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Assessment of Drinking Water Quality for the Case of Hawassa City in Sidama Regional State, Ethiopia

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Assessment of Drinking Water Quality for The Case Of Hawassa City In Sidama Regional State, Ethiopia

By:

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CERTEFICATION

This Thesis has been submitted for examination with my approval as the university supervisor

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DECLARATION

I, Yirged Antehun Mengstie declare that, the thesis is my original work and it is not previously published by another person nor has been accepted for the award of any other academic degree of the University. Where assistance was sought, it has been accordingly acknowledged.

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ABSTRACT

Water quality and the risk of water-related diseases are a serious public health problem in many developing countries like Ethiopia. The aim of the study was to assess the drinking water quality from source to household tap water and it was conducted in Sidama Regional State, Southern Ethiopia, Hawassa city. The Study area map and sampling points were prepared using Arc GIS 10.4 and QGIS respectively. 21 water samples were collected to characterize and analysis drinking water quality parameters. 11 water samples from sources, 4 from service reservoirs and 6 from tap water were taken. The main physio-chemical parameters analyzed for the study were Total Dissolved Solids (TDS),Temperature, Turbidity, Electrical conductivity (EC), pH, Fluoride, Nitrate (No_3), Total Hardness (TH), Calcium and Magnesium, Phosphate, Sulphate, residual chlorine and Microbiological (Total Coliform and coliform/CFU).The results were determined using on site measurements and laboratory experiments. The result of the finding was compared with the WHO and Ethiopian water quality standards and it shows that most of the water quality parameters tested are within the standard of WHO and National drinking water quality standards. However, there are some physio-chemical parameters (Temperature, Turbidity, fluoride and residual chlorine) that are not inconformity with the standards. The mean temperature at the source, reservoir and tap water was 22.01^{o}C, 22.5 ^{o}C and 21.83 ^{o}C respectively. The turbidity levels for source samples ranged from 10 to 45 NTU, with a mean of 24.5 NTU, which was higher than the WHO's recommendation of less than 5NTU.High Fluoride content (3.9mg/l) was recorded from BokoAlamura well which is above the permissible limit of WHO and NDWQS. Therefore, the water sector should use DE fluorination technology or minimizing use of this source for drinking purpose to minimize the risk at the consumers. There was no free residual chlorine in the tap water sample which indicates there might be recontamination of the water till consumption. On the other hand, the results depicts that Hawassa drinking water supply did not contain total and feacal coliform for all samples analyzed, which might be because the sources are properly protected from contamination and sufficient treatment for the water before distribution. The overall WQI was also determined for water source, reservoir and tap water sample and it was found 89, 71 and 69.7 respectively. Therefore, Based on the WQI result the Hawassa drinking water quality is good for source and fair at reservoir and tap water.

Key words: water quality, physio-chemical, bacteriological ,water quality index, Ethiopia

Table of Contents

LISTS OF TABLE

LIST OF FIGURE

ACRONYMS

CFU	Colony forming Unit
CSA	Central Statistical Agency
BOD	Biological oxygen Demand
COD	Chemical oxygen Demand
DWAF	Department of water Affairs and forestry
EC	Electrical conductivity
ES	Ethiopian Standard
GIS	Geographical Information System
GPS	Global Positioning System
MOWIE	Ministry Of Water, Irrigation and Electricity
NTU	Nephelometric Turbidity Units
NDWQS	National Drinking Water Quality Standard
TH	Total Hardness
TDS	Total Dissolved solids
UNICEF	The United Nations International children's emergency fund
WHO	World Health Organization
WQI	Water Quality Indexes

1. INTRODUCTION

1.1. Background

Water is a natural resource of fundamental importance. It supports all forms of life and creates jobs and wealth in the water sector, tourism, and recreation. As global slogan, “Water is Life” implies that water is one of the critical life needs for a human being. Without water, life as it exists on our planet is impossible (Bekele,et al,2018).Water quality is continuously under pressure as it is vital to the human body and ecosystem. The growing human population is causing a negative impact on surface waters and watersheds worldwide. Although the process of urbanization is a global phenomenon with far reaching impacts upon natural ecosystems. Within urban areas, freshwater ecosystems are exposed to a multitude of risks including increased catchment impermeability (e.g. artificial surfaces) and population density, habitat fragmentation and degradation and poor water quality (Grimm et al., 2008).

Water quality monitoring is a fundamental tool in the management of freshwater resources. Monitoring is defined by the International Organization for Standardization (ISO) as “the programmed process of sampling, measurement and subsequent recording or signaling, or both, of various water characteristics, often with the aim of assessing conformity to specified objectives”. It is to control the physical, chemical and biological characteristics of water most commonly related to water quality management (Bartram and Ballance, 1996). According to Bartram and Ballance (1996) and DWAF (2004), “water quality” is a term used to express the suitability of water to sustain various uses or processes. Such suitability includes the physical, chemical and biological characteristics of the water. The most popular definition of water quality is “it is the physical, chemical, and biological characteristics of water”(Hassan T,2019).The main aims of this study are to examine the drinking quality of Hawassa City by onsite and laboratory experimentation, and to analyze the results by comparing and contrasting them to national and international guidelines and standards, as well as previous research.

1.2 Statements of the problems

Water quality and the risk of water-related diseases are a serious public health problem in many developing countries like Ethiopia. Access to improved water supply and sanitation has been very low and hence majority of the communicable diseases are associated with unsafe and inadequate water supply (UNICEF, 2016).The safety of potable water and the danger of water-borne diseases are major public health issues in Ethiopia. About 60% of health problem is communicable disease associated with unsafe and inadequate water and poor human excreta disposal (Meride et al., 2016).

SNNP was one of the regions most affected by water-borne diseases, especially diarrhea, coliforms, E.coli microorganisms. This is due to a lack of thorough investigation and subsequent control of water quality parameters. The region's health sector frequently reports that water-related diseases are among the top ten diseases, and there are several signs that the region's population is suffering from water-related diseases, most likely as a result of low drinking water quality. (CSA and ICF 2016).

So far, there was no research activity conducted on the drinking water quality of the city that may enable to know the quality of drinking water, it has been observed that some people in the study area did not use tap water for drinking and they complained that the water has a taste, it is salty. In general they have no trust on the quality of tap water and prefer to use bottled water. Therefore, it was prudent to conduct a research on water supply system of the city may enable one to know the quality of drinking water and the aim of this study was to assess and expose the true state of the water quality in the Hawassa city.

1.3 Research questions

The principal research question that were attempted to be addressed were:

1) what is the level of water quality parameters for Hawassa city drinking water
2) Dose the drinking water quality parameters of Hawassa city fit the guidelines set in the WHO standard and that of the NDWQS?
3) What is the Water quality index for drinking water in study area?

1.4 Objectives

1.4.1 General objective

The main objective of the study was to assess the drinking water quality of Hawassa city,Ethiopia

1.4.2 Specific objective

- To characterize the drinking water quality from source to Tap water through laboratory and on-site analysis.
- To analyze the results of the study with WHO guidelines and Ethiopian recommended values.
- To determine the Drinking Water Quality Index of the study area

1.5 Significance of the Study

In several developing countries, such as Ethiopia, water safety and the possibility of water-related diseases are serious public health issues. This is primarily due to a lack of thorough study and subsequent checking of water quality parameters. Accurate information about drinking-water, sanitation and hygiene related issues are invaluable to national leaders, decision-makers and stakeholders when making policy decisions. However, the main focus in this study was assessing the water quality and giving evidence-based information that can be used in a variety of ways

- To assess progress towards national and international goals and strategies;

- To promote increased investments in the sector for improving the drinking water quality;

Furthermore, this finding will serve as a required document for future studies by other researchers.

1.6 Scope and limitation of the study

The study's scope limited to assessing the city of Hawassa's drinking water quality. The parameters of water quality were determined using both on-site and laboratory analysis. With the parameters evaluated, a water quality index for drinking water in the study region also calculated. The main limitation encountered during this study was the covid-19 pandemic as it affected the duration of the research. Therefore, due to time constraint the analysis does not include a quality analysis for storage and point use.

2 LITERATURE REVIEW

2.1 Water quality

According to Bartram and Ballance (1996) and DWAF (2004), "water quality" is a term used to express the suitability of water to sustain various uses or processes. Such suitability includes the physical, chemical and biological characteristics of the water. The most popular definition of water quality is "it is the physical, chemical, and biological characteristics of water"(Hassan T,2019). It is a measure of the condition of water relative to the requirements of one or more both species and or to any human need or purpose.

Water quality is continuously under pressure as it is vital to the human body and ecosystem. The growing human population is causing a negative impact on surface waters and watersheds worldwide. Although the process of urbanization is a global phenomenon with far reaching impacts upon natural ecosystems (Grimm et al., 2008). Within urban areas, freshwater ecosystems are exposed to a multitude of risks including increased catchment impermeability (e.g. artificial surfaces) and population density, habitat fragmentation and degradation and poor water quality.

Water quality is influenced by multiple factors including climate, precipitation, underlying geology, ground water, surface water, anthropogenic activities, pollutants, and other natural and human processes (Ahuja, 2013). As human populations continue to grow and land uses expand, the capacity to negatively impact our surface waters and watersheds throughout the world through contamination and human disturbances likewise increases. This potential for adverse effects on our world's water often results in reduced water quality. It is for this reason that water quality monitoring has become an important aspect of environmental science over the past several decades and is continuing to be an issue of community concern (Ahuja, 2013). Drinking water quality is described as water that is free of disease-causing microbes and potentially harmful chemicals (Tebutt, 1983). According to different studies, even well-protected sources and well-managed systems cannot guarantee that homes receive safe water. Many countries ofthe globe do not have access to reliable household water, and many of them must still transport water and store it in their houses. Even water gathered from safe sources is likely to become faecally polluted during transit, containerization, and storage,

2.2 Water Quality Analysis

Water quality refers to the physical, chemical, and biological characteristics and conditions of water and aquatic environments that affect water's ability to serve the uses for which it was intended. The physical, chemical, microbiological, radiological, and biological properties of water are all considered when determining its consistency. It is mostly affected by human actions, which can affect/change all of these properties to the point that aquatic and terrestrial species that rely on it are affected (Daba Desissa, 2016).

2.3 Drinking Water Quality Standards

The WHO Guidelines for Drinking Water describe reasonable minimum safe practice criteria to protect consumers' health and establish numerical "guideline values" for water constituents or indicators of water quality. WHO, on the other hand, recognizes that local or national environmental, social, economic, and cultural situations may impose additional mandatory restrictions, resulting in national, local, or regional norms. As a result, there is a wide range of drinking water standards because there is no universally applicable method to drinking water standards. (WHO, 2011). Unfortunately, WHO does not support the adoption of international drinking-water quality standards because the conditions that force the adoption of other standards may mandate even lower quality. Thus, Ethiopia has its own standard, compulsory Ethiopian Standard (CES), which is utilized together with established worldwide and regional standards that apply to various test and analysis specifications in the drinking water sector

2.3.1 Drinking Water Quality Standards in Ethiopia

The Compulsory Ethiopian Standard for Drinking Water Specification (CES 58) provides the physical, chemical, and bacteriological standards for water for drinking and household purposes in order to assure access to clean drinking water. It establishes quality and safety standards that meet all toxic, bacteriological, and organoleptic requirements, and is aligned with the new SDG aims(MOWIE,2017).

2.4 Improved and Unimproved Water Supply Systems

According to WHO’s , 2008 3rd edition of guidelines for drinking-water quality; public, improved and Unimproved water supply include the following;

- Improved water supply technologies:
  - Household connection
  - public standpipe
  - Borehole
  - protected dug well
  - protected spring
  - rain water
- Unimproved water supply technologies:
  - Unprotected well
  - Unprotected spring
  - Vendor-provided water
  - Bottled water
  - Tanker truck provision of water

2.5 Drinking Water Quality Parameters

2.5.1 Physical Drinking Water parameters

2.5.1.1 Temperature

Temperature is an important parameter in characterization of water. It affects the water chemistry such as saturation and concentration of dissolved gases, especially oxygen. The rate of chemical reactions generally increases as temperature increases. Temperature also affects biological activity and regulates the kinds of organisms that can survive in the water (fomanana, 2009). Temperature affects the growth and reproduction of aquatic organisms. A sudden change in a temperature of river water can lead to a higher rate of mortality of aquatic biota (Fakayode, 2005). The growth and reproduction of aquatic species are influenced by temperature. A abrupt change in river water temperature might result in a higher rate of aquatic biota mortality (Fakayode, 2005). The rate at which algae and aquatic plants photosynthesis, the metabolic rate of other species, and how pollution, parasites, and other pathogens interact with aquatic residents are all affected by temperature. It's essential in aquatic systems since it can cause death and affect the solubility of dissolved oxygen and other molecules in the water column (such as ammonia) (Buren et al., 2000). Furthermore, temperature has an impact on water treatment. (Yi-Hsu Ju et al., 2014).

2.1.1.1 Turbidity

Turbidity is a measurement of the visual purity of water (Wilson,2019). Turbidity in water bodies is caused by suspended and colloidal particles such as clay, silt, organic material, algae, and other inorganic material. The presence of turbidity in water indicates the presence of particles other than water molecules that contaminate or pollute water bodies (Nicholas, 2002). It is an expression of the absorbent of optical light and causes light to be scattered rather than transmitted with no change in direction through the sample. As the presence of dissolved and suspended solids increases, light scattering increases and turbidity is usually measured in nephelometric turbidity units (NTU). Although the weight and particle concentration of suspended matter are the key controlling factors for turbidity, the size, shape, and refractive index of particles can all influence the suspension's light-scattering properties. (Copes et al, 2008).

