Hailu, 2020). Water derived from these sources is exposed to constant pollution and dangerous for human use due to high population growth, expansion of industries, disposal of sewage and chemical effluents into canals and other water sources (Hailu, 2020). Most of Ethiopia's residents do not have access to reliable and safe sanitation facilities. Moreover, the majority of families do not have an adequate understanding of hygiene practices in relation to food, water and personal hygiene. As a result, more than 75% of health problems in Ethiopia are contagious diseases resulting from unsafe and insufficient water supplies, and unsanitary waste management, especially human waste (Mohamed, 2016).

There are many industrial and other activities in Mojo town. The waste generated from these activities is the main waste in the city. It is the solid and liquid waste (such as binary products for tanneries) that is produced from industrial by-products, household commercial centers, establishments and livestock. This waste is not properly managed and disposed by the concerned authorities. Also, there is no site for solid and liquid waste disposal and a sewage system. This problem directly affects the quality of water in the city, which may pose a risk to human health.

1.2 Statement of the problem

Access to safe drinking water and hygienic living conditions are a global concern and these issues are particularly serious in sub-Saharan countries. Developing countries such as Ethiopia have suffered from a lack of safe drinking water and inadequate sanitation services (Amenu et al., 2013). Mojo, like another town in Ethiopia, lacks adequate sanitation services. The sanitation coverage of the city was only 30%, from this more than 65% is pit latrine The sanitation and hygiene situation, especially in low-income areas, is very poor. Poor sanitation practices and environmental pollution lead to direct and indirect threats to public health (MWSSE, 2013).

Most of the people in the study area dispose of solid waste in the farmland around their compound. Others dispose of their solid waste in an open field seven kilometers from Mojo town collected by private collector Those who dispose in open field account 88% and almost all of households discharge solid waste to open area. The sludge is leaked into the drainage system, and infiltrates to the ground water polluting both surface and groundwater. The water supply for human consumption in Mojo is often sourced directly from the borehole without any chemical treatment and the fair of pollution has become a major concern (MWSSE, 2013).

Previously, no study has been conducted on the physical, chemical and bacteriological quality of drinking water from the source, main distribution system (reservoir) and households. Due to the various problems mentioned above, the quality of drinking water has been affected in the town, and the report of the Office of Water Supply and Sanitation in Mojo town shows that there is a microbial problem with drinking water. Because of the above problem this study was needed

The aim of this study was to assess parameters that deteriorate the quality of drinking water in its sources to the household level in Mojo town, to compare it with the standards set by the World Health Organization and national guide line value and factors that related to water quality problem.

1.3 Objectives of the study

1.3.1 General objective

The general objective of this study was to assess the drinking water quality from source to point of use in the case Mojo town.

1.3.2 Specific objective

1. To measure and analyze the basic water quality parameters from point of source up to point of use.
2. To compare selective water quality parameters with WHO and Ethiopians water quality standard.
3. To analyze the relationship between water quality parameters and sanitation and hygiene practice.

1.4 Research questions

1. How to measure and analyze the basic water quality parameters from point of source up to point of use?
2. How to compare selective water quality parameters with compared with WHO and Ethiopians water quality standard?
3. How to analyze the relationship between water quality parameters and sanitation practice?

1.5 Scope of the study

The study was focused basically on the water quality urban places of Ethiopia particularly Oromia region, Mojo city and also limited itself only to issue of water quality and its associated risk, basic sanitation and hygiene practice regarding water quality. The emphasis was to identify the current water quality situation start from point of source to point of use. The investigation from sources to the customer's point of distribution focused specifically only on the main water quality parameters (physical, chemical and bacteriological: total coliform and faecal coliform). The study also identified what the water quality situation looks like from the perspective of community members and water bureau officials.

1.6 Significance of the study

The study was used to assess the water quality in Mojo town. The study is expected to increase knowledge, updated information about water quality and its negative impact on urban residents. It also serves as a working document for policymakers in the water sectors, non-governmental organizations (NGOs), society and environmental advocates. In addition, it will serve as essential data for any further investigation as useful material for academic purposes as literature adding to existing knowledge.

2. LITRETURE RIVEWE

This section provides a review of related and relevant work such as the definition of water quality, basic water quality standards, health risks associated with water, causes of water pollution and sanitation inspection. In general, this review focuses on the evaluation of scientific work that relates to the subject matter of this study.

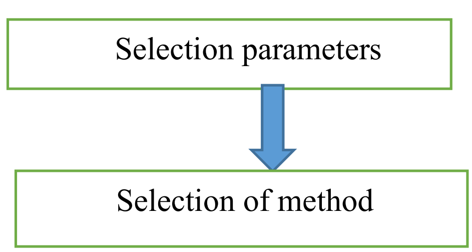
2.1 Water quality

Water quality refers to the chemical, physical and biological properties of water. It is a measure of the state of water in relation to the requirements of one or more biological species, or for any human need or purpose. It is the most frequently used by reference to a set of standards against which compliance, generally achieved through treatment of the water, can be assessed. The most common criteria used for evaluation based on the characteristics of the water in terms of guideline values for what is suitable for human consumption and for all usual household purposes, including personal hygiene (Berhanu, 2015).

2.2 Water quality analysis

Water quality analysis is the measurement of the required parameter of water by following standard methods, to check whether it is in compliance with the standard and thus suitable or not for the specific use. It also mainly requires monitoring whether the water quality is in compliance with rules and regulations to monitor system efficiency and work towards maintaining water quality. It is also required to verify whether an upgrade or change to an existing system is required and to determine which changes need to be made. Before identifying sources of surface or ground water, it is important to perform water quality tests with representative samples. Ideally these tests should be performed on site and through samples taken to the laboratory for final analysis (Lin et al., 2010).

Steps of water quality analysis



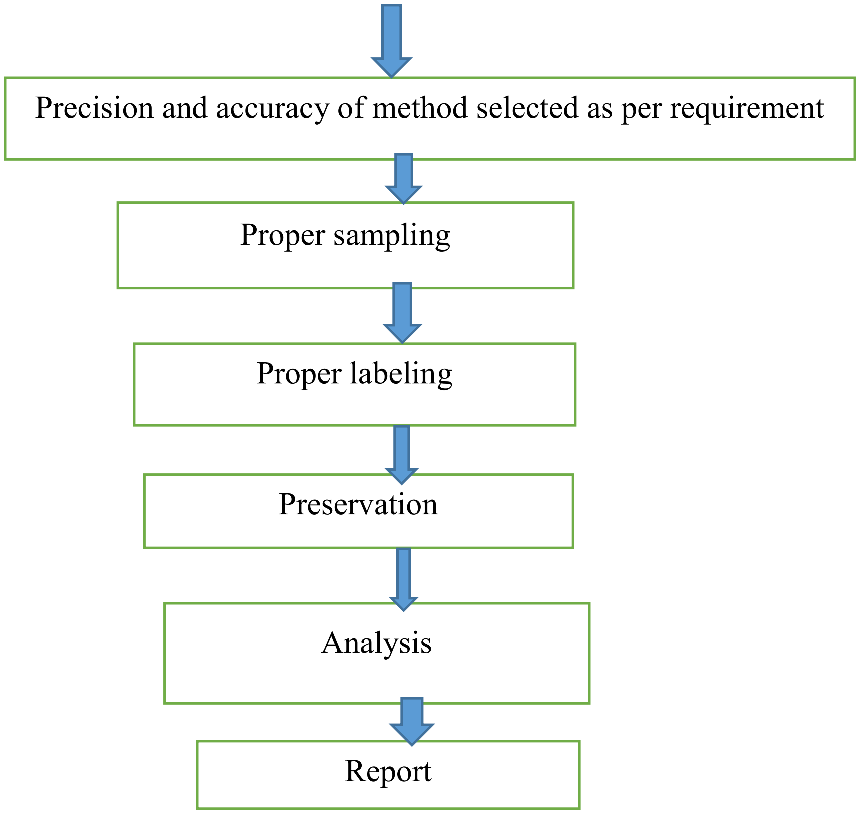


Figure 2.1 Steps of water quality analysis

2.3 Water quality parameters

Water quality parameter are classified into three aspects such as the physical, chemical and biological characteristics of water associated with the set of standards (Viswanathan et al., 2017).

2.3.1 Microbial (bacteriological) water quality

The main risks associated with the water supply are infectious diseases related to faecal contamination. Hence, as described, the microbiological examination of drinking water confirms the assessment of the hygienic quality of the supply. This requires isolating and enumerating the organisms that indicate the presence of fecal contamination. In certain circumstances, the same organism index can also be used to assess the efficiency of drinking water treatment plants, which is an important component of quality control. Other microbiological indicators, not necessarily related to faecal contamination (Ell-Amin et al., 2012)

Indicator organisms: - The presence of some microorganisms in the water is used as an indicator of possible pollution and an index of water quality. 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 both humans and animals (Edessa et al., 2017).

The most common and widespread health risks associated with drinking water are contamination, directly or indirectly, by human or animal excreta, and microorganisms present in faces. Monitoring of bacterial, viral, and primary pathogens is usually complex, expensive, and time-consuming, and you may fail to detect their presence. In monitoring for microbiological quality, reliance is therefore placed on relatively rapid and simple tests for the presence of indicator organisms. The common organisms used as microbial markers are total coliform (TC) and E. *coli* (Amenu et al., 2013).

Total coliform: - Total coliform bacteria (TC) consist of many members of the intestinal bacterium family, and they are those that can grow in selective medium at 35 ° C and ferment lactose or possess the enzyme B-galactosidase, as an indicator of fecal contamination. They are not useful as an indicator of faecal pathogens, but can be used as an indicator of treatment effectiveness and to assess the cleanliness and integrity of distribution systems and the potential presence of biofilm (Ell-Amin et al., 2012). On the other hand, the total coliform bacteria population are unreliable indicators of fecal contamination because many organs are able to grow and persist in the long term (have a non-fecal origin) in many environments, including water distribution systems. On the other hand, there are more TC bacteria in untreated fecal matter than in any of the fecal indicators or other indicator groups, which makes the TC test the most sensitive of all indicator tests. Because of this sensitivity, TC bacteria test as a preliminary test to detect the potential presence of fecal contamination in the delivered water, as well as to evaluate the effectiveness of water treatment and the integrity of the distribution system. Water from a distribution system that is free of TC bacteria should have no or minimal levels of pathogens(Tabor et al., 2011).

Fecal coliform: - Under the TC test result is positive, this sample is then tested for the presence of fecal coliform (FC) bacteria. Since it is difficult to directly monitor diseases that transmit microorganisms, we use the FC bacterial count as a standard measure and an indicator of disease potential. The presence of FC bacteria in the water indicates the presence of fecal matter from mammals or birds, so the organisms that cause waterborne diseases may also be present. The FC organism group is a subgroup of the TC group that can grow in selective medium at 44.5 ° C and ferment lactose, and most FC bacteria are E. coli (Alemu et al., 2015).

Principal analytical techniques: -The principal methods used in the isolation of indicator organisms from water are the membrane-filtration (MF) method, the multiple tube method (MT) or the most probability method (MPM) and the presence and absence tests method (Amenu et al., 2013).

Membrane-filtration method: - In the membrane- filtration (MF) method, a minimum volume of 10ml of sample (or dilution of the sample) is introduced aseptically into a sterile or properly disinfected membrane containing a sterile membrane assembly (nominal pore size 0.2 or 0.45µm). A vacuum is applied and the sample is drawn through a membrane filter. All indicator organisms are preserved on or inside the strainer, which are then transferred to a suitable selective culture medium in a Petri dish. After a period of resuscitation, during which the bacteria acclimatize to the new conditions, a petri dish is transferred to an incubator at an appropriate selective temperature where they are incubated for an appropriate period to allow the proliferation of indicator organisms. Visually identifiable colonies are formed and counted, and results are expressed in numbers of "colony forming units" (CFUs) per 100 ml of the original sample (WHO, 2017).

Multiple-tube method: - The multi-tube method is also referred to as the most probable method (MPM) because, unlike the MF method, it relies on an indirect assessment of the microbial density in the water sample by reference to the statistical tables to determine the most probable number of microorganisms present in the original sample. It contains a sterile nourishing medium at a concentration that ensures the mixture is compatible with a medium of single strength. For example, 10ml of sample is usually added to 10ml of double strength medium or 1ml of sample to 10ml of single strength medium etc. The tube should also contain a small inverted glass tube (Durham tube) to facilitate detection of gas production. The growth in the medium is affected by visible turbidity and / or discoloration. The tubes are incubated without resuscitation, and the number of positive reactions is recorded after 24 and / or 48 hours, depending on the type of analysis (Clark, 2015).

Presence–absence tests: - Presence–absence tests may be appropriate for monitoring good quality drinking water as positive results are known to be rare. It is not quantitative and, as the name suggests, it only indicates the presence or absence of the desired indicator. These results are of very little use in countries or situations where pollution is common. The purpose of the analysis is to determine the degree of contamination rather than indicating whether or not there is a contamination. Thus, presence and absence tests are not recommended for surface water analysis, small untreated community supplies, or larger water supplies that may sometimes experience difficulties in operation and maintenance (Herschy, 2012).

Choice of methods: - The choice between the multi-tube and the membrane method depends on national or local factors, for example the equipment already available or the cost of certain consumables. The advantages and disadvantages of each method must be taken into account when choosing (Herschy, 2012). They are summarized in Table 2.1.

Table 2.1 Comparison methods for analysis of coliform bacteria

Most probable number method	Membrane-filtration method
Slower: requires 48 hours for a negative or presumptive positive result	Quicker: quantitative results about 18 hours
More labour-intensive	Less labour-intensive
Requires more culture medium	Requires less culture medium
Requires more glassware	Requires less glassware
More sensitive	Less sensitive
Result obtained indirectly by statistical approximation (low precision)	Result obtained directly by colony count (high precision
Not readily adaptable for use in the field	Readily adaptable for use in the field
Applicable to all types of water	Not applicable to turbid waters
Consumables readily available in most countries	Consumables costly in many countries

Based on the above comparison table and different study conducted before on different place for this study I was selected membrane-filtration method for bacteriological analysis.

Table 2.2 WHO water quality counts per 100mL and the associated risk

water quality counts per 100mL and the associated risk Count per 100ml	Risk Category
1-10	Low risk
11-100	Intermediate risk
101-1000	High risk

Source: WHO 2010

2.3.2 Physicochemical water quality parameter

Chemical impurities of drinking water supply sources may be causes due to natural sources such as; Some agricultural industries and exercises. While there are toxic chemicals in drinking water, there is a risk that they may cause acute or chronic health effects. Chronic health effects are more common than acute effects because levels of chemicals in drinking water are rarely high enough to cause severe health effects (Temesgen & Hameed, 2015).

The main chemical or inorganic factors for drinking water quality are mainly classified as follows: hardness, calcium, magnesium, chloride, sulfate, fluoride, dissolved solids, nitrates, nitrites and some toxic minerals such as; Iron, manganese, etc. (Sani Nahannu, 2017).

Temperature: - Temperature affects biological and chemical functions. The constants of chemical equilibrium, solubility, and rates of chemical reactions depend on temperature. High water temperature promotes the growth of microorganisms and may increase taste, odor, and color problems of drinking water. It also affects the dissolved oxygen concentration and can influence bacterial activity in bodies of water (Mohsin et al., 2013).

