EVALUATION OF DRINKING WATER QUALITY IN URBAN WATER SUPPLY SYSTEM FROM SOURCE TO END USERS: THE CASE OF BISHOFTU CITY, ETHIOPIA

BEHAILU KURABACHEW

A Thesis Submitted to

The Department of Water Resources Engineering

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Water Supply and Environmental Engineering

Office of Graduate Studies

Adama Science and Technology University

October 2024

Adama, Ethiopia

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DECLARATION

I hereby declare that this Master Thesis entitled “Evaluation of Drinking Water Quality in Urban Water Supply System from Source to End Users: The Case of Bishoftu City, Ethiopia ” is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Behailu Kurabachew ______________________ _______________

Name of student Signature Date

RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "Evaluation of Drinking Water Quality in Urban Water Supply System from Source to End Users: The Case of Bishoftu City, Ethiopia**"** prepared under my/our guidance Behailu Kurabachew -submitted in partial fulfillment of the requirements for the degree of Mater's of Science Water Supply and Environmental Engineering. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

Yemane G. Asfaha (PhD)	______________________	________________
Major Advisor	Signature	Date

APPROVAL PAGE

I, the advisor of the thesis entitled "**Evaluation of Drinking Water Quality in Urban Water Supply System from Source to End Users: The Case of Bishoftu City, Ethiopia**

" and developed by Behailu Kurabachew; hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Yemane G. Asfaha (PhD)	______________________	_______________
Major Advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis Bahilu Kurabachew have read and evaluated the thesis entitled "**Evaluation of Drinking Water Quality in Urban Water Supply System from Source to End Users: The Case of Bishoftu City, Ethiopia**

" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Water Supply and Environmental Engineering.

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ACKNOWLEDGEMENTS

First and foremost, I want to offer God all the glory for giving me an inexhaustible gift in life and the perseverance to go this far in my academic career. Next, I would like to express my sincere gratitude to Dr. Yemane G. Asfaha for his close advice, direction, and real aid with my paperwork from beginning to conclusion.

I'm also glad to convey my gratitude to the staff at the Bishoftu City Water office, especially Ms. Mulu Hika and his colleagues, whose candid remarks, ideas, and knowledge were crucial inputs for the study.

I appreciate the Adama Water and Sewage Authority's central laboratory team for their assistance with the experiment. I want to thank Mr. Gemeda Ayans and Gamechu Daba for their assistance and insightful criticism throughout the lab analysis.

Finally, I'd like to express my gratitude to my family, friends, and all the people in my community who helped me with my master's study to come to this level.

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LIST OF ACRONMYS AND ABBREVIATIONS

AFD	African Development Fund
APHA	American Public Health Association
CCME	Canadian Council Ministers of the Environment
DWAF	Department of Water Affairs and Forestry
ES	Ethiopia Standard
ES ISO	Ethiopia Standard International Standard Organization
FDRE	Federal Democratic Republic of Ethiopia
GIS	Geographical Information System
GPS	Global Positioning System
MCL	Maximum Contaminant Level
MoWRD	Ministry of Water Resource Development
MS EXCEL	Microsoft Excel
NTU	Nephelomethic Turbidity Unit
RADWQ	Rapid Assessment of Drinking Water Quality
UNEP	United Nations Environmental Program
UNICEF	United Nations International Children's Emergency Fund
WASH	Water, Sanitation and Hygiene.
WHO	World Health Organization
WHO	World Health Organization

ABSTRACT

Water quality refers to the physical, chemical, and biological factors that control how water is used in daily life. Water-related diseases are caused by tainted drinking water. The purpose of the study was to investigate Bishoftu City's drinking water supply system at both the source and the end user. A total of 45 water samples were taken from 31 homes (end-user outlets), 12 boreholes, and two reservoirs. Using the standard methods of analysis procedure, the samples' pH, Electrical conductivity (EC), Chloride, Magnesium (Mg^{2+}), Calcium (Ca^{2+}), Total Hardness, and Microbiological parameters (Total Coliform E- coli measured in colony forming units CFU) were all analyzed. All of the water samples had findings ranging from 7.9 to 6.32 pH, 358 to 491 s/cm electrical conductivity, 25 to 78 mg/l chloride, 78 to 127 mg/l calcium, 26 to 64 mg/l magnesium, and 181 to 350 mg/l total hardness. Except for calcium from all sources, all other physicochemical parameters complied with WHO guidelines and national standards. Moreover, the results revealed that all biological parameters were in compliance with the standards, excluding Escherichia coli (1- 7/100ml) at sample point 14 and sample point 15, and total coliform (1-22/100ml). Furthermore, the finding showed that the tap water samples were more contaminated as they were refilled from end users suggests that Bishoftu City water supply system is insufficiently treated at the end user. Regarding bacteriological water quality, bacterial coliforms and E-coli were found in outlet tap water samples, indicating that the water supply system requires treatment in the form of adding chlorine. Therefore, to reduce the hazards and problems associated with the current water quality, notably the bacteriological water quality and chlorine issue, the City water utility must give the Bishoftu city water supply system more attention.

Key Words: *Drinking Water Quality Parameters, Water* Quality Index, Water Supply, microbiological parameter,

CHAPTER ONE

INTRODUCTION

1.1 Background

One of the most significant biotic elements of the environment is water. Only 3% of the world's water is deemed fresh; of that, 2.97% is located in glaciers and ice caps. Approximately 97% of the total water is found in oceans, which is unfit for human use. Only 0.03% of the remaining small part is available for human use as surface and groundwater (Muhammad et al., 2013). A fundamental element of good health and a basic human right is access to clean drinking water (WHO, 2011). Additionally, it is difficult to picture a sterile and clean atmosphere without water. Access to clean drinking water is a vital requirement for good health and a fundamental human right.

Many regions of the world already have limited supplies of fresh water. It will become increasingly more constrained in the following century due to rising population, urbanization, and climate change (Jackson et al., 2019). Unfortunately, due to rapid population growth, industry expansion, and the discharge of wastewater and chemical effluents into water courses and other water sources in developing nations like Ethiopia, the drinking quality of water is continuously deteriorating and dangerous for human consumption. Recent estimates indicate that the amount of water available in emerging parts of Africa, the Middle East, and South Asia is significantly declining while the quality of the water is rapidly worsening due to growing urbanization, deforestation, soil degradation, etc. (Annachhatre, 2016).

Worldwide, more people are dying from poorer quality of water per year than from all forms of violence, including war, and it is estimated that about 27% of all deaths are outcomes of contagious diseases caused by pathogenic bacteria (WHO, 2012)

The inadequate and poor quality of the water supply may result in various health issues. The high infant death rate is a result of poor water quality. Poor environmental sanitation is linked to high rates of trachoma, helminthiasis, and other fatal diseases in children, as well as overall high mortality rates (Mengesha et al., 2017). According to the Globe Health Organization, poor sanitation, contaminated water, or a lack of access to water are to blame for up to 80% of all illnesses and diseases in the world.

More than 60% of communicable infections in Ethiopia are attributable to poor environmental health conditions brought on by a lack of access to potable water and inadequate sanitary and sanitation practices. In addition to continuing to be a major source of sickness and mortality worldwide, researchers have shown that the range of diseases is expanding, and the incidence of many water-related microbial diseases is rising (WHO, 2004).

Accordingly, 80% of illnesses in developing nations are related to water and sanitation, and 15% of all child deaths under the age of five in developing nations are due to diarrheal infections. Diarrhea continues to be a leading cause of death among children WHO, 2010). If water is used without proper treatment, water contaminated with pathogens, physical contaminants, or chemical contaminants at the source during distribution, transit, and handling in homes or other working environments may pose a health concern (Mark, 2004; WHO, 2002). Moreover, poor hygiene and unprotected water collecting and storage containers also lead to contamination at home (Nath and Johns, 2016).

In developing countries, the majority of water quality management and pollution control policies are not sustainable because they do not incorporate more effective mitigation and remediation measures into the management strategy. Particularly in Ethiopia, the issues related to water supply are ascribed to the need for support of the already built frameworks, the need for community association when the prior water frameworks were built, the need for safe parts and neighborhood support capabilities, etc. (Asamnew, 2004). Southern Asia and sub-Saharan Africa still battle with moo scope in sanitation, 41 percent and 30 percent, separately (WHO and UNICEF, 2018). As a result, Ethiopia is one of the nations in the world with the most exceedingly bad of all water quality issues. It has the most reduced water supply and sanitation scope in Sub-Saharan nations, with 68.5% and 56% for water supply and sanitation coverage, separately (MoWR, 2010).

The household of Bishoftu City get their drinking water supply from the distinctive profound well that is arranged within the City. The quality of the drinking water in the city is deteriorating at times, possibly due to the anticipated effluents of squandered water from the can and seepage system. Thus, water contamination in a deep well could be possible. However, it is important to distinguish whether the water obtained from the profound well, along its different stages until it comes to the customers, is secure regarding water quality parameters.

Researchers (Sarkar and Bharat, 2021) suggest that a detailed water quality investigation could help with effective pollution management and practical remediation strategies. In line with this, to address pollution signs in the community's water supply system, it is recommended to study physicochemical, bacteriological, pollution loads at the source, and other water quality parameters. Therefore, this investigation endeavors to assess the drinking water quality from the existing drinking water framework of Bishoftu City in terms of water quality parameters such as physicochemical, bacteriological, and pollution loads at the source. The extreme result of this research is valuable in addressing the most common cause of open well-being issues related to disintegrated drinking water quality and in pointing out the way to deliver secure water for the City's population.

1.2 Statement of the Problem

The deterioration of water quality in the water supply system could be a serious issue that mainly impacts the user's general health. This may happen at the source or on the way from the source to the end user. As a result, it is essential to figure out and recognize precisely where the problem originated from. For this purpose, it is possible to evaluate the whole water distribution system from the source to the end users through the major water quality parameters.

According to (GTZ, 2016), the problems of urban water distribution system contamination do not originate from a single source. Wastes from improper sanitation (sewage) and agricultural and other activities collectively contribute to the pollution of quality water in the distribution system. Furthermore, breaks in the distribution system, inverse pumping of soil contaminants through interruption of the water supply, age and improper maintenance of the distribution system, and low levels of chlorine (treatment efficiency) usually compromise the integrity of the distribution system and quality of potable water (Geberyohannes, 2020)

In the same way, the study area of Bishoftu City, which was detailed assessed and analyzed, has several problems and challenges pertaining to water quality in the community. To state some of them: in places where fluid and strong squanders are not appropriately overseen, the probability of water quality weakening is evident to be high, and utilization of this water supposedly causes waterborne diseases in the community-dwelling in the study area. Not limited to that only, improper fluid and inappropriate waste management systems are the major issues that significantly deteriorate the water quality. As a result, if there is a possibility of connecting defective channels around the borehole, this may contribute to the weakening of social well-being. In effect, the study area is experiencing reports of major waterborne illnesses and water that is too heavy and unsuitable for drinking.

Due to the aforementioned problems, assessing the status of drinking water quality deterioration from sources to end users in Bishoftu City is critical. In addition, the water quality status and water quality index of this City have not been studied yet. Hence, it is crucial to carry out a detailed investigation and analysis of the physicochemical and bacteriological parameters of the water distribution system. In addition, the water quality for drinking water was evaluated using the Water Quality Index. Therefore, this study aims to assess the variance in the physicochemical and bacteriological water quality parameters at Bishoftu from source to end user. The research findings of this study were compared with the WHO and national standards to comprehend its status compared to the standard levels and address public health issues.

1.3. Objectives

1.3.1 General Objective of the Study

The general objective of this study was to investigate the quality of drinking water from the source (boreholes) to the end users in Bishoftu City.

1.3.2 Specific Objectives of the Study

The specific objectives of the study were:

- to investigate the Physical parameters of water quality in the study area.
- to evaluate the chemical parameters of the drinking water in the study area.
- to analyze the microbiological quality of the drinking water in the study area.