2.1.1.2 Electrical Conductivity (EC)

Conductivity is the ability of a substance to conduct electricity. The conductivity of water is a more-or-less linear function of the concentration of dissolved ions. Electrical conductivity of the water is also be related to total concentration, concentrations of the dissolved substances, their ions in the water, their valence charge and mobility. If the conductivity of a river or a stream suddenly increases, it indicates there is a source of dissolved ions in the neighborhood. Therefore, conductance can be used to distinguish pollution sources (Stoddard et al., 1999). According to AWWA (2000) conductivity measurements can be used as a quick way to locate potential water quality problems. As a result, changes in the conductivity of a water sample may indicate significant changes in the mineral content of the water, seasonal variation in reservoirs, and water pollution from industrial pollutants.

The ability of an aqueous solution to carry an electric current is measured using parameters such as ion concentration, mobility, valence, and temperature. Clean water is a strong heat proofing rather than an electrode for electric current, and an increase in ions concentration increases water's electrical conductivity. In general, the electrical conductivity of water is determined by the amount of dissolved solids in the water. Electrical conductivity (EC) is a measurement of a solution's ionic phase that allows it to transmit current (Hassan et al, 2017).

2.1.1.3 Color

The colour is caused by the presence of colorful compounds in solution, such as vegetable debris and iron salt. It does not always have a detrimental impact on one's health. It's not a good idea to drink colored water (Aesthetic as well as toxicity reasons). As a result, colorless drinking water is required. For the purposes of studying public water sources, it is sufficient to merely observe the presence or absence of visible color at the time of sample. Changes in water color and the appearance of new colors are signs that further study is required (WHO, 2004). The color of the water is determined by contrasting it to regular color solutions or colored glass disks. A color unit is the color formed by a platinum solution (potassium chloroplatinate (K_2PtCl_6)) at a concentration of 1 mg/L(Apha ,2005).

2.1.1.4 Odor and tastes

Foreign matter, such as organic materials, inorganic compounds, or dissolved gasses, can induce a bad taste and odor in water. These materials may come from a number of areas, including the natural environment, domestic life, and agriculture. The numerical value of odor or taste is calculated by measuring a volume of sample A and diluting it with a volume of odor-free distilled water until the odor of the resulting mixture is just detectable at a total mixture volume of 200 ml (Nayla Hassan,2019).

2.1.1.5 Total dissolved Solids

Total dissolved solids (TDS) differ from total suspended solids (TSS) in that TSS cannot pass through a two-micrometer screen but remain suspended in solution indefinitely. Total Dissolved Solids (TDS) in water originate from natural sources, sewage, urban runoff, and industrial wastewater. These solids include inorganic salts, principally calcium, magnesium, potassium, sodium, bicarbonate, chlorides, sulphates, and small amounts of organic matter that are dissolved in water (WHO, 2004). According to Nadia (2006) discharge of wastewater with a high TDS level would have adverse impact on aquatic life, render the receiving water unfit for drinking and domestic purposes, reduce crop yield if used for irrigation, increase conductivity, and exacerbate corrosion in water networks. The presence of high levels of TDS in drinking water may be objectionable (WHO, 2004

Water can be categorized based on the amount of TDS content per litter of water as follows:

Table 2.1: Types of Water Based On TDS

Water type	TDS(mg/l)
Fresh water	<1500
Brackish water	1500-5000
saline water	>5000

(Hassan T, 2019)

2.5.2 Chemical drinking water parameters

2.5.2.1 PH of pure water

The pH of a solution is a measure of the concentration of hydrogen ions (H+), which is a measure of acidity. PH shows the level of acidity or alkalinity in water, which influences biological and chemical reactions held within the solution. Low pH, for example, reduces microorganism activity and development, influencing biological reactions. The solubility and availability of chemical constituents such as nutrients and heavy metals decide the pH of water. (Tegereda, 2011). According to the WHO guidelines, "No health-based guideline value is proposed for pH, although eye irritation and exacerbation of skin disorders have been associated with pH values greater than 11. Although pH usually has no direct impact on consumers, it is one of the most important operational water quality parameters". Whenever water treatment or storage is taking place (arsenic removal, clarification, disinfection, rainwater harvesting), careful attention to the level of pH is necessary and the optimum pH required is generally within the range 6.5–8.5 (WHO, 2006, NDWQS, 2011).

2.5.2.2 Dissolved Oxygen (DO)

DO refer to the amount of oxygen present in dissolved form in a water body. Organic matter from water treatment, intense fertilizer application, and agriculture-based industries all alter the concentration of dissolved oxygen in the aquatic system, resulting in an increase in oxygen demand. (Hassan et al, 2017).

2.5.2.3 Biological Oxygen Demand (BOD)

The amount of oxygen consumed during the oxidation or decomposition of organic compounds in biological-oxidation or aerobic conditions are referred to as biological oxygen demand. (Yang et al, 2009). It's a test for determining the amount of biologically oxidized organic matter present and the rates at which oxidation or BOD exertion will occur. It's also a metric for comparing the relative polluting potential of various organic substances. As it is stated by (Ronaldo et al., 2006), oxygen demand is the amount of dissolved oxygen consumed over the course of five days by biological oxidation for the breakdown of organic matter in the water. Allowing biochemical oxidation to continue under standard conditions for 5 days could be used to assess biological oxygen demand

$$BOD_5(mg/L) = \frac{(DOi - DOf)}{DOf}$$

Where; DOi = initial dissolved oxygen,

DOf = final dissolved oxygen and

Df = dilution factor (Tadesse Mosissa,2012)

2.5.2.4 Chemical oxygen demand

The chemical oxygen demand (COD) is a metric for calculating all organics, both biodegradable and non-biodegradable. It’s a chemical test that uses heavy oxidizing chemicals (potassium dichromate), sulfuric acid, and heat to achieve a result in as little as 2 hours . For the same sample, COD values are often higher than BOD values (Hassan T,2019).

2.5.2.5 Total Hardness

Hard water has a high mineral concentration, which is generally not detrimental to humans (Safdar et al.,2013). The main sources of hardness in drinking water are calcium and magnesium carbonates and bicarbonates (which can be eliminated by boiling), as well as calcium and magnesium sulfate and chloride (which can be removed by chemical precipitation using lime and sodium carbonate). Since it includes primarily calcium and carbonates, which are the most dissolved ions in hard water, it is commonly measured as calcium carbonate ($CaCO_3$). The calcium ion has a taste threshold of 100–300 mg/l, with a maximum allowable concentration of 500 mg/l for total hardness as Caco3 (Girmay et al, 2011)

2.5.2.6 Calcium

Calcium is an essential nutrient accounting for about 2 percent of body weight, ranking fifth after oxygen, carbon, hydrogen and nitrogen. Nearly 99 percent of the body's calcium (1 200 g or 30 mol) is stored in the skeleton; the remainder is in the teeth and soft tissues (each containing 7 g or 175 mmol) and the extracellular fluid (ECF) (1 g or 25 mmol) (Christopher Nordin, 1997). according to WHO (1996) its acceptable range in drinking water, is up to 75 mg/l. Calcium salts and calcium ions are among the most commonly occurring in nature. They may result from the leaching of soil and other natural sources or may come from artificial sources such as sewage and some industrial wastes. Calcium is usually one of the most important contributors to hardness. Calcium concentration in natural waters are typically less than 15mg/l , for waters associated with carbonate-rich rocks concentrations may reach 30-100mg/l. According to AWWA *et al*., 1990 even though the human body requires approximately 0.7 to 2.0grams (g) of calcium per day as a food element, excessive amounts can lead to the formation of kidney or gallbladder stones. High concentrations of calcium can also be detrimental to some industrial processes.

2.5.2.7 Magnesium

Magnesium (0.3-0.5 g/day) is a common and important mineral for humans. It accounts for 15-20% of overall hardness expressed as CaCO3 and is the second most important component of hardness (Environmental Protection Agency, 2001). Around 25 grams of magnesium are found in the human body (60 percent in bones and 40 percent in muscles and tissues). The maximum level of magnesium in water, according to WHO guidelines, should be 150 mg/l (Muhammad et al., 2013).

2.5.2.8 Fluoride

A moderate level of fluoride ions (F^-) in drinking water helps to prevent tooth decay. Dental health is critical. Tooth decay can be prevented with a concentration of 1.0 mg/L, particularly in children (apha,2005).Too much fluoride causes dental fluorosis, which is characterized by discolored teeth. The overall fluoride levels in public water sources are determined by the local environment. The highest permissible fluoride concentration for potable water in the warmer parts of the country is 1.4 mg/L; in the cooler parts of the country, it's 1.4 mg/L. Up to 2.4 mg/L is required in colder climates (Nayla Hassan,2019).

2.5.2.9 Nitrates

Total nitrogen represents the summation of ammonia nitrogen, nitrite plus nitrate nitrogen, and organic nitrogen. Nitrogen in the aquatic environment occurs in four forms: ammonia (NH3), nitrate (NO3-), nitrite (NO2-) and ammonium ion (NH4+). Nitrate is a final oxidation product of the nitrogen cycle in natural waters and is considered to be the only thermodynamically stable nitrogen compound in aerobic waters (Michalski1 and Kurzyca, 2005). The nitrate limit in public sources of drinking water was set to safeguard against infant methemoglobinemia, but additional health impacts were not taken into account. When nitrate is consumed under conditions that promote the creation of N-nitroso compounds, the risk of certain cancer and birth abnormalities may be raised. (Ward et al.,2018)

2.5.2.10 Phosphate

Phosphorus in small quantities is essential for plant growth and metabolic reactions in animals and plants. Sources of phosphate include animal wastes, sewage, detergent, fertilizer, disturbed land, and road salts used in the winter. Orthophosphate (reactive) is analyzed directly on an unpreserved sample within 48 hours of sampling. Phosphates in surface waters come mostly from sewage effluents containing phosphate-based synthetic detergents, industrial effluents, and land runoff from farms using inorganic fertilizers (Kundu et al.,1015).

2.5.3 Biological parameters

Practitioners in the field of drinking water are concerned with water supply and purification through a treatment procedure. The fundamental concern in water treatment is, of course, creating potable water that is safe to drink (pathogen-free) and does not have any disagreeable features, such as a foul taste or odor. (NRC,1998).The existence or absence of living organisms may be one of the most useful measures of water quality. Biologists can survey fish and insect life in natural waters and use a computed species diversity index (SDI) to determine water quality; therefore, a water body with a sufficient number of well-balanced species is considered a healthy system. Some species have the ability to be harmful (Nayla Hassan,2019). determining the presence of all pathogenic organisms is challenging, the presence of particular indicator species is utilized to provide an indication of pathogen presence. Indicator organisms come in a variety of forms. Total coliforms and fecal coliforms are the most commonly utilized indicator species for assessing household water quality. (Motlagh and Yang, 2019).

2.5.3.1 Fecal coliform bacteria

Fecal coliform bacteria are a collection of relatively harmless microorganisms that live in large number in the intestines of the warm and cold blooded animals. They aid in the digestion of food. Specific subgroups of this collection are the fecal coliform bacteria, the most common member being *Escherichia coli*. These organisms may be repeated from the total coliform group by their ability to grow at elevated temperatures and are associated only with the fecal material of warm blooded animals (Kumar and Pur,2012).The presence of fecalcoliform bacteria in aquatic environmental indicate that the water has been contaminated with the fecal material of man or other animals (Obiri-Danso et al 2008). Some water-borne pathogenic diseases include typhoid fever, viral, and bacterial gastroenteritis and hepatitis A. The presence of fecal contamination is an indicator that a potential health risk exists for individuals exposed to this water (Kumar and Pur,2012).

2.5.3.2 Total Coliforms

To avoid confusion with other members of the group, coliform organisms are better referred to as total coliforms. They are not an indicator of fecal contamination or health risk, although they can provide basic information on source water quality. Total coliforms have long been used as a microbiological indicator of drinking water quality, owing to their ease of detection and enumeration in water (Dufour et al.,2003). They have traditionally been defined in terms of the method employed for the groups enumeration and hence there have been many variations dependent on the method of culture. In general, definitions have been based around the following characteristics; gram-negative, non-spore forming, road shaped bacteria capable of growth in the presence of bile salts or other surface active agents with similar growth inhibiting properties, oxidize-negative, fermenting lactose at 35-37oC with the production of acid, gas, and aldehyde within 24-48 hours according to Assessing Microbial Safety of Drinking Water (2002).