Turbidity: - Turbidity is a measure of the cloudiness of water, the cloudier the water, the greater the turbidity. Turbidity occurs in water due to suspended substances such as clay, silt, and organic matter and by plankton and other microorganisms that interfere with the passage of light through the water. It can be caused by soil erosion, urban runoff, and high flow rates. Although turbidity itself is not a major health concern, its high concentration can interfere with disinfection and provide a mediator for microbial growth. Turbidity is also an indirect indicator of the presence of microbes, and thus, the microbiological parameter is closely related to the microbiological safety of drinking water. Therefore, turbidity must be associated with bacterial contamination, and the potential presence of pathogens that are a concern to human health (Duressa et al., 2019).

pH: - The pH of pure water indicates the acidity and alkalinity states of a solution with respect to hydrogen and hydroxide ions. It can be expressed as a series of positive numbers between 0 to 14. In general, water with a pH of 7 is neutral while less than this indicates acidity and the pH is greater than 7 known as basic Typically, the pH of the water ranges from 6 to 8.5. It is observed that water with a lower pH tends to be toxic, and with a high pH it turns into a bitter taste. According to WHO standards, the pH of the water should be 6.5 to 8.5 and it is important to measure the pH at the same time as the residual chlorine because the effectiveness of chlorination is highly dependent on the pH: when the pH exceeds 8.0, the disinfection is less effective. To verify that the pH is in the optimal range for chlorination (less than 8.0), simple tests can be performed in the field using comparisons such as those used with residual chlorine. With some chlorine comparisons, it is possible to measure the pH and residual chlorine simultaneously (H. R. Sharma et al., 2013).

Total Dissolved Solids: -Total solids refer to the presence of substances suspended or dissolved in water and are related to both electrical conductivity and turbidity. Total dissolved solids (TDS) are mainly characterized by major anions and actions such as carbonate, bicarbonate, sulfate, chloride, nitrate, sodium, calcium, magnesium and potassium (Khan et al., 2012)

Total solids include both total suspended solids (TSS), the fraction of total suspended solids (TSS), retained by the filter, and total dissolved solids (TDS), the fraction that passes through a filter. Concentrations greater than 500 ppm of dissolved solids may cause adverse effects on the taste of drinking water Regarding drinking water quality, water with very low concentrations of total dissolved solids may be unacceptable due to its flat taste. On the other hand, the high concentration of TDS causes some physiological problems (Mohsin et al., 2013).

Fluoride: -Fluoride minerals are abundant in some types of rocks. Heavy immunoglobulin (IGH) concentrations of fluoride can be released into groundwater by dissolving these fluoride minerals, especially after long periods of contact within aquifers. According to WHO standards and Ethiopian standards, the permissible range for fluoride in drinking water should be 1.5 mg / L (Ameer et al., 2018).

Total hardness: - Water hardness is primarily caused by the presence of carbonate, calcium bicarbonate, magnesium, sulfate, chlorides, and nitrates. Depending on the pH and alkalinity, hardness above 200 mg / L can cause scale precipitation especially when heated. Soft water with hardness of less than 100 mg / L has a lower buffering capacity and may be more corrosive to water pipes. A number of environmental and epidemiological studies showed a statistically significant inverse relationship between hardness of drinking water and cardiovascular disease. The degree of hardness of the water may affect its acceptability to the consumer in terms of taste and scale deposition. The general acceptability of the degree of hardness may vary greatly from one community to another, depending on local conditions, and in the taste of water with hardness in excess of 500 mg/L is tolerated by consumers in some instances (Haylamicheal, 2012).

The hardness of natural water depends mainly on the presence of dissolved calcium and magnesium salts. The total content of these salts is known as total hardness, which can also be divided into carbonate hardness (determined by calcium and magnesium carbonate concentrations), and non-carbonate hardness (determined by calcium and magnesium salts of strong acids. When the total hardness of drinking water is greater than 300 mg / l, there will be an increase in blood pressure in the consumer community). Total water hardness has been classified into three ranges, low, medium and high (Napacho & Manyele, 2010) .

Nitrate (NO3): - The main source of nitrates in water is from the atmosphere, legumes, plant residues and animal excrement. It also originates from sewage, septic tanks, and natural drains that carry municipal waste. 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 nitrate concentration in normal water is less than 0.5 mg/L. Nitrates and nitrites are naturally occurring ions that are part of the nitrogen cycle. Nitrate is mainly used in inorganic fertilizers, and sodium nitrite is used as a food preservative, especially in cured meats. The concentration of nitrates in groundwater and surface water is usually low but can reach high levels due to leaching or runoff from farmland or pollution from human or animal wastes as a result of ammonia oxidation and similar sources. Guideline value for nitrate is 0.5 mg/L to protect against methaemoglobinaemia in bottle-fed nitrate infants (WHO, 2017).

Ammonia: - Pure ammonia is a colorless gas with a strong odor. It is manufactured from nitrogen and hydrogen or from coal gas. In nature, ammonia is formed by the action of bacteria on proteins and urea. Ammonia makes a powerful detergent when mixed with water. For this reason, it is one of the most popular industrial and household chemicals. The formula of ammonia, NH_3, means that it is made up of one nitrogen and three hydrogen atoms. Ammonia is rich in nitrogen so it makes an excellent fertilizer. In fact, ammonium salts are a major nitrogen source for fertilizers. like nitrates, ammonia may accelerate eutrophication in waterways (Loan et al., 2013). If certain dissolved components are present in the water, both disinfectants may react and convert to fewer chemical forms of biocides. In the case of chlorine, these reactions mainly involve reactions with ammonia. This typically occurs in drinking water treatment when ammonia is incubated in the water system alongside or immediately following the addition of chlorine or hypochlorite. In the presence of the ammonia nitrogen ion, the free chlorine reacts in a stepwise manner to form chloramine, and the ammonia concentration is measured at the entry point, the tank inlets / outlets, and the end result is important for developing baseline data to predict the onset of nitrification. Degradation of nitrogenous organic matter and discharge of industrial and municipal waste are typical sources of ammonia (Khan et al., 2012).

Sulphate (SO_4): - Sulfates come from several sources such as dissolving gypsum and other mineral deposits that contain sulfates from seawater intrusion, from oxidation of sulfides, sulphates, and thiosulfates in well-ventilated surface waters and from industrial effluents where sulfates or sulfuric acids have been used in a process such as tanning and pulp manufacturing. (A. Sharma & Rout, 2011). High levels of sulfates in the drinking water supply can impart taste, and when combined with magnesium or sodium, they can have a laxative effect (like Epsom salts). The concentration of sulfate in natural water species ranges from a few hundred to several hundreds of mg per liter, but no significant negative effect of sulfate on human health has been reported so far. According to the guide line, the maximum recognized permissible value is 250 mg/l SO_4 based on taste and corrosion potential (WHO, 2012).

Iron: - Iron is the second most abundant mineral in the Earth's crust, and it makes up about 5% of the mineral. Iron is commonly found in nature in the form of iron oxides. In anaerobic groundwater the iron will be in the form of iron (II). Iron concentrations in drinking water are usually less than 0.3 mg/L but may be higher in countries where different 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 (Properzi, 2010).

Iron dissolved in groundwater is controlled by pH and reduction conditions and is dependent on iron-bearing minerals in the aquifer. Iron dissolution can occur as a result of oxidation and low pH in drinking water supplies, iron (II) salts are unstable and are deposited as insoluble iron (III) hydroxide, which settles as a rust-colored silt. Laundry and plumbing staining may occur at concentrations higher than 0.3 mg / L and the maximum contamination level. Iron also promotes the growth of unwanted bacteria ("iron bacteria") within the waterworks and distribution system, which causes a sticky layer to be deposited on the pipes. Iron in water can cause yellow, red, or brown stains to appear on laundry, dishes, and plumbing fixtures such as sinks. Additionally, iron can clog wells, pumps, sprinklers, and other devices like dishwashers, which can lead to costly repairs. Iron gives a metallic taste to water, can affect foods and drinks that turn tea, coffee and potatoes black, and warns that iron poisoning can affect the central nervous system (Yasin et al., 2015).

Residual Chlorine: - In developing countries, many domestic water supplies are treated with chlorine and maintain a certain concentration of residual chlorine to disinfect potential bacterial contamination within the supply infrastructure. Monitoring residual chlorine concentrations within the distribution system can indicate if water quality degradation is occurring. Any rapid deterioration or sudden disappearance of residual chlorine concentrations could indicate contamination of water supplies. Measuring residual chlorine in water samples is important to ensure safe water delivery to consumers (Duressa et al., 2019).

Chlorine is a powerful oxidant and effective disinfectant due to its ability to oxidize enzymes of microbial cells and reduce their viability. Drinking water obtained from surface or ground water is often contaminated with microbes. This water is often treated to destroy harmful microorganisms and is an essential process in providing safe drinking water. As a result, the World Health Organization recommends a minimum of 0.2 mg / L of free residual chlorine in household water to ensure it is free of harmful microbes (WHO, 2012).

2.4 WHO and Ethiopian standard of drinking water quality

Safe drinking water, as defined in the guidelines, does not represent any significant risk to health over a lifetime of consumption, including the various sensitivities that may occur between life stages. In another direction, the nature and form of drinking-water standards may differ between countries and regions and no single approach is universally applicable. When developing and implementing standards, it is essential to consider current or planned legislation related to water, health, local government, and the capacity of state regulators. In addition, approaches that may operate in one country or region will not necessarily transfer to other countries or regions (WHO, 2012). For this work WHO and Ethiopian guidelines values for drinking water are presented in Table 2.3 WHO and Ethiopian guide line values of drinking water number.

No	Parameter	WHO(1993) standard	Ethiopian(1998) standard
1	PH	6.5 – 8	6.5 – 8
3	Free chlorine residual (mg/l)	0.2 - 0.5	0.5
4	Fecal coliform (CFU/100 ml)	0	0
5	Total coliform (CFU?100 ml)	0	0
6	Nitrate (mg/l)	0.5	0.5
7	Ammonia (mg/l)	0.5	1.5
8	Fluoride(mg/l)	1.5	1.5
9	Total hardness(mg/l)	300	300
10	Iron(mg/l)	0.3	0.3
11	Manganese(mg/l)	0.1	0.5
12	Sulphate(mg/l)	250	250

2.5 Causes of water pollution

In rural areas of most developing countries, women and children collect water from a community source, often hundreds of meters away from home. The sources themselves may be unimproved (hand-dug wells, unprotected springs, rivers), with low and seasonal flow rates, or improved (general taps, wells or pumps, protected wells, protected springs or harvested rainwater). A systematic review of 57 studies published prior to 2018 by (Francis, 2019) showed that water pollution occurs between source and point of use. Even fully protected sources and well managed systems do not guarantee safe water delivery to homes. The majority of the world's population does not have reliable home water connections, and many of them still have to carry and store water in their homes. Several studies show that even water collected from safe sources is likely to become faecallly contaminated during transportation, containers, and storage and Microbiological contamination between source and point of use prescribed that covered water container will reduce 50% of water born and water related diseases (Berhanu, 2015).

Safe sources are important, but the quality of the water consumed by people can only be guaranteed through improved hygiene, improved water storage and handling, improved sanitation and, in some cases, household water treatment. A growing body of evidence shows that water quality interventions have a greater impact on the incidence of diarrhea than previously thought, especially when interventions at the household level (or point of use) are applied in conjunction with improving water treatment and storage. Providing drinking water to rural and urban residents is essential to prevent health risks. Before describing water as potable, it must comply with some physical, chemical and microbiological criteria, which are designed to ensure that the water is palatable and potable (Lin et al., 2010).

2.5.1 Pipelines leakage

Water at source is usually safe if groundwater, or fit for human consumption if treated from surface water, but is contaminated in the transmission system when pipelines are tempered for illegal connections or when abandoned hydrants are not properly closed or left unattended. The old, rusted, substandard and exposed distribution pipelines can trigger holes and cracks in the network and pave the way for intrusion of sewage or polluted water (Paul et al., 2008)

2.5.2 Location of pipelines

Drinking water supply lines are often located close to, parallel and beneath the sewerage system or wastewater channels. This practice is very common especially in unplanned towns and localities. As a result, leakage from the sewerage system moving towards the lower level enveloping the supply lines and infiltrating them through holes, cracks or damaged parts especially when back pressure develops in the system. Under water rationing, consumers are forced to pump water from supply lines which promotes back pressure development and contaminated water leakage. Personal experience has shown that at the time of installation of service supply lines, the consumers prefer to get the service line passed through wastewater disposal drains holes instead of drilling a new hole for the purpose Any damage or leak in the service line becomes a regular passage for easy access to microbial contamination (Temesgen & Hameed, 2015).

2.5.3 Clogging of sewerage system

Municipal solid waste that is not properly collected or disposed of makes its way into towards sewerage drains and manholes resulting in suffocation. Often sewage serves the dual purpose of disposing of wastewater and rain water and remains clogged due to poor maintenance and overload resulting in floods mixed with natural water channels and municipal water works. In severe storm conditions, contaminated water may enter borehole, open wells and domestic water tanks. Adequate cleansing and disinfection is rarely done after such events. Solid waste and rainwater disposal require due consideration in the planning and design stage of sewage systems (Dfid, 2012).

2.6 Sanitation inspection

Sanitation as defined by the World Health Organization (WHO); In general, it refers to the provision of facilities and services for the safe disposal of human urine and faeces. Insufficient sanitation is a major cause of disease worldwide and improved sanitation is known to have a significant beneficial effect on health in both households and across societies. The word sanitation also refers to the maintenance of hygienic conditions, through services such as garbage collection and wastewater disposal (Rizwan, 2016).

Water supply system sanitary survey is a complete, accurate and detailed investigation of the entire water supply system, from source to end users, in order to detect the presence of actual or potential sources of pollution. The water supply system health survey report is the only reliable and practical source of information to ensure the suitability of the drinking water supply. Sanitary inspection and acknowledging the status is very important to minimize pollution. It is an on-site assessment by trained persons of actual and potential pollution hazards and pathways in and around water supply systems. Pathways are routes through which contamination may occur, such as leaking pipes or cracked well aprons. Hazards and paths can be indirect or intermittent, such as a broken gate that lets animals into well enclosures or corrosion revealing buried pipelines. The Sanitary survey focuses on sources of microbiological contamination. However, in some cases, the survey can identify chemical hazards from local industries or agricultural activity such as intensive fertilization near a surface water source outlet or effluent from a tannery near a source point (Sisay et al., 2017).

An analysis of water quality standards alone cannot provide a complete picture of a community's water quality situation and its water supply systems. The periodic quality test is just a snapshot: it provides limited information on the source of contamination and can miss important seasonal quality fluctuations. Actual and potential water quality problems can only be addressed if information is available on the sources and pathways of pollutants, and this information can only be provided through a health survey (Edessa et al., 2017).

2.7 Health risk associated with water

Water is a basic necessity for life. Unfortunately, not all water helps a person survive. Water from polluted sources causes many diseases and premature deaths. The fact that a person needs water and cannot live without it forces him to use it even for drinking purposes, from any source whether pure or polluted (Edessa et al., 2017).

Usage of quality deteriorated water may be a cause for the existence of water born, water washed water based and water related diseases. The term water related diseases is used to describe all types of infections that are transmitted through water. These are cholera, bacillary dysentery, Escherichia coli (E. coli), viral hepatitis A, shigellosis, typhoid fever, cryptosporidiosis, and giardiasis. In general, outbreaks of waterborne diseases typically include source contamination, breakdown of treatment systems, contamination of distribution systems and use of untreated water (Viswanathan et al., 2017).