1.4 Research Question

1. How the drinking water quality at source and what is the current drinking water quality compliance level compared to the national and WHO standards?
2. What is the quality of the chemical composition parameters of the study area?
3. What is the microbiological water quality in the study area?

1.5 Significance of the Study

This study will provide a comprehensive overview of the water quality variation through the water distribution lines from source to end and show the relationship between sanitation practices, water quality, and public health concerning the prevalence of waterborne and water-related diseases. The results of this study will be used as input for the Bishoftu City water supply utility and other concerned stakeholders about the potential risks associated with water quality variation in Bishoftu City. Additionally, this study will provide a baseline for future research on water quality study in other areas.

1.6 Scope of the Study

The scope of the research was to evaluate the status of drinking water quality from source to end user in the distribution system of Bishoftu City based on the set water quality parameters. The research was conducted and analyzed through detailed data collection from primary and secondary sources. The scope of this research study covers undertaking analysis using chosen parameters such as electrical conductivity, pH, Chloride, Magnesium(Mg^{2}+), Calcium(Ca^{2+}), Total Hardness, TDS, e-coli, total coliform, and recommend the solutions to ensure safe drinking water quality delivery to communities of Bishoftu City. The research considered the quality of the water supply system, including water source, and reservoir.

CHAPTER TWO

LITERATURE REVIEW

2.1. Water

Water is a liquid at ambient conditions, but it often co-exists on Earth, with its solid state being ice and gaseous state being water vapor or steam (Ameyibor and Wiredu, 1991). Human bodies are approximately 60% water, blood is at least 50% water, and the human brain is made of 77% water (Stanistski et al, 2000)**.**

2.1.1 Sources of Water

Water can be grouped into Surface water comprising of oceans, rivers, lakes, reservoirs, lagoons, streams, and many others. Groundwater is considered mostly purer than the surface water and rainwater, which falls due to condensation and precipitation of the clouds (Stanistski et al., 2000). Surface water frequently contains substances that must be removed before it can be used as drinking water. At the same time, groundwater is pumped from wells and boreholes that have been drilled from underground aquifers and is usually free from harmful contaminants.

2.1.2 Wells

A well is an excavation or a structure created in the ground by digging, driving, boring or drilling to access groundwater in underground aquifers (Roger, 1982). An electric submersible pump, a vertical turbine pump, a hand pump, or a mechanical pump (e.g., a water-pumping windmill) may draw the well water. It can also be drawn up using containers, such as buckets that are raised mechanically or by hand (ObiriDanso et al., 2019). Wells can vary greatly in depth, water volume and water quality. Well water typically contains more minerals in solution than surface water and may require treatment to soften the water. In Ethiopia, groundwater (Shallow/hand pump or Deep Well) is an important water source and dominant domestic supply source in many areas, especially in the dry areas where surface waters are scarce and seasonal (e.g. Afar north and Somali region in the east). Few data exist for the general state of groundwater quality across Ethiopia. From those available, the quality is shown to be highly variable, ranging from fresh waters in many of the springs issuing from the crystalline basement rocks to more saline waters in parts of the Rift and the sedimentary formations of the plains (Aberra, 2020).

2.1.3 Drinking water quality

Drinking water quality is characterized as water that is free from illness, creating microorganisms and chemical substances pernicious to well-being (Tebutt, 2015). Indeed, completely secured sources and well-managed frameworks do not ensure that secure water is conveyed to households. The majority of the world's individuals do not have solid family water associations, and numerous of these must still physically carry water and store it in their homes. Studies show that even water collected from safe sources is likely to become face fully contaminated during transportation, container, and storage. Assessing drinking water quality from source to point of use in rural areas (D.Seib, 2018) and Microbiological contamination between source and point of use (Jim Wright, 2004) prescribed that covered water containers will reduce 50% of waterborne and water-related diseases. Safe sources are essential, but it is only with improved hygiene, better water storage and handling, improved sanitation, and, in some cases, household water treatment that the quality of water consumed by people can be assured (D.Seib, 2011). An increasing body of evidence is showing that water quality interventions have a greater impact on diarrhea incidence than previously thought, especially when interventions are applied at the household level (or point-of-use) and combined with improved water handling and storage (Fewtrell, 2007).

The provision of potable water to the rural and urban population is necessary to prevent health hazards. Before water can be described as potable, it has to comply with certain physical, chemical, and microbiological standards, which are designed to ensure that the water is palatable and safe for drinking (Tebutt et al., 2019).

2.2 Water Quality Analysis

High water quality satisfaction describes the physical, chemical, and organic traits and situations of water and aquatic ecosystems, which have an effect on the capacity of water to assist the uses unique to it (CCME, 2020). Water's physical, chemical, microbiological, radiological, and organic properties play a role in its high satisfaction level. It can especially be altered through human activities, which might also additionally affect/ alternate any of those residences to the quantity of affecting aquatic and terrestrial organisms relying on it (DWAF, 2016). According to (WHO, 2006) fitness precedence potential of chemical substances have been Arsenic and

Fluoride which could arise naturally, Nitrate that is carried out to massive regions of agricultural land as fertilizers, microbiological and additionally turbidity.

2.3 Ethiopian Drinking Water Quality Standards

Ethiopia has also developed its own standards derived from WHO guidelines. According to (ESA, 2013), the recent, Ethiopian Standard has been prepared under the direction of the Technical Committee for Water Quality (TC 78) and published by the Ethiopian Standards Agency (ESA). This Compulsory Ethiopian Standard (ES) cancels and replaces ES 261:2001. Implementation of this standard has been effective as of 01 October 2013. The guideline is dynamic and must be improved and updated with new findings and developments in the field. The full document is annexed.

2.4 Water Quality Parameters

2.4.1 Physical parameters

2.4.1.1 PH of water

PH is the degree of the Potential hydrogen ion (H^+) to be had in the water. The acidity of groundwater is because of the presence of natural acids inside the soil as properly as the ones of atmospheric beginning infiltrated into the water (Chapman and Kimstach, 2006). According to the WHO guidelines, "No health-primarily based totally tenet price is proposed for pH, despite eye infection and exacerbation of pores and skin issues being related to pH values more than 11. Although pH generally has no direct effect on consumers, it's by far one of the most essential operational water excellent parameters". Whenever water remedy or garage is taking place (arsenic removal, clarification, disinfection, rainwater harvesting), careful interest to the extent of pH is necessary, and the most beneficial pH required is commonly within the variety 6.5–8.5 (WHO, 2006, ES, 2011) consistent with the parameter.

2.4.1.2 Electrical Conductivity (EC)

Electrical conductivity signifies the amount of total dissolved salts (Dahiya and Kaur, 2015) and is a useful tool to evaluate the purity of water (Acharya et al., 2016). Conductivity shows a significant correlation with ten parameters such as temperature, pH value, alkalinity, total hardness, calcium, total solids, total dissolved solids, chemical oxygen demand and chloride and iron concentration of water.

2.5. Chemical Drinking water quality Parameters

2.5.1. Total Hardness

Hardness is caused fundamentally by calcium and magnesium salts and is communicated in terms of equivalent amounts of calcium carbonate. Depending on other figures, such as pH and alkalinity of water with hardness over around 200 mg/L, scale stores in the distribution framework may occur and result in over-the-top cleanser utilization. Again, soft water with less than 100 mg of hardness may cause corrosion. Hardness may range from zero to several hundreds of mg (ppm). Although acceptability levels vary according to consumers acclimation to hardness, the generally accepted scale is based on taste and household use consideration, and with this basis of reference, the WHO recommends a guideline value of hardness. Actually, there are no health effects or drinking water standards for hardness, but hard water can cause numerous aesthetic problems, especially when water is heated. Because hardness reduces corrosion of household plumbing, a level of 90 to 100 mg/L is often considered optimum to reduce corrosion while also preventing unwanted aesthetic effects. Total hardness is usually reported in one of four categories as follows:

Hardness mg/l as $CacO_3$	-Water Class
0-75	Soft Water
75-150	Moderately Hard Water
150-300	Hard Water
Above 300	Very Hard Water

(Source:-Sawyer and McCarty, 2010)

2.5.2 Magnesium

Magnesium is the foremost plenteous component of soil outside and a normal water constituent. It is essential for the legitimate working of living beings and is found in minerals like dolomite, magnetite etc. The human body contains almost 25g of magnesium (60% in bones and 40% in muscles and tissues). According to WHO measures, the reasonable extent of magnesium in water should be 150 mg/l (Faryal; 2013).

2.5.3 Calcium

Calcium is the most noteworthy critical and inexhaustible within the human body and adequate utilization is essential for typical development and well-being. Around 95 percent of calcium in human 13 body is stockpiled in bones and teeth. The tall insufficiency of calcium in people may cause rickets, poor blood clotting, bone break, etc. The extreme day-by-day necessity is a range of 1- 2 grams that come from mostly dairy items. There's certain proof that the incidence of heart malady is decreased in regions served by an open water supply with a tall degree of hardness, the essential constituent of which is calcium, so that the nearness of the component in a drinking water supply is invaluable to well-being. According to WHO (2015), its reasonable run in drinking water is up to 75 mg/L.

2.5.4 Chloride (Cl)

Sometimes special significance is given to the chloride contents of water, particularly sodium chloride, which is mainly obtained from the dissolution of salts of hydrochloric acid as table salt (NaCl), $NaCO_2$, and sources of chlorides are mainly from road salts, wastewater, storm sewers, and animal feed, etc. (Terence, 1979). Surface water bodies often have low concentrations of Cl and are concentrations of Cl and are the home of main physiological processes. High chloride concentration demolition metallic pipes and structures as harms growing plants. Permitting to WHO guidelines, the maximum permissible limit values of the concentration of chloride should not exceed 250 mg/L

2.6. Bacteriological Aspects of Drinking Water Quality

The microbial quality of water is decided by the nearness of the microbe's demonstrative of fecal (sewage) defilement, to be specific, adding up to coliforms and fecal coliforms such as Escherichia coli. Coliforms happen normally in soil and within the intestines of people and creatures. Hence, their nearness to water may demonstrate defilement. E. coli and certain species of Enterobacter aerogenes are present as they were within the intestines of people and creatures. Their nearness subsequently demonstrates unequivocal fecal pollution. The nearness of coliform microbes in well water may result from surface water infiltration or leakage from a septic framework (Obiri-Danso et al 2008). Coliforms are a gathering of microbes commonly found within the environment, for illustration, in soil or vegetation, as well as the intestines of well evolved creatures, counting people. E. coli is, as it were, a member of the overall coliform bunch of microscopic organisms found within the digestion tracts of warm-blooded creatures, including humans. The nearness of E. coli in water demonstrates later fecal defilement and may show the conceivable nearness of disease-causing Pathogens, such as microbes, infections, and parasites. In spite of the fact that most strains of E. coli microbes are safe, certain strains, such as E. coli O157:H7, may cause ailment, such as hemorrhagic runs and hemolytic uremic disorder (HUS), which causes kidney disappointment, particularly in youthful children and elderly people (Karch et al, 2005). Coliforms and E. coli are utilized as pointers to measure the degree of contamination and clean quality of well water since testing for all known pathogens may be complicated and costly.

2.6.1 Health impact associated with water

Water is a basic necessity for life. Unfortunately, not all water helps humans to survive. Water from contaminated sources causes numerous diseases and untimely deaths. The fact that a human needs water and cannot live without it forces him to use it, even for drinking purposes, from any source, whether pure or contaminated (Zeyede and Tesfaye, 2004). Water-associated disease can be defined as a disease related to water supply and sanitation.