Table 2.2: Bacteriological Count per 100ml

No	Bacteriological count per 100ml	Risk to health
1	0	None

2	1-10	Low risk
3	11-100	Intermediate risk
4	101-1000	High risk
5	>1000	Very high risk

(Source: Michael et al. 2006)

Table 2.3 Standard Of Drinking Water Quality Guide Fulfillment Criteria

Parameter		Unit	Maximum permissible limit	
			WHO	NDWQS limits
Physical	Color		Un objectional	15
	Test and odor		Un objectional	Unobjectionable
	Turbidity	NTU	5	7
	Electric conductivity	µS/cm	1000	1500
Chemical	Temperature	^{o}C	15	-
	TDS	Mg/l	1000	1000
	PH	PH	6.5–8.5	6.5 to 8.5
	Total alkalinity (Caco3) (mg/l)	Mg/l	200	500
	Calcium (mg/l)	Mg/l	75	75
	Magnesium	Mg/l	150 mg/l	50
	Fluoride	Mg/l	1.5	3
	Hardness	Mg/l	300	300
	Sodium	Mg/l		200
	Iron	Mg/l	0.3	0.3
	Nitrate(NO3)	Mg/l	50	50

	Total Coliform	CFU	0/100	0/100 ml
	Bacteria		0/100	0/100

2.6 Water Quality Index (WQI)

WQI was first introduced in the United States by Horton (1965), who chose ten of the most frequently used water quality variables, such as dissolved oxygen (DO), pH, coliforms, basic conductance, alkalinity, and chloride, among others. It has since become widely used and accepted in European, African, and Asian countries (Shweta Tyagi *et al*.,2023). One of the most basic approaches for determining water quality is to use a water quality index. It's a tool that generates understandable summaries of water quality data for both technical and non-technical people that are interested in water quality data. (Al-Janabi,et al.,2012).

2.7 Research gap

Water is an essential component for living things, so its presence with adequate and suitable quality is very vital. There are a lot of projects and researches are conducted on drinking water quality. Meride and Ayenew, 2016 carried out a detail investigation Drinking water quality assessment and its effects on resident's health. Gonfan, *et al.*, 2019 also did a research to assess the Bacteriological and Physicochemical Quality of Drinking Water from Source to Household Tap Connection. According to their finding some water quality parameters does not meet the water quality standards. As their recommendation, proper drainage, sewage disposal systems, and sufficient disinfection of water with chlorine are of prime importance to deliver safe drinking water to the residents of Nekemte city. However, for the present study area different researches were done related to the water quality but most of them are on the quality of Lake Hawassa and there was no research which is done on the drinking water quality of the Hawassa city.

3 RESEARCH METHDOLOGY

3.1 Description of the Study Area

This research was conducted in a city in Ethiopia's Sidama regional state, Hawassa city. The city is located at a height of 1708 meters above sea level and is situated between 7° 3' 1.3464" N latitude and 38° 29' 43.8144" E longitude. Addis Ababa is 273 kilometers south of the city (Claire Furlong, 2016). The city serves as the capital and a special zone of the Southern Nations, Nationalities, and Peoples' Region. It is located on the Cairo-Cape City Trans-African Highway 4 (http://174.127.109.64/en/Map-Awasa_340763.html).

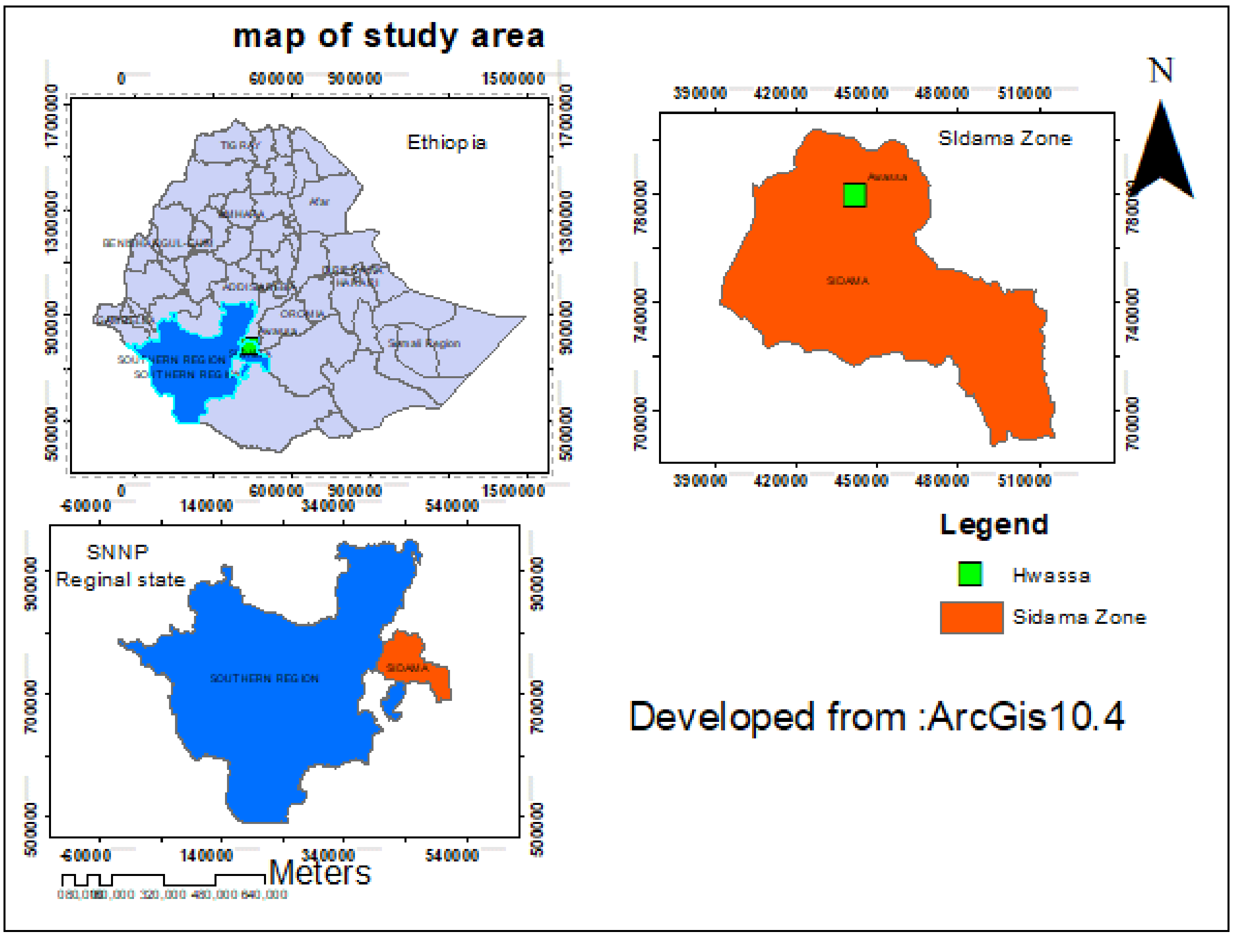


Figure 3.1: Map of Study Area

3.2 Geography

In the Great Rift Valley, Hawassa city is situated on the beaches of Lake Hawassa. Volcanic rock from the Pliocene era makes up Lake Hawassa's catchment. The area's highly permeable soil and unconfined aquifers are caused by significant faults and ground fissures in the rock. The depth to the static groundwater level varies from a few meters in low-lying areas to as much as 40 meters in high-lying places (Ayenew and Tilahun, 2008).

3.3 Climate

The average annual rainfall in Hawassa is around 950 mm, with a temperature of 20°C. The annual rainfall varies roughly from June to October (Scott,et al.,2016).

3.4 Population

Hawassa's population is estimated to be 351,469 people, with an annual population growth rate of 4%, according to the Ethiopian Central Statistical Agency (CSA, 2015).

3.5 Drinking water supply source in the city

The Water supply in the city is from three types of sources: springs, deep wells and treated river water. All the sources are located out of the city (an average of 15 km).Hawassa city obtains largest water supply sources from deep well sources with 1649 l/sec safe yield capacity and followed by spring water source (74l/sec).The Kedo river yields 38.8l/sec for the city. The Kedo Treatment plant has a capacity of 38.8 l/comprises chemically aided sedimentation units, rapid sand filters and balanced chambers. The treated water directed to the city reservoir (Two reservoirs 500 m^3 capacity each) through transmission pipeline DCI DN 300mm, which has a length of 11kms.the water source from the springs pumped to the reservoir(2000m^3) located in Loke Mountain.

3.6 Study design

The study conducted to assess the drinking water quality parameters. The following chart shows the flow chart for study design.