According to the World Health Organization; Water related disease can be defined as a disease related to water supply and sanitation. There are four categories: -

1. Waterborne disease
2. Water-washed disease
3. Water-based disease
4. Water-related disease

Table 2.4 Water associated disease

No	Water associated disease	Example	Transmission

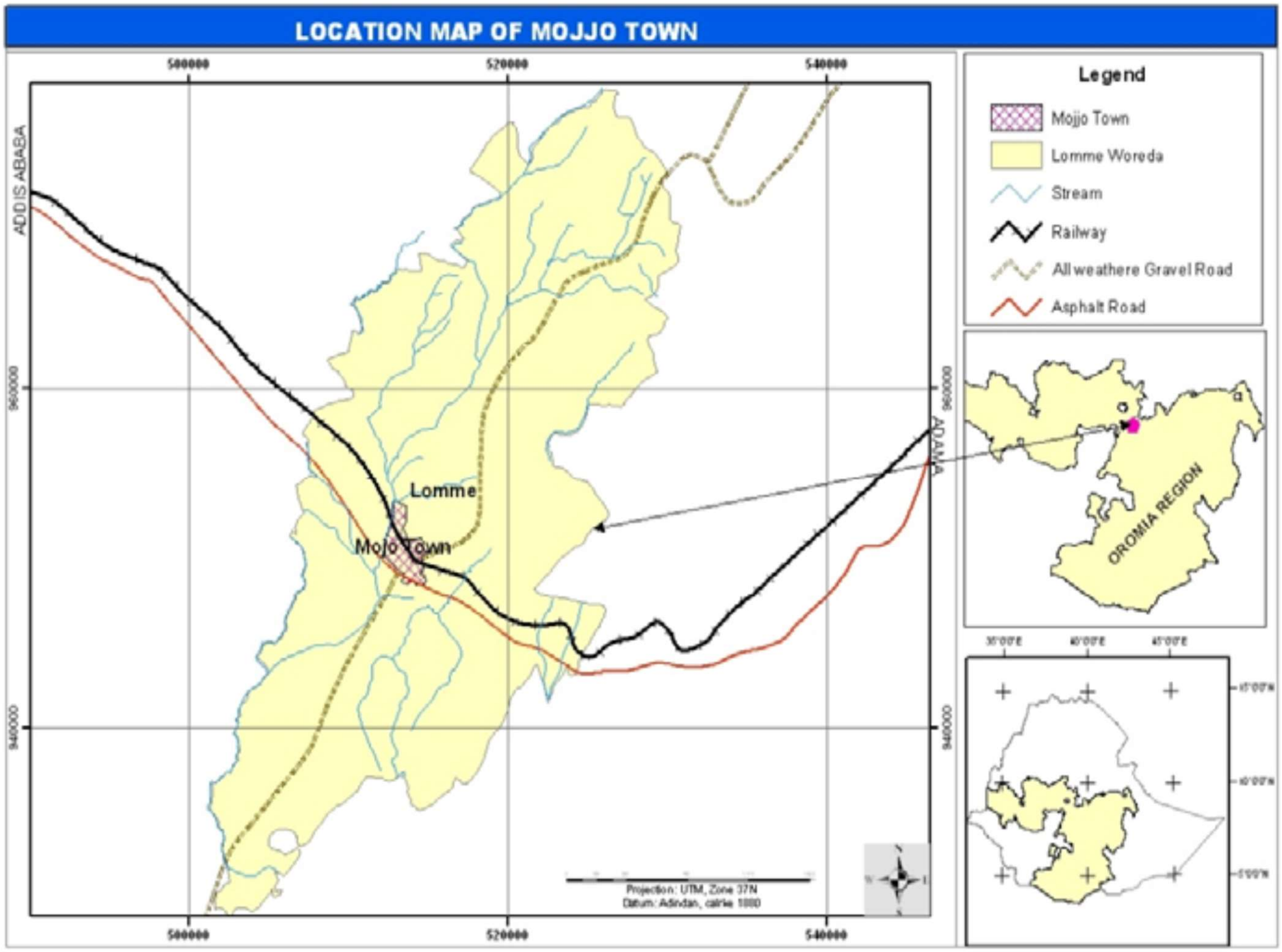
1	Water born	Typhoid , cholera ,Amoebic dysentery	transmitted through water contamination by fecal matter
2	Water washed	Trachoma , scabies	caused by a lack of water for personal hygiene
3	Water based	Schistomia ,Guinea worms	caused by infectious agents that are spread by contact with water
4	Water related	Mosquito , test fly	transmitted by insects that live close to water

3.MATERIAL AND METHOD

3.1 Study area

Mojo town is located in Oromia regional state, East Showa zone, Lume woreda at a distance of 70 km from Finfinnee. Mojo is found at about 26 KM to the West of Adama town. The town is located at the juncture of the road to Hawassa and Adama roots and passes way to the southern and eastern parts of the country (Source: Mojo WSS Study and Design Document).

Administratively the town is divided in to two Kebele (Kebele 01 & 02). Facts show that the foundation of Mojo town is closely related to Addis Ababa-Djibouti Railway line which grew from a mere station into a multifaceted town and highly urbanized area. Based on the CSA (2010) census Source: (Source: Mojo WSS Study and Design Document). result the total population of Mojo town about 36,169. However, presently the total population of the town is about 40000.



(Source: Mojo town google map)

Figure 3.1 Location map of Mojo

3.2 Mojo town existing water supply and sanitation status

3.2.1 Water supply

The water supply system of Mojo town is established in the 1950s and managed under the Municipality to serve railway workers and to serve as a coolant for the locomotives. The existing system consists of 9 boreholes; four boreholes located in Dibandiba, Dibora, Kolba well field namely – BH1, BH2, BH3, respectively and; two boreholes located inside the Cotton mills factory compound, namely – BH6 and BH7; one borehole located on the way to Meki, namely BH8; and two borehole located sheradiben, namely BH4 and BH5. But currently four boreholes are not functional which is (BH6, BH7, BH8, BH9). These boreholes are run by the electricity from the EEPCO grid. No standby generator is provided. BH4 and BH5 which is recently connected to the system by transmission main with one storage reservoir and distribution network. According to the data obtained from Mojo town water supply and sewerage enterprise currently there are 5,118 private connections, 28 public Taps and 4,074 shared yard taps available in the town (DH consult, 2013).

3.2.2 Sanitation services

There are different industrial and other activities in Mojo town, domestic and industrial wastes are the major wastes in the town. They are solid as well as liquid wastes (like bi-product of tanneries) generating from industrials byproducts, household's commercial centers, institutions and livestock. The major types of wastes that come out from these sources are human excreta, garbage, rubbishes and cow dung. The wastes emanate from industrial such as tanneries a serious for human health and needs intervention.

3.3 Health

In the town there are one health center, 8 clinics and 14 pharmacies. From health office data the number and percentage of prevalence ten top diseases recorded in the year 2010 E.C.

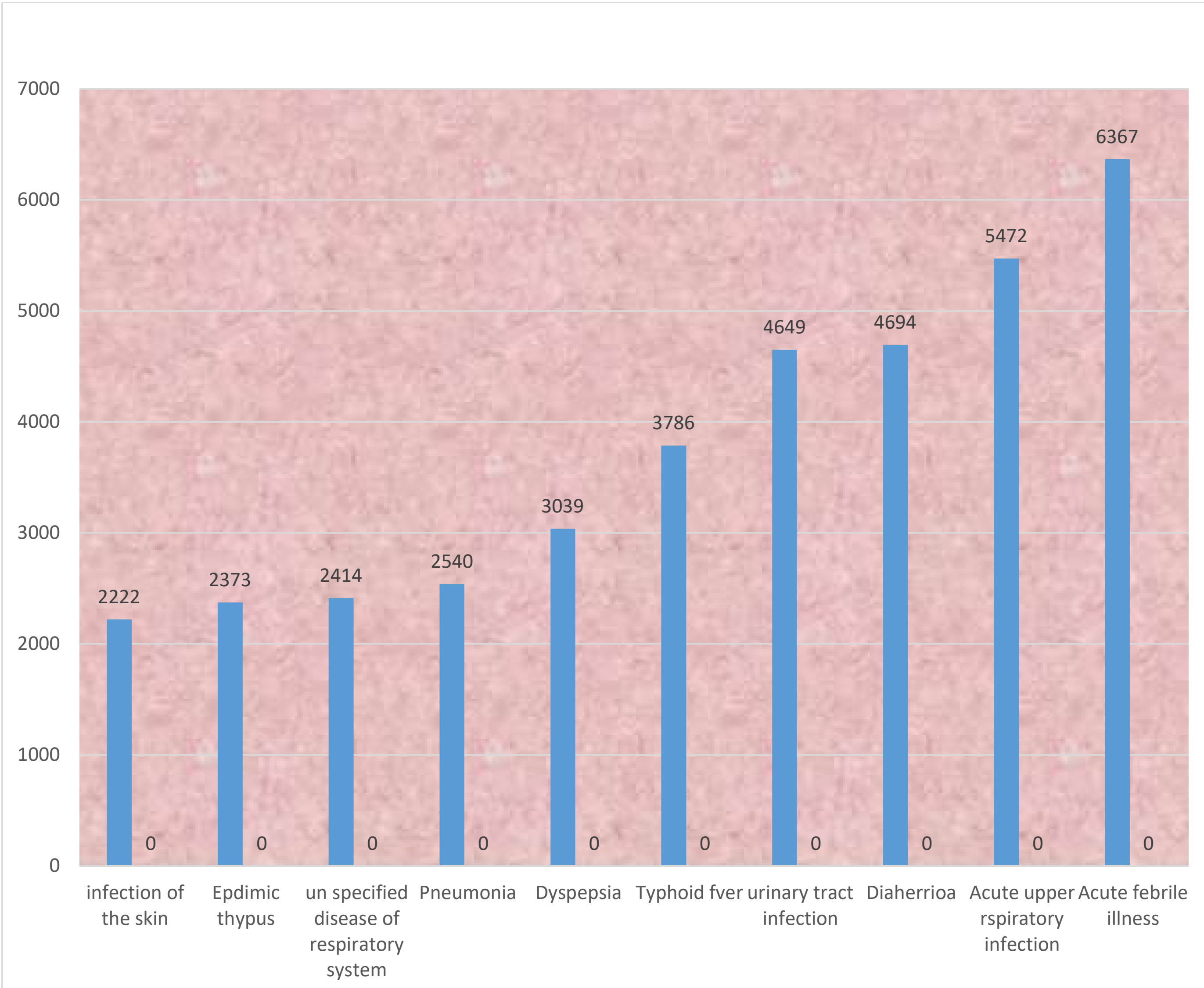


Figure 3.2 Top ten disease of Mojo town

(Sources: Mojo Town Health Centre,2010)

3.4 Study design

Descriptive and cross-sectional study designs were applied to complete the study. The descriptive study design was applied to examine the sanitary condition of the study area. Whereas, a cross-sectional study design was used to assess the physical, chemical and bacteriological quality of drinking water in sources, reservoir and consumer taps. The sanitary conditions of the study area were assessed using questionnaire and checklist. The survey questionnaire and checklist were approved by (WHO, 2012), and they were modified according to the objectives of the study.

3.5 Data collection

All the necessary data required for the study were obtained from both primary and secondary sources.

3.5.1 Secondary data collection

The Secondary data were collected from government and non-governmental publications, city annual and inventory reports, previous studies, and books.

3.5.2 Primary data collection

Primary data were obtained from field observation, key informant interview, questionnaires and laboratory analysis.

3.5.2.1 Questionnaire

A questionnaire which have twenty-nine questions was prepared to assess the sanitary services, handling system of both solid and liquid waste, condition of current water quality, placement of drinking water pipe and other basic environmental condition on the study area. 360 household sample was selected to fill the questionnaire. Household head means the person who plays the main role in the decision-making process of a family were selected to answer the questionnaire and in absence of the household head, the second important adult member of the family was selected. In doing so, the study objectives were clearly explained to the households and each household was assured that the information provided would be kept confidential. Beside this, Information was also collected through photographic observation.

3.5.2.2 Field observation

Observation was done to obtain some qualitative data which was obviously supplement the quantitative data collected by other tools. Accordingly, critical observations were made to water supply sources, pipe lines, reservoirs, sewerage system and solid waste disposal site.

3.5.2.3 Key informant interview

Interview to key informants at various levels was held to exploit the basic data and other important issues to get sufficient information for the study. Specifically, the interview was made with mojo water supply and sewerage office water experts, municipality leaders and mojo health office center leader.

3.5.3 Sampling

3.5.3.1 Sample size determination

Sample size was calculated based on the minimum sample number piped drinking water in the distribution system which adopted in the world health organization (WHO, 2012).

Table 3.1 Minimum sample number for drinking water quality

No	Population served	Recommended minimum sample number
1	Less than 5000	1
2	5000 – 100,000	1 per 5000 population
3	Greater than 100,000	1 per 10,000 population plus additional 10 sample

Source: - Guide line for drinking water quality second edition volume 3 surveillance and control of community supplies by (WHO, 2012)

According to CSA 2013 projection the total population of Mojo town is 40,000.

$$n = \frac{P}{10,000}$$

$$= \frac{40,000}{10,000}$$

$$= 4$$

Sample size = 4+10=14

Where, n ………………. number of sample

P…………………….…total number population

The total sample size that needed to fill the questioner on assessment of the sanitation and hygiene practice with regarding to water quality was determined by using the following statistical formula (CochranWG, 1977).

$$n(i) = \frac{N*Z^2*P*Q}{W^2*(N-1)+Z^2*P*Q}$$

n (i) ……………….sample household

N……………………..…total number of house hold

P………………………………. proportion (50%)

Q…………………………………1-P

Z………………………95%confidence interval (1.96)

W……………………………………...5%

$$\mathbf{n(i)} = \frac{10100*1.96^2*0.5*0.5}{0.05^2*(10100-1)+1.96^2*0.5*0.5}$$

= 359.255 Approximately 360

3.5.3.2 Sample location

A cross sectional study was conducted to determine the level of water contamination between the sources and at point-of-use in Mojo town. purposive probability sampling method was applied, based on the distance from the service reservoir, borehole and household. Sample collection were started from the borehole then I was followed the main water supply line from the water tank to the individual household taps. A total of fourteen water samples were collected from the study area. Five samples were allocated for borehole, one sample for a reservoir and eight samples for household taps. The study area has two kebeles, from those I was taken five and three sample from kebele one and two respectively, the sample size was assigned based on the number of population lives in those kebele and household taps samples were distributed by using a purposive sampling method based on;

- ✓ Costumers life style and economy
- ✓ Lower elevation area
- ✓ Dead end of water distribution area
- ✓ Intermittent water supply area

- ✓ Old water distribution area

The sample location was arranged and located by using GPS and the study area google earth map.