CHAPTER THREE

MATERIAL AND METHODS

3.1 Description of Study Area

Bishoftu City (Fig. 3.1) is one of the so-called railway Citys of Ethiopia, which was established following the construction of the Ethio-Djibouti railway in 1917. It is located 47 km away from the capital city of the country, southeast of Finfinne's main asphalt road, and 52 km from the capital city of East Shewa zone, Adama, and surrounded by the district of Kebeles in Adea. In the North, the city is bordered by Yerer Silassie, in the south by Wedo and Keta Jara, in the East by Kaliti, and in the West by Dire City and the Peasant Association. The name of Bishoftu is derived from Afan Oromo, which means "the land of Lakes." It is situated at 8º 43‟- 8º 45‟ North Latitude & 38º 56‟- 39º 01‟ East Longitude (http://www.mwud.gov.et/web/bishoftu/home

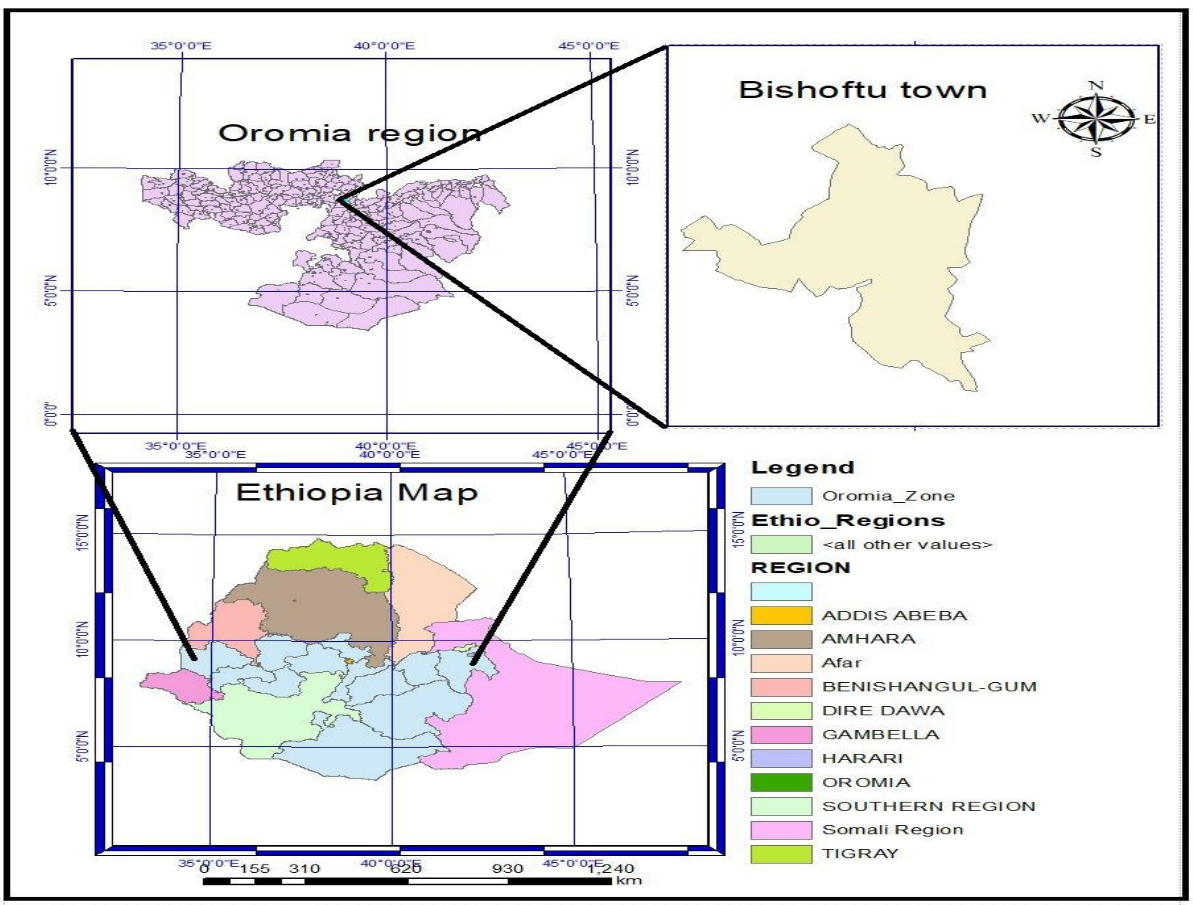

Figure 3. 1: *Location map of the study area*

3.2. Sample Size Determination

The amount of statistical power that the researchers are ready to tolerate for the study must be decided before the investigation can begin to determine the sample size. The actual difference between groups or the strength of the associations is referred to as observed in a study are the effective size. (WHO, 2011) suggested a population-based approach to sampling the minimum sample number for piped drinking water to conduct microbiological tests in the distribution system.

Table 1. 1: *WHO Population-Based Approach (2011)*

Population Served	Number of Samples
<5000	1
5000-100000	1 per 5000 population
>100000	1 per 10000 population, plus 10 additional samples

For estimating a population proportion, the sample size n can be calculated using the formula:

= (207,383/10000) +10)

Therefore, for Bishoftu City, which has a population of 207,383 people, the sample size was 21 samples. An additional ten samples were added for end users. Out of 20 boreholes, only 12 boreholes are functional, and from 5 reservoirs, only two reservoirs are functional, so the total water quality sample size was 45.

3.3. Location of Sampling taken and Water Supply system Covered

Samples were collected from sources, reservoirs, and end users that are typical of the water delivery system. Each locality was considered separately, and while choosing sampling locations, the following standard criterion was applied nonetheless. In discussion with Bishoftu City water supply and sanitation utility, these criteria were selected for this research, considering the potential health risk scenarios.

- Sampling stations were chosen carefully to ensure that the samples gathered represent the various water supply facilities.
- The sampling point locations were chosen based on the population of each source served.

- According to WHO (2011), A piped distribution network's sample locations are categorized as;
  - ✓ Fixed and agreed with the supply agency: are necessary for using legal action to enforce improvement; otherwise, the supply agency may contest a sample result on the grounds that water quality may have declined in the residence, beyond the supplier's scope of obligation. However, fixed sample points are uncommon or nonexistent in some nations.
  - ✓ Fixed but not agreed with the supply agency: They are routinely used in investigations, including surveillance. They are particularly helpful when findings need to be compared across time, but they make it harder to spot regional issues like cross-connection and contamination from faulty distribution systems.
- Water sampling sites: random or variable sampling sites have the advantage of being better at spotting local issues but are less effective at tracking changes over time. Therefore, for this research, random or variable sampling sites were selected.

3.4. Sampling Frequency and Methods

Considering the resource limitation in this research, a sample was taken twice with a one-month interval. In addition, duplicated water samples were collected from one sample from each source outlet (borehole), reservoir outlet, and end-user sampling point. Moreover, a stratified random sampling method was utilized to choose 36 water samples. The procedure for collecting samples from each sampling location was done in accordance with the WHO (2004) guidelines for determining the quality of drinking water. Based on logistics and convenience, convenience (nonprobability) sampling was used to choose water from various water facilities. Furthermore, a random sampling method was employed to select representative samples from the source (borehole) of ten water supply distribution network zones of four urban kebeles.

3.5. Sampling and Data Analysis (Physicho-chemical water quality)

Water samples were collected using adequately cleaned plastic bottles (500 ml volume). Moreover, the sampling points (taps) were appropriately disinfected using alcohol. The bottles were labeled and maintained in an ice box while being transported to the laboratory in Koka for further chemical and bacteriological analysis.

The pH and electrical conductivity were measured in-situ using a multi-pH meter (HQ440d). To determine the concentration of other chemical water parameters in the sampled water, the sample was measured using a DR-6000 (Hach) UV-Vis spectrophotometer.

All physicochemical water quality parameters and biological tests were conducted at Oromia water and energy laboratory center and Koka- Adama water treatment laboratory.

Furthermore, the results of the analysis were compared with different standards and guidelines: WHO and National (Ethiopian Drinking Water Standard). All the water samples from sources and private outlet taps were also analyzed for selected physicochemical, faecal, and total coliform.

3.6. Bacteriological Test (Membrane filter Technique)

In taking the sample from the source, a sterilized plastic bag of 200ml has been used after wearing a latex glove on hand. The water samples were filtered using the filter unit comprising the filter membrane after sterilizing the filter unit of a pore size 45µm with fire and alcohol. M-Coli Blue 24 broth Ampoules has been used as a media (nutrient) to grow bacteria. An incubation unit of ELE Paqualab 25 has been used at site until the sample is taken to the laboratory where another incubation unit called Pot lab is used. The prepared samples have been incubated for 24 hours before opening and examining for bacterial growth.

3.7. Water Quality Index

The Water Quality Index (WQI) provides a numerical representation of the overall quality of water for any intended purpose. The calculation of WQI was made using Canadian water quality guidelines index method.

3.8. Overall Overview of the CCME WQ Index

According to CCME, Following the calculation of the water quality index value, the following categories of water quality are identified:

Excellent :(CCME WQI Value 95-100) – An almost complete lack of threat or impairment; conditions that are very close to natural or pristine levels; protects water quality.

Good: (CCME WQI Value 80-94) - Water quality is safeguarded with just a slight threat or harm; rarely do conditions deviate from ideal or natural levels.

Fair :(CCME WQI Value 65-79) – Water quality is often safeguarded, but occasionally it may be jeopardized or compromised; occasionally, conditions may deviate from what is ideal or natural.

Marginal: (CCME WQI 45-64) – Water quality is frequently in danger or degraded; circumstances routinely deviate from ideal or natural levels.

Poor :(CCME WQI Value 0-45) – water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

The method of assigning CCME WQI values to these categories is crucial but rather arbitrary. The classification is based on the most up-to-date facts, professional opinion, and public expectations for water quality.

Each of the three components of the BWQI must be calculated after the water body, the time frame, and the parameters and recommendations have been established.

3.9 Calculation of Water Quality Index

The Canadian Water Quality Index 1.0 - Technical Report describes the WQI's precise formulation in detail as follows:

Scope, F1

F1 is the scope metric. This reflects the degree of non-compliance with water quality standards for the relevant time frame.

$$F1=\left(\frac{Number\ of\ failed\ varibles}{Total\ number\ of\ varibale}\right)*100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

F2 for frequency

F2 is the frequency measurement unit. This indicates the proportion of individual tests (sometimes known as "failed tests") that do not achieve their goals.

$$F_2=\left(\frac{Number\ of\ failed\ tests}{Total\ number\ oftests}\right)*100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..2$$

F3 for amplitude

F3 is used to measure amplitude. This reflects the degree to which the objectives of failed tests were not met. Three steps are taken in the calculation:

Step 1: Determine the excursion. Excursion is the number of times a person's focus exceeds (or falls short of, if the purpose is minimal) the goal.

When the test value must not exceed the objective:

$$\text{Excursion}_{i} = \left(\frac{failed\ test\ value\ i}{Objective\ \ j}\right) - 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..3$$

When the test value must not fall below the objective:

$$\text{Excursion}_{i} = \left(\frac{Objective\ j}{failed\ tests\ value\ i}\right) - 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.4$$

The second step is the normalized sum of excursions. The total amount by which distinct tests are out of compliance is known as the normalized sum of excursions, or nse. This is estimated by adding up each test's deviations from its goals and then dividing by the total number of tests (including successful and unsuccessful ones).

$$\text{nse} = \frac{\sum_{i-1}^{n} \text{Excursion i}}{Number\ of\ test} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..5$$

F3 calculation in step three. The normalized total of the excursions from targets is scaled by an asymptotic function to produce a range of F3 from 0 to 100.

$$F_3 = \left(\frac{nse}{0.01nse + 0.01} - 1\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.6$$

The WQI is then calculated as:

$$\text{CCME WQI} = 100 - \left(\frac{\sqrt{F1+F2+F3}}{1.732}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.7$$

The generated values are normalized to a range between 0 and 100 using the divisor 1.732, where 0 denotes the "worst" water quality and 100 denotes the "best" water quality.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1. Physical Parameters of Water Quality of Bishoftu City

4.1.1. pH Water Quality at Borehole

Table 4. 1: *Compliance with national standard and WHO guidelines for pH at borehole.*

NO	Laboratory Result first round	Laboratory Result second round	Average	WHO Standard	National Standard		National Standard Test Method	Compliance with WHO Guide Lines	Compliance with National Standard
B1	7.81	6.46	7.13	6.5-8.5	6.5-8.5		ES ISO 10523	Yes	Yes
B2	7.7	6.57	7.1	"	"		"	Yes	Yes
B3	7.15	6.69	6.9	"	"		"	Yes	Yes
B4	7.6	6.56	7.08	"	"		"	Yes	Yes
B5	7.59	6.57	6.72	"	"		"	Yes	Yes
B6	7.45	6.85	7.15	"	"		"	Yes	Yes
B7	7.58	7.4	7.49	"	"		"	Yes	Yes
B8	7.3	6.2	6.75	"	"		"	Yes	Yes
B9	7.19	6.84	7.015	"	"		"	Yes	Yes
B10	7.16	6.42	6.79	"	"		"	Yes	Yes
B11	7.1	7	7.05	"	"		"	Yes	Yes
B12	7.4	6.6	7	"	"		"	Yes	Yes

Note: B represents the borehole.