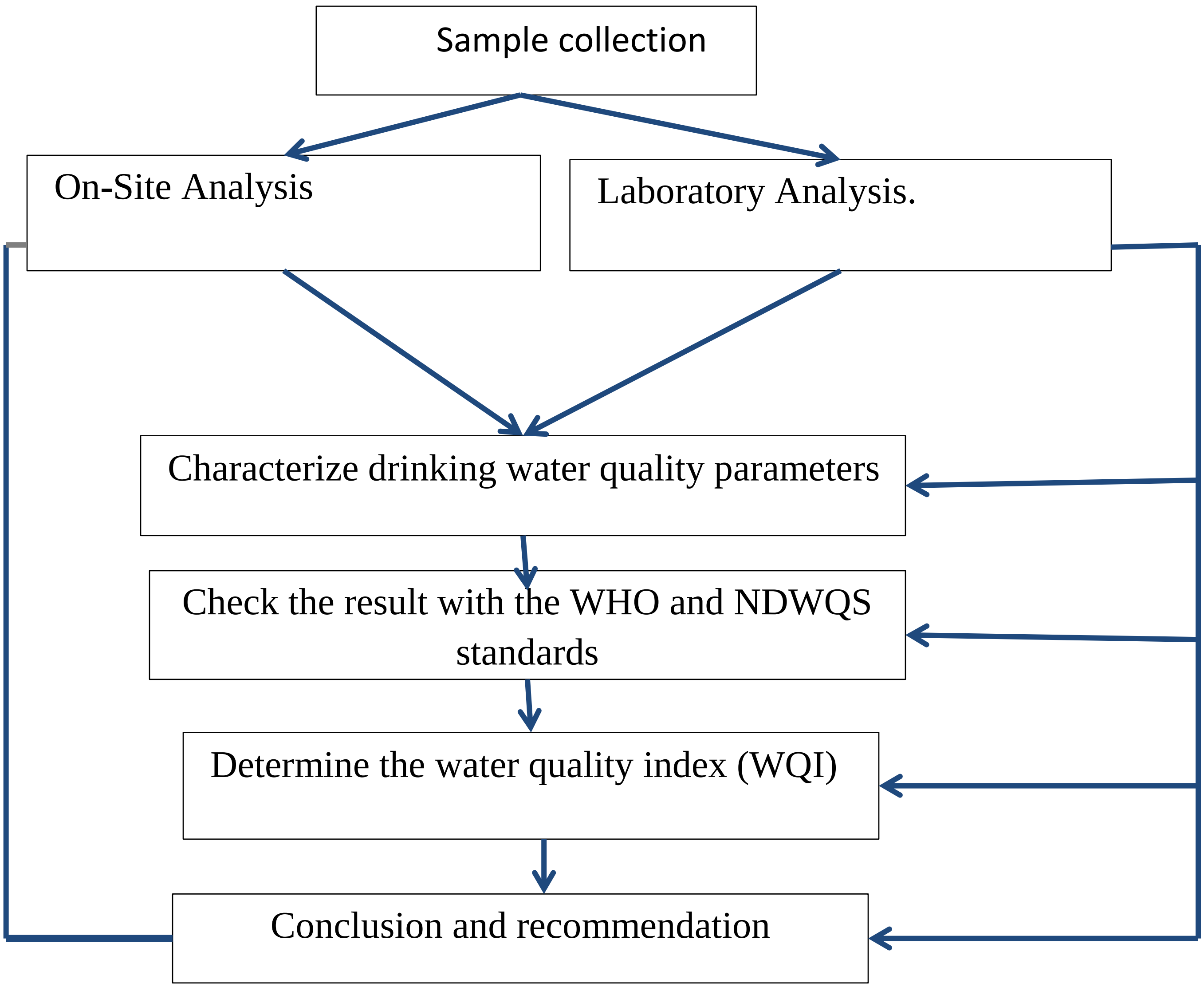


Figure 3.2: Flow Chart of the Study

3.7 Data collection process

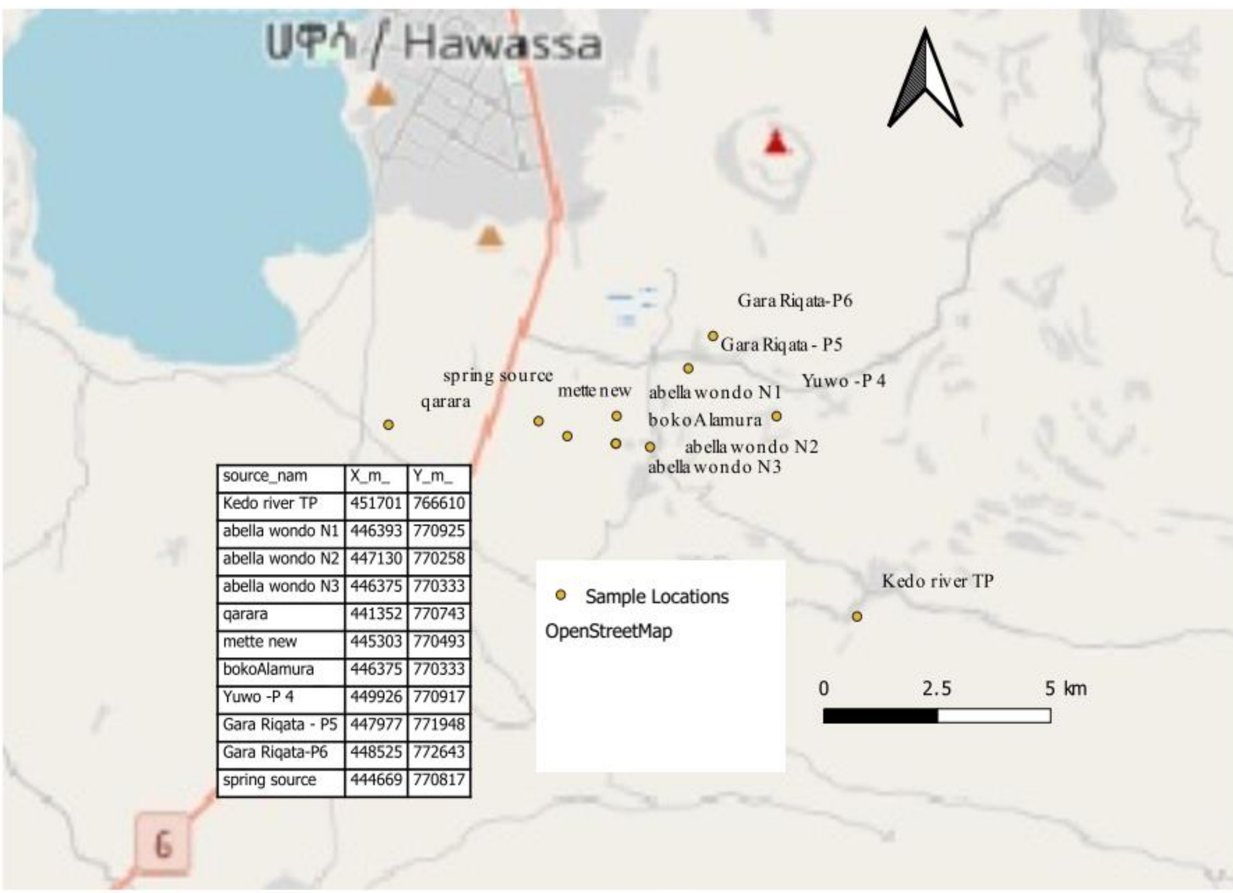
The data collection carried out by personal observation and field measurement. This was achieved through using primary data collection method to get the necessary information that meets the objective. Both qualitative and quantitative analysis done on primary and secondary data. Data were evaluated qualitatively using tables, maps, and/or phrases. Quantitative data, on the other hand, was analyzed using excel.

3.8 Study variables

The study variables are the variables that tested as well as the outcomes during the research phase. There are two kinds of variables: independent and dependent variables. Independent variables specifically linked to the study's basic target. The chosen physical, chemical, and biological drinking water quality parameters were the key independent variables in this analysis.

3.9 Sampling method

Samples was collected from locations that reflect the raw water source, reservoirs, and water taps where the customer receives water. The sample for the tap water was collected two samples from each kebeles (it is collected randomly from ketena one and two of the kebele).



source_nam	X_m_	Y_m_
Kedo river TP	451701	766610
abella wondo N1	446393	770925
abella wondo N2	447130	770258
abella wondo N3	446375	770333
qarara	441352	770743
mette new	445303	770493
bokoAlamura	446375	770333
Yuwo -P 4	449926	770917
Gara Riqata - P5	447977	771948
Gara Riqata-P6	448525	772643
spring source	444669	770817

Figure 3.3 Sampled Locations, Coordinates for Source Samples

3.10 Water Quality parameter analysis and instruments

Water samples have been collected from 21 drinking water supply stations in Hawassa drinking water supply system. At service reservoirs four samples of water were taken,From three kebeles (small administrative) of water taps were also used to obtain six water samples. To ensure a representative sample, taps were turned on or left running for at least some minutes prior to sampling (temperature and electrical conductivity were monitored to verify this). the remaining 11 samples were from the source water.At the time of sampling, various physico–chemical parameters of water samples (electrical conductivity, TDS, pH, and temperature) were measured using portable meters in the field. Water samples were collected in clean containers provided by the analytical laboratory.

3.10.1 Physico-chemical test procedures

On-site measurements were used to determine sensitive water quality parameters as temperature, pH, EC, and TDS. Temperature and pH were measured using a thermometer and a portable digital pH meter .Before being utilized for the analysis, the pH meter was calibrated with pH 4.0 and pH 7.0, and it was washed with distilled water from one sample to the next, as indicated in the pH meter operation guide. Electrical conductivity and Total Dissolved Solids were measured using a portable digital conductivity meter (TDS). Their measurements were taken immediately following the collection of samples at each location. The remaining water-quality indicators were measured following the standards. Before each use, the equipment was thoroughly cleaned and disinfected to prevent secondary contamination and ensure accurate findings.

3.10.2 Bacteriological parameter analysis

To avoid the growth or death of microorganisms in the sample, bacteriological tests were done the same day the sample was collected. Using the membrane filtration method, a 100 ml water sample was sucked through a filter with a little hand pump. After filtration, the bacteria on the filter paper were placed in a Petri dish with a nutritive solution (also known as culture media, broth or agar). The temperature and period of incubation differed based on the type of indicator bacteria and culture media applied (for example, total coliforms were incubated at 35 °C and fecal coliforms were cultured at 44.5 °C with some types of culture media).

3.11 Method of Data Analysis

The results of water quality testing at the source, in reservoirs, and in tap water were compared to Ethiopian (ES) (2002) and WHO standards. The water quality indices were calculated using the mathematical equation proposed by Yisa and Jimoh (2010) based on the results of the water quality parameters. Tables and different bar graphs are used to show the results of the findings.

3.11.1 Calculation of Water Quality Index (WQI)

The Water Quality Index (WQI) is a simple and effective approach for determining the quality of water. It's also a great method for communicating information about water quality. The Water it is defined as "a ranking that reflects the composite influence of a variety of water quality criteria on overall water quality" WQI is a measure of the acceptability of water (including surface and groundwater) for human consumption that takes into account the combined effects of various water quality factors (Bashar and AL-Sabah, 2016).The Water Quality Index (WQI) calculated using the Weighted Arithmetic Index method adopted from (Yisa and Tijani, 2010). The quality rating scale for each parameter qi was calculated by using this expression:

$q_i = (C_i/S_i) \times 100$ ………………………………………………………………… *eq*.(3.1)

A quality rating scale (qi) for each parameter assigned by dividing its concentration (Ci) in each water sample by its respective standard (Si) and the result multiplied by 100. The inversely proportional value of the recommended standard (Si) of the corresponding parameter used to calculate relative weight (Wi). $Wi = 1/Si$ …………………………………..*eq*.(3.2)

The overall Water Quality Index (WQI) calculated by aggregating the quality rating (Qi) with unit weight (Wi) linearly: $\mathrm{WQI} = (\sum_{i=1}^{i-n} \mathrm{Wiqi}$ ……………………………………….... *eq*.(3.3)

Generally, WQI discussed for a specific and intended use of water. In this study the WQI for drinking purposes is considered and permissible WQI for the drinking water is taken as 100:

$$Overall WQI = (\frac{\sum q_i w_i}{\sum w_i})$$ ………………………………………………..……………….*eq*.(3.4)

Table 3.1: Water Quality Index

Rank	WQI value
Excellent	<50
Good	50-100
Poor water	100-200
Very poor water	200-300
Unsuitable for drinking	>300

(Yisa and Tijani, 2010)

4 Results and Discussions

4.1 Phiso-chemical results of source, reservoir and tap water sample

4.1.1 Total dissolved Solids (TDS)

There is no health-based limit for TDS in drinking water. Hence, TDS occurs in drinking water in concentrations considerably below harmful effects. However, water with TDS levels of less than 100 mg/L is typically considered to be good in terms of palatability(WHO,2008) . The mean concentration of TDS of the study area ranged from 67.3-190.9 mg/l in water samples. The highest TDS value (190.9 mg/l) is recorded at the source. The TDS at the source and water tap sample is higher than the TDS in reservoir sample. However, the health risks are not significant as the value of TDS is much less than 1,000 mg/l, which is the WHO and NDWQS maximum permissible limit. The TDS values of water in present study are higher than the results of previous studies, i.e the mean TDS records of various cities water sources, TDS at Nekemte is 48 mg/ l67.79 mg/l at Damot Sore Woreda and 150.7 mg/l in Tula sub city.

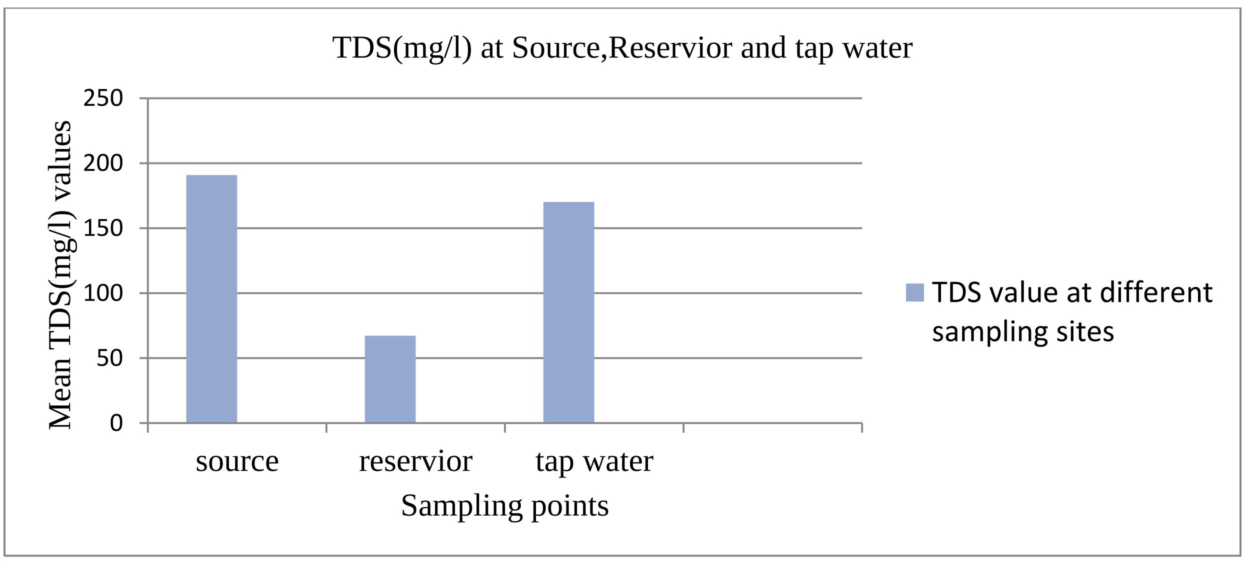


Figure 4.1 Total dissolved solid result of source, Reservoirs and Tap waters

4.1.2 Turbidity

Source samples had turbidity levels ranging from 10 to 45 NTU, with a mean of 24.5 NTU, which was greater than the WHO's recommendation (<5NTU) and (<7 NTU) by NDWQS. The mean turbidity value at the reservoir and tap water, on the other hand, is determined to be within the permissible limits of 1.55NTU and 2.48NTU, respectively (figure 4.2). Turbidity is generated by sewage matter in water, which raises the danger of pathogenic organisms being shielded by turbidity particles and therefore escaping the disinfectant's effect.

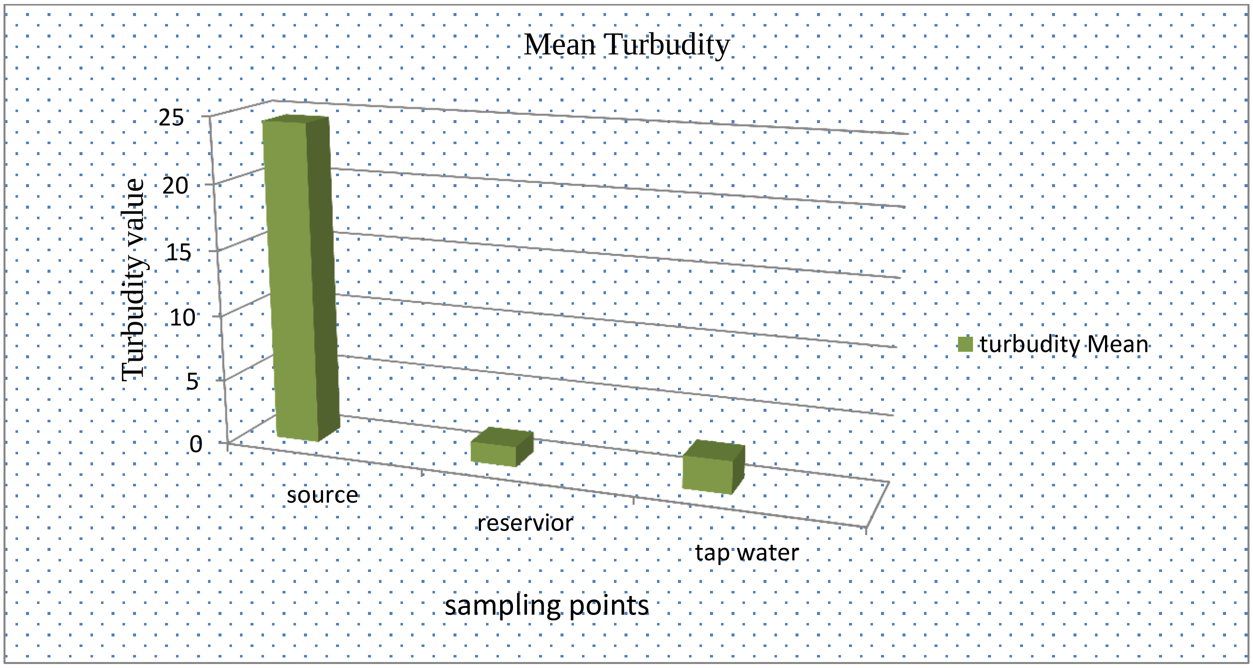


Figure 4.2 Mean Turbidity of Source, Reservoirs and Tap waters

4.1.3 Electrical conductivity (EC)

Electrical conductivity (EC), a measure of water's ability to conduct an electric current, is related to the amount of dissolved minerals in the water, although it does not tell which element is present.A higher EC value, on the other hand, indicates the presence of pollutants like sodium, potassium, or chloride (Orebiyi,et al.,2010). The samples from the Hawassa water source have a mean EC value of 339, with maximum and minimum values of 243 and 569 (µS/cm), as shown in the figure below. The average EC for the Hawassa water reservoir is 72.75 µS/cm, with a range of 35 to 115 S/cm. Similarly, the average EC value of Hawassa tap water is 338.67 S/cm, with a range of 166 to 388 µS/cm. When compared to the WHO and NDWQS standard, the tested values for Hawassa drinking water at source and tap water is within permissible limit.