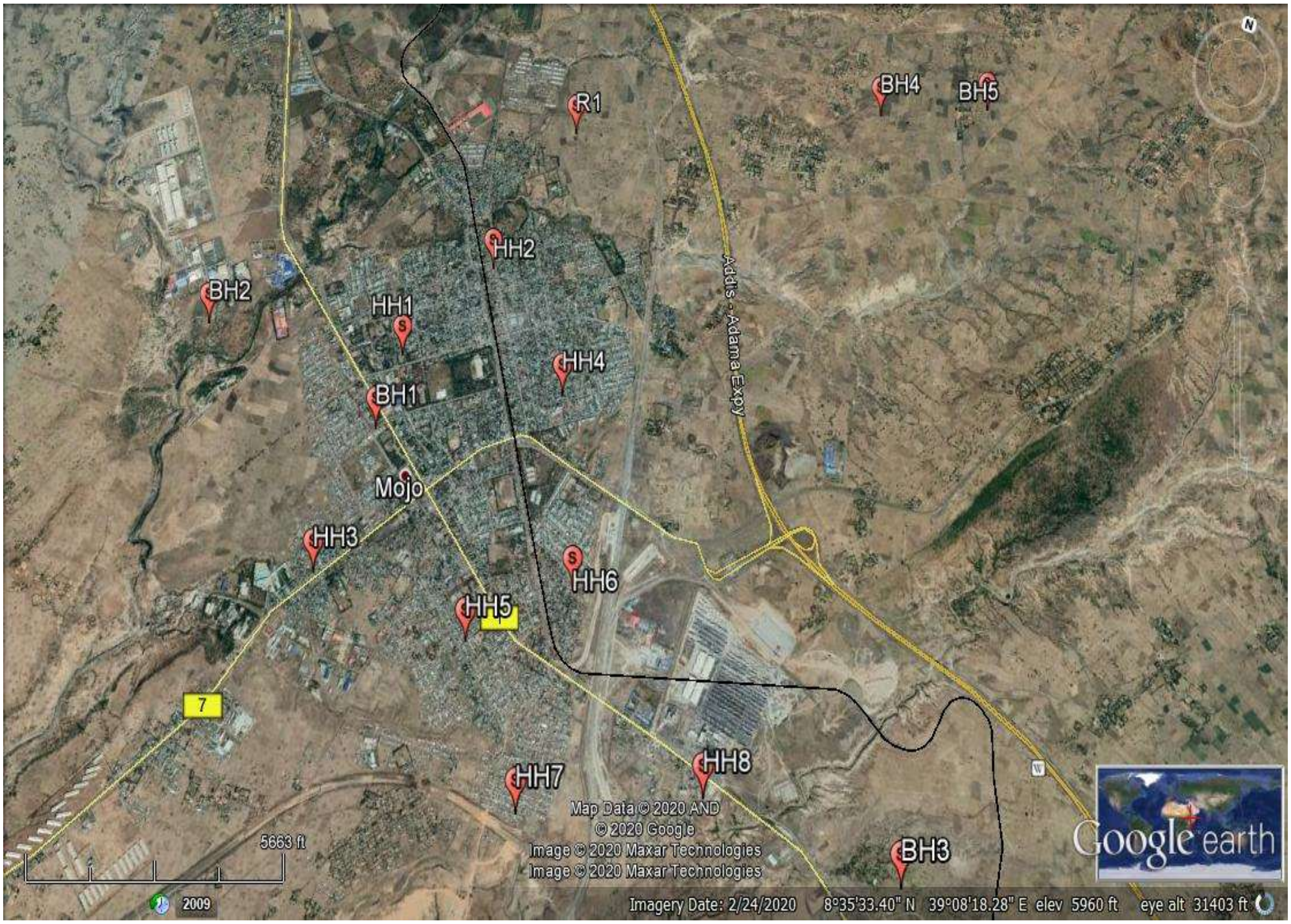


Figure 3.3 Sample site of the study area

3.5.3.3 Analytical instrument

Table 3.2 Analytical instrument

No	Parameter	Instrument used
1	Temperature	Mercury in glass thermometer.
2	pH	pH

3	TDS(mg/l)	Thermos scientific multi- mater
4	Total hardness, mg/l as Ca Co_3	Photometer
5	nitrate(No_3^-), mg/l	Photometer
6	Fluoride(F^-)	Photometer
7	Sulphate (So_4^{2-}), mg/l	Photometer
8	Iron(Fe^{2+}), mg/l	Photometer
9	Manganese(Mn^{2+}) mg/l	Photometer
10	Ammonia	Photometer
11	Residual chlorine	Color while test kit
12	Bacteriological water quality	Membrane filtration

3.5.3.4 Sample, storage and transportation

The method of sample storage and transportation was according to WHO drinking water guideline. Residual chlorine, pH and temperature was measured immediately after sampling as they change during storage and transport. For the bacteriological analysis, water samples were collected in sterile glass bottles and transported to the laboratory in ice box containing ice freezer packs. The bacteriological testes were undertaken within 8 hours after collection to avoid the growth or death of microorganisms in the sample. With regard to the physicochemical analysis, water samples were collected by plastic bottle, labeled and transported to both Addis Ababa water and sewerage office and water, irrigation and energy ministry office laboratory.

3.6 Method of analysis

Physicochemical and bacteriological analyses were conducted at laboratories of both Addis Ababa water and sewerage authority and water and energy minister office in Addis Ababa. The laboratory analyses were undertaken according to procedures outlined in the standard methods for the examination of water quality.

3.6.1 Bacteriological analysis

The membrane filtration method is used to measure the concentrations of total and fecal coliform bacteria in a water sample. All laboratory equipment including forceps, Petri dishes, and a filter funnel device were first sterilized using the heat of a flame. The workbench was disinfected with Dettol liquid as described in the laboratory guide. First, a sterile pad was applied to a Petri dish, a liquid bacterial growth medium, that was uniformly applied to the dressing. A 100 mL water sample was filtered through a 47μm membrane filter. The filter paper was then transferred to the pad in the Petri dish containing the growth medium using sterile forceps. The Petri dish was then incubated at 37 ° C for 24 hours and 44 ° C for 48 hours respectively for both total and faecal coliforms. After incubation the bacterial colonies were identified and counted on the filter using a flash light and a 10-15X microscope. This method detects bacteria based on their color. The blue/ purple colonies were counted as E. coli. The sum of the blue / purple and pink colonies were counted as total coliforms.

3.6.2 Physicochemical analysis

3.6.2.1 Temperature

The temperature of the samples was measured at the point of collection using mercury in glass thermometer.

3.6.2.2 pH

The pH was measured using pH meter. The instrument was switched on and warm for 5 minutes. I was calibrated the instrument before analysis using PH 4.0 and PH 7.0 and I was rinsed with distilled water from one sample to the other following the pH meter operation manual and then standardized with a buffer solution. I was immediately introduced into the water sample and a stable reading was taken.

3.6.2.3 Total dissolved solid(TDS)

The total dissolved solid was determined using a thermo scientific multi-meter. I was switched the multi meter and 100 ml of the samples was prepared into the beaker and the electrode was introduced into the sample. The results of total dissolved solid were displayed on LCD screen and recorded.

3.6.2.4 Nitrate (NO_3)

Nitrate ($N0_3$) were analyzed using photometer. I was prepared 20 ml sample and added one nitrates powder and one nitra test tablet. I was allowed the tube to stand for one minute then gently invert three times to aid flocculation. The prepared sample were filed with 10 ml tube and added one nitracol tablet, crushed and mixed to dissolved. After 10 minutes the full colour was developed and I was selected photo 23 on the photometer. I was read the result on the photometer screen.

3.6.2.5 Total hardness

Total hardness was analyzed using photometer. I was filled 10ml of water sample, added one hardicol No 1 and one hardicol No 2 tablet, crushed, mixed to dissolved. I was stand for two minutes to allowed full colour development and selected the photo 15 on the photometer. I was read the result of total hardness as $CaCo_3$ on photometer screen.

3.6.2.6 Free residual chlorine

Free residual chlorine was analyzed directly in the field using a portable test kit that comes with a color disk comparison. Two test tubes were used. The first test tube serves as a comparator and the second test tube is used to measure the remaining chlorine in the sample. The first tube was filled with its 10 mL mark line with a sample of water to serve as blank sample and inserted into the left hole for comparison and the second tube was filled with a 10 mL sample and a DPD-free chlorine powder pillow was added. Then the sample was stirred for mixing. The immediate reaction of the reagent results in a red/pink color if chlorine is present in the sample. After developing the color, the tube was inserted into the right hole of the comparator and the color wheel was rotated until the color matched the specified color standards. Thus the residual free chlorine concentration in the sample was recorded in mg/l.

3.6.2.7 Sulphate (So4)

Sulphate was analyzed using photometer. I was filled 10ml of water sample onto the test tube, added one Sulphate turb tablet, crushed, mixed to dissolved and a cloudy solution indicated the presence of Sulphate. I was stand for five minutes then mix again to ensure uniformity. I was selected the photo 32 on the photometer. I was read the result of Sulphate on photometer screen.

3.6.2.8 Fluoride

Total hardness was analyzed using photometer. I was filled 10ml of water sample, added one Fluoride No 1 and one Fluoride No 2 tablet, crushed, mixed to dissolved. I was stand for five minutes to allowed full colour development and selected the photo 14 on the photometer. I was read the result of Fluoride on photometer screen.

3.6.2.9 Iron

Iron was analyzed using photometer. was filled 10ml of water sample on the test tube, added one Iron HR tablet, crushed, mixed to dissolved. I was stand for one minutes to allowed full colour development and selected the photo 19 on the photometer. I was read the result of Fe mg\l on photometer screen.

3.6.2.10 Ammonia

Ammonia was analyzed using photometer. I was filled 10ml of water sample, added one Ammonia No 1 and one Ammonia No 2 tablet, crushed, mixed to dissolved. I was stand for ten minutes to allowed full colour development and selected the photo 4 on the photometer. Then I was read the result on photometer screen.

4.RESULTS AND DISCUSSION

4.1 Physicochemical water quality analysis

The physical and chemical water quality parameters analyzed in the laboratory were bacteriological, pH, Turbidity, Temperature(℃), Total dissolved solids (TDS), Total hardness (TH), Fe, Nitrate (No_3^-), Sulphate, Ammonia and Fluoride.

4.1.1 Turbidity

In this study, 57.12%, 35.47% and 7.14% water sample collected from bore hole, household tap and reservoir respectively. As illustrated on table 4.1, fig 4.1 and appendix B from the total water sample 21.43% sample above WHO and Ethiopian standard. The turbidity measurements taken from tap water samples especially around kebele one HH4, HH5 and HH6 were found to be higher than the source BH4 and BH5 (2.1 and 1.3) respectively and during the filed visit this area have old water distribution network, have not integrated sewer line and some pipe lines installed inside the dich, this implicate both liquid and solid waste generate from different sources contamination occur on the node of pipe. Since turbidity is the measure of cloudiness of water, it mainly indicates growth of pathogen along the distribution system. As table 4.12 illustrated the sample taken from most of kebele one bacteriological contamination recorded both total and fecal coliform. This indicates the pathogens contaminate the water and entrance of any objectionable matter towards the distribution. Although the findings of this particular study showed that the turbidity level of all source water samples were compliant with both WHO and NGL of less than 5NTU it has been reported that turbidity-related problems of drinking water are common in all regions of the country, except Dire Dawa town (Amenu et al., 2013).

Table 4.1 Turbidity laboratory result

Parameter	Turbidity		
Samples area	Average values (NTU)	WHO St. value (NTU)	Ethiopian St. values (NTU)
BH_1	1.9	5	5
BH_2	1.5	5	5

BH_3	1.8	5	5
BH_4	2.1	5	5
BH_5	1.3	5	5
R_1	2.3	5	5
HH1	4.3	5	5
HH2	6.5	5	5
HH3	5.5	5	5
HH4	7.8	5	5
HH5	2.9	5	5
HH6	3.4	5	5
HH7	2.1	5	5
HH8	3.5	5	5

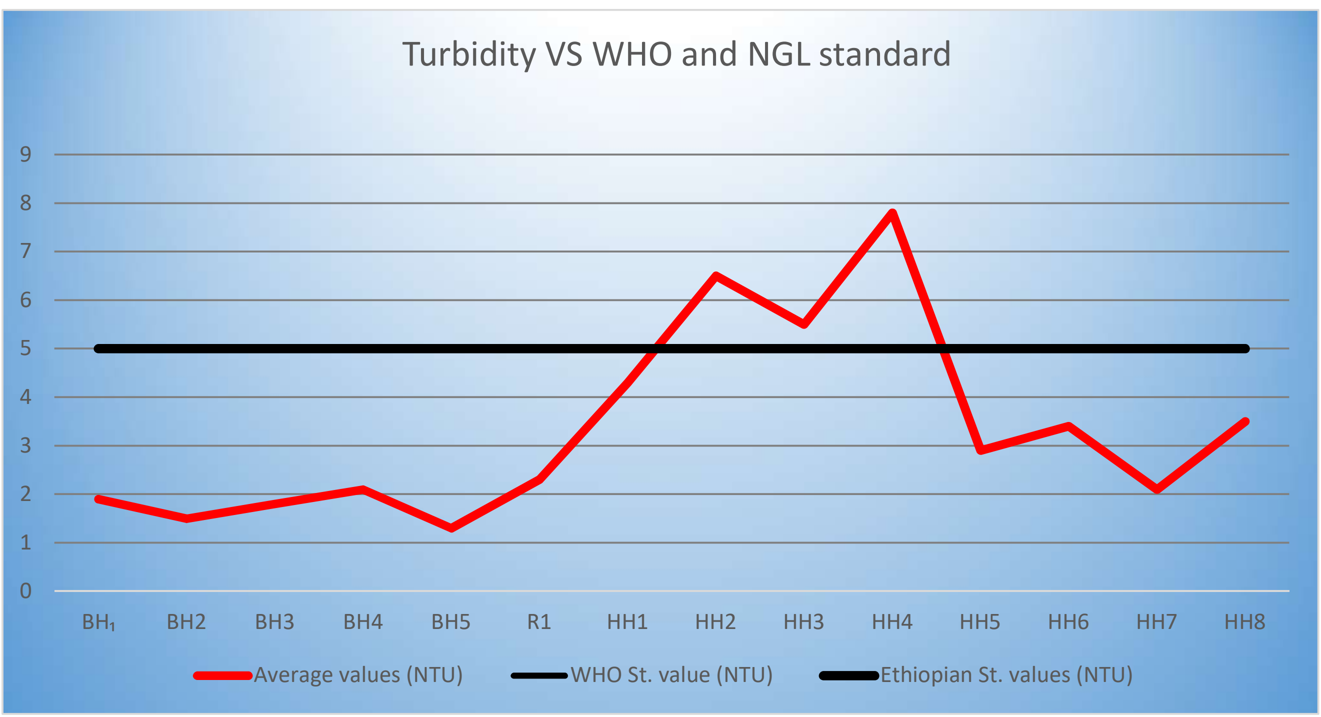


Figure 4.1 Turbidity of study area compare with WHO and NGL maximum permissible Limit

4.1.2 Temperature (°C)

Based on laboratory result from the total of 14 water samples 42.86% were found to be above the WHO and National standard (<15°C). As shown fig 4.2, appendix B and table 4.2 the highest temperature was recorded at BH1, BH2 and BH3 (25,31,29) respectively which is 60% from the total of borehole water samples. The above three bore hole supplied the water directly to kebele two area without stored on the reservoir. Due to this 3 (37.5%) house hold water tap samples were beyond the recommended value. This due to the climatic of rift valley area making the temperature to be high. This mainly enhances the growth of bacteria, increase the reaction rate of chemicals and increase water test. Similar study conducted by (Desissa, 2016) quality assessment of rural drinking water supply schemes from source to -point of- use in the case study of ada‟a woreda, in oromia regional state of Ethiopia water temperature range of Ada‟a Woreda water scheme was recorded between 22.9 (Godino kebele) and 28.7°C (Wajitu kebele). It is beyond recommended unit of WHO <15°C