The average pH of the borehole water, measured at 6.7 (as shown in Table 4.1), falls within the acceptable range specified by both the World Health Organization (WHO) guidelines and Ethiopian drinking water standards. According to these standards, the recommended pH range for safe drinking water typically lies between 6.5 and 8.5. The fact that the borehole water's pH is comfortably within this range indicates that it is neither too acidic nor too alkaline, making it suitable for human consumption without posing any significant health risks associated with pH imbalance.

This alignment with international and national standards suggests that the borehole water is well suited for drinking purposes. Maintaining an appropriate pH level in drinking water is crucial, as it can influence the effectiveness of disinfection processes, the solubility of metals and other contaminants, and the overall taste and safety of the water. Given that the borehole water's pH falls within the ideal range, it can be confidently concluded that, from a pH perspective, this water source is safe and reliable for the local community's drinking needs.

4.1. 2 pH Water Quality at Reservoir

The pH observed in the two reservoirs closely mirrors that of the borehole, indicating consistent water quality throughout the supply system. This similarity suggests that as the water traveled from the borehole to the reservoirs, its pH remained stable and within acceptable limits. Consequently, when the water reached the reservoirs, it continued to meet both the WHO guidelines and the national standard ES ISO 10523, which stipulates the permissible pH range for drinking water.

This consistency in pH values across the different points in the water supply chain underscores the effectiveness of the water management practices in place. It ensures that the water remains safe for consumption even after being stored in the reservoirs, without experiencing significant changes in its chemical properties. Therefore, the water in the reservoirs, like that in the borehole, is compliant with international and national standards, making it suitable for drinking purposes.

4.1.3. pH Water Quality at End User

Table 4. 2: *Compliance with national standard and WHO guide lines for pH at end user*

No Code	Laboratory Result first round	Laboratory Result second round	Average reading	WHO Standard	National Standard	National Standard Test Method	Compliance with WHO Guide Lines	Compliance with National Standard
S1	6.32	6.5	6.41	6.5-8.5	6.5-8.5	ES ISO 10523	Yes	Yes
S3	7.05	6.69	6.87	"	"	"	Yes	Yes
S4	6.86	6.8	6.83	"	"	"	Yes	Yes
S5	7.01	7	7.005	"	"	"	Yes	Yes

S6	7.3	7.1	7.2	"	"	"	Yes	Yes
S7	6.54	6.67	6.605	"	"	"	Yes	Yes
S8	7.5	7.5	7.5	"	"	"	Yes	Yes
S9	7.3	7.23	7.265	"	"	"	Yes	Yes
S10	6.68	6.72	6.7	"	"	"	Yes	Yes
S11	6.92	6.89	6.905	"	"	"	Yes	Yes
S12	7.02	7.01	7.015	"	"	"	Yes	Yes
S13	6.99	7	6.995	"	"	"	Yes	Yes
S14	6.65	6.67	6.66	"	"	"	Yes	Yes
S15	7.04	7.02	7.03	"	"	"	Yes	Yes
S16	7.6	7.5	7.55	"	"	"	Yes	Yes
S17	7.4	7.4	7.4	"	"	"	Yes	Yes
S18	6.69	7	6.845	"	"	"	Yes	Yes
S19	7.9	7.5	7.7	"	"	"	Yes	Yes
S20	7.5	7.44	7.47	"	"	"	Yes	Yes
S21	7.3	7.1	7.2	"	"	"	Yes	Yes
S22	6.68	6.9	6.79	"	"	"	Yes	Yes
S23	6.92	6.8	6.86	"	"	"	Yes	Yes
S24	7.84	7.01	7.425	"	"	"	Yes	Yes
S25	7.8	7.56	7.68	"	"	"	Yes	Yes
S26	6.9	7.1	7	"	"	"	Yes	Yes
S27	6.5	6.8	6.65	"	"	"	Yes	Yes
S28	6.66	6.89	6.77	"	"	"	Yes	Yes
S29	7.5	7.1	7.4	"	"	"	Yes	Yes
S30	6.7	6.5	6.6	"	"	"	Yes	Yes
S31	7.4	7.2	7.3	"	"	"	Yes	Yes

Note: S represents the sampling number

The results from Table 4.2 above revealed that the average pH level of the water sample collected from end users closely matches the pH level of the water from boreholes and reservoirs. This finding indicates that there were no significant changes in pH levels in the end user system that could have had an impact on the pH value. Therefore, the pH level of the end users complies with WHO guidelines and national standards.

4.1.4 Water Quality at the Reservoir in Terms of Electrical Conductivity

Electrical conductivity (EC) was used to calculate the total dissolved salts (TDS). It determines if the water is suitable for drinking purposes. The WHO and national guidelines state that the EC value of drinking water supplies should not be higher than 400 S/cm. This study revealed that the EC levels of Bishoftu City's water supply range from 389 to 386, with an average value of 387.5 S/cm, which falls within the maximum acceptable limits set by the WHO and national standards.

4.1.5 Water Quality at End User in Terms of Electrical Conductivity

A standard that, if not met, would prevent water from being used for drinking and domestic purposes due to a potential health risk.

Table 4. 3: *Compliance with national standard and WHO guide lines for electrical conductivity (E.C) at end user.*

NO	Laboratory Result first round	Laboratory Result second round	Average	WHO Standard	National Standard	National Standard Test Method	Compliance with WHO Guide Lines	Compliance with National Standard
S1	369	375	372	400	400	Field	Yes	Yes
S2	416	412	414	"	"	"	No	No
S3	421	415	418	"	"	"	No	No
S4	382	387	384.5	"	"	"	Yes	Yes
S5	486	492	489	"	"	"	No	No
S6	457	455	456	"	"	"	No	No
S7	395	389	392	"	"	"	Yes	Yes
S8	415	413	414	"	"	"	No	No
S9	403	397	400	"	"	"	No	No
S10	456	453	454.5	"	"	"	No	No
S11	358	360	359	"	"	"	Yes	Yes
S12	479	482	480.5	"	"	"	No	No
S13	482	477	479.5	"	"	"	No	No
S14	358	356	357	"	"	"	Yes	Yes

S15	1264	1318	1291	"	"	"	No	No
S16	383	380	381.5	"	"	"	Yes	Yes
S17	388	389	388.5	"	"	"	Yes	Yes
S18	434	432	433	"	"	"	No	No
S19	491	493	492	"	"	"	No	No
S20	494	489	491.5	"	"	"	No	No
S21	350	351	350.5	"	"	"	Yes	Yes
S22	387	376	381.5	"	"	"	Yes	Yes
S23	456	460	458	"	"	"	No	No
S24	373	375	374	"	"	"	Yes	Yes
S25	484	483	483.5	"	"	"	No	No
S26	372	370	371	"	"	"	Yes	Yes
S27	355	360	357.5	"	"	"	Yes	Yes
S28	460	465	462.5	"	"	"	No	No
S29	442	398	420	"	"	"	No	No
S30	459	463	461	"	"	"	No	No
S31	350	345	347.5	"	"	"	Yes	Yes

The EC's first, second, and average readings at the end-user water (Table 4.3) were 455.24, 456.36, and 455.8, respectively. These results clearly demonstrate that the quantity of soluble materials in the study locations caused the water to be highly ionized and have a higher ionic concentration activity.

4.1.6 Water Quality at Borehole in Terms of Electrical Conductivity

Table 4. 4: *Compliance with national standard and WHO guide lines for electrical conductivity (E.C) at borehole.*

NO code	Laboratory Result Frist Round	Laboratory Result second Round	Average	WHO Standard	National Standard	National Standard Test Method	Compliance with WHO Guide Lines	Compliance with National Standard
B1	436	450	443	400	400	Field	No	No
B2	358	363	360.5	"	"	''	Yes	Yes
B3	373	353	363	"	"	''	Yes	Yes
B4	479	463	471	"	"	''	No	No
B5	614	535	574.5	"	"	''	No	No
B6	602	605	603.5	"	"	''	No	No

B7	593	447	520	"	"	''	No	No
B8	1318	1260	1289	"	"	''	No	No
B9	361	316	338.5	"	"	''	Yes	Yes
B10	682	614	648	"	"	''	No	No
B11	351	348	349.5	"	"	"	Yes	Yes
B12	365	352	358.5	"	"	"	Yes	Yes

The EC results of the source or borehole (Table 4.4) indicate that the water in the study areas was highly ionized and had ionic concentration activity due to the abundance of soluble solids. In addition, sampling point (B8) exhibits extremely high electrical conductivity due to dissolved salts and other inorganic chemicals that act as electrical conductors; conductivity rises as salinity rises.

4.2 Chloride Level at Reservoir

Sewage and industrial effluents are two common and fabricated sources of chloride. Chloride can contaminate groundwater if salt is used for de-icing through roadway seepage. Chloride concentrations are often higher in rivers and groundwater than they are in upland and mountain water supplies. The ability of chloride to increase water's corrosiveness, especially in water with high alkalinity, is its main operating problem.

They are still soluble in water, unaffected by biological activity, and reducible via dilution. High chloride levels are bad for pipelines and metallic buildings as well as growing plants. According to national regulations and WHO recommendations, chloride concentrations should not be more than 250 mg/l. The laboratory test findings for reservoir samples showed chloride values of 49, 51, and 50 in the first, second, and average readings, respectively. Because of this, the reservoir samples' chloride concentration is below the national standard level and the maximum allowable limit value established by the World Health Organization.

4.3 Chloride Level at End User

Table 4. 5: *Compliance with national standard and WHO guide lines for chloride at end user.*

code NO	Laboratory Result first round	Laboratory Result second round	average	WHO Standard	National Standard	National Standard Test Method	Compliance with WHO Guide Lines	Compliance with National Standard
s1	38	40	39	250	250	ES ISO 9297	Yes	Yes
s2	56	54	55	"	"	"	"	"
s3	42	41	41.5	"	"	"	"	"
s4	27	25	26	"	"	"	"	"
s5	35	34	34.5	"	"	"	"	"
s6	60	58	59	"	"	"	"	"
s7	53	51	52	"	"	"	"	"
s8	58	60	59	"	"	"	"	"
s9	78	81	79.5	"	"	"	"	"
s10	66	66	66	"	"	"	"	"
s11	65	70	67.5	"	"	"	"	"
s12	62	65	63.5	"	"	"	"	"
s13	40	38	39	"	"	"	"	"
s14	53	50	51.5	"	"	"	"	"
s15	35	37	36	"	"	"	"	"
s16	25	27	26	"	"	"	"	"
s17	28	30	29	"	"	"	"	"
s18	47	45	46	"	"	"	"	"
s19	50	50	50	"	"	"	"	"
s20	44	41	42.5	"	"	"	"	"
s21	46	51	48.5	"	"	"	"	"
s22	54	53	53.5	"	"	"	"	"
s23	45	43	44	"	"	"	"	"
s24	58	57	57.5	"	"	"	"	"
s25	48	50	49	"	"	"	"	"
S26	46	48	47	"	"	"	"	"
S27	61	57	59	"	"	"	"	"
S28	58	58	58	"	"	"	"	"

S29	45	42	43.5	"	"	"	"	"
S30	55	51	53	"	"	"	"	"
S31	56	55	55.5	"	"	"	"	"

The content of chloride should not be more than 250 mg/l, as per national regulations and WHO guidelines. The laboratory test findings for end-user samples showed chloride concentrations of 48.52, 48.68, and 48.6 in the first, second, and average readings, respectively. As a result, the end-user samples contain chloride concentrations below the national standard level and the maximum allowable limit value established by the World Health Organization.