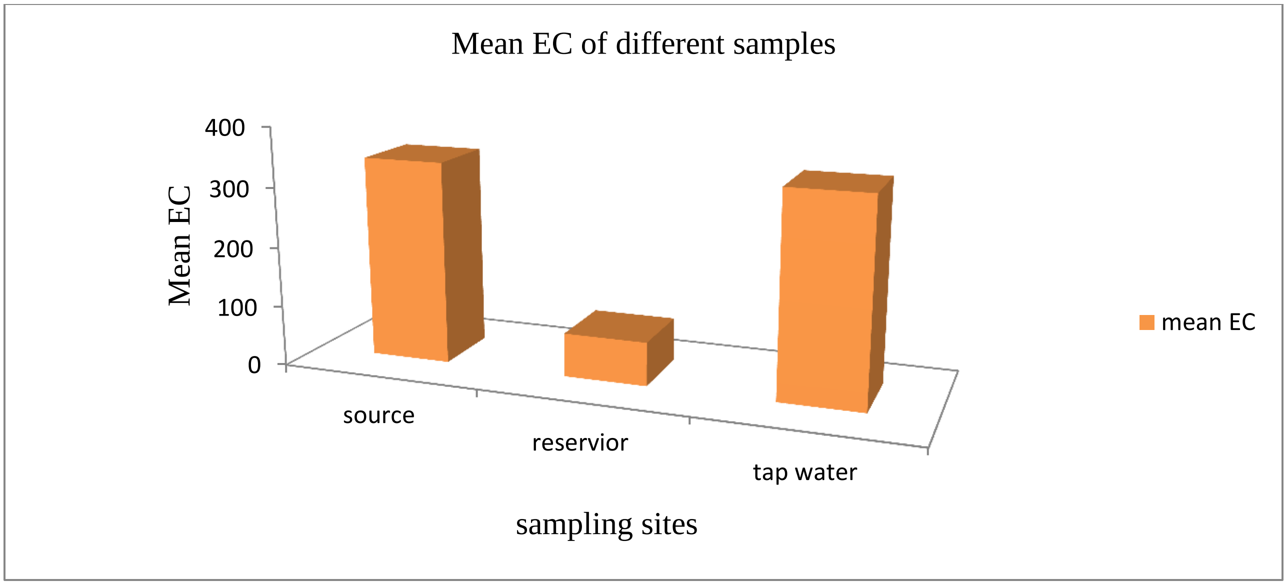


Figure 4.3 Mean Electric Conductivity Values of Source, Reservoirs and Tap waters

4.1.4 Temperature

Temperature is one of the physico-chemical factors used to determine the quality of drinking water. As the temperature of the water rises, so does disinfectant demand and microbial activity, decreasing the water's palatability (Daniel, et al., 2016). The results, however, demonstrate that all of the temperature values for the hawassa water samples from several samples are outside the WHO recommendation limit. Temperature of the source had a range of 21-22.8 ^{o}C, which corresponded to the water source's minimum and maximum temperature. Similarly, the reservoir and tap water samples have temperatures of 21 ^{o}C to 24 ^{o}C and 21 ^{o}C to 23 ^{o}C, respectively, which are not within the acceptable temperature range (WHO, 2006). Most sampled sites had temperature variations from the sources to the water taps, and this characteristic did not meet the WHO requirement of 15 degrees Celsius. At the reservoir (New reservoir 1) sample, the maximum temperature (24°C) was observed (shown on the figure 4.2 below). The climate in the tropics is characterized by high temperatures and rainfall, which may have contributed to the high temperatures recorded in water samples from various Ethiopian cities (Duressa et al.,2019).Similarly, earlier research in the Damot sore woreda of the south regional state (Meseret Bekele et al., 2018) reported a mean temperature of 23.27 ^{o}C.

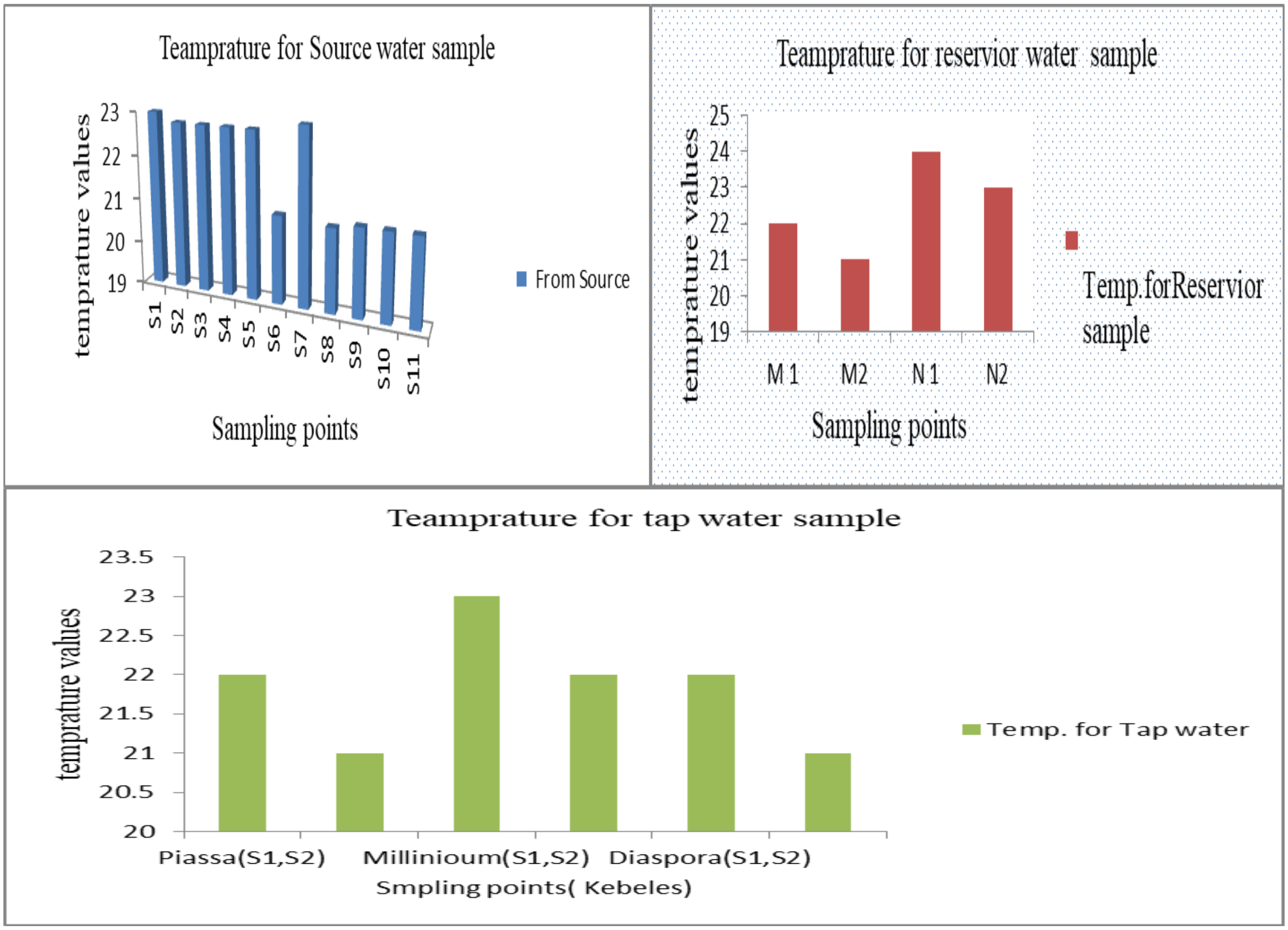


Figure 4.4 Temperature Variation of Source, Reservoirs and Tap waters

4.1.5 PH

The pH scale is based on the use of neutral chemicals as a starting point. The p H of alkaline or basic compounds is greater than 7.0. (7.1-14.0). the p H value of acidic compounds is less than 7.0. (0-6.9). PH adjustment is a common method in water treatment, and it's one of the most important operational elements for water treatment processes including disinfection and flocculation (Daniel et al., 2016). According to the WHO, the lowest and maximum permissible p H for drinkable water ranges from 6.5 to 8.5 (WHO, 2008). The PH range of all water samples was 6.5–7.99 but, the mean pH result increased from source to tap water (figure 4.5). Were no significant differences between sampling stations and the pH levels in this research area meet WHO and national guidelines.

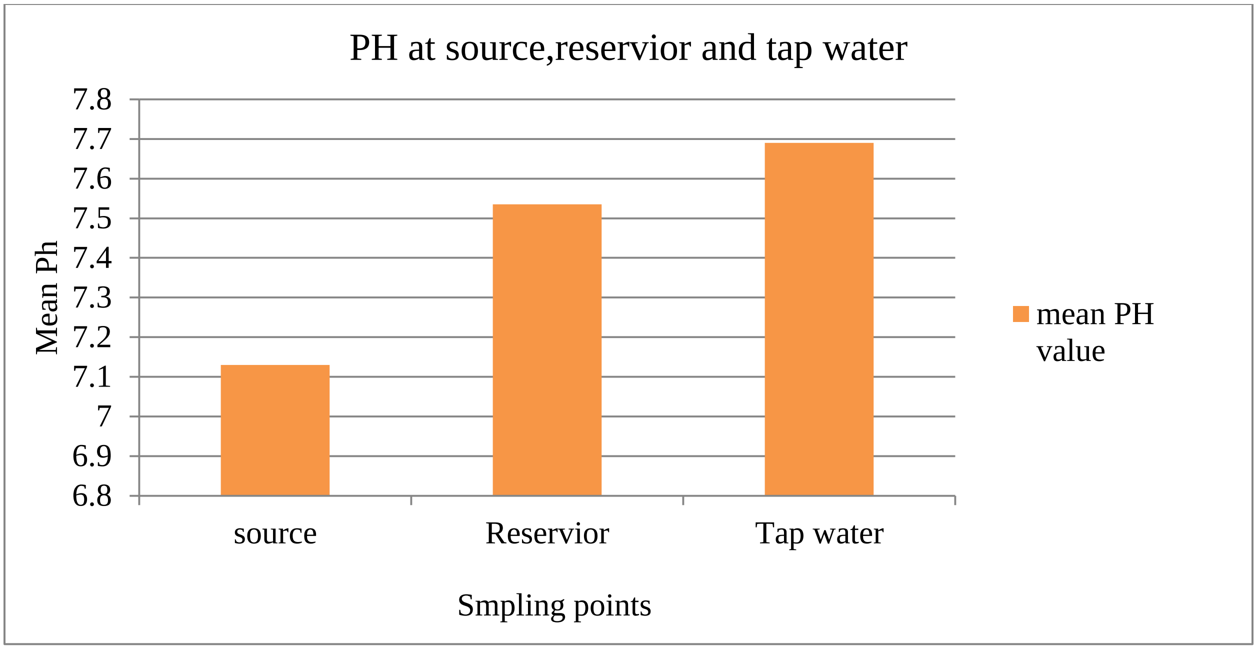


Figure 4.5 Mean Ph of Source, Reservoirs and Tap waters

4.1.6 Calcium and Magnesium

Calcium is derived from both natural and human sources. When water flows inside an aquifer, it could be internal. According to the study's laboratory results, the average calcium levels in source, reservoir, and tap water are 72.31 mg/l, 32.1 mg/l, and 21.3 mg/l, respectively. The source water (abella wondo No2 well with 160mg/l) has a maximum calcium value that does not meet the WHO's calcium limit for drinking water (WHO, 2008). These variations might originate from geological contents of the well. All samples from the Reservoir and water taps, on the other hand, are within the recommended level of 75 mg/l. Magnesium, on the other hand, was found to have a mean value of 9.9 mg/l, 12 mg/l, and 10.33 mg/l for the source, reservoir, and tap water, respectively, in this investigation.

Magnesium was found to have a mean value of 9.9 mg/l, 12 mg/l, and 10.33 mg/l in this study's source, reservoir, and tap water samples, respectively. This implies that the magnesium level is within the acceptable range and has no negative health consequences.

