ASSESSMENT OF DRINKING WATER QUALITY DETERIORATION FROM SOURCE TO THE END USER, THE CASE OF DUKEM TOWN, ETHIOPIA.

Dejene Diriba Senbeta

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

June, 2023

Adama, Ethiopia

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DECLARATION

I hereby declare that this Master Thesis entitled "**Assessment of drinking water quality deterioration from source to the end user, the case of Dukem town, 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.

Dejene Diriba	_____	_____
Name of student	Signature	Date

RECOMMENDATION

I, the advisor(s) of this thesis, hereby certify that I have read the revised version of the thesis entitled "**Assessment of drinking water quality deterioration from source to the end user, the case of Dukem town, Ethiopia"** prepared under my/our guidance Dejene Diriba submitted in partial fulfillment of the requirements for the degree of Mater's of Science Water Supply and Environmental Engineering. Therefore, I/we recommend the submission of revised version of the thesis to the department following the applicable procedures.

Keredin Temam (PhD)	_____	_____
Major Advisor	Signature	Date
_____	_____	_____
Co-advisor	Signature	Date

APPROVAL PAGE

I, the advisors of the thesis entitled "**Assessment of drinking water quality deterioration from source to the end user , The case of Dukem town, Ethiopia"** and developed by **Dejene Diriba**; hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Keredin Temam (PhD)	_____	_____
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Co-advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis Dejene Diriba have read and evaluated the thesis entitled "**Assessment of drinking water quality deterioration from source to the end user , the case of Dukem town, 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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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 ISO	Ethiopia Standard International Standard Organization
ES	Ethiopia Standard
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
UNEP	United Nations Environmental Program
UNICEF	United Nations International Children's Emergency Fund
RADWQ	Rapid Assessment of Drinking Water Quality
WASH	Water, Sanitation and Hygiene.
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 evaluate Dukem Town's drinking water supply system at both the source and the end user. A total of 108 water samples were taken from 25 homes (end user outlets), 10 boreholes, and one reservoir. Using the conventional methods of analysis Procedure, the samples' pH, Electrical Conductivity (EC), Chloride, Magnesium (Mg2+), Calcium (Ca2+), Total Hardness, and Microbiological parameters (Total Coliform E- coli measured in colony forming units CFU) were all calculated. 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. While all other physico-chemical parameters were in compliance with WHO guidelines and national standards, only calcium from all sources and total hardness from the Kera borehole did not. Escherichia coli (1–7/100ml) at sample codes s14 and s15 and total coliform (1-22/100ml) did not comply with WHO guidelines and national standards, according to biological results, while all other biological results were in compliance with these guidelines and standards. The finding that some of the tap water samples were more contaminated as they were refilled from end users suggests that Dukem Town's water supply system is insufficiently treated at the end user. Regarding bacteriological 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. The results of the study's sanitary inspection also showed that jerry can storage by families, a sanitation practice, was a factor in the bacteriological pollution of the water supply. In order to reduce the hazards and problems associated with the current water quality, notably the bacteriological water quality and chlorine issue, the town water utility must give the Dukem town water supply system more attention.

Key Words: *Water Quality Contamination, Drinking Water Quality Parameters, Water Quality Index*

1. 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, and 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 (Peter., 2013). According to (Mohammed Mohsen, (2013)the remaining tiny part is only 0.03% usable by humans in the form of surface and ground water. A fundamental element for good health and a fundamental human right is access to clean drinking water (WHO, 2002), additionally, it is difficult to picture a sterile and clean atmosphere without water. A vital requirement for good health as well as a fundamental human right is access to clean drinking water.

There are already scarce fresh water resources in many parts of the world. As a result of the coming century's population growth, urbanization, and climate change, it will become more and more limited. Water quality in developing countries like Ethiopia is sadly continuously declining and harmful for human consumption as a result of fast population growth, industry expansion, and the discharge of waste water and chemical effluents into canals and other water sources (Jackson, 2013). According to recent estimations, the amount of water available in developing regions of Africa, the Middle East, and South Asia is drastically decreasing, and the water's quality is fast deteriorating as a result of expanding urbanization, deforestation, soil degradation, etc. (Annachhatre, 2006).

Worldwide, more people are dying from poor quality of water per year than from all forms of violence including war and it is estimated that about 26% of all deaths are outcome from contagious diseases caused by pathogenic bacteria (WHO, 2002).