4.4 Chloride Level at Borehole

Table 4. 6: *Compliance with national standard and WHO guide lines for chloride at borehole.*

NO	Laboratory Result first round	Laboratory Result second round	average	WHO Standard	National Standard	National Standard Test Method	Compliance with WHO Guide Lines	Compliance with National Standard
B1	48	51	49.5	250	250	ES ISO 9297	Yes	Yes
B2	61	63	62	"	"	"	"	"
B3	49	52	50.5	"	"	"	"	"
B4	61	57	59	"	"	"	"	"
B5	58	54	56	"	"	"	"	"
B6	51	55	53	"	"	"	"	"
B7	61	59	60	"	"	"	"	"
B8	49	48	48.5	"	"	"	"	"
B9	60	58	59	"	"	"	"	"
B10	36	38	37	"	"	"	"	"
B11	37	38	37.5	"	"	"	"	"
B12	56	56	56	"	"	"	"	"

Although the test of water may be discernible at high chloride concentrations (e.g., NaCl, KCl, and $CaCl_2$), consumer approval varies widely depending on the type of chloride. If monitoring was necessary, it was usually done at the treatment center. The frequency would be minimal and would be based on the source water's unpredictability.

Chlorides are substances made of chlorine. They continue to be soluble in water and unaffected by biological processes, making them reducible by dilution. High chloride concentrations injure growing plants as well as metallic pipelines and structures. The content of chloride should not be more than 250 mg/l, as per national regulations and WHO guidelines. The chloride values in source or borehole samples ranged from 36 to 61 mg/l according to laboratory test results. As a result, the chloride maximum permitted limit value established by World Health Organization guidelines and national standard level is lower in all of the samples.

4.5 Calcium Level at Reservoir

Calcium, an alkaline earth element that reacts with water, is an essential part of bones and teeth. It makes up 3% of the fifth most abundant element in the crust of the earth. The most common calcium compounds are limestone (CaO_3), gypsum ($CaSO_4.2H_2O$), fluorite (CaF_2), hypochlorite ($Ca(ClO)_2$), and nitrate ($Ca(NO_3)_2$).

Since no specific disease has been linked to calcium in the drinking water supply, an upper limit, such as 75 mg/l in relation to hardness, may be used as a guidance [2012]. The calcium of the laboratory test findings for a reservoir sample was 88, 85, and 86.5 in the first, second, and average readings, respectively. The average result was higher than the WHO and national standard, which is the maximum allowable limit not established by WHO guidelines and national standard level. This shows that the community's health is being impacted by the almost mild hardness of the water in the reservoir.

4.6 Calcium Level at End User

Table 4. 7: *Compliance with national standard and WHO guide lines for calcium Ca2+ at End user.*

code NO	Laboratory Result first round	Laboratory Result second round	Average	WHO Standard	National Standard	National Standard Test Method	Compliance with WHO Guide Lines	Compliance with National Standard
S1	130	128	129	75	75	ES ISO 7980	No	No
S2	98	100	99	"	"	''	No	No
S3	85	90	87.5	"	"	''	No	No

S4	80	82	81	"	"	''	No	No
S5	97	95	96	"	"	''	No	No
S6	127	128	127.5	"	"	''	No	No
S7	70	69	69.5	"	"	''	Yes	Yes
"	''	93	94.5	"			No	No
"	''	132	131	"			No	No
"	''	89	88.5	"			No	No
S11	90	92	91	"	"	''	No	No
S12	101	96	98.5	"	"	''	No	No
S13	100	105	102.5	"	"	''	No	No
S14	104	98	101	"	"	''	No	No
S15	109	110	109.5	"	"	''	No	No
S16	102	100	101	"	"	''	No	No
S17	99	98	98.5	"	"	''	No	No
S18	110	108	109	"	"	''	No	No
S19	114	116	115	"	"	''	No	No
S20	120	127	123.5	"	"	''	No	No
S21	110	112	111	"	"	''	No	No
S22	105	107	106	"	"	''	No	No
S23	109	111	110	"	"	''	No	No
S24	111	114	112.5	"	"	''	No	No
S25	117	113	115	"	"	''	No	No
S26	120	118	119	"	"	"	No	No
S27	131	131	131	"	"	"	No	No
S28	81	85	83	"	"	"	No	No
S29	66	62	64	"	"	"	No	No
S30	56	56	56	"	"	"	No	No
S31	75	73	74	"	"	"	No	No

At the End User calcium Ca^{2+} also there above the WHO guideline and national standard. All the laboratory results indicated that the calcium Ca^{2+} level in Bishoftu City the end user water was not complied with WHO guide line and national standard and health effect on the community (ES ISO 7980).

4.7. Calcium Level at Bore hole

Table 4. 8: *Compliance with national standard and WHO guide lines for calcium at Borehole.*

NO	Laboratory Result first round	Laboratory Result second	Laboratory Result average	WHO Standard	National Standard	National Standard Test Method	Compliance with WHO Guide Lines	Compliance with National Standard
B1	79	90	84.5	75	75	ES ISO 7980	No	No
B2	106	102	104	"	"	''	No	No
B3	80	83	81.5	"	"	''	No	No
B4	82	96	89	"	"	''	No	No
B5	98	85	91.5	"	"	''	No	No
B6	101	100	100.5	"	"	''	No	No
B7	77	75	76	"	"	''	No	No
B8	82	85	83.5	"	"	''	No	No
B9	78	75	76.5	"	"	''	No	No
B10	93	81	87	"	"	''	No	No
B11	99	100	99.5	"	"	"	No	No
B12	86	86	86	"	"	"	No	No

At the Source (Borehole) calcium Ca^{2+} also there above the WHO guideline and national standard. All the laboratory results indicated that the calcium Ca^{2+} level in Bishoftu City the Borehole water was not complied with WHO guide line and national standard and health effect on the community (ES ISO 7980).

4.8. Magnesium Level at Reservoir

Magnesium is a light, silver-white, malleable, ductile, metallic chemical element that makes up the eighth most abundant element in the crust of the earth. It is never discovered as a free element. Magnesium is believed to be non-toxic to humans at amounts that are present in water or that are not unpleasant to the taste. Magnesium has been utilized in flash photography, alloys, incendiary bombs, and pyrotechnics. When magnesium is a sulfate, it is referred to as "milk of magnesia" or "Epsom Salts" in medicine. As a nutrient, it benefits both plant and animal life. The WHO and national Standard of Drinking Water (1963) list the maximum acceptable amount as 50 mg/l, while the maximum permissible level is 150 mg/l.

Mg^{2+} laboratory test results for reservoir samples were 31, 34, and 32.5 in the first, second, and average readings, respectively. These values fall below the World Health Organization's and National Standard's maximum acceptable level.

4.9 Magnesium Level at End User

Table 4. 9: *Compliance with national standard and WHO guide lines for magnesium at end user.*

CODE	Laboratory Result first round	Laboratory Result second round	Laboratory Result average	WHO Standard	National Standard	National Standard Test Method	Compliance with WHO Guide Lines	Compliance with National Standard
s1	48	49	48.5	50	50	ES ISO 7980	Yes	Yes
s2	41	40	40.5	"	"	"	Yes	Yes
s3	34	32	33	"	"	"	Yes	Yes
s4	35	37	36	"	"	"	Yes	Yes
s5	37	38	37.5	"	"	"	Yes	Yes
s6	42	42	42	"	"	"	Yes	Yes
s7	39	41	40	"	"	"	Yes	Yes
s8	33	32	32.5	"	"	"	Yes	Yes
s9	51	50	50.5	"	"	"	Yes	Yes
s10	47	49	48	"	"	"	Yes	Yes
s11	29	33	31	"	"	"	Yes	Yes
s12	37	35	36	"	"	"	Yes	Yes
s13	41	45	43	"	"	"	Yes	Yes
s14	42	39	40.5	"	"	"	Yes	Yes
s15	48	46	47	"	"	"	Yes	Yes
s16	60	58	59	"	"	"	No	No
s17	64	63	63.5	"	"	"	No	No
s18	44	42	43	"	"	"	Yes	Yes
s19	48	47	47.5	"	"	"	Yes	Yes
s20	42	45	43.5	"	"	"	Yes	Yes

s21	40	38	39	"	"	"	Yes	Yes
s22	43	39	41	"	"	"	Yes	Yes
s23	41	40	40.5	"	"	"	Yes	Yes
s24	40	43	41.5	"	"	"	Yes	Yes
s25	39	41	40	"	"	"	Yes	Yes
S26	44	44	44	"	"	"	Yes	Yes
S27	38	37	37.5	"	"	"	Yes	Yes
S28	49	48	48.5	"	"	"	Yes	Yes
S29	46	46	46	"	"	"	Yes	Yes
S30	40	40	40	"	"	"	Yes	Yes
S31	42	42	42	"	"	"	Yes	Yes

The WHO International Standard of Drinking Water (1963) states that the maximum permissible level is 150 mg/l and the maximum acceptable level is 50 mg/L.

The laboratory test results for the Bishoftu City Water Supply at End User samples showed levels of (Mg^{+2}) between 42.6 and 42.58 mg/L, which are below the World Health Organization's and National Standard's Maximum Acceptable Level.

4.10. Magnesium Level at Borehole

Table 4. 10: *Compliance with national standard and WHO guide lines for magnesium at Borehole*

NO	Laboratory Result first round	Laboratory Result second round	Average	WHO Standard	National Standard	National Standard Test Method	Compliance with WHO Guide Lines	Compliance with National Standard
B1	29	30	29.5	50	50	ES ISO 7980	Yes	Yes
B2	18	23	20.5	"	"	"	"	"
B3	27	24	25.5	"	"	"	"	"
B4	27	25	26	"	"	"	"	"
B5	72	64	68	"	"	"	No	No
B6	30	35	32.5	"	"	"	Yes	Yes
B7	47	45	46	"	"	"	Yes	Yes
B8	64	65	64.5	"	"	"	No	No
B9	28	26	27	"	"	"	Yes	Yes
B10	58	55	56.5	"	"	"	No	No

B11	25	27	26	"	"	"	No	No
B12	43	40	41.5	"	"	"	No	No

The magnesium (Mg^{2+}) level at the borehole was also above the WHO guideline and national standard. The laboratory results indicated that the Mg^{2+} level in Biahoftu City, the Borehole's sample water S5, S8, and S10 did not comply with the WHO guidelines and national standards, which affected the community. The remaining results of the borehole water in terms of magnesium level complied with the WHO guideline and national standard (ES ISO 7980).

4.11. Total Hardness at Reservoir

The hardness of water is one of its physical or chemical characteristics. It displays the overall concentration of calcium and magnesium ions. Based on how much soap would precipitate, hardness was initially researched and evaluated in raw water sampling as an indicator of water quality. The two main precipitating ions in this assay are magnesium and calcium. To put it another way, more soap is required to make foam or lather with "hard" water. The other negative aspect of hard water versus soft water is the natural capacity of hard water to produce scale in hot water pipes, boilers, and heaters.

According to WHO guidelines and national standards, the maximum allowable limit of overall hardness should not exceed 300mg/l as $CaCo_3$. The Bishoftu City Water Supply laboratory test results for the first, second, and average readings of $CaCo_3$ were 119 mg/l, 121 mg/l, and 120 mg/l, respectively. Therefore, the World Health Organization and National regulations classify the Bishoftu City water supply at the reservoir's level of hardness as moderately soft water, which is not harmful to consumers.