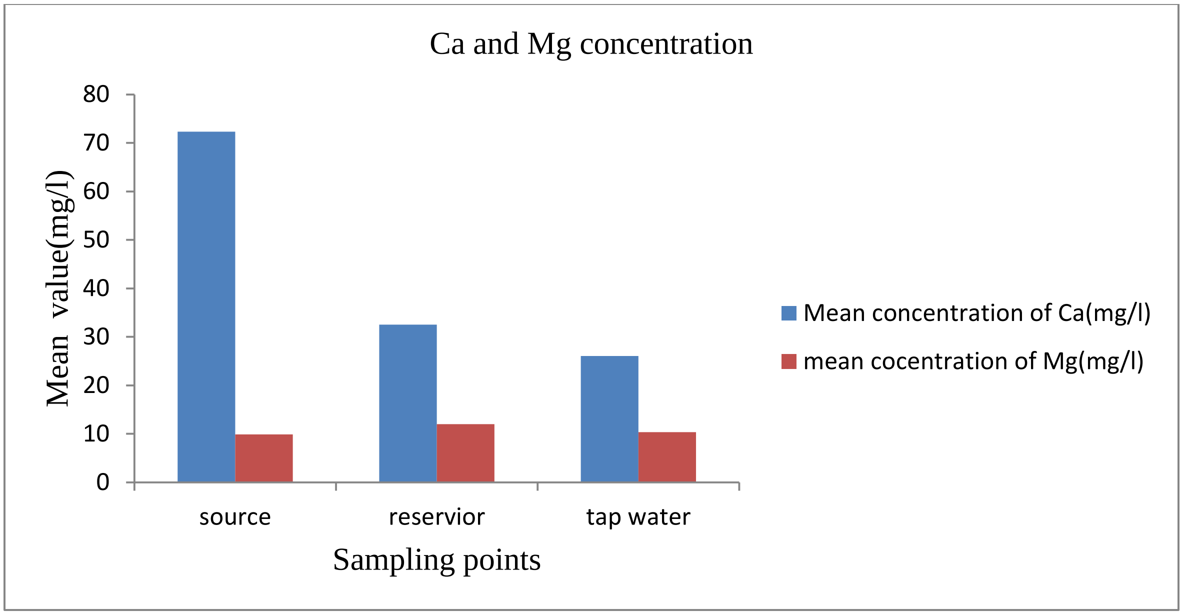


Figure 4.6 Mean Ca and Mg value for sampled water

4.1.7 Total hardness

It represents the total amount of calcium and magnesium ions in the body. Hardness was originally tested and analyzed in raw water sampling as a proxy for water quality in terms of precipitating soap.

Table 4.1 Hardness category

No	Concentration(Mg/l)	Hardness category
1	0-50	Soft water
2	50-150	Moderately hard
3	150-300	Hard water
4	>300	Very hard water

The highest permissible limit of total hardness as CaCo3 according to the WHO,2008 is 300mg/l. According to laboratory result of this study, the mean total hardness at the source, reservoir, and tap water is 89.86, 30 Mg/l, and 52.50 Mg/l, respectively. The degree of hardness of the Hawassa city water supply can be categorized as moderately soft water, which is not detrimental to users, according to WHO regulations.

4.1.8 Alkalinity

Extremes in these ranges are tolerated in water sources, with alkalinity values ranging from 5 to 125 mg/l being normal. The maximum acceptable permitted value of CaCo3 should not exceed 200mg/l, according to the WHO standard guideline for drinking water potability. The total alkalinity of the Hawassa City Water Supply samples ranged from 124 to 280 mg/l of CaCo3 at the source sample, 125 mg/l to 230 mg/l at the reservoir sample, and 195 mg/l to 310 mg/l at the tap water sample, according to laboratory test results. based on the result of this study one source sample from the source,samples from New Reservior1 and 2 and sample from pissa kebele Sample 2 did not meet the standerd set by WHO and NDWQS.

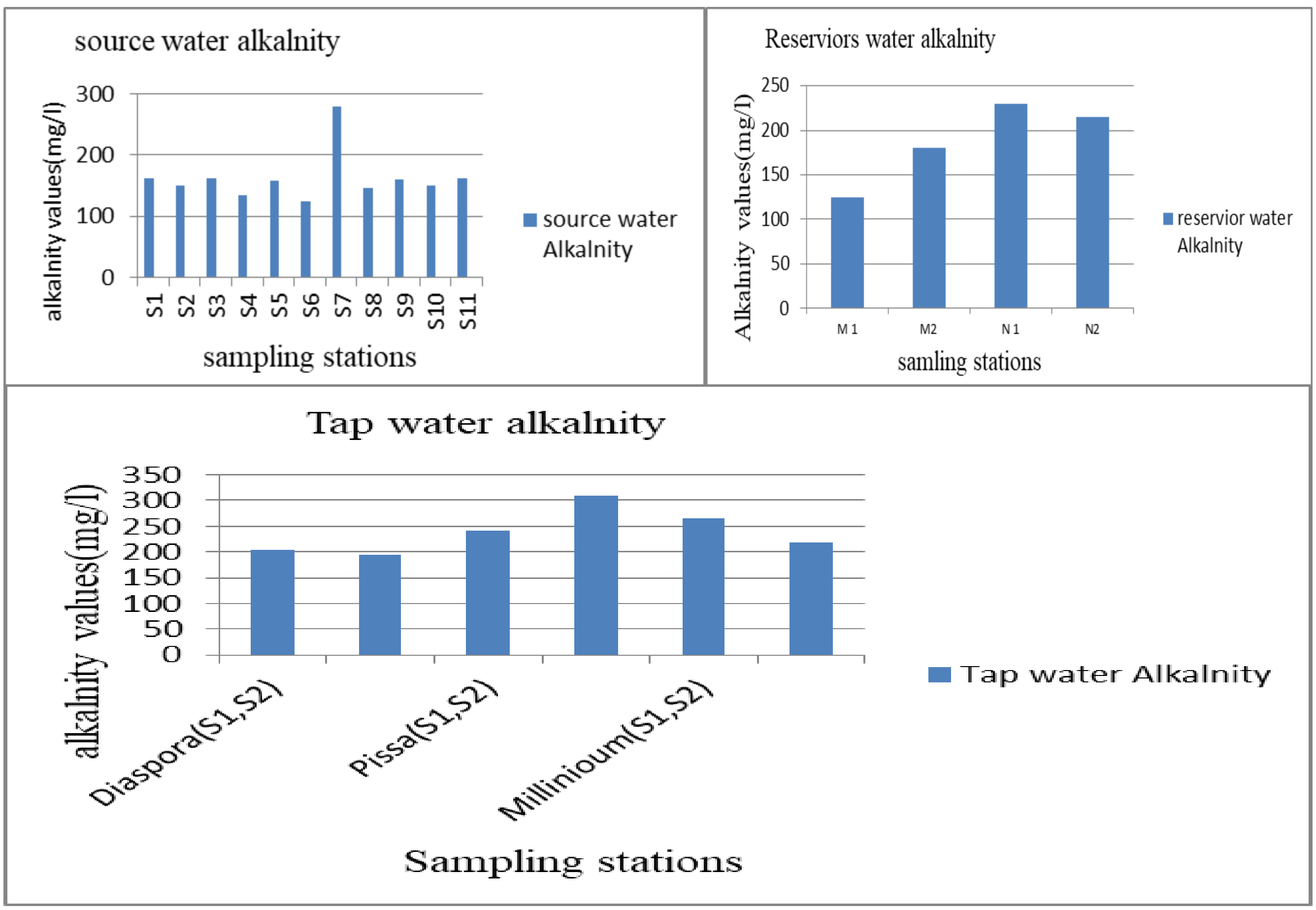


Figure 4.7 Alkalnity values at different sampling sites

4.1.9 Fluoride

The fluoride concentration of the water sources in Hawassa city ranged from 0 to 3.9 mg/l. The sources bokoAlamura well had a fluoride concentration of 3.9 mg/l, which was above WHO and national standards. The WHO recommends a fluoride concentration of 1.5 mg/l, but Ethiopian drinking water recommendations demand a concentration of less than 3 mg/l (O Aga,2018). Other water tests (reservoir and water tap samples) came up short of the acceptable limit. The fluoride levels in this study exceeded the maximum values of Damot sore wereda (1.13 mg/l) (meseret bekele,et al,2016) and ADA"A WOREDA(0.63 mg/l) water sources. 2016 (Daba Desissa).

4.1.10 Nitrate (NO_3)

Runoff from fertilizer use, sewage leakage, and erosion of natural deposits are the main sources of nitrates in drinking water (Ocheli et al., ,2020) The mean nitrate levels of Hawassa's water source, reservoir, and water tap are 3.78, 2.73, and 2.23 mg/l, respectively, according to laboratory results (figure 4.8). All of the samples tested were found to be within WHO and Ethiopian standards. Guideline advice water with nitrate concentration above 10 mg/l nitrate - N will cause Methaemoglobinaemia up on the users (O Aga, 2018).As a result; referring the guideline there is no nitrate problem in Hawassa's drinking water supply, according to the findings.

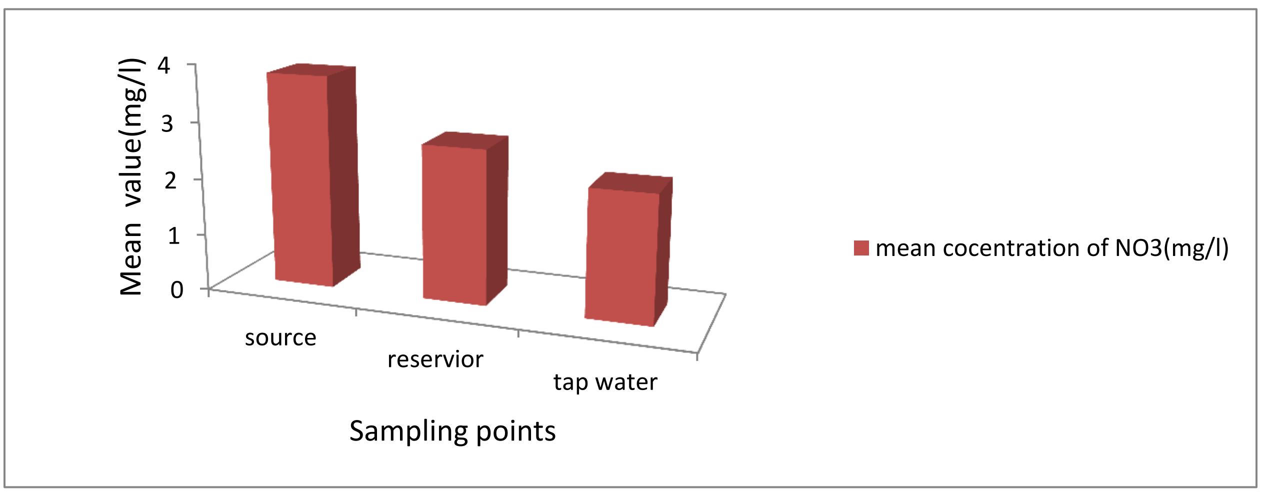


Figure 4.8 No_3 mean for sampling sites

4.1.11 Sulphate (SO_4)

There are no health-based guidelines for sulphates.However,since ingestion of drinking water with a high concentration of sulphate can cause gastrointestinal effects, it is recommended to inform the health authorities of drinking water sources with a sulphate concentration of more than500 mg/l. The presence of sulfate in drinking-water may also cause noticeable taste and may contribute to the corrosion of distribution systems (WHO, 2008).The laboratory result of the study shows that the mean sulphate level of source, reservoir and tap water of hawassa water supply is 4.63mg/l, 7mg/l and 0.31mg/l (figure 4.9) respectively. The highest mean value is recorded at the reservoir sample. However, referring the standards set by WHO the study area has no problem related to sulphate.