Table 4.2 Temperature laboratory analysis result

Results		
Recommended level of Parameters Temperature (°C)	Temperature at source water %	Temperature household tap%
0-15	40	50
15-20	0	37.5
>20	60	12.5

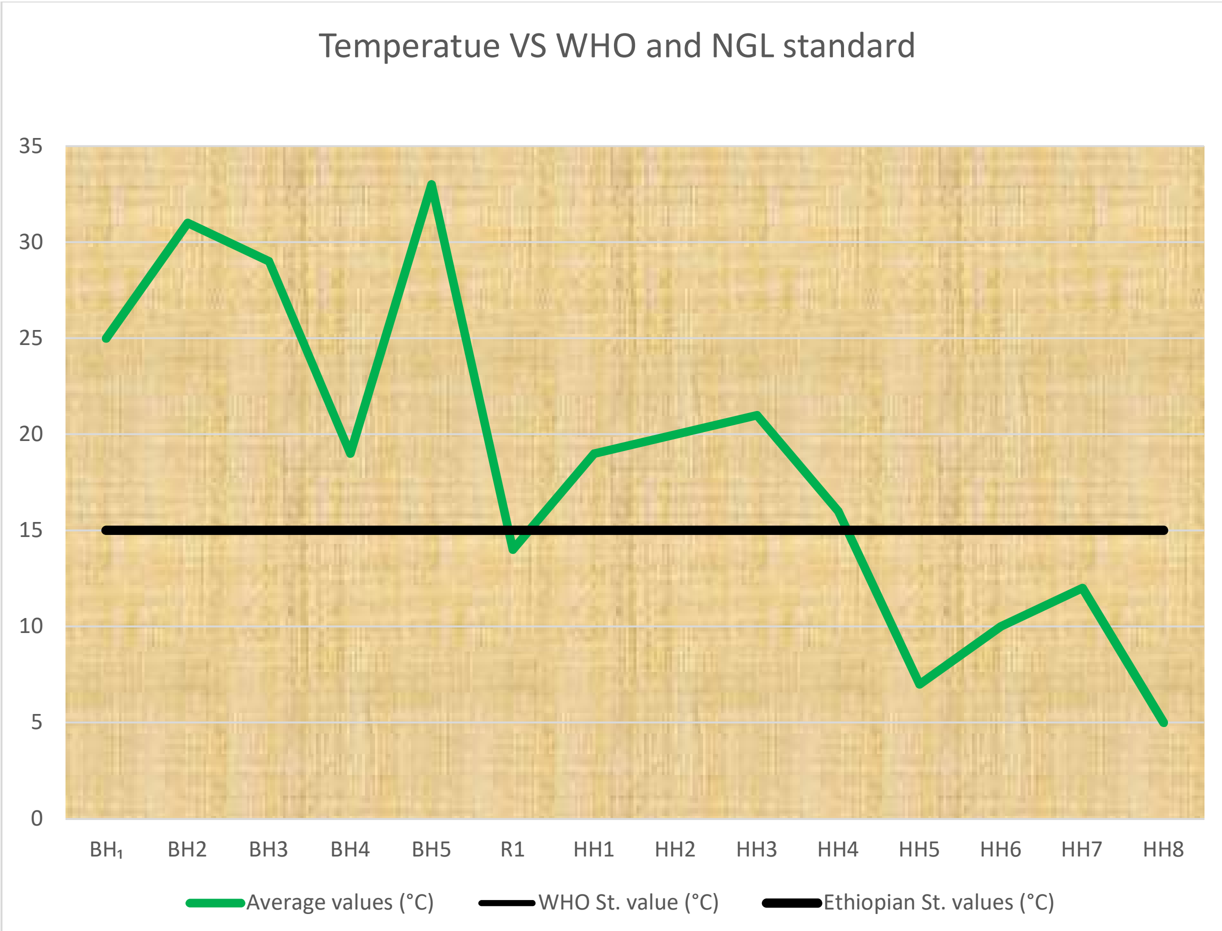


Figure 4.2 Temperature of study area compare with WHO and NGL maximum permissible Limit

4.1.3 pH

Table 4.3 shows the PH values of water in the study area. The PH values study area ranges from 7.29 to 7.95. All water sample in the study area the pH value within WHO standard. But unfit for the minimum allowable pH WHO Value. In general, the overall pH records of water samples from the sources up to point use were found to be slightly basic. Similar study conducted in wondogenet district, southern Ethiopia, the PH value reported 6.6 to 7.8 (Haylamicheal and Moges, et al,2012).

Table 4.3 Laboratory result of pH

Parameter	PH		
Samples area	Average values	WHO St. value	Ethiopian St. values

BH_1	7.36	6.5-8.5	6.5-8.5
BH_2	7.77	6.5-8.5	6.5-8.5
BH_3	7.36	6.5-8.5	6.5-8.5
BH_4	7.27	6.5-8.5	6.5-8.5
BH_5	7.95	6.5-8.5	6.5-8.5
R_1	7.69	6.5-8.5	6.5-8.5
HH1	7.29	6.5-8.5	6.5-8.5
HH2	7.36	6.5-8.5	6.5-8.5
HH3	7.36	6.5-8.5	6.5-8.5
HH4	7.49	6.5-8.5	6.5-8.5
HH5	7.33	6.5-8.5	6.5-8.5
HH6	7.34	6.5-8.5	6.5-8.5
HH7	7.39	6.5-8.5	6.5-8.5
HH8	7.43	6.5-8.5	6.5-8.5

4.1.4 Total dissolved solids

The total dissolved solid values of the samples were varied between a minimum 269.8 mg/l and a maximum of 316.9 mg/l (Table 4.4, appendix B and fig 4.3). The health risks are not significant as the value of TDS is much less than 1,000PPM, which is the WHO standard maximum permissible limit. The similar study conducted by (H. R. Sharma et al., 2013) a total dissolved solid result of the sample study area was between 215-357 ppm. Thesis is no health effect because the value of TDS is much less than 1,000PPM, which is the WHO standard maximum permissible limit.

Table 4.4 Laboratory result of TDS

Parameter	TDS		
Samples area	Average values (PPM)	WHO St. value (PPM)	Ethiopian St. values (PPM)
BH_1	314	1000	1000
BH_2	269.8	1000	1000
BH_3	254.2	1000	1000
BH_4	321.5	1000	1000
BH_5	316.9	1000	1000
R_1	321.5	1000	1000
HH1	316.9	1000	1000
HH2	270.4	1000	1000
HH3	313.6	1000	1000
HH4	283.6	1000	1000
HH5	315.1	1000	1000
HH6	284.3	1000	1000
HH7	284.5	1000	1000
HH8	271.4	1000	1000

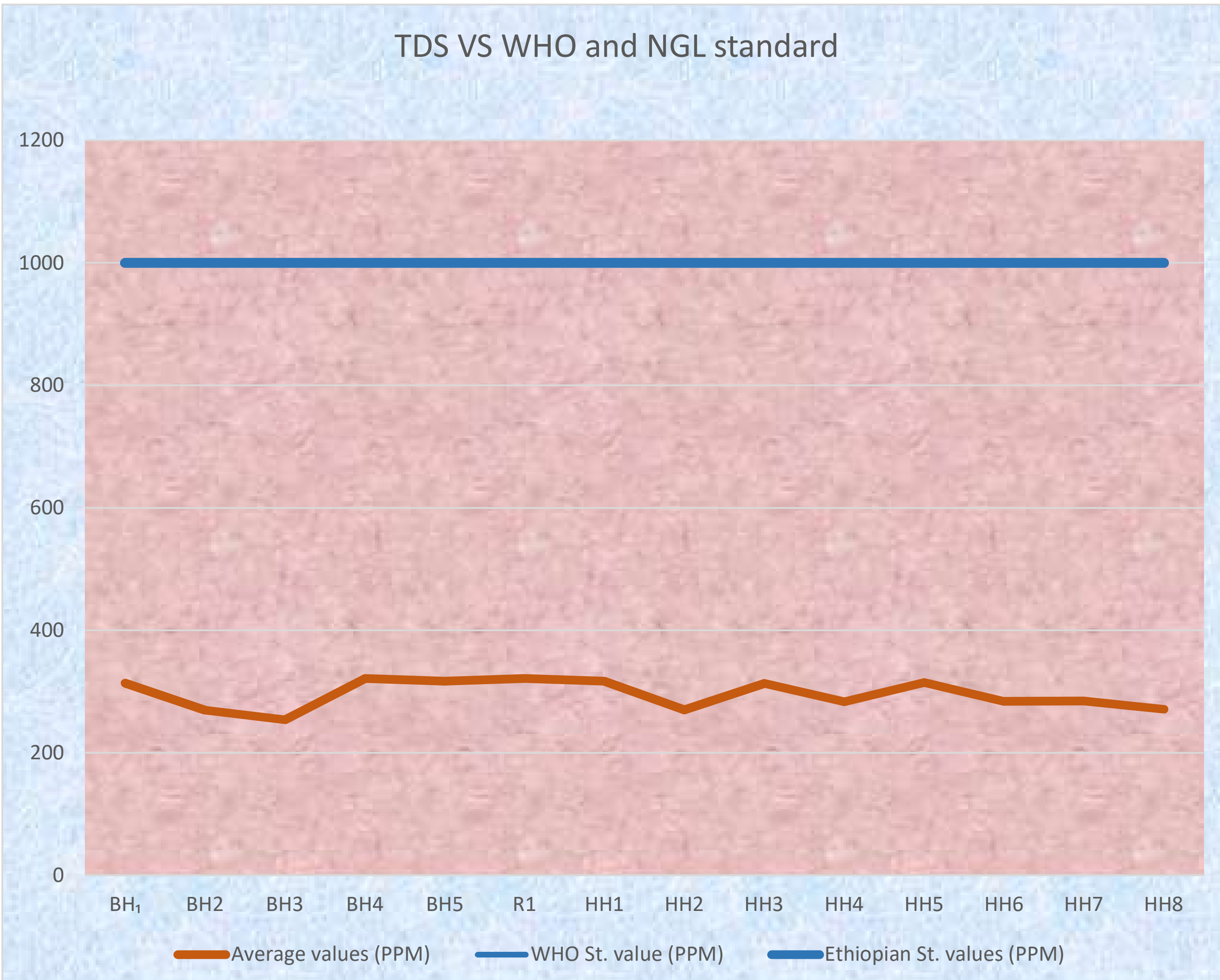


Figure 4.3 TDS of study area compare with WHO and NGL maximum permissible Limit

4.1.5 Total hardness

The total hardness concentrations measured in samples collected from the mojo town ranged from 75 HH8 mg/l to BH1 185 mg/l (Table 4.5, appendix B and fig 4.4). WHO guidelines drinking water quality recommends that the total hardness levels should be kept below 300 mg/l as $CaCO3$. Since, the laboratory results of the study area within recommended guideline. Similar study was conducted in Temeke district of Dares salaam, total hardness reported from 30mg/L to 710mg/L

(Napacho & Manyele, 2010).Therefore, according to the WHO standard the study area improved water supply of Temeke district is harmful for consumer.

Table 4.5 Laboratory result of total hardness

Parameter	Total hardness		
Samples area	Average values (PPM)	WHO St. value (PPM)	Ethiopian St. values (PPM)
BH_1	145	300	300
BH_2	145	300	300
BH_3 \	130	300	300
BH_4	120	300	300
BH_5	115	300	300
R_1	185	300	300
HH1	110	300	300
HH2	180	300	300
HH3	155	300	300
HH4	140	300	300
HH5	175	300	300
HH6	120	300	300
HH7	75	300	300
HH8	155	300	300

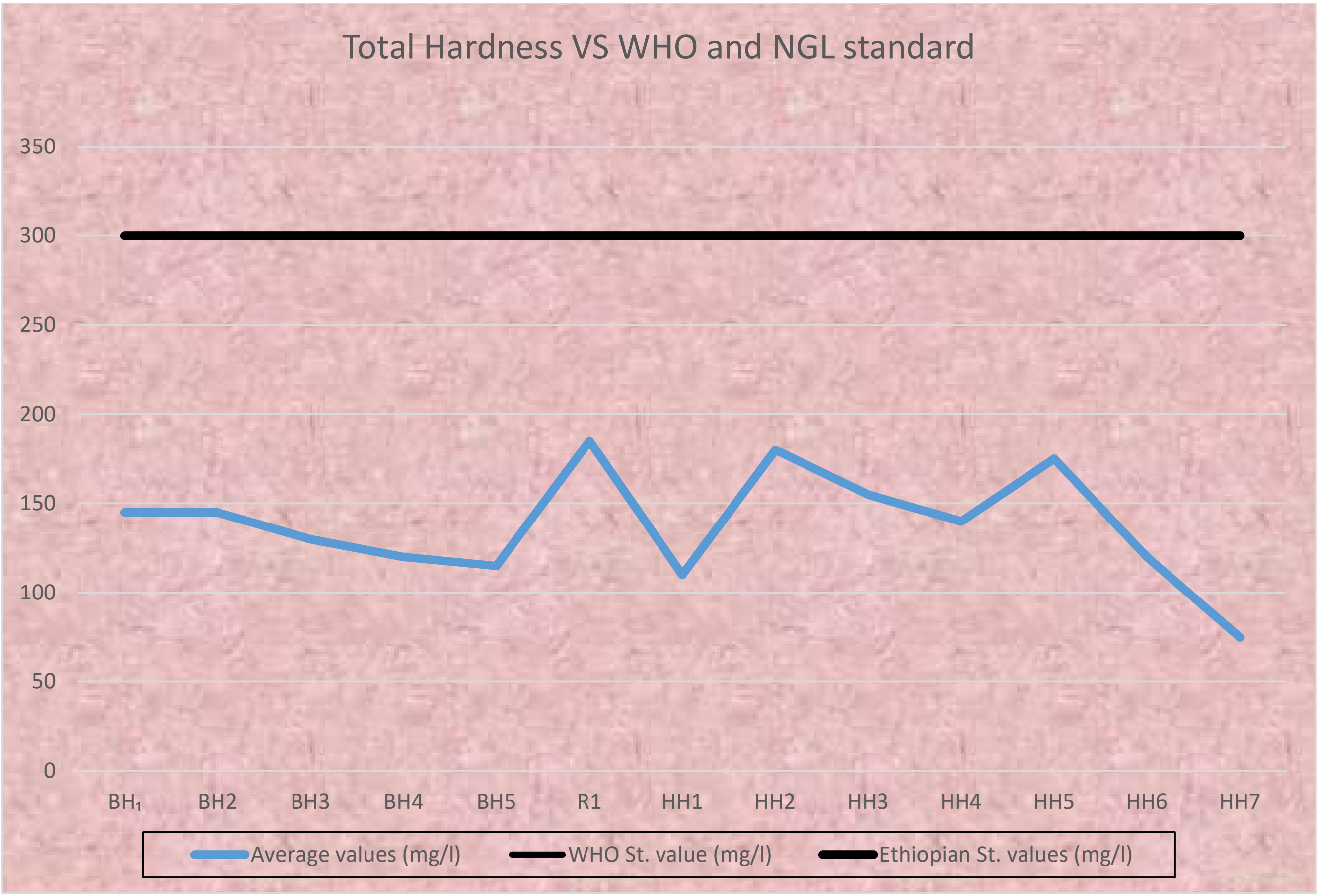


Figure 4.4 Total hardness of study area compare with WHO and NGL maximum permissible limit

4.1.6 Fluoride

In study areas, results show table 4.6, appendix C and fig 4.5 that the concentration of fluoride in BH5 have above WHO guideline (1.5mg/l). This is due to Rift Valley region of Ethiopia is characterized by higher level of groundwater Fluoride. BH4 and BH5 mix on reservoir around Biyo therefore the Fluoride concertation decreases when the water supply to household tap due the low amount of fluoride BH4 (1.08). This result shows Fluoride quantities in all kebeles were no health problem according the WHO Guide value. For instance, (Hailu, 2020) reported that out of 668 wells (deep and shallow) analyzed for fluoride level in the Rift Valley region of Ethiopia, 44.5% of the wells had values above 1.5 mg/l.