4.12 Total hardness at Borehole

Table 4. 11: *Compliance with national standard and WHO guide lines for total hardness at Borehole.*

NO	Laboratory Result first round	Laboratory Result second	Average	WHO Standard	National Standard	National Standard Test Method	Complianc e with WHO Guide Lines	Complianc e with National
B1	114	117	115.5	300	300	ES ISO 607	Yes	Yes
B2	124	125	124.5	"	"	"	"	"
B3	106	103	104.5	"	"	"	"	"

B4	110	109	109.5	"	"	"	"	"
B5	278	281	279.5	"	"	"	"	"
B6	230	227	228.5	"	"	"	"	"
B7	240	245	242.5	"	"	"	"	"
B8	242	239	240.5	"	"	"	"	"
B9	142	146	144	"	"	"	"	"
B10	350	345	347.5	"	"	"	No	No
B11	220	219	219.5	"	"	"	"	"
B12	141	138	139,5	"	"	"	"	"

According to the laboratory test results for the Bishoftu City Water Supply at Source or borehole samples (S1, S2, S3, S4, S9), the $CaCo_3$ concentrations ranges from 110 mg/L to 142 mg/L. As a result, based on the national and World Health Organization criteria, the water supply in Bishoftu City can be classified as moderately soft at the source, which is safe for users.. The values of $CaCo_3$ for the remaining S5, S6, S7, and S8 vary from 230 mg/L to 278 mg/L. As a result, according to national and international standards set by the World Health Organization the level of hardness of the water at the source can be classified as hard water.

According to World Health Organization and national guidelines, hard water, defined as having a concentration between 10 and more than 300 mg/L, is considered harmful to consumers.

4.13 Total Hardness at End User

Table 4. 12: *Compliance with national standard and WHO guide lines for total hardness at end user.*

NO	Laboratory Result first round	Laboratory Result second round	Laboratory Result average	WHO Standard	National Standard	National Standard Test Method	Compliance with WHO Guide Lines	Compliance with National Standard
s1	178	177	177.5	300	300	ES ISO 607	Yes	Yes
s2	139	140	139.5	"	"	"	Yes	Yes
s3	119	122	120.5	"	"	"	Yes	Yes
s4	115	119	117	"	"	"	Yes	Yes
s5	134	133	133.5	"	"	"	Yes	Yes
s6	169	170	169.5	"	"	"	Yes	Yes

s7	109	110	109.5	"	"	"	Yes	Yes
s8	129	115	122	"	"	"	Yes	Yes
s9	181	182	181.5	"	"	"	Yes	Yes
s10	135	138	136.5	"	"	"	Yes	Yes
s11	119	125	122	"	"	"	Yes	Yes
s12	138	131	134.5	"	"	"	Yes	Yes
s13	141	150	145.5	"	"	"	Yes	Yes
s14	146	137	141.5	"	"	"	Yes	Yes
s15	157	456	306.5	"	"	"	Yes	Yes
s16	162	158	160	"	"	"	Yes	Yes
s17	161	161	161	"	"	"	Yes	Yes
s18	154	150	152	"	"	"	Yes	Yes
s19	162	163	162.5	"	"	"	Yes	Yes
s20	162	172	167	"	"	"	Yes	Yes
s21	150	150	150	"	"	"	Yes	Yes
s22	148	146	147	"	"	"	Yes	Yes
s23	150	151	150.5	"	"	"	Yes	Yes
s24	151	147	149	"	"	"	Yes	Yes
s25	156	154	155	"	"	"	Yes	Yes
S26	152	151	151.5	"	"	"	Yes	Yes
S27	148	145	146.6	"	"	"	Yes	Yes
S28	165	167	166	"	"	"	Yes	Yes
S29	162	159	160.5	"	"	"	Yes	Yes
S30	150	150	150	"	"	"	Yes	Yes
S31	160	158	156	"	"	"	Yes	Yes

Laboratory test results for the Bishoftu City Water Supply at End User samples show CaCo3 concentrations ranging from 115 mg/L to 178 mg/L. Accordingly, the World Health Organization and national guidelines classify the hardness of the Bishoftu City water supply at the end user as moderately soft water and hard water, neither of which is harmful to consumers.

The test for total coliform bacteria is the simplest way to determine whether a water supply is contaminated with bacteria. The total coliform counts provide an overview of a water supply's hygienic status.

The WHO and national standard state that none must be detected per 100 mL, which indicates that for every 100 ml of drinking water tested for total coliforms, there must be none. Thus, the total coliform reading at the Source or borehole was zero, which complied with the WHO guideline and national standard ES ISO 9308-1.

4.14 Total Coliform at Reservoir

With respect to the total Coliform Test at the reservoir, the water samples were positive or zero for Total coliform. Thus, the total Coliform reading at the Source or reservoir was zero, which complied with the WHO guideline and the national standard (ES ISO 9308-1).

4.15 Total coliform at End User

When the water left the reservoir and borehole, it went through the distribution system and may be exposed to total coliform bacteria. Out of 25 sampling locations in the end user system, only fifteen sample locations were found free from total coliform bacteria. In the remaining 10 samples, bacteria were obtained in the laboratory result. So that, 40% of the water in the end user addressed in this research did not comply with WHO guideline and national standard ES ISO 9308-1 related to total coliform.

There was no E. coli in the water in any borehole, and all laboratory results were zero E. coli/100 ml of water. Therefore, the zero E. coli result continued in the Borehole. The borehole water complied with WHO guidelines and the national standard of ES ISO 9308-2.

4.16 Total Coliform at Borehole

The laboratory result revealed that no E.coli was found in the borehole. Therefore, the zero E. coli concentration result continued in the borehole. The water quality complied with WHO guidelines and the national standard of ES ISO 9308-2.

4.3 The Bishoftu Water supply WQI

Gathering, evaluating, and disseminating data on water quality (WQ) is a crucial part of managing water resources (WR). Inherently technical WQ data must frequently be communicated to a variety of audiences, and communicating WQ data to the general public can be particularly difficult.

Water quality data are not significantly relevant to the majority of participants, including the general public. Instead of worrying about the information that the WQ data provides, they are more interested in the knowledge that arises from it.

However, when the information is translated into the understanding that the water quality is within acceptable WQ parameters, stakeholders become interested in the data. If the data is further processed to convey the idea that adhering to the WQ standards shows that the WQ is suitable for aquatic life, the value of the data is significantly boosted. Therefore, WQ data must first be transformed into information and then into knowledge to be communicated.

4.3.1 How the CCME WQI is influenced by varying measurement scales and ranges of exceedances

Analyses of water quality often use a variety of measurement scales. Pesticides, for example, may influence the ecosystem at ng L^{-1} ranges, while other compounds affect at mg•L-1 ranges. These data can be combined in the same multivariate index formulation using a guideline-oriented approach because the important metric is comparing the measured data to its guideline.

This method also deals with parameter weighting. Further weighting is not necessary because the relative toxicities of various contaminants are addressed during the establishment of water quality criteria.

The F3 function's asymptotic nature also reduces the unwarranted influence that parameters with extremely wide ranges in values (like bacteria counts) have compared to those with very tight ranges (like pH).

Results below the analytical detection limit are a common issue when reporting on water quality data. Values below detection can be utilized in the index as observations that are compared to the guideline while being at the detection limit, avoiding all associated statistical issues. Additionally, the method handles common challenges in water quality reporting, such as results falling below the analytical detection limit. By treating these undetectable values as being at the detection limit and comparing them to the guideline, statistical complications are avoided. In cases where the detection limit exceeds the guideline, such as with certain contaminants the detection limit itself is treated as the guideline to ensure that the index remains accurate and relevant.

Table 4. 13: Physico-chemical parameter Borehole sample collected for borehole WQI

Code	pH	EC	chloride mg/L	mg^{2+} mg/L	Ca^{2+} mg/L	Total Hardness mg/Ll
S1	7.68	385.7	49	31.3	86.3	121.7
S2	6.5	444.0	50.3	28.7	84.7	114.3
S3	4.4	353.7	61.0	20.7	104.3	122.0
S4	6.7	358.7	52.0	25.3	80.3	104.7
S5	6.7	466.0	55.7	24.7	89.7	109.0
S6	6.7	558.0	55.3	63.7	90.7	279.7
S7	6.9	605.7	52.0	34.3	102.0	232.3
S8	7.2	497.0	58.3	46.0	77.7	242.3
S9	6.3	1294.7	47.3	60.7	84.7	240.0
S10	6.9	329.7	58.0	28.0	75.0	141.0
S11	6.7	648.0	38.7	54.3	87.7	347.7
S12	6.5	371.3	38.7	47.3	129.3	176.3
WHO	**6.5-8.5**	**400.0**	**250.0**	**50.0**	**75.0**	**300.0**

4.3.2 WQI calculation for borehole

Note; Each value represents the average of two assessments.

Three metrics (EC, Mg^{2+}, and Ca^{2+}) out of a total of six parameters do not fulfill standards. Therefore:

$F_1 = \left(\frac{3}{6}\right) * 100 = 50$

There were 29 tests that did not adhere to the rules, and there were 72 tests overall.

$F_2 = \left(\frac{22}{72}\right) * 100 = 30.6$

The excursions, their normalized sum, and F3 are calculated as follows: Excursion $= \left(\frac{444}{400}\right) - 1 = 0.11$ (calculated for every value that is higher than its upper limit)