Primarily used for drinking, food preparation and cooking, personal hygiene, bathing, cleaning, and washing, watering gardens, and watering livestock. The inadequate and poor quality of the water supply may result in a variety of health issues (Gwimbi, 2011). The high infant death rate is a result of the 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, (2017). Up to 80% of all illnesses and disorders in the world, according to the World

Health Organization, are caused by inadequate sanitation, tainted water, or a lack of access to water.

In Ethiopia, poor environmental health conditions caused by a lack of access to clean water and insufficient hygiene and sanitation practices are to blame for more than 60% of communicable diseases. Research has demonstrated that the range of diseases is expanding and the frequency of many water-related microbial diseases is rising, in addition to the fact that they continue to be a major cause of sickness and mortality around the world (WHO, 2004).

According to estimates, 15% of all child deaths under the age of five in poor countries are caused by diarrheal diseases, and 80% of illnesses in those countries are linked to water and sanitation. According to the (WHO, 2004), diarrhea is still the main cause of death among children. Water that has been polluted with pathogens, physical contaminants, or chemical contaminants at the source, during distribution, transit, and handling in homes or other working places, in general, may constitute a health issue if used without treatment (Mark, 2004; (WHO, 2002). Additionally, contamination occurs at home as a result of bad hygiene and exposed water collection and storage containers (Johns, 2006).

According to (Abayneh A. , 2004), the main causes of Ethiopia's water supply problems include a lack of community support for previously constructed frameworks, a lack of spare parts, a lack of neighborhood support capacities, etc. According to WHO and (UNICEF, 2018), sub-Saharan Africa and southern Asia both still struggle with low sanitation coverage at 41% and 30%, respectively. Ethiopia is one of the countries in the world with the worst water quality problems as a result. Its water supply and sanitation coverage rates are the lowest among Sub-Saharan countries, with 68.5% and 56%, respectively (MoWR, 2010).

Even though increasing access to these sources is crucial, the idea that better water resources are of greater microbiological cleanliness do not always hold true once the water has been delivered and kept in the home. For instance, the possibility of recontamination the water between the water source and the residence as a result of filthy hands could extend the cycle of low drinking water quality. Recontamination usually occurs when water is removed with a cup through the top opening of the storage container, whether it be a normal clay pot or a plastic bucket (Meseret, 2018). Water is the most common element on earth and is essential for all life. Surface water bodies

like rivers and lakes, subterranean aquifers, and pore spaces below the water table are the principal sources of water. Because it frequently includes dissolved inorganic and organic materials as well as live organisms (viruses, bacteria, etc.), the water from these sources is not always pure. Therefore, toxic chemicals and potentially harmful bacteria should not be present in water meant for residential consumption (Desta, 2009)

Regular monitoring of the physicochemical and bacteriological quality of water is required for effective management. Purity, lack of saltiness, and the absence of contaminants are all requirements for potable water. Bacteria, inorganic, organic, and radioactive substances that are water soluble are the main water contaminants that cause water quality to deteriorate and a number of public health issues.

To safeguard consumers from diseases spread through contaminated water, drinking water utilities must make sure that the water they supply is absolutely free of dangerous chemicals and pathogenic or potentially pathogenic microorganisms. If the quality of the drinkable water is low, water-related diseases can have negative social and economic effects (Suma et al., 2015).

The current research was done in Dukem town Oromia Region of Ethiopia. Dukem town is located at 37km South East of Addis Ababa along the main road to Adama. The total population of the urban residence was 152,244. Of those 77,074 were men and 75,170 women (CSA, 2007). The water supply uses Direct and gravity system for distribution from one reservoir and ten (10) boreholes.

The primary goal of this research was to assess the drinking water quality parameters to check whether the water is safe for drinking or not in the Dukem town. The purpose of the study was to assess the physicochemical and microbiological quality of drinking water from sources, reservoirs and End User in Dukem Town.

1.2 STATEMENT OF THE PROBLEM

The deterioration of water quality in the water supply framework could be a serious issue that mainly impacts the general health of the user. This could be because of the presence of physical, chemical, and biological components. This may happen at the source, after clearing out the source or on the way from the source to the end user. At this point we cannot figure out and recognize exactly where the problem originated from. Whether, it's from the source or on the way to the end user. By saying so, evaluating water quality based on major parameters such as Electrical Conductivity, PH, faucal microorganisms and data from the health center.