Table 4.6 Laboratory result of Fluoride

Parameter	Fluoride		
Samples area	Average values (mg/l)	WHO St. value (mg/l)	Ethiopian St. values (mg/l)
BH_1	1.12	1.5	1.5
BH_2	1.21		
BH_3	1.43		
BH_4	0.96		
BH_5	1.95		
R_1	1.37		
HH1	1.08		
HH2	1.04		
HH3	1.11		
HH4	1.28		
HH5	1.33		
HH6	1.31		
HH7	1.26		
HH8	1.34		

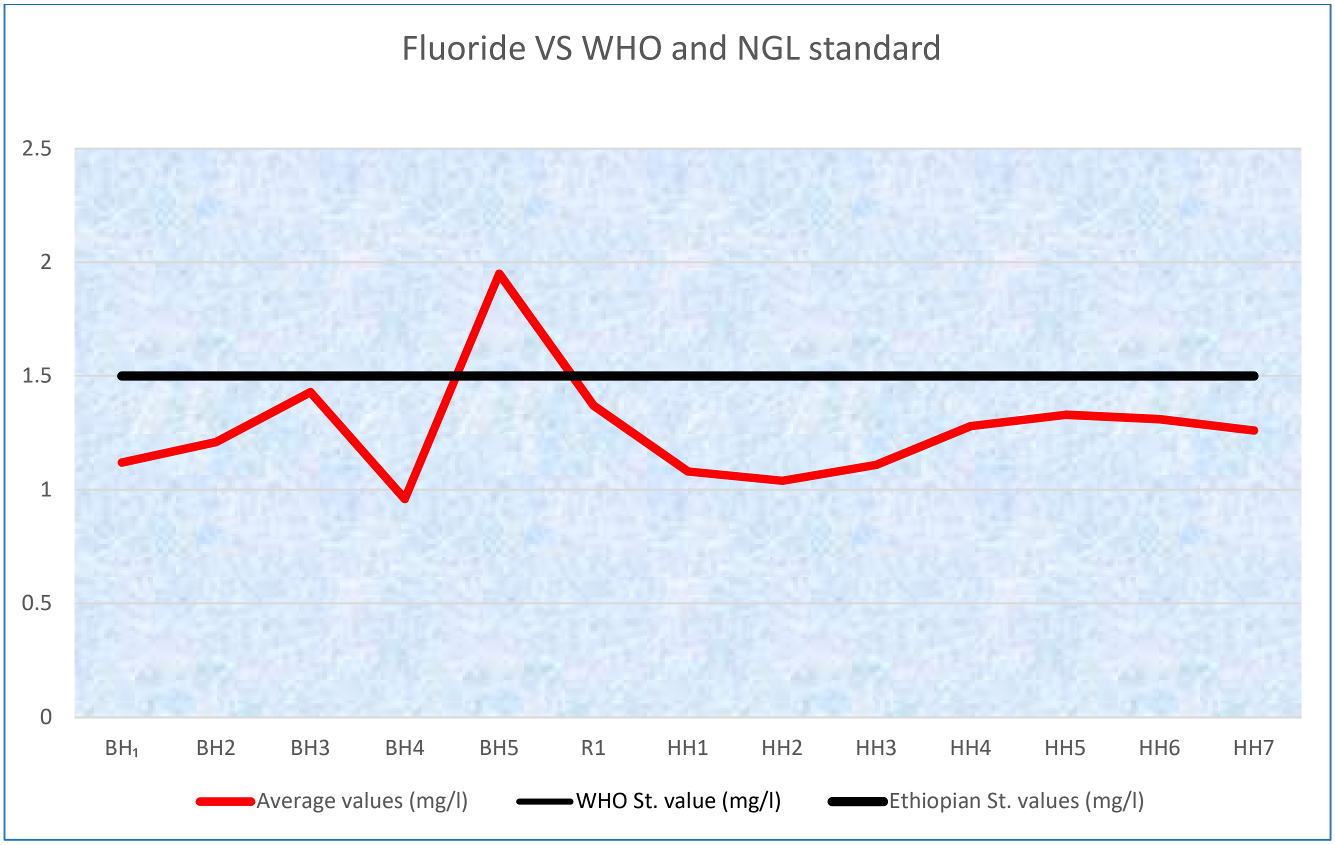


Figure 4.5 Fluoride of study area compare with WHO and NGL maximum permissible limit

4.1.7 Iron (Fe)

The Iron concentrations measured in samples collected from the mojo town ranged from 0.01-0.85 mg/. As shown table 4.7, appendix B and fig 4.6 from the total water sample 21.43% above WHO recommended level (0.3 mg/l) which is 25% from household water tap sample, HH1 (0.85mg/l), HH5 (0.67mg/l) and 20% from the borehole BH5(0.76mg/l). The desirable concentration 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. Similar study was conducted by (Erena, 2015) investigation of drinking water quality from source to point of distribution the case of Gimbi town in Oromia regional state of Ethiopia almost all the total water sample iron result indicates above WHO recommended value.

Table 4.7 Laboratory result of Iron

Parameter	Total Iron (Fe)		
Samples area	Average values (PPM)	WHO St. value (PPM)	Ethiopian St. values (PPM)
BH_1	0.01	0.3	0.3
BH_2	0.15		
BH_3	0.01		
BH_4	0.20		
BH_5	0.76		
R_1	0.20		
HH1	0.85		
HH2	0.10		
HH3	0.20		
HH4	0.25		
HH5	0.05		
HH6	0.67		
HH7	0.1		
HH8	0.05		

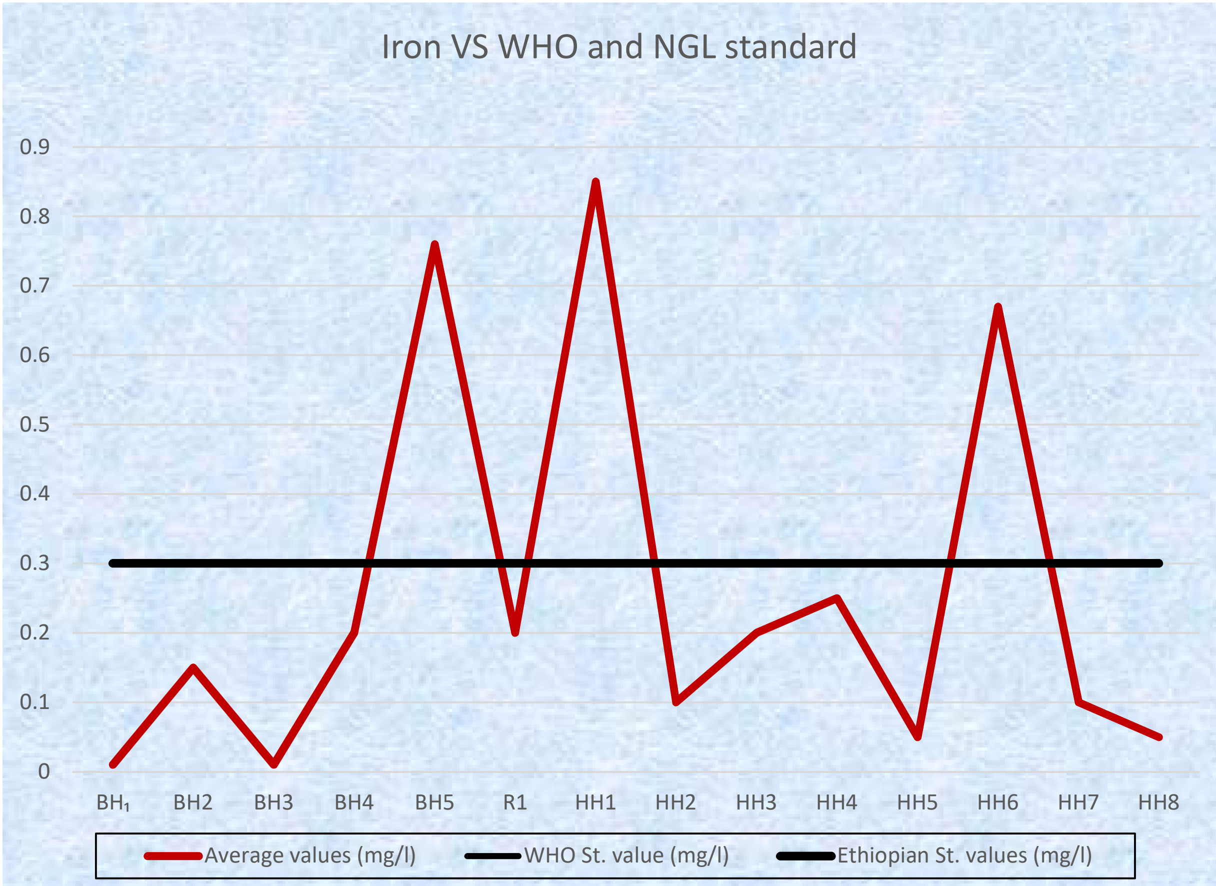


Figure 4.6 Iron of study area compare with WHO and NGL maximum permissible limit

4.1.8 Ammonia

Fourteen water samples was tested but 64.3% were greater than WHO and national standard. Regarding to the guideline values concentration of Ammonia must be less than 0.5mg/l. Large proportion of the community get Ammonia concentration that possess impact on them. 75% house hold and 60% of bore hole water sample were beyond the recommended value. As we see fig 4. 7, table 4.8 And appendix C almost all the result of the study area above the recommended value. During field visit the bore hole sites were found on agricultural farm land when runoff occur ammonia that found on farm land percolated down ward and also the study area have not proper sewerage line and solid waste disposal system as a result cross- contamination of drinking water pipes line occur. Due to this great chance of enhanced the concentration of ammonia. In addition, people day to day activities plays vital role in the increment of Ammonia concentration due to their in appropriate management of both liquid and solid wastes. As fig 4.12 below on bacteriological water quality test those areas also have total and fecal coliform contamination. The presence of Ammonia at higher concentration than the standard levels is an important indicator of fecal pollution. And also taste and odor problems as well as decreased disinfection efficiency are to be expected. Similar study was done by (Mulugeta, 2012) on assessment of drinking water quality in Mercato Addis Ababa showed different sources of water was above the recommended value.

Table 4.8 Laboratory result of Ammonia

Parameter	Ammonia		
Samples area	Average values (mg/l)	WHO St. value (mg/l)	Ethiopian St. values (mg/l)
BH_1	4.32	0.5	0.5
BH_2	2.29		
BH_3	4.32		
BH_4	0.47		
BH_5	0.36		
R_1	0.36		
HH1	7.11		
HH2	1.00		
HH3	0.81		
HH4	0.48		
HH5	0.33		
HH6	1.00		
HH7	0.74		
HH8	0.90		

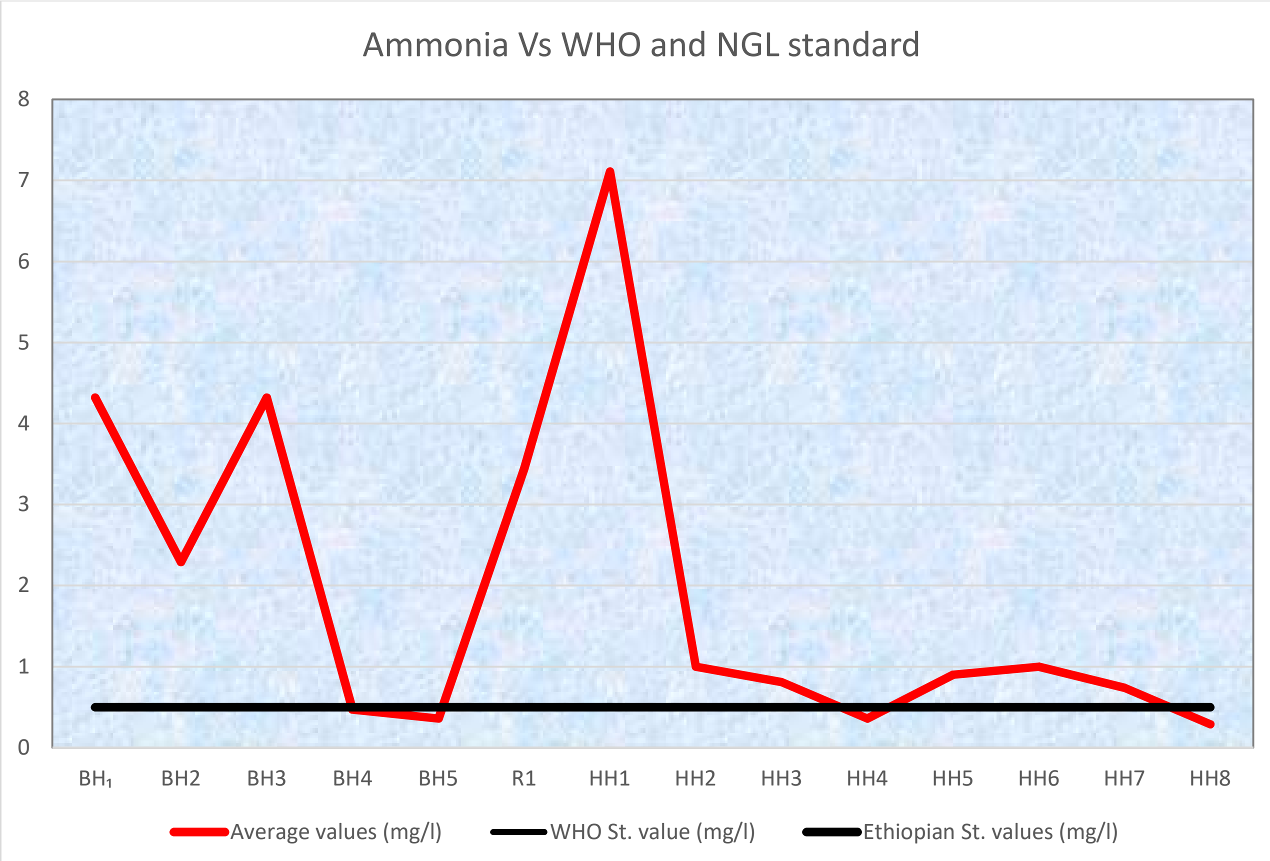


Figure 4.7 Ammonia of study area compare with WHO and NGL maximum permissible limit