$\text{NSE} = \frac{\sum_{i-1}^{n} \text{Excursion i}}{\text{Number of test}}$

$= \frac{13.79}{72} =$ **<u>0.19</u>**

$F_3 = \left(\frac{\text{nse}}{0.01\text{nse}+0.01}\right)$

$= \left(\frac{0.19}{0.01*0.19+0.01}\right)$

$=\frac{0.19}{0.0119}$

=<u>15.96</u>

$$WQI = 100 - \left(\frac{\sqrt{F1+F2+F3}}{1.732}\right)$$

$$100 - \left(\frac{\sqrt{50 + 30.6 + 15.96}}{1.732}\right)$$

=$\underline{\underline{69.04}}$

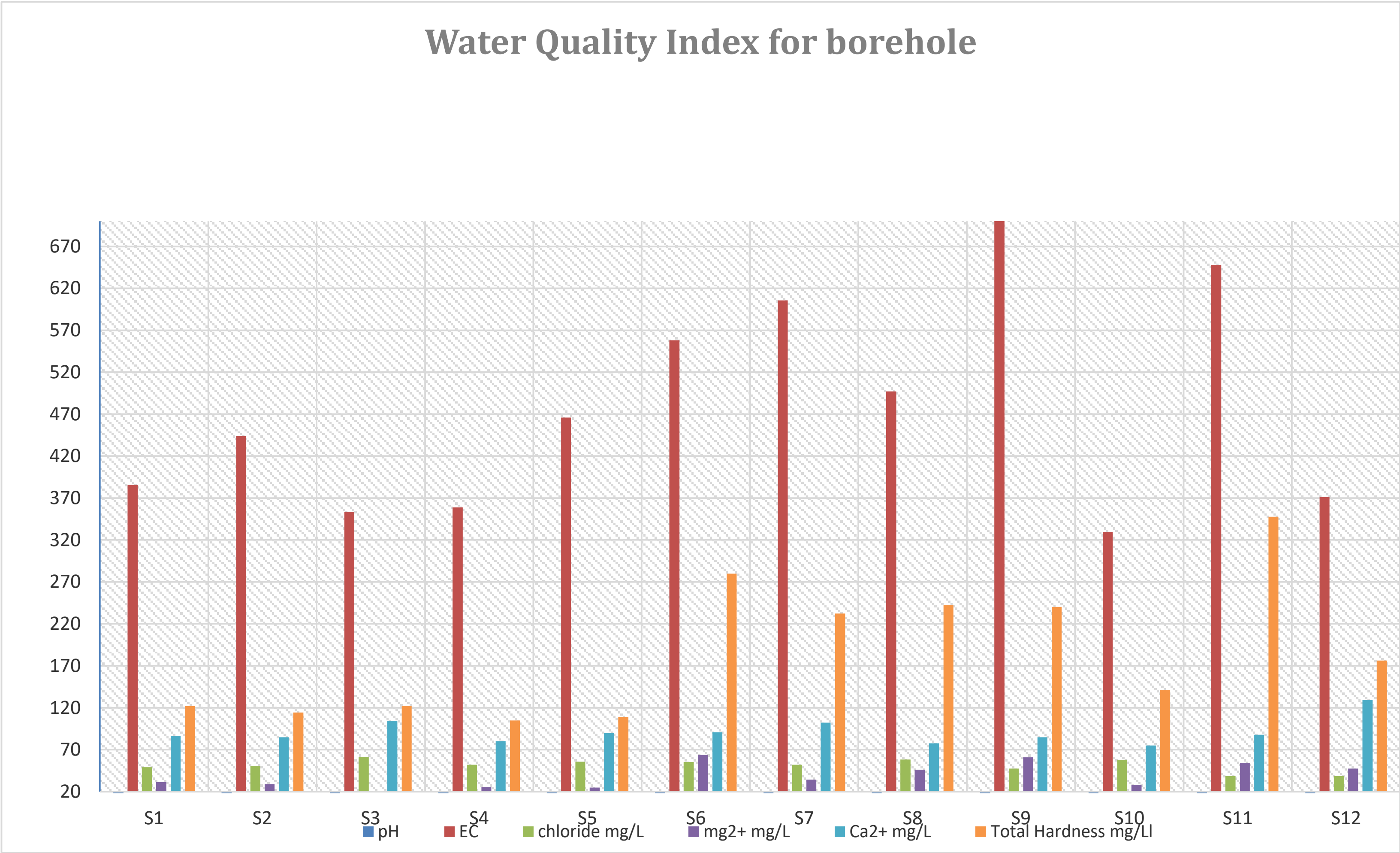

Figure 4. 1: *water quality index for borehole*

4.3.3 WQI calculation for End User

Table 4. 14: *Physico-chemical parameter sample collected for end-user WQI*

Code	pH	EC	chloride mg/L	mg^{2+} mg/L	Ca^{2+} mg/L	Total Hardness mg/Ll
S1	6.1	414.3	55.7	41.3	94.3	138.0
S2	6.9	413.7	42.7	33.7	87.3	122.0
S3	6.8	386.3	24.7	35.0	82.3	117.3
S4	6.9	491.0	33.0	36.7	97.3	134.7
S5	7.3	454.3	57.3	40.3	126.7	169.0
S6	6.7	389.7	51.0	39.3	69.7	110.7
S7	7.4	414.3	59.7	33.7	94.7	121.7
S8	7.2	395.7	78.0	48.7	130.0	182.0
S9	6.7	453.7	64.7	49.0	89.0	136.3
S10	6.8	357.7	66.7	31.0	90.3	122.3
S11	7.0	480.3	63.0	34.7	95.7	135.3
S12	7.1	478.0	39.3	42.7	102.7	145.3
S13	6.6	358.3	50.7	40.3	101.3	141.7
S14	7.0	1297.3	35.7	48.3	108.0	257.7
S15	7.6	379.3	27.7	58.3	99.0	159.7
S16	7.4	389.3	28.3	61.7	94.7	159.0
S17	6.9	436.0	45.0	42.3	108.0	152.3
S18	7.6	490.0	49.3	46.7	115.0	159.0
S19	7.4	490.0	41.0	43.3	124.0	167.3
S20	7.2	348.7	48.3	39.3	110.7	151.7

S21	6.7	378.0	52.3	39.3	103.0	148.3
S22	6.8	457.0	43.3	40.0	109.7	149.7
S23	7.4	373.3	56.7	41.7	114.0	152.0
S24	7.7	480.0	48.0	37.7	116.7	155.0
S25	7.6	452	46	38	119	152.1
S26	7.6	350	49.2	37.8	123.4	149.7
S27	7	490	43	35	110	130
S28	7	339	46	33	120	142
S29	6.7	352	45.6	37	114	149
S30	6.5	350	35	25	150	146
S31	7.3	350	41	38	133	132
S32	7.1	350	49	45	120	167
WHO	**6.5-8.5**	**400.0**	**250.0**	**50.0**	**75.0**	**300.0**

Note; Each value represents the average of two assessments.

Three metrics (EC, Mg^{2+}, and Ca^{2+}) out of a total of six parameters do not fulfill standards. Therefore:

$F_1 = \left(\frac{3}{6}\right) * 100 = 50$

There were 50 tests that did not adhere to the rules, and there were 129 tests overall.

$F_2 = \left(\frac{50}{129}\right) * 100 = 38.76$

The excursions, their normalized sum, and F3 are calculated as follows: Excursion $= \left(\frac{414.3}{400}\right) - 1 = 0.036$ (calculated for every value that is higher than its upper limit)

$$\text{NSE} = \frac{\sum_{i-1}^{n} \text{Excursion i}}{\text{Number of test}}$$

$$= \frac{20.4246}{129} = \underline{\mathbf{0.158}}$$

$$F_3 = \left(\frac{\text{nse}}{0.01\text{nse} + 0.01}\right)$$

$$= \left(\frac{0.158}{0.01 * 0.158 + 0.01}\right)$$

$$= \frac{0.158}{0.0116}$$

=<u>13.62</u>

$$\text{WQI} = 100 - \left(\frac{\sqrt{F1+F2+F3}}{1.732}\right)$$

$$100 - \left(\frac{\sqrt{50 + 38.76 + 13.62}}{1.732}\right)$$

=<u>65.67</u>

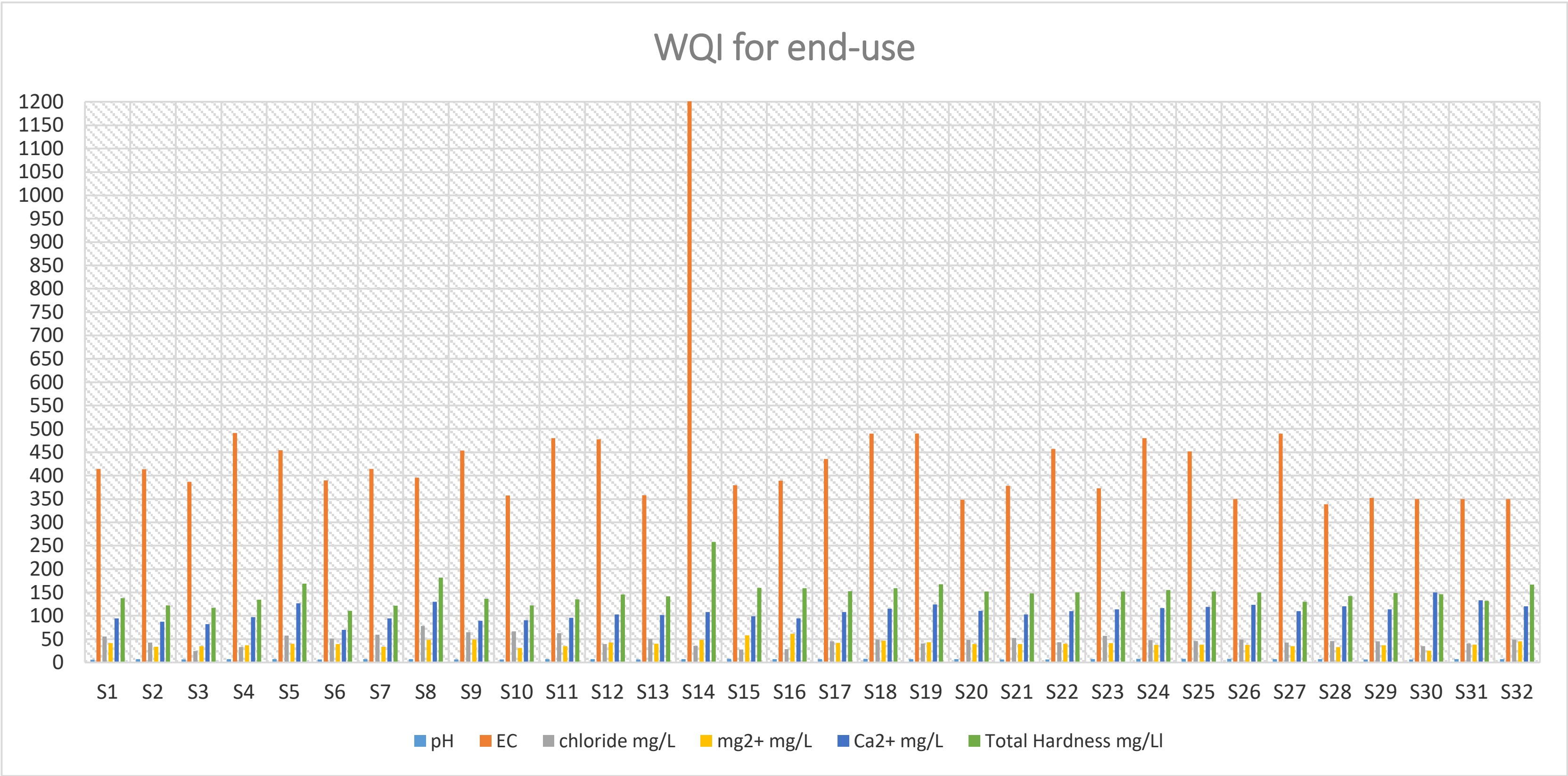

Figure 4. 2: *water quality index for end-user*

With a calculated result of borehole and end-user 69.04 and 65.67, the water quality in Bishoftu City is classified as "fair" according to the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI). This indicates that the water in this area meets most of the water quality guidelines, posing minimal risk to aquatic life. The favorable rating suggests that the environmental conditions in Bishoftu are conducive to sustaining healthy aquatic ecosystems, supporting biodiversity, and maintaining overall ecological balance. The results imply that the water quality in this region is generally safe for both human consumption and the preservation of aquatic life, making it a not positive indicator of environmental health in the area.

CHAPTER FIVE

CONCLUSION AND RECCOMENDATION

5.1 Conclusion

To summarize, the overall goal of this study was to assess the current water services that these source (Borehole) provide to end user in order to determine the quality of drinking water supply schemes at the source, reservoir and end user point. A total of 108 water samples were collected from a source, reservoir and a representative end user in Bishoftu City for the characterization and analysis of drinking water quality parameters. In order to determine a safe and acceptable level of drinking water for consumers, the water quality parameters were compared to the WHO allowable limit and the Ethiopian recommended values.

The main physco-chemical parameters considered for investigation, PH, electrical conductivity, Magnesium, Calcium, chloride, total hardness. Bacteriological tests such as E-coliforms and total coliforms were analyzed.

The result indication was not chlorination in the treatment system contamination occurs more at the end user. In addition, the presence of water-quality indicator microorganisms could be connected to poor waste disposal and water-source management. As a result, an effective waste disposal system and a catchment area management system are necessary surrounding water sources.

All water samples taken from source, reservoir and End User taps, on the other hand, were not all infected with EC, showing that contamination occurs both at the source and throughout the end user. In addition, the presence of water-quality indicator microorganisms could be connected to poor waste disposal and water-source management. As a result, an effective waste disposal system and a catchment area management system are necessary surrounding water sources.

The total coliform group has been chosen as the main indicator bacteria for disease-causing organisms in drinking water. It is a key determinant of water's appropriateness for human consumption. If coliforms are found in significant numbers in water, there is a good chance that additional dangerous bacteria or organisms are present. The World Health Organization (WHO) and Ethiopian drinking water recommendations demand it. Regular drinking water quality examinations of the source, primary distribution tanks, end user and pipes should be used to guarantee that the water is fit for human use. The current study was confined to analyzing bacteriological and physical chemical parameters from the source of the water supply system to end user tap connections. Additional water-quality parameters, such as heavy metals and their sources and end user should also be researched further. As a result of human activities, the decline in water quality in end user is greater than the decline at the source.