According to (Fuest, 2007) there are multiple sources contributing to the issues with contamination in the urban water distribution system. The distribution system's quality water is contaminated by wastes from bad sanitation (sewage), agriculture, and other activities. Additionally, a distribution system break, the inverse pumping of soil contaminants through a water supply interruption, ageing and poor maintenance of the distribution system, and a low level of chlorine (treatment efficiency) typically jeopardize the distribution system's integrity and the quality of potable water (Geberyohannes, 2020).

Several test issues Most of the time, the neighborhood states that the water is too heavy for us and uses water treatment equipment, yet there are still particles in the system at home. These results imply that problems with water quality are pervasive in the community water distribution systems. These problems motivate to assess the status of drinking water quality Deteriorate from sources to End User in Dukem town. Previously, not studies have been done on the water quality status and sanitation practice of this Town. Hence, it is important to carry out an analysis of the physicochemical and bacteriological parameters of the water and water quality index. Therefore, the purpose of this study is to assess the variance in the physicochemical and bacteriological water quality parameters at Dukem from source to end user. The findings of this study are compared with WHO Guideline and National Standard in order to comprehend its status in relation to the entrance levels and to address public health issues.

1.3 OBJECTIVE

1.3.1 General objective the study

The general objective of this research is to assess drinking water quality deterioration from source to end user in the Dukem Town.

1.3.2 Specific objectives the study

1. To assess drinking water quality deteriorate from source to end user and to examine the compliance level of drinking water quality with the quality parameters.
2. To evaluate water quality index in the study area.
3. To identify the main contaminants in the study area.

1.4 Research Question

1. How the drinking water quality deteriorate from source to end user and what is the compliance level of the current drinking water quality compared to the national standards?
2. How water quality index in the study area?
3. How do identify the main contaminants in the study area?

1.5 Significance of the Study

A few test-related bugs the majority of the time, the community argues that the water is too heavy for us and uses water treatment equipment, although there are still particles in the treatment equipment in their homes. These results indicate that there are widespread problems with water quality in the nation's water distribution systems.

It is anticipated that the research, which focuses on analyzing the performance of Dukem Town's water supply quality, would advance knowledge of and provide updated data on urban water supply quality. The socioeconomic and health status of the populace could be improved as a result. It could also be used to demonstrate the degree of water quality in the locality and provide insight into a potential solution to the town's water quality issue. Future researchers with a similar area of interest may utilize this as a starting point. It may even provide hints to other towns that are experiencing a similar situation.

By pinpointing the location of the issue, contamination, or degeneration (affected by coliforms, high calcium levels, or an increase in electrical conductivity), it may also help to alleviate the

problem. Additionally, it decreases the price of purchasing alternative water sources, including packaged water. It will provide a way for determining how vulnerable the supply is to contamination now and in the future, as well as any significant operational or infrastructure problems. Additionally, it demonstrates how the procedures used in the borehole, reservoir, and end-user treatment facility compare to those advised by the WHO and the national norms for pH, total hardness, calcium, and bacteriological parameters. The findings of the investigation will also demonstrate the variations between sources and end user in Dukem's water supply. Generating baseline data for further studies and interventions is very useful for monitoring acute outbreaks, regardless of the difference between the source and the end user. This research investigates the causes and associated impacts of water quality problems, thereby helping to develop remedial measures.

1.6 Scope of the Study

The research was limited in space, time and theme. Spatially, the research was conducted to know the performance of water quality and sanitation practice in Dukem town by using different indicators, compared with WHO and Ethiopian standards. The physio-chemical parameters cover electrical conductivity, PH, Chloride, Magnesium (Mg^{2}+), Calcium (Ca^{2+}), Total Hardness whereas. The analyses also considered bacteriological total Coliform and E- coli. On the other hand, temporally, the water quality index was assessed. The research is limited to water quality and not the service or access of the water. And alkalinity, Iron and some chemical parameters (heavy metals) were not analyzed. The study focused only from source to End User and did not include Distributions line.

1.7 Limitation the study

Due to the town's limited number of populations, a lack of infrastructure (Logistic), finances, time, and enough laboratory technicians, the number of water sampling points was limited to 36. However, due to budgetary constraints (increase the cost of reagents), a lack of logistic infrastructure, time, a sparse population, and a lack of laboratory technicians to assist me during data collecting, I was unable to address what was planned for within the budget and schedule. Furthermore, the majority of the taps share the same distribution line. Due to a lack of water and funds, the study was only able to conduct the experiment twice for biological and three times for physic-chemical during the two month interval samples was analyzed.