4.1.9 Nitrate (NO_3)

As shown table 4.9, appendix C and fig 4.8 from total water sample 57.12% of samples were tested from household tap which is kebele one and two, 35.47% tested from borehole and 7.14% from reservoir. Whereas 33.33% of samples in kebele two and 60% of samples in kebele one and 60% from bore hole or 50% from the total water sample have Nitrate concentration of greater than 5mg/l. Increasing in Nitrate concentration due to the presence of Ammonia because it is the final stage of oxidation of Ammonia caused by interconnection of drinking water pipes with sewer line, improper management of both liquid and solid waste. Generally, the study area has high nitrate concentration because of the percolating sewage, industrial waste, chemical fertilizers, leaches from solid waste landfills, to the ground water. High levels of nitrate in drinking water are a health concern primarily because of the potential for the nitrate to be converted to nitrite. It is characterized by shortness of breath and blueness of skin. As a result, it is often called the blue baby syndrome. Similar study was done by (Duressa et al., 2019) Assessment of Bacteriological and Physicochemical Quality of Drinking Water from Source to Household Tap Connection in Nekemte, Oromia, Ethiopia the results of this study showed that the nitrate concentration was in the range of 2.2–6 mg/l with the lowest record from Kebele 02, site 01 and Kebele 04 site 03, and the highest record was from Kebele 01, site 0. This might be due to the over leaching of nitrate-containing organic wastes and from the use of fertilizers in the nearby agricultural fields

Table 4.9 Laboratory result of Nitrate (NO3-)

Samples area	Average values (mg/l)	WHO St. value (mg/l)	Ethiopian St. values (mg/l)
BH_1	5.38	5	5
BH2	5.4		
BH3	5.75		
BH4	3.34		
BH5	3.56		
R1	2.73		
HH1	6.99		
HH2	2.73		
HH3	2.53		
HH4	2.98		
HH5	1.6		
HH6	6.18		
HH7	6.26		
HH8	6.58		

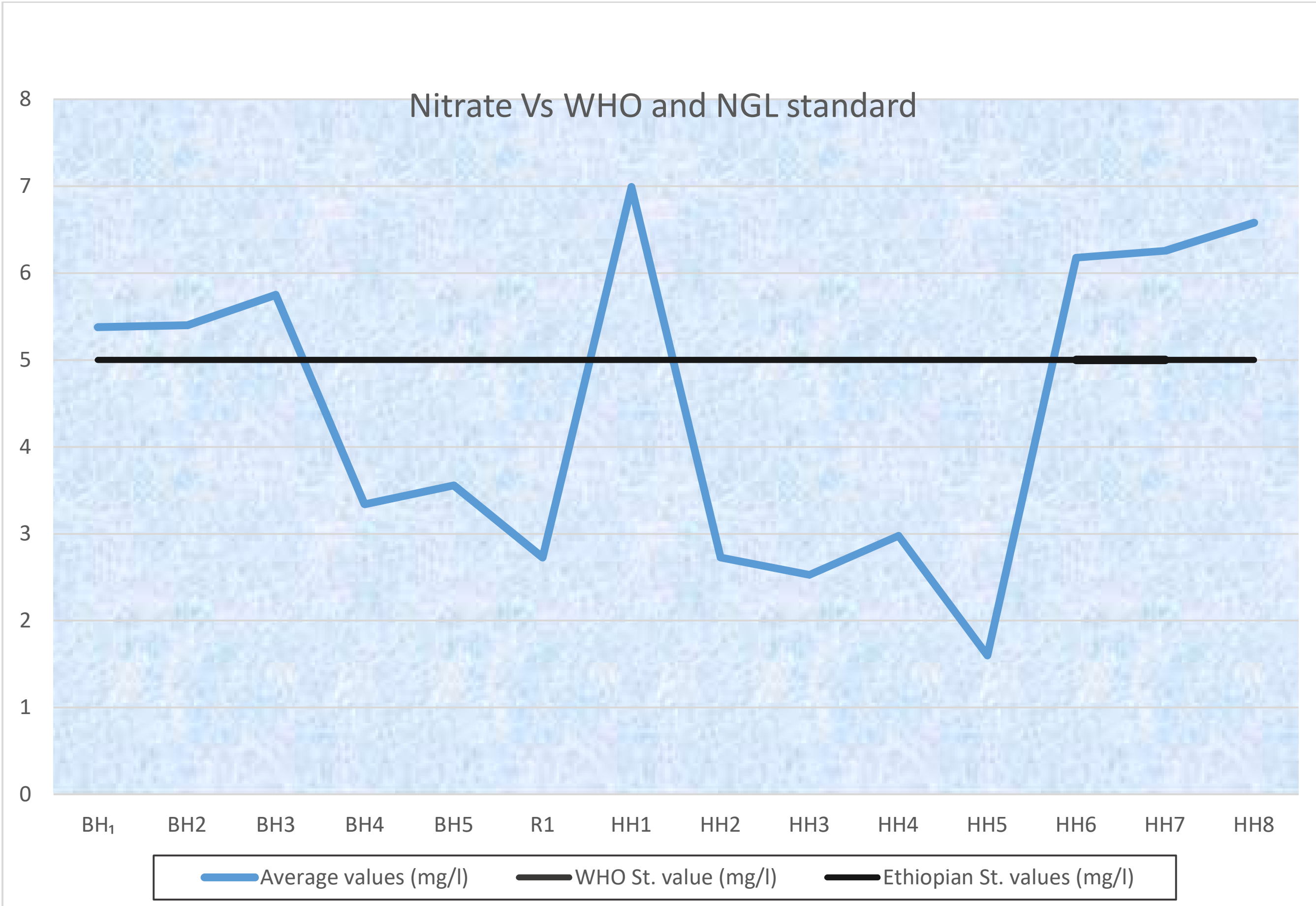


Figure 4.8 Nitrate of study area compare with WHO and NGL maximum permissible limit

4.1.10 Sulphate

According to WHO (2012) guidance level the maximum permissible limit of Sulphate in drinking water supply is limited to 250mg/l. Accordingly, the laboratory results of study area at all points of sample location were shown in table 4.10 fig 4.9 and (Appendix C), and the values were very below the maximum permissible limit set by WHO. Therefore, the results clearly indicate that there is no significance effect on the health of the users. The study conducted by(Rizwan, 2016)Assessment of Drinking water Quality in Relation To Sanitation in Haripur City Pakistan All result of sulfate found permissible limit recommended by WHO in study area.

Table 4.10 Laboratory result of Sulphate

Samples area	Average values (mg/l)	WHO St. value (mg/l)	Ethiopian St. values (mg/l)
BH_1	4	250	250
BH2	0		
BH3	0		
BH4	5		
BH5	6		
R1	8		
HH1	9		
HH2	3		
HH3	7		
HH4	9		
HH5	4		
HH6	4		
HH7	2		
HH8	9		

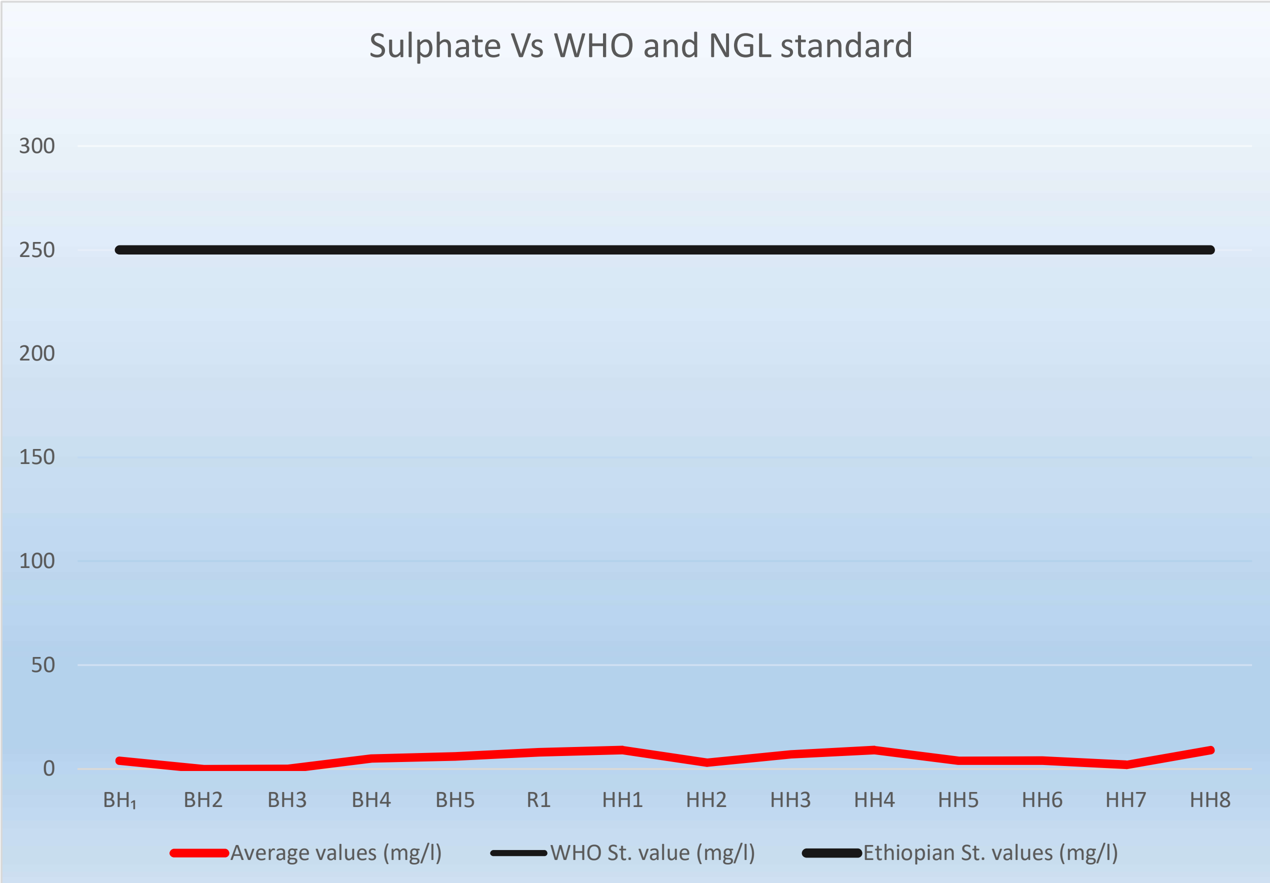


Figure 4.9 Sulphate of study area compare with WHO and NGL maximum permissible limit

4.1.11 Residual chlorine

As shown table 4.10 and appendix C the laboratory results of the study area have no residual chlorine in the system. In mojo town water supply system as the source is ground water the disinfection method is addition of chlorine on reservoir when any bacteriological induction occurs. However, this result shows that the study area was not get sufficient chlorine to control bacteriological contamination in the system. With regard to public health, bacteria and selected viruses called bacteriophage are able to multiply in water that was not properly disinfected. Moreover, depending on the species, could potentially cause waterborne diseases. While recommendations only state minimum residual chlorine levels (0.2-0.5mg\l), it is important that a careful balance be maintained in drinking water and needs to be enough chlorine to make sure everything is properly disinfected. As shown table 4.12 the laboratory results on bacteriological water quality both total and fecal coliform contamination occurs HH7 and HH8. This is occurred due to lack of chlorine that apply on the distribution network to control cross- contamination. The similar study conducted by (Duressa et al., 2019), Assessment of bacteriological and physicochemical quality of drinking Water from source to household tap connection in Nekemte, Oromia, Ethiopia free residual chlorine (FRC) content of water samples from disinfection point and main distribution tank were 0.23 mg/l and 0.28 mg/l, respectively these values were less than the maximum concentration set by WHO.

Table 4.11 Residual chlorine of laboratory result

Results		
Recommended level of Parameters Residual chlorine	Residual chlorine at source water %	Residual chlorine household tap%
0	100	100
0-0.2	0	0
0.2-0.5	0	0

4.2 Bacteriological water quality

A total of 14 water samples were analyzed for total and fecal coliforms. The result indicates no contamination recorded in all water source (borehole) but majority taps kebele two and some of kebele one were contaminated. With the help of laboratory analysis as table 4.12 66.67% household tap water samples in kebele two and 60% water samples in kebele one indicate presence of total coliform. On average of 25% from total household tap shows existence of (fecal) coliform. In drinking water presence of fecal coliform should not be ignored as the basic assumption that pathogens would not be presented in drinking water but this result shows the presence of fecal coliform. Since they are indicator of possible presence of waterborne pathogens one can expect waterborne diseases on the study area especially kebele one. This was proved by the results of the questioner, the report from the sub-city health center and interview obtained from the key informant person which is mojo heath center director and mojo water supply enterprise director shows the people are rapidly exposed to waterborne diseases. As shown in fig 3.2 among the ten top diseases in the study area as an example diarrhea is caused by ingestion of contaminated water and poor sanitation. The presence of coliform in drinking water on the study area could be attributed to cross-contamination between the municipal water supply and sewer, and reduction in efficiency of chlorine.

Table 4.12 Bacteriological water quality result

Sample site	Total Coliform 100ml/CFU	Fecal Coliform 100ml/CFU	Risk Category
BH_1	Nil	Nil	No risk
BH2	Nil	Nil	No risk
BH3	Nil	Nil	No risk
BH4	Nil	Nil	No risk
BH5	Nil	Nil	No risk
R1	Nil	Nil	No risk
HH1	6	Nil	Intermediate risk
HH2	Nil	Nil	No risk
HH3	8	Nil	Intermediate risk
HH4	Nil	Nil	No risk
HH5	Nil	Nil	No risk
HH6	17	Nil	Intermediate risk
HH7	17	11	Intermediate risk
HH8	18	5	Intermediate risk

The summarized result of the two kebele is presented in table 4.12. In this study the average count of total coliforms was above the recommended value of WHO and Ethiopian Standards Risk classification. Especially the total coliform counts were higher in household water samples compared to that of water from reservoir and the borehole. The similar study present by (Mulugeta, 2012) bacteriological water quality tests more than half tap water samples do not meet the TC standard set by WHO and Ethiopia. Due to this the samples failed to meet safe water quality with regard to TC and FC criteria of 0 CFU/100ml, respectively

4.3 Sanitary inspection

A sanitary inspection was done by preparing questioners for consumer, interview with focal persons and checklist based WHO sanitary checklist standard for household water tap, reservoir and borehole site to identify actual and potential source of contamination water supply facility based on risk category which is stated by WHO standard. For sanitary inspection purpose 360 respondent was selected depended on sanitary facility.

4.3.1 Solid waste disposal

From field observation and municipality reports factory waste, commercial and hotel waste, private houses waste and industry waste were the main solid wastes in the study area. As gained from focal person interview from mojo town municipality information 12% of household units have big sack (which serves as compound) at a selected place for solid waste storage outside and inside their compound. At last private waste collectors collect the wastes, by moving home to home with the aid truck, and then they transport to dumping site which is found 7 km far from the town. But most of the people about 88% residents were dumping out the waste materials along the streets and on open spaces. Some people in the study area practice waste removal through paying for private waste collector, they paid 8 birr for one sack. On the above the result shows the solid waste collection the study area was poorly managed this due to lack of awareness of the people on solid waste collection and the municipality has finance problem, lack of professional person, improper plan for dumping site, to improve the solid waste management system.

4.3.2 Liquid waste disposal

The improper management of Liquid waste in the study area as the main problem like the Solid waste management system. During field observation and focal person interview from mojo town water supply and sewerage enterprise report showed there is no proper liquid waste drainage system in the study area. Some dich was found in the study area but most of them is not functional. Therefore, the people were discharging liquid wastes on the nearby place around their gate. These result occurrences of bad smell to the community, cross contamination occur in water supply line and can cause the water born and brithing system disease.