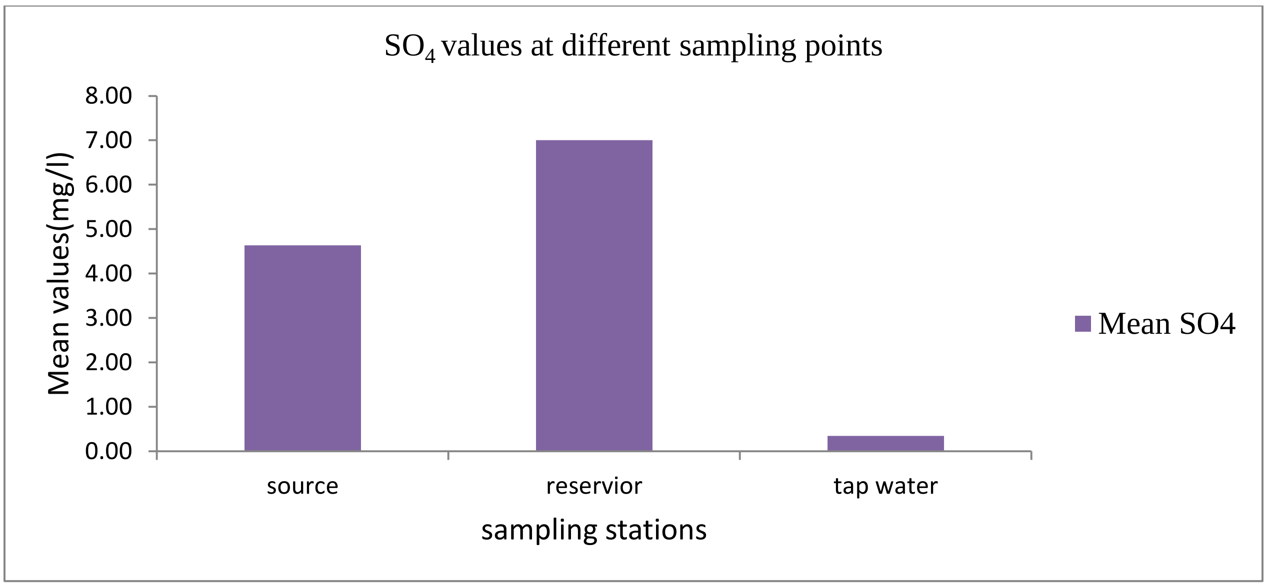


Figure 4.9 Sulphate mean for the samplings

4.1.12 Phosphate (PO_4)

Orthophosphate, condensed phosphate, and organically bound phosphate are the most common forms of phosphorus in water. Phosphorus is released in phosphate form as a result of microbial detraction of organic materials. Phosphorus' importance stems from its capacity to promote eutrophication in the presence of other nutrients, particularly nitrogen. The only purpose of phosphorus quality criterion in water is to prevent undesired algal growth (Nkansah.et.at, 2010).In this analysis, the mean phosphate concentrations for source, reservoir, and water tap samples were 0.38 mg/l, 0.43 mg/l, and 0.54 mg/l, respectively. Higher concentration of phosphate observed at the tap water (0.54 Mg/l). The observed value which was higher than the permissible level recommended by the WHO and ES for drinking water The household tap water had a greater phosphate concentration than the source and reservoirs samples, indicating that there is phosphate ion pollution in the supply network, as seen in the figure below (figure). The mean phosphate value for Hawassa water supply, on the other hand, does not differ much from prior findings (Gonfa Gonfa et al.,2019 in Nekemte, Oromia and Meseret Bekele et al.,2018 in Damot sore wereda drinking water supply).

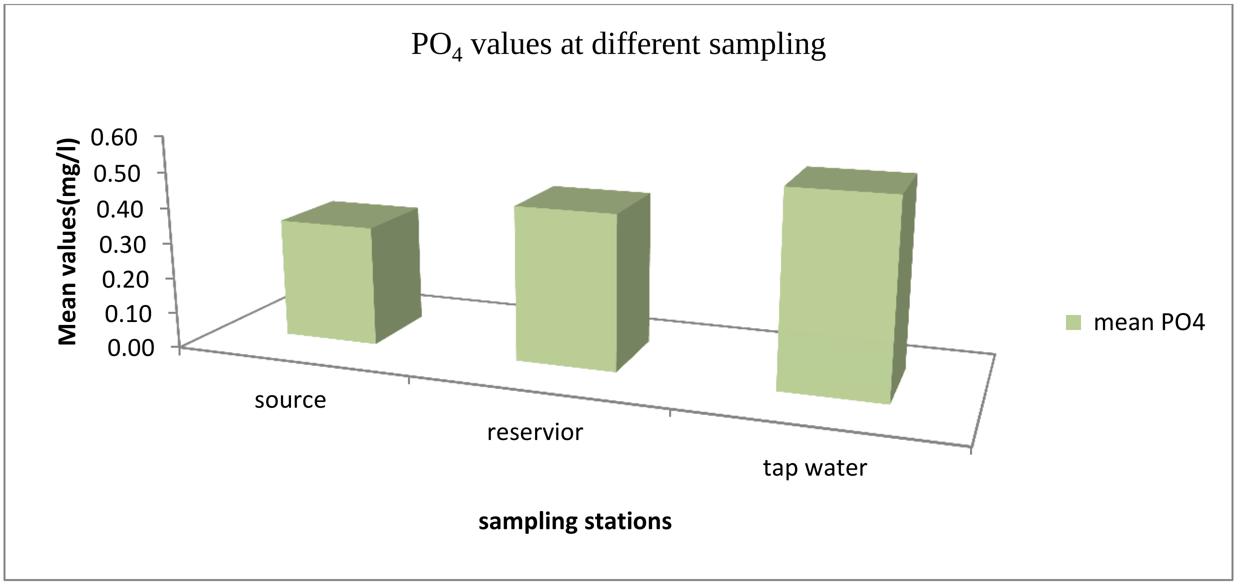


Figure 4.10 Phosphate mean values of samplings

4.1.13 Residual chlorine

In the distribution networks of any water supply, the World Health Organization recommends a minimum free chlorine residual of 0.2 mg/L and a maximum residual chlorine of 0.5 mg/L (www.Safewater.Org). Several studies have found that when residual chlorine levels fall below recommended levels, a variety of water quality issues might arise. In terms of public health, bacteria and viruses known as bacteriophage can multiply in water that hasn't been thoroughly disinfected. Furthermore, depending on the species, it may be capable of causing waterborne infections.

the Ethiopian drinking quality standard also recommends the Residual chlorine in drinking water should be 0.5 mg/l. However, In this study, the mean free residual chlorine (FRC) concentration of water samples from the reservoir and the tap was 0.08 mg/l and 0 mg/l, respectively.. , these values were less than the maximum concentration set by WHO and ES. This indicates that the water can be recontamination and there is no reserved chlorine that can disinfect it which may lead the consumer to water related disease. The result found is also less than the findings reported in the previous studies. For example, at main distribution tank of Nekemte (0.23mg/l and 0.28mg/l) respectively (Gonfa Duressa et al,2019).

Table 4.2: Bacteriological analysis result

sampling kebeles			
Diaspora	Total coliform/100ml	feacal coliform/100ml	Remark
S1	Nill	Nill	no risk
S2	Nill	Nill	no risk
Pissa			
S1	Nill	Nill	no risk
S2	Nill	Nill	no risk
Millinioum			
S1	Nill	Nill	no risk
S2	Nill	Nill	no risk

4.2 Evaluation of water quality index in the study area

Water quality data is extremely significant for policy adjustment, thus the Water Quality Index (WQI) is the most convenient way to transmit the quality of water resources for consumption. Several water quality indices have been established by national or international organizations over the years and are used to assess water quality in various scenarios. The WQI and overall

WQI of all the samples obtained, as determined using the procedures given above, are shown in Figure 4.11.The WQI of Hawassa's drinking water supply is within acceptable limits (100), according to the findings of this research. The WQI was classified into five categories, ranging from "excellent water quality" to "unfit for use water."

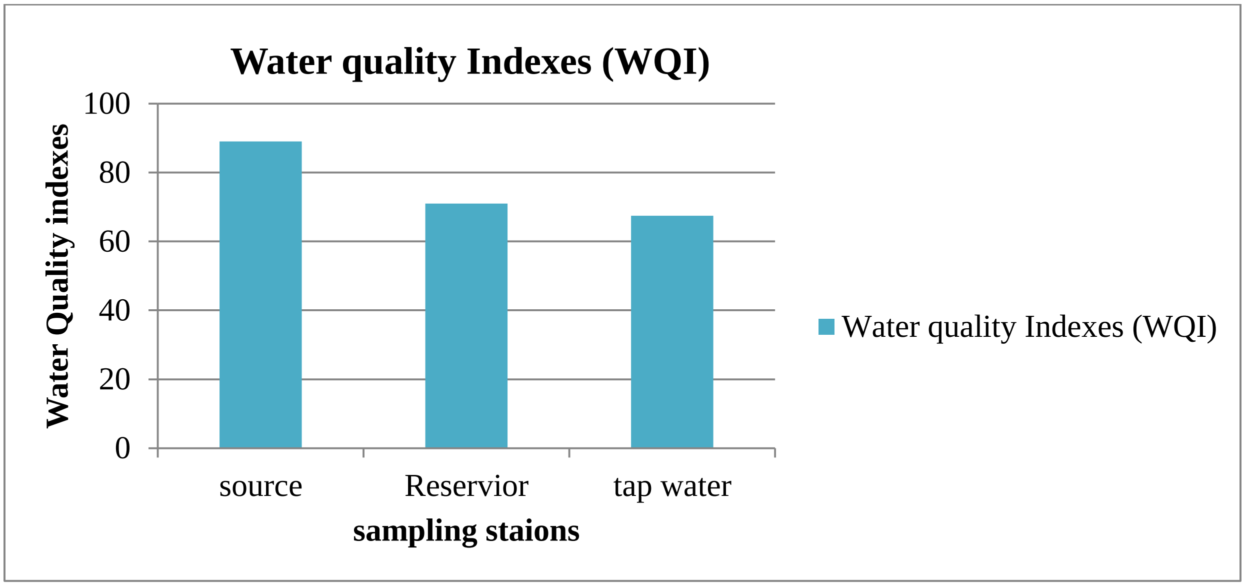


Figure 4.11 Water quality indexes result of Hawassa drinking water

The indices were created primarily to reflect changes in surface water physicochemical quality. They also, however, be utilized as aspects of environmental change. Within an aquatic system, there are temporal variations. The impact of this modification on the system can be measured by linking water quality to potential water use (Al-Janabi, 2012). In this study area, average WQI scores (ranging from 67.5 to 89) suggest that water quality for drinking purposes is good to fair

5 CONCULUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The study aimed to assess the drinking quality (by Considering physical, chemical and bicteroligical drinking water parametres) of Hawassa city, Ethiopia The drinking water quality parameters from source, main Reservoirs and tap water of Hawassa city water supply were analyzed by on-site measurement and experimental analysis. The result of the finding revealed that majority of the water quality parameters were within the permissible limit of both WHO and Ethiopian drinking water quality standards. These are: Total dissolved solids (TDS),Electric conductivity (EC), Ph, Total Hardness(TH), Phosphate (PO_4),Nitrate (No_3),Sulphate (So_4) ,Calcium (Ca) and magnesium(Mg)).However, there are some physio-chemical parameters *(*Temperature, Turbidity fluoride at one well source and residual chlorine) that are not inconformity with the standards. All the water samples from source, reservoir and tap water has has above 15 ^oC. The highest mean turbidity (24.5 NTU) is measured at the source sample. However the samples from reservoir and tap water has allowable turbidity limit (1.55NTU and 2.48 NTU respectively). 0.08 mg/l and 0 mg/l free residual chlorine is recorded at tap water samples and this indicates that insufficient amount of chlorine is added at the treatment plant and might lead recontamination of drinking water and cause health issues for the user. On the other hand, the result showed that the sample analyzed is not contaminated with both total and feacal coliform which is also an indication the water supply is well protected from the human excreta and animal wastes. All over average values of WQIs in this study area for source, reservoir and tap water were 89, 71 and 67.5 respectively. Therefore, the finding of this study showed that the drinking water quality of hawassa city can be rated good and fair based on the water quality indexs classifications.

5.2 Recommendation

To improve Hawassa City water supply system, quality analysis and operational modifications will be are very crucial. Based on the assessment result the following sets of recommendations are drawn to eternally modify Hawassa water supply system:

i. Documentation of data with simple and reliable method is another way of creating a well-organized management and a key for conducting various tasks at a time; otherwise, it hinders lot of activities through time, cost and quality. Therefore, every piece evident shall be recorded and documented for setting out different target plans.

ii. The result of this study depicted that, the amount of residual chlorine in the distribution system was below the limiting value. This indicates there might be recontamination of drinking lead to health issue for the users. Therefore, enough amount of chlorine should be added in the Reservoir to have adequate residual chlorine in the distribution system.

iii. Based on the study result, the fluoride amount on bokoAlamura well was above both the WHO and Ethiopian water quality standards. So, the water sector should be use DE fluorination technology or minimizing use of this source for drinking purpose to minimize the risk at the consumers.

iv. The status of the water quality is varying with in season due to different factors. This research was done in summer season due to research schedule. Therefore, further research should be done by considering in different season.

v. Regular checking of the water supply system is necessary so as to verify whether the Observed water quality is suitable for intended uses.