The pumps failed repeatedly that the researcher was idle for some time during data collection, waiting for the pumps to restart. Another problem was that the majority of borehole not taps faucet and end user locked and thus the majority of samples were taken from end user tap and source. The data on physicochemical and bacteriological quality of water may not reflect the actual condition that can be checked in different monthly of the year, as the data on water quality parameters was examined in the study in February, March, April, May, June.

2. LITERATURE REVIEW

2.1 Drinking Water quality

Drinking water quality is defined as the absence of pathogenic microorganisms and chemicals that are harmful to health (Tebutt, 2015). In fact, even completely secure supplies and well-run systems cannot guarantee that homes receive safe water. Studies show that even water collected from safe sources is likely to become faecally contaminated during transportation, containerization, and storage. The majority of people in the world do not have strong family water associations, and many of these must still physically carry water and store it in their homes. A covered water container will prevent 50% of water-borne and water-related infections, according to assessments of drinking water quality from source to point of use in rural areas (D.Seib, 2011) and Microbiological contamination between source and point of use (Jim Wright, January, 2004). Safe sources are crucial, but the quality of water that people consume can only be guaranteed with enhanced hygiene, better water storage and handling, improved sanitation, and in some circumstances, household water treatment (D.Seib, 2011). The prevalence of diarrhea is affected by water quality interventions more than was previously believed, particularly when interventions are implemented at the home level (or point-of-use) and in conjunction with improved water handling and storage (Fewtrell, 2007).

To avoid health risks, it is essential to provide both the rural and urban population with potable water. In order for water to be considered drinkable, it must meet a number of physical, chemical, and microbiological standards that are intended to make sure the water is tasty and secure for consumption (Tebutt, 1983).

2.2 Water Quality Analysis

According to the (CCME (2006), water high-satisfaction refers to the physical, chemical, microbiological, radiological, and organic properties of water as well as its aquatic ecosystems. These properties affect how well water can support its specific uses. It can specifically be changed as a result of human actions, which may also impact or change any of those dwellings to the extent of hurting terrestrial and aquatic organisms reliant on it (Kahlon & kahlon, 2018). Arsenic and fluoride, which can occur naturally, nitrate, which is applied to vast tracts of agricultural land as fertilizer, microbiological contamination, and turbidity were the chemicals that were deemed to

have the highest potential for harming human health, according to the World Health Organization in 2006.

2.3 WHO Drinking Water Quality standards

WHO has set guidelines for lower and upper limits of physicochemical and bacteriological concentration of drinking water. In this guide lines the concentration of various kinds of inorganic elements, compounds and bacteriological concentrations clearly specified. These guidelines have been widely used globally and used as a base for developing country specific drinking water quality standards. So that, countries are developed their own drinking water quality standards to monitor their water quality (WHO, 2017). WHO Guide Lines Value for Physicochemical Parameters is annexed.

2.4 Ethiopian Drinking Water Quality Standards

Ethiopia has also developed its own standard derived from WHO guide lines. 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) cancel 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. Full document is annexed.

2.5 Water Quality Parameters

2.5.1 Physical Parameters

2.5.1.1 pH of Water

The hydrogen ion (H+) potential in water is measured by the PH scale. The presence of natural acids in the soil and those from air evaporation that have permeated to the water are the causes of the acidity of groundwater (Chapman and Kimstach, 1996). The WHO guidelines state that despite the fact that eye infection and the escalation of skin conditions were linked to pH values higher than 11, "No health-based totally tenet price is proposed for pH. While often having little direct impact on consumers, pH is one of the most crucial operational water quality indicators.

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 with inside the variety 6.5–8.5(as according to WHO, 2006,ES,2011)consistent with the parameter.

2.5.1.2 Electrical Conductivity (EC)

A measurement of the ability of water to carry electric current is called electrical conductivity (EC). It is a valuable method to assess the purity of water (Achary, Ghosh, Khatua, & Mitra, 2016). And denotes the amount of total dissolved salts (Singh & Kaur, 2015). Temperature, pH, alkalinity, total hardness, calcium, total solids, total dissolved solids, chemical oxygen demand, and the concentrations of iron and chloride in the water all have strong correlations with conductivity.