4.3.3 Sanitary inspection at borehole

The checklist was prepared based on WHO a standard. The checklist had 9 questions to evaluate the sanitary conditions of water sources in the study area. Risk category based on WHO the risk assessment out of nine (7-9=very high risk, 3-6= Medium risk, and 0-2=low risk). These forms consist of a set of questions which have "yes" or "no" answers. Each "yes" answer scores one point and each "no" answer scores zero point. At the end of the inspection the points are added up, and the higher the total of identified risks, the greater the risk of contamination, as prescribed in table 4.13

Table 4.13 Sanitary inspection at borehole

No	Checklists at borehole	BH1	BH2	BH3	BH4	BH5
1	Is there a latrine or sewer within 100m of pump house?	No	No	No	No	No
2	Is the nearest latrine unsewered?	No	No	No	No	No
3	Is there any source of other pollution within 50m?	Yes	Yes	Yes	Yes	Yes
4	Is there an opened well within 100m?	No	No	No	No	No
5	Is the drainage around pump house faulty?	Yes	No	Yes	No	No
6	Is the fencing damaged allowing animal entry?	Yes	Yes	Yes	Yes	Yes
7	Is the floor of the pump house permeable to water?	No	No	No	No	No
8	Does water forms pools in the pump house?	Yes	Yes	No	No	No
9	Is the well unsealing insanitary?	No	No	No	No	No
Rask category		Medium risk	Medium risk	Medium risk	Low risk	Low risk

The above table 4.13 illustrated that thee borehole with the medium risk and the other two boreholes at low risk. Because almost all borehole far from the town and constructed at farm area due to this there is no pollution related to lateral.

4.3.4 Sanitation and hygiene at household and pipeline

The results of sanitation and hygiene practices of the consumers at the households are shown in Table 4.15. According to the consumers' responses, 75.84%(273) collect water without contact with their hands, 56.12% (202) have separate water containers for storing drinking water in the house. 22.22% (80) reported that they wash water collecting containers every day. Thirty-one 31.05%(115) have no latrines in their house and 42.12% (152) replied that they wash their hands with soap after visiting toilet. 36.9% (133) study area respondents said that pipe line of the distribution network has leakage problem. Similar study reported in Bahir Dar City (Tabor et al., 2011) 23 HHS out of 12HHs selected sample frequency of every day

Table 4.14 Sanitation and hygiene at household and pipeline

No	questioners for water sanitation and hygiene at household and pipeline	Response	
		Yes	No
1	Are there signs of leaks in pipe line?	36.9% (133)	63.1%(227)
2	Does water collect around water tap stands?	66% (237)	34%(123)
3	Is a latrine within 30m of water stand tap?	53% (191)	47%(169)
4	While you are collecting water from the tap, there was contact of the hands to water?	24.16% (87)	75.84%(273)
5	In your house, water for drinking is stored in a separate container from water intended for other purposes?	42.22% (152)	57.78% (208)
6	The drinking water that you take from the storage containers has no contact with your hands?	56.12% (202)	43.88%(158)
7	Do you clean your water collection containers every day?	22.22% (80)	77.78(280)
8	Is drinking water container kept above floor level and away from contamination?	32.23% (116)	67.77%(244)

9	Do you have latrine in your house?	68.05% (245)	31.05%(115)
10	After visiting toilet, do you wash your hands with soap?	42.12% (152)	57.88%(208)

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

- In this study, the physical, chemical and bacteriological quality of water samples from borehole, reservoirs, and tap water supply systems for Mojo town was analyzed, and most of them were above the permissible range of both WHO and Ethiopian drinking water standards. However, pH, TDS, TH, and SO4 are within the recommended level.
- From the total household tap water sample, 66.67% of keble 2 and 60% of keble 1 indicates the presence of total coliforms. On average, 25% of the total household tap shows the presence of (faecal) coliforms. On the contrary, the majority of water samples from the borehole were not contaminated with FC. This means that poor household waste disposal, the interconnection of drinking water pipes with sewage, and the presence of leaky pipes, which leads to cross-contamination with surrounding areas, seem to contribute to a large extent to the high level of bacterial contamination of water in distribution systems.
- From this study, both the water source and the taps were grossly contaminated with nitrates and ammonia. This result increases the bacterial indicator as the water moves from the source to the tap water systems
- All water samples analyzed in the study area showed 0 mg/L FRC and this indicates that there is no addition of chlorine in the source and reservoir.
- From filed observation, questioner and checklist high risk on sanitation and hygiene in household were the main factors for the contamination of water during transportation and after storage at home.
- Generally, poor sanitation, low level of hygiene, uncontrolled solid and liquid waste disposal were the causes of the water contamination in the study area. With regards the physicochemical parameter most of the parameter especially ammonia almost all sample site result was beyond the recommended value of WHO and some of the water sample at the household tap were contaminated with bacteria. Therefore, comparing with the WHO and NGL standard the study area has poor water quality.

5.2 Recommendations

To improve the current condition of the Mojo water quality system, proper management of both liquid and solid wastes, promotion of improved sanitation practices and constant inspection of water quality are essential. Therefore, the responsible authority and the beneficiaries should effectively use the following appropriate recommendations in order to maintain the current quality of water: -

- There is a need to design an efficient waste disposal system. In addition, regular assessment of the drinking water quality of the source, reservoir and distribution systems to ensure that the water is safe for human use.
- BH1, BH2 and BH3 recorded a high temperature above WHO recommended value, this may cause a health problem to the customer over time, and as a result, the water supplied from those boreholes recommended to store and cool in the reservoir before it reaches the consumer to reduce the high temperature.
- Maintenance of water distribution systems, integrated and programmed sectoral activities are essential to minimize interruptions and exposure of the pipeline.
- Regular inspection of sanitary and hygiene aspects should be carried out, strict control and appropriate management of the distribution system should be carried out to prevent contamination and pipelines that found inside dich must be replaced.
- Proper implementation and adequate disinfection of water with chlorine is a priority. The addition of chlorine is a must for all water sources and it is suggested to increase the initial dose of chlorine at the source to meet the required standards of the World Health Organization. Also, adding chlorination stations through the water network, especially area that to expose to contamination and did not meet the required standards of the World Health Organization is highly recommended.
- Solid and liquid wastes should be managed properly and the frequency of waste removal should be increased, and the private sector participation should be appreciated
- Public awareness and participation must be exercised. All concerned body must work cooperatively and integrated to raise people's level of understanding of the causes of contaminants and how to use domestic water treatment mechanisms.

- The Mojo water and sewerage enterprise should fulfil laboratory and instruments for water quality assessment.
- Further studies are needed, because the present work is limited to few physicochemical parameters. Therefore, additional parameters of water quality must be undertaken to know the detail water quality problem.

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APPENDIXES A: Location sample site

	Location	Coordinates		
Samples code	Sample location	X	Y	Elevation
BH_1	Diban diba	8° 35' 24.90"	39° 7' 8.22"	5844
BH_2	Dibora	8° 35' 32.15"	39° 6' 22.02"	5770
BH_3	Kolba	8° 34' 31.31"	39° 9' 35.15"	5936
BH_4	Shera diben	8° 37' 8.94"	39° 8' 55.26"	6124
BH_5	Shera diben	8° 37' 17.53"	39° 9' 22.39"	6174
R_1	Biyo	8° 36' 42.65"	39° 7' 37.72"	5883
HH1	Megala	8° 35' 38.8"	39° 7' 12.52"	5838
HH2	Technic sefer	8° 36' 4.54"	39° 7' 27.63"	5858
HH3	Tota sefer	8° 34' 49.40"	39° 7' 9.15"	5809
HH4	Shashmene tera	8° 35' 41.81"	39° 7' 54.06"	5884
HH5	Kuteba sefer	8° 35' 33.40"	39° 8' 18.28"	5888
HH6	Kera	8° 35' 3.35"	39° 89' 43"	5915
HH7	Selase	8° 34' 19.74"	39° 8' 10.46"	5900
HH8	Menehariya	8° 34' 34.13"	39° 8' 49.65"	5937

APPENDIXES B: Physicochemical water quality parameters laboratory results

	Average value of Parameters					
Samples area	Turbidity	Temperature (°C)	PH	Total dissolved solid	Total hardness	Total iron
BH_1	1.9	25	7.36	314	145	0.01
BH_2	1.5	31	7.77	269.8	145	0.15
BH_3	1.8	29	7.36	254.2	130	0.01
BH_4	2.1	19	7.27	321.5	120	0.20
BH_5	1.3	33	7.45	316.9	115	0.76

R_1	2.3	14	7.69	321.5	185	0.20
HH1	4.3	19	7.29	316.9	110	0.85
HH2	6.5	20	7.36	270.4	180	0.10
HH3	5.5	21	7.36	313.6	155	0.20
HH4	7.8	16	7.49	283.6	140	0.25
HH5	2.9	7	7.33	315.1	175	0.05
HH6	3.4	10	7.34	284.3	120	0.67
HH7	2.1	12	7.39	284.5	75	0.1
HH8	3.5	5	7.43	271.4	155	0.05

APPENDIXES C: Physicochemical water quality parameters laboratory results

	Average value of Parameters			
Samples area	Fluoride	Ammonia	Nitrate	Sulphate
BH_1	1.12	4.32	5.38	4
BH_2	1.21	2.29	5.4	0
BH_3	1.43	4.32	5.75	0
BH_4	0.96	0.47	3.34	5
BH_5	1.95	0.36	3.56	6
R_1	1.37	0.36	2.73	8
HH1	1.08	7.11	6.99	9
HH2	1.04	1.00	2.73	3
HH3	1.11	0.81	2.53	7

HH4	1.28	0.48	2.98	9
HH5	1.33	0.33	1.6	4
HH6	1.31	1.00	6.18	4
HH7	1.26	0.74	6.26	2
HH8	1.34	0.90	6.58	9

APPENDIXES D: Laboratory results bacteriological water quality parameters laboratory results

Samples area	Total Coliform CFU/100 ml	Fecal Coliform CFU/100ml	WHO St. value (mg/l)	Ethiopian St. values (mg/l)	Risk Category
BH_1	Nil	Nil	0CFU/100ml	0CFU/100ml	No risk
BH_2	Nil	Nil	0CFU/100ml	0CFU/100ml	No risk
BH_3	Nil	Nil	0CFU/100ml	0CFU/100ml	No risk
BH_4	Nil	Nil	0CFU/100ml	0CFU/100ml	No risk
BH_5	Nil	Nil	0CFU/100ml	0CFU/100ml	No risk
R_1	Nil	Nil	0CFU/100ml	0CFU/100ml	No risk
HH1	6	Nil	0CFU/100ml	0CFU/100ml	Intermediate risk
HH2	Nil	Nil	0CFU/100ml	0CFU/100ml	No risk
HH3	8	Nil	0CFU/100ml	0CFU/100ml	Intermediate risk
HH4	Nil	Nil	0CFU/100ml	0CFU/100ml	No risk
HH5	Nil	Nil	0CFU/100ml	0CFU/100ml	No risk
HH6	17	Nil	0CFU/100ml	0CFU/100ml	Intermediate risk
HH7	17	11	0CFU/100ml	0CFU/100ml	Intermediate risk
HH8	18	5	0CFU/100ml	0CFU/100ml	Inter9mediate risk

APPENDIXES E: - Image on filed observation and laboratory analysis

Image on open filed solid waste disposal

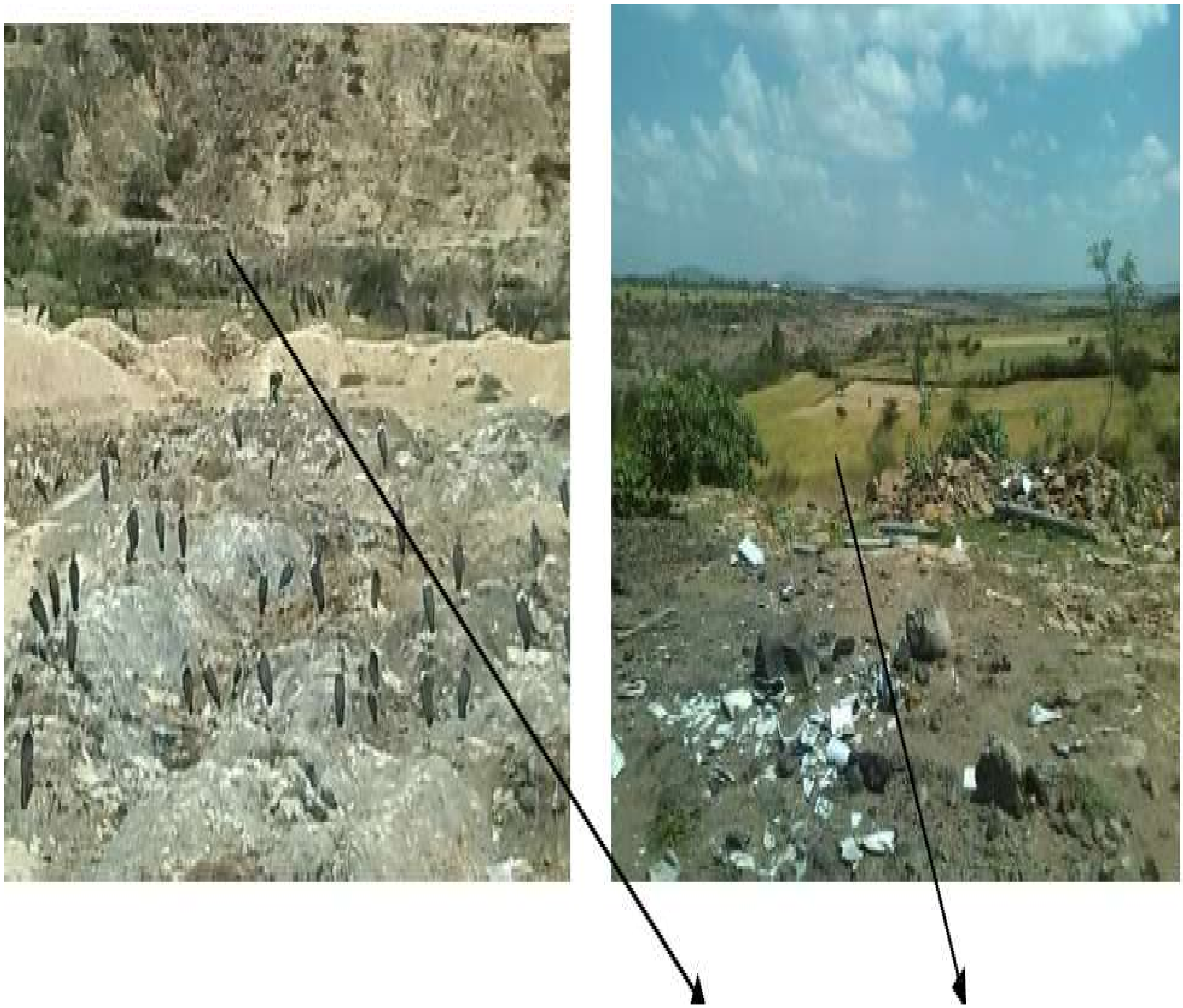

Image on Open field solid waste disposal along a) Mojo river b) agricultural field (Field survey).