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APPENDIXES

Appendex1: Laboratory results of Source water samples

Source	TDS	Temperature	EC	Turbidity	PH	Ca	Mg	F	No3	So4	Po4	Total hardness	Alkalnity
Kedo river Treatment plant	250	23	265	25	7.5	85	13	1.32	0.95	0.55	0.13	66	162
abella wondo No1	170	22.8	282	30	7.16	74	10.35	1.3	1.29	0.1	0.64	94.8	150
abella wondo No2	218	22.8	282	45	7.03	160	2.35	1.47	4.16	7.29	0.77	105.84	162
abella wondo No3	190	22.8	282	55	7.26	130	11.04	0.9	3.25	17.28	0.38	94	134
Qarara	188	22.8	282	26	6.99	130	9.6	0.67	0.43	2.55	0.25	66	158
mette	152	21	243	12	6.55	60	16	0.56	4.35	1	0.25	68	124
BokoAlamura	320	23	569	33	7.46	25.6	10.4	3.9	0.25	1.11	0.24	136	280
Yuwo	170	20.9	470	8.5	7.35	24	12.15	0.8	7.04	3	0.17	110	146
Gara Riqata	180	21	360	13	7.35	14.4	8.262	0.66	4.84	5	0.06	70	160
Gara Riqata	230	21	310	12	7.65	26.4	9.234	0.71	6.16	5	0.2	104	150
spring source	91	21	310	10	6.5	66	9.6	0	5.99	4	0.41	50	162

Appendex2: laboratory results of reservoir water sample

Reservoirs	Main 1	Main 2	New 1	New 2
Parameters	measured value			
TDS	104.2	78	61	26
Temp.	22	21	24	23
EC	115	95	46	35
Turbidity	2.21	1.18	1.4	1.41
PH	7.6	7.52	7.57	7.45
Ca	34	32	28	36
Mg	13	17	9	9
F	1.52	1.6	1.06	1.01
No3	2.6	2.3	3.2	2.8
SO4	14	2	5	Nill
Po4	0.18	0.9	0.47	0.18
TH as CaCO2	10	25	65	20
Alkalinity	125	180	230	215
Residual chlorine	0.07	0.06	0.06	0.13

Appendex3: laboratory Results of Tap water sample

sampling points	TDS	temprature	EC	Turbidity	PH	Ca	Mg	F	No3	So4	Po4	Total hardness	Alkalnity	Residual chlorine
Diaspora														
S1	180	22	360	2.84	7.99	26	13	1.32	2.9	0.1	0.41	55	205	0
S2	194	21	388	3.03	7.98	20.38	12	1.3	3	2	0.7	65	195	0
Pissa														
S1	186	23	372	2.4	7.67	38.42	8	1.47	1.96	0	0.49	50	240	0
S2	188	22	366	2.38	7.52	19.2	10	0.9	1.82	0	0.56	40	310	0
Millennium														
S1	190	22	380	2.16	7.53	10.4	10	0.71	2.08	0	0.44	50	265	0
S2	83	21	166	2.05	7.44	16	9	0.56	1.64	0	0.61	55	220	0

Appendex4:. Summary Mean value of physic-chemical parameters for the source, reservoir tap water samples.

Parameter	Units	Source 12		Reservoir 4		Tap water 6		Standard	
		Mean	Std	Mean	Std	Mean	Std	ES	WHO
TDS	Mg/l	190.90	58.82	67.30	32.77	170.17	42.95	1000	1000
Temp.	Mg/l	21.91	0.98	22.50	1.29	21.83	0.75	-	<15
EC	Mg/l	339	99.68	72.75	38.39	338.67	85.17	1500	1000
Turbudity	Mg/l	24.45	16.21	1.55	0.45	2.48	0.38	7	5
PH	Mg/l	7.13	0.37	7.54	0.07	7.69	0.24	6.5-8.5	6.5-8.5
Ca	Mg/l	71.04	52.08	32.50	3.42	21.73	9.66	-	75
Mg	Mg/l	9.90	3.40	12.00	3.83	10.33	1.86	50	50
F	Mg/l	1.10	1.06	1.30	0.31	1.04	0.37	3	1.5
No3	Mg/l	3.776	2.43	2.73	0.38	2.23	0.58	50	50
SO4	Mg/l	4.633	4.95	7.00	6.24	0.35	0.81	-	250
Po4	Mg/l	0.337	0.22	0.43	0.34	0.54	0.11	0.02	0.05
TH as CaCO3	Mg/l	89.864	25.95	30.00	24.15	52.50	8.22	300	300
Alkalinity	Mg/l	162.5	40.88	187.50	46.64	239.17	42.83	-	200
Residual chlorine	Mg/l	4.51	4.04	0.08	0.03	0.00	0.00	0.5	0.2-0.5

Appendex5: Water quality index analysis for source sample

Parametres	Sn	1/Sn	Sum(1/Sn)	K=1/sum(1/Sn)	Wi=K/Sn	Ideal valve	Vn	Vn/SN	Vn/SN*100=Qn	Wn*Qn	WQI=Wn*Qn/sum (Wn)
TDS	1000	0.001	2.12	0.47	0.00	0	190.9	0.19	19.1	0.01	89.06
Temp.	15	0.067	2.12	0.47	0.03	0	21.91	1.46	146.1	4.60	
EC	1000	0.001	2.12	0.47	0.00	0	339	0.34	33.9	0.02	
Turbudity	5	0.200	2.12	0.47	0.09	0	24.45	4.89	489.0	46.16	
PH	8.5	0.118	2.12	0.47	0.06	7	7.13	0.37	37.0	2.05	
Ca	75	0.013	2.12	0.47	0.01	0	26.08	0.35	34.8	0.22	
Mg	50	0.020	2.12	0.47	0.01	0	9.8986	0.20	19.8	0.19	
F	1.5	0.667	2.12	0.47	0.31	0	0.934	0.62	62.3	19.59	

No3	50	0.020	2.12	0.47	0.01	0	3.776	0.08	7.6	0.07	
SO4	250	0.004	2.12	0.47	0.00	0	4.633	0.02	1.9	0.00	
Po4	1	1.000	2.12	0.47	0.47	0	0.337	0.34	33.7	15.91	
TH as CaCO2	300	0.003	2.12	0.47	0.00	0	89.864	0.30	30.0	0.05	
Alkalinity	200	0.005	2.12	0.47	0.00	0	162.6	0.81	81.3	0.19	

Appendix 6. **Water quality index analysis for Reservior samples sample**

	Sn	1/Sn	Sum(1/Sn)	K=1/sum(1/Sn)	Wi=K/Sn	Ideal value	(Vn)	Vn/SN	Vn/SN*100=Qn	Wn*Qn
TDS	1000	0.00	2.12	0.47	0.00	0	67.3	0.07	6.73	0.00
Temp.	15	0.07	2.12	0.47	0.03	0	22.5	1.50	150.00	4.72
EC	1000	0.00	2.12	0.47	0.00	0	72.8	0.07	7.28	0.00
Turbudity	5	0.20	2.12	0.47	0.09	0	1.6	0.31	31.00	2.93
PH	8.5	0.12	2.12	0.47	0.06	7	7.5	1.00	100.00	5.55
Ca	75	0.01	2.12	0.47	0.01	0	32.5	0.43	43.33	0.27
Mg	50	0.02	2.12	0.47	0.01	0	12.0	0.24	24.00	0.23
F	1.5	0.67	2.12	0.47	0.31	0	1.6	1.05	105.33	33.14

No3	50	0.02	2.12	0.47	0.01	0	2.7	0.05	5.45	0.05
SO4	250	0.00	2.12	0.47	0.00	0	7.0	0.03	2.80	0.01
Po4	1	1.00	2.12	0.47	0.47	0	0.4	0.43	43.25	20.41
TH as CaCO2	300	0.00	2.12	0.47	0.00	0	30.0	0.10	10.00	0.02
Alkalinity	200	0.01	2.12	0.47	0.00	0	187.5	0.94	93.75	0.22

Appendix 7. Water quality index analysis for tap water samples

Parameters	Sn	1/Sn	Sum(1/Sn)	K=1/sum(1/Sn)	Wi=K/Sn	Ideal value	(Vn)	Vn/SN	Vn/SN*100=Qn	Wn*Qn
TDS	1000	0.00	2.12	0.47	0.00	0	67.3	0.07	6.73	0.00
Temp.	15	0.07	2.12	0.47	0.03	0	22.5	1.50	150.00	4.72
EC	1000	0.00	2.12	0.47	0.00	0	72.8	0.07	7.28	0.00
Turbudity	5	0.20	2.12	0.47	0.09	0	1.6	0.31	31.00	2.93
PH	8.5	0.12	2.12	0.47	0.06	7	7.5	1.00	100.00	5.55
Ca	75	0.01	2.12	0.47	0.01	0	32.5	0.43	43.33	0.27
Mg	50	0.02	2.12	0.47	0.01	0	12.0	0.24	24.00	0.23
F	1.5	0.67	2.12	0.47	0.31	0	1.6	1.05	105.33	33.14
No3	50	0.02	2.12	0.47	0.01	0	2.7	0.05	5.45	0.05
SO4	250	0.00	2.12	0.47	0.00	0	7.0	0.03	2.80	0.01
Po4	1	1.00	2.12	0.47	0.47	0	0.4	0.43	43.25	20.41
TH as	300	0.00	2.12	0.47	0.00	0	30.0	0.10	10.00	0.02

CaCO2										
Alkalinity	200	0.01	2.12	0.47	0.00	0	187.5	0.94	93.75	0.22

Where,

Sn=Base standard

vo=ideal value

Vn=mean concentration(measured)

Wi=unit weight for each parameter

Figure: on-site sample measurement

figure: Sample parameter measurement in laboratory

Figure: Hawassa water supply Reservoirs

Figure: Collected samples from different tap waters

HAWASSA UNIVERSITY
INSTITUTE OF TECHNOLOGY
Department of Water supply and Environmental Engineering
ENVIRONMENTAL ENGINEERING LABORATORY
Aim:Water Quality Analysis
Sampling Date: 10-15/12/2013 E.C and 16-18/12/2013
sampled by: Fantahun Yehune and Yirged Antehun.

	source	TDS	Temprature	EC	Turbudity	PH	Ca	Mg	F	No3	So4	Po4	Total hardness	Alkalnity
1	Kedo river Treatment plant	250	23	265	25	7.5	85	13	1.32	0.95	0.55	0.13	66	162
2	abella wondo No1	170	22.8	282	30	7.16	74	10.35	1.3	1.29	0.1	0.64	94.8	150
3	abella wondo No2	218	22.8	282	45	7.03	160	2.35	1.47	4.16	7.29	0.77	105.84	162
4	abella wondo No3	190	22.8	282	55	7.26	130	11.04	0.9	3.25	17.28	0.38	94	134
5	qarara	188	22.8	282	26	6.99	130	9.6	0.67	0.43	2.55	0.25	66	158
6	mette	152	21	243	12	6.55	60	16	0.56	4.35	1	0.25	68	124
7	bokoAlamura	320	23	569	33	7.46	25.6	10.4	3.9	0.25	1.11	0.24	136	280
8	Yuwo	170	20.9	470	8.5	7.35	24	12.15	0.8	7.04	3	0.17	110	146
9	Gara Riqata	180	21	360	13	7.35	14.4	8.262	0.66	4.84	5	0.06	70	160
10	Gara Riqata	230	21	310	12	7.65	26.4	9.234	0.71	6.16	5	0.2	104	150
11	spring source	91	21	310	10	6.5	66	9.6	0	5.99	4	0.41	50	162

Analyzed by:
Fantahun Yehunie
Tibebu Desalegn

Approved by:

HAWASSA UNIVERSITY
INSTITUTE OF TECHNOLOGY
Department of Water supply and Environmental Engineering
ENVIRONMENTAL ENGINEERING LABORATORY
Aim:Water Quality Analysis
Sampling Date: 18/12/2013 & 19/12/2013
sampled by: Fantahun Y & Yirgad Antehun

	Sample Name	Main 1	Main 2	New 1	New 2
	parametres	measured value			
1	TDS	104.2	78	61	26
2	Temp.	22	21	24	23
3	EC	115	95	46	35
4	Turbudity	2.21	1.18	1.4	1.41
5	PH	7.6	7.52	7.57	7.45
6	Ca	34	32	28	36
7	Mg	13	17	9	9
8	F	1.52	1.6	1.06	1.01
9	No3	2.6	2.3	3.2	2.8
10	SO4	14	2	5	Nill
11	Po4	0.18	0.9	0.47	0.18
12	TH as CaCO2	10	25	65	20
13	Alkalinity	125	180	230	215
14	Residual chlorine	0.07	0.06	0.06	0.13

Analyzed by:
Fantahun Yehunie
Tibebu Desalegn

Approved by:
Tizita Girma
Water Supply & Environmental Engineering Department

Department of Water Supply & Environmental Engineering
Hawassa University Institute of Technology

Budget Summary

S/No.	Item	Unit	Quantity	Rate (Unit price)	Amount*	Link to Research Activity**	Comment*** (For Evaluator Only)	Invoices (in order with PDF version)
(A) Material and Supplies								
1	Printing	Number	200	0.3	60.00 €	This includes printing of research data, reports, photocopying data and scanning documents during research work and final Thesis.		**Invoice_1**
	coping	Number	800	0.25	200.00 €			
2	Scanning	Number	20	0.35	7.00 €			
3	binding	Number	3	5	15.00 €			
VAT (15%)					42.30 €			
4	Face mask	Number	150	0.55	82.50 €	Protection from covid-19 during the research period. Materials used in lab work.		
	sanitizer	litter	2	20	40.00 €			
	Glove	Number	45	2	90.00 €			
	eye safty glass	Number	1	40	40.00 €			
5	sampling bottle	Number	45	0.78	35.10 €			
VAT (15%)					43.40 €			
6	Internet	Day	90	1.9	171.00 €	For receiving & sending documents, literature and data downloading etc.		
VAT (15%)					25.65 €			
	Sub Total				**851.95 €**			
(B) Equipment								

7	lab analysis		15 parameter	25.00	375	15 drinking water quality parameters were analyzed in laboratory work		
	Sub Total				**375.00 €**			
(C) Travel + Visa Costs								
	filed transportation (car rent)	Day	30	23.66	**709.80 €**	I have rented a car for one month during the research period for the purpose of sample collection		
	Sub Total				**709.80 €**			
(E) Contingencies (%) (reserve at least $100 from which eventual bank transfer fees will be taken from								
Contingencies					100.00 €	Unexpected cost events that may arise during the research		
TOTAL								

A	Material & Supplies	851.90 €			
B	Data	375.00 €			
C	Travel				
D	Field Transportation	709.80 €			
E	Contingencies (%)	100.00 €			
	Grand Total	**2,036.70 €**			