The results of bacteriological analyzes have shown that all sample sources (wells) of all 10 water systems and one reservoir have 0/100 ml total coliforms (TC) at source and reservoir level. However, the bacteriological results of end-user water samples range from 0 TC/100mL (TNTC), mainly due to end-user poor water management, lack of application of chemical treatment and poor sanitation practices in most communities. And the results of the Escherichia Coli analyzes have shown that all sample wells (wells) of all 10 water systems and one reservoir contain 0/100 ml Escherichia Coli at the well and reservoir level. However, the Escherichia Coli end-user water sample result was recorded at s14 and s15 and the remaining samples are 0/100mL.

The current study revealed that a few of the water samples look contaminated and hence fast and reliable tools are required to regularly inspect the water samples before being distributed to the end users. Moreover, the water distribution system needs checking up the status within same time in Bishoftu city only focus on quality rather than quantity.

5.2. Recommendations

Bacteriological testing method and physicochemical testing on time at source and end user could be a good option to reduce water born disease. In developed communities, the preferred technology is a piped distribution system with indoor end user taps, but this is also the most expensive. Until such a solution can be made a reality for everyone more cost effective solutions need to be employed; water access in the form of communal taps are likely intermediate solutions. The myriad different waterborne pathogens, and removal requirements associated with each, suggests that an effective system for communities that can only afford to have communal water collection points would be to adopt a two-tiered approach. Part one would be to provide an improved well and Reservoir, to preserve source water quality and minimize contamination.

Chemical disinfection at End of User, to eliminate many common waterborne pathogens introduced from collection, transport, storage, and use. Sustainable access to safe drinking water needs to include increased availability of consistent water supplies and a means of ensuring that water is safe up to the time it is consumed (Nath, et al. 2006)

The current study is restricted to a small number of physico-chemical parameters and a low sampling frequency. As a result, additional water quality parameters such as fluoride and heavy metals should be sampled and analyzed all year.

The proper implementation and sufficient chlorine disinfection of water are critical. Water supplies should be properly sanitized, managed, monitored, and maintained on a regular basis.

The surroundings of some Source (boreholes) are subject to pollution due to the lack of a flood control channel and a suitable fence. Therefore, flood protection and a fence must be erected.

The water supply does not have a chlorination system; therefore, the entire water supply system must be disinfected at regular intervals (periodic shock chlorination) and after disinfection, the residual chlorine in the distribution line should be checked by the laboratory.

To ensure that the water is suitable for human use, regular drinking water quality assessments fr om the source, reservoirs, distribution systems, and piping lines should be used.

To maintain water quality and protect water sources, effective drinking water system management and catchment rehabilitation should be addressed.

To prevent pipeline breakage and exposure in the system (may be the means for coliforms), integrated and programmed sectorial actions are required for water distribution system maintenance.

Furthermore, researcher should be conducted on the trend, also including on other missed parameters in this research and Deteriorate status of Bishofu city drinking water supply and it should be search for multiple barriers to avoid contamination.

REFERENCE

Abayneh, A. (2018). collaboration with the Ethiopia public health training initiatives. *public health training initiatives.*

Addendum, E. (2017). Guidelines for drinking-water quality. (F. Edition, Ed.) . *WHO Guidelines*.

Addisie, M. (2012). Assessment of drinking water quality and determinants of house hold potable water consumption in Sidima District, Ethiopia. *research*.

ADWG. (2019). National Health and Medical Research Council and the Agriculture and Resource Management . *Australian Drinking Water Guidelines*.

B, K. (2018). Assessment of physico-chemical and Bacteriological Quality of Drinking Wate. *Assessment of physico-chemical and Bacteriological Quality of Drinking Water in the Central Rift valley System, Ziway City Oromia Region, Ethiopia.*

Birhanu, M. (2007). Assessment of Physico-chemical and Microbiological Quality of Drinking Water . *Assessment of Physico-chemical and Microbiological Quality of Drinking Wate*.

D.Seib, M. (2019). Assessing Drinking Water Quality at Source and Point-Of-Use. *Assessing Drinking Water Quality*.

Desta Kassa, E. (2009). Physico- Chemical and Bacteriological Quality Assessment of Drinking Water from Source to Households Distribution point In Debrezeit City. *Physico- Chemical and Bacteriological Quality Assessment of Drinking Water from Source*.

Fewtrell, L. P.-Ü. (2017). Water, sanitation and hygiene. World Health Organization. , *Geneva. World Health Organization.*

Geberyohannes. (2020). Status of water quality in municipaly tap drinking water supply in selected slum areas of addis ababa(doctoral dissertation. *Research*.

GTZ. (2015). Environmental Hand Book Volume I: Cross Sectoral Planning. *Environmental Hand Book Volume I*.

Health, M. O. (2011). National Drinking Water Quality Monitoring and Surveillance Strategy in Addis Ababa. *Monitoring and Surveillance Strategy in Addis Ababe.*

K, G. (200-8). Physico-chemical and bacteriological drinking water quality assessment of Bahir Dar City water supply from source to yard connection. *Physico-chemical and bacteriological drinking water quality assessment.*

kassa, D. (2019). physico- chemical and bacteriological Quality assessment of drinking water From source to households distribution Point in Debrezeit City. . *research.*

M, A. (2016). Assessment of Bacteriological Quality of Drinking Water Supply at the Sources and Point-of–Use at Home in Worebabo District, . *research.*

Mengstayehu, B. (2017). Assessment of Physico-chemical Microbiological Quality of Rural Drinking Water Supply at the Sources and Selected Communities of Akaki-Kalit Sub-City, Addis Ababa City Administration. *M.Sc Thesis, Addis Ababa University*.

Mohammed Mohsen. (2023). Assessment of Drinking Water Quality and its Impact on Residents Health. . *Assessment of Drinking Water Quality and its Impact on Residents Health* .

WHO. (1996). International Program on Chemical Safety. *Geneva:. Guidelines for Drinking-Water Quality*.

WHO. (2004). Guideline for Drinking Water Quality. *WHO Guideline.*

Appendix

4.14 At Borehole **Total Coliform**

Table 4.1 1: Compliance with National Standard and WHO Guide Lines for Average Total Coliform (TC) (no/100ml) at Borehole .

No	Laboratory 1st round (no/100ml)	Laboratory 2nd round (no/100ml)	Average	WHO Standard 0/100 ml	National Standard Level)	National Standard Test Method	Compliance with WHO Guide Lines	Compliance with National Standard
B1	0	0	0	0/100 ml	must not be detectable	ES ISO 9308-1	Yes	Yes
B2	0	0	0	"	"	"	Yes	Yes
B3	0	0	0	"	"	"	Yes	Yes
B4	0	0	0	"	"	"	Yes	Yes
B5	0	0	0	"	"	"	Yes	Yes
B6	0	0	0	"	"	"	Yes	Yes
B7	0	0	0	"	"	"	Yes	Yes
B8	0	0	0	"	"	"	No	No
B9	0	0	0	"	"	"	Yes	Yes
B10	0	0	0	"	"	"	Yes	Yes
B11	0	0	0	"	"	"	Yes	Yes
B12	0	0	0	"	"	"	Yes	Yes

Table 4.1 2: Compliance with National Standard and WHO Guide Lines for Average Total Coliform (TC) (no/100ml) at End Users.

No	Laboratory result	Laboratory result 2nd	average	WHO Standard 0/100 ml	National Standard	National Standard Test Method	Compliance with WHO Guid	Compliance with National Standard
s1	0	0		0/100 ml	must not be detectable	ES ISO 9308-1	Yes	Yes
s2	0	0	0	"	"	"	Yes	Yes
s3	0	0	0	"	"	"	Yes	Yes
s4	0	1	0	"	"	"	Yes	Yes
s5	0	0	0	"	"	"	Yes	Yes
s6	0	0	0	"	"	"	Yes	Yes
s7	0	0	0	"	"	"	Yes	Yes

s8	0	0	0	"	"	"	Yes	Yes
s9	0	0	0	"	"	"	Yes	Yes
s10	0	0	0	"	"	"	Yes	Yes
s11	0	0	0	"	"	"	Yes	Yes
s12	4	0	0	"	"	"	No	No
s13	0	0	0	"	"	"	Yes	Yes
s14	23	3		"	"	"	No	No
s15	TN TC	1		"	"	"	No	No
s16	0	0		"	"	"	Yes	Yes
s17	0	0		"	"	"	Yes	Yes
s18	22	0		"	"	"	No	No
s19	18	0		"	"	"	No	No
s20	11	0		"	"	"	No	No
s21	1	0		"	"	"	No	No
s22	4	1		"	"	"	No	No
s23	5	0		"	"	"	No	No
s24	1	0		"	"	"	No	No
s25	0	0		"	"	"	Yes	Yes
S26	0	0		"	"	"	Yes	Yes
S27	0	0		"	"	"	Yes	Yes
S28	0	0		"	"	"	Yes	Yes
S29	0	0		"	"	"	Yes	Yes
S30	0	0		"	"	"	Yes	Yes
S31	0	0		"	"	"	Yes	Yes

4.15 At Borehole Escherichia Coli

Table 4.1 3: Compliance with National Standard and WHO Guide Lines for Average Escherichia Coli (E-Coli) (no/100ml) at Borehole.

No	Laboratory 1st Samples (no/100ml)	Laboratory 2nd round (no/100ml)	average (no/100ml)	WHO Standard	National Standard	National Standard Test Method	Compliance with WHO Guide Lines	Compliance with National Standard
B1	0	0	0	0/100 ml	must not be detectable	ES ISO 9308-2	Yes	Yes
B2	0	0	0	"	"	"	"	"
B3	0	0	0	"	"	"	"	"
B4	0	0	0	"	"	"	"	"

B5	0	0	0	"	"	"	"	"
B6	0	0	0	"	"	"	"	"
B7	0	0	0	"	"	"	"	"
B8	0	0	0	"	"	"	"	"
B9	0	0	0	"	"	"	"	"
B10	0	0	0	"	"	"	"	"
B11	0	0	0	"	"	"	"	"
B12	0	0	0	"	"	"	"	"

4.16 At End User Escherichia Coli

Table 4.1 4: Compliance with National Standard and WHO Guide Lines for Average Escherichia Coli (no/100ml) at End User.

No	Laboratory 1st Samples (no/100ml)	Laboratory 2nd Samples (no/100ml)	Laboratory average	WHO Standard 0/100 ml	National Standard	National Standard Test Method	Compliance with WHO Guide Lines	Compliance with National Standard
1	0	0	0	0/100 ml	must not be detectable	ES ISO 9308-2	Yes	Yes
2	0	0	0	"	"	"	Yes	Yes
3	0	0	0	"	"	"	Yes	Yes
4	0	0	0	"	"	"	Yes	Yes
5	0	0	0	"	"	"	Yes	Yes
6	0	0	0	"	"	"	Yes	Yes
7	0	0	0	"	"	"	Yes	Yes
8	0	0	0	"	"	"	Yes	Yes
9	0	0	0	"	"	"	Yes	Yes
10	0	0	0	"	"	"	Yes	Yes
11	0	0	0	"	"	"	Yes	Yes
12	0	0	0	"	"	"	Yes	Yes
13	0	0	0	"	"	"		
14	7	0	3.5	"	"	"	No	No
15	2	0	1	"	"	"	No	No
16	0	0	0	"	"	"	Yes	Yes
17	0	0	0	"	"	"	Yes	Yes
18	0	0	0	"	"	"	Yes	Yes
19	0	0	0	"	"	"	Yes	Yes
20	0	0	0	"	"	"	Yes	Yes

21	0	0	0	"	"	"	Yes	Yes
22	0	0	0	"	"	"	Yes	Yes
23	0	0	0	"	"	"	Yes	Yes
24	0	0	0	"	"	"	Yes	Yes
25	0	0	0	"	"	"	Yes	Yes
26	0	0	0	"	"	"	Yes	Yes
27	0	0	0	"	"	"	Yes	Yes
28	0	0	0	"	"	"	Yes	Yes
29	0	0	0	"	"	"	Yes	Yes
30	0	0	0	"	"	"	Yes	Yes
31	0	0	0	"	"	"	Yes	Yes