2.6.1. Chemical Parameters for drinking water quality

2.6.1.1 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 figure such as pH and alkalinity of water with hardness over around 200 mg/lit may cause scale stores in the distribution framework and comes about in over the top cleanser utilization. Again, corrosion may result from soft water that has a hardness of less than 100 mg. From zero to several hundred mg (ppm), hardness can vary. The WHO sets a guideline value of hardness based on this basis of reference. Consumers' tolerance levels for hardness may affect acceptance levels, although there is a generally acknowledged scale based on flavor and household use. Hard water can have a variety of aesthetic issues, especially when heated, even if there are no known health concerns or drinking water requirements for its. A quantity of 90 to 100 mg/L is frequently regarded as ideal to limit corrosion while also avoiding unfavorable aesthetic consequences since hardness slows corrosion of residential plumbing. The four following categories are typically used to report total hardness:

Table 1: classification of water based on hardness

Sr. No	Hardness mg/l as CaCO3	Water Class
1	0-75	Soft Water
2	75-150	Moderately Hard Water

3	150-300	Hard Water
4	Above 300	Very Hard Water

(Source:-Sawyer and McCarty, 1987)

2.6.1.2 Magnesium

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

2.6.1.3 Calcium

In the human body, calcium is the most important and inexhaustible mineral, and proper use is crucial for normal growth and wellbeing. The human body stores 95 percent of its calcium in the bones and teeth. The severe lack of calcium in people can result in rickets, poor blood coagulation, broken bones, etc. The most pressing daily requirement is 1–2 grams, which are primarily found in dairy products. The presence of calcium in a drinking water supply is crucial for health because there is concrete evidence that shows the incidence of heart disease is reduced in areas with open water supplies that are very hard and contain calcium as their primary component. Its reasonable run in drinking water is up to 75 mg/l, according to (WHO, 1996).

2.6.1.4 Chloride (Cl)

Occasionally, the chloride content of water, particularly sodium chloride, which is primarily produced by the dissolution of hydrochloric acid salts such as table salt (NaCl) and sodium carbonate, is given special attention (Brock & A, 1979). Other sources of chlorides include animal feed, wastewater, storm sewers, and road salts. Major physiological processes can be found in surface water bodies, which frequently have low concentrations of chlorine. High chloride concentrations destroy metallic structures and pipelines and injure developing plants. According to WHO recommendations, the maximum chloride concentration permitted limit values should not be more than 250 mg/l.

2.7.1 Drinking Water Quality Bacteriological Aspects

The presence of bacteria that are indicative of faecal (sewage) contamination, more specifically coliforms and faecal coliforms like Escherichia coli, determines the microbiological quality of water. Coliforms naturally occur in soil and in both human and animal intestines. As a result, their proximity to water may indicate defilement. The intestines of both humans and other animals contain E. coli and certain Enterobacter aerogenes species. Therefore, their proximity proves categorically that there is faecal pollution. The nearness of coliform microbes in well water may be as a result of surface water infiltration or leakage from a septic framework (Goss & Richards, 2008). Add up to coliforms are a gather 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 the as it were member of the overall coliform bunch of microscopic organisms that's found as it were within the digestion tracts of warm blooded creatures, counting humans.

The presence of E. coli in water illustrates subsequent faecal contamination and may indicate the potential presence of pathogens that cause diseases, such as bacteria, illnesses, and parasites. Even though the majority of E. coli strains are harmless, some, like E. coli O157:H7, can cause illness like hemorrhagic uremic disorder (HUS), which results in kidney failure, especially in young children and the elderly (Mellmann, et al., 2005). Due to the difficulty and expense of testing for every known disease, total coliforms and E. coli are used as indicators to gauge the level of contamination and water quality of wells.

2.7.2 Common Water Use Practices, Beliefs, and Concepts

The majority of the following common habits that have been observed everywhere in the world in relation to water storage, transportation, and community capacity were observed here (Trevett, Carter, & Tyrrel, 2005).

Water gathered in jerry cans or buckets with an open top bucket washed with water and scrubbed by hand before use. Storage bins are kept in a location that might also be used by animals. Clay pots with unfastened lids holding water While most water-related behaviors are universal, their roots may come from many differences in culture, beliefs, and understanding.

2.7.3 Health impact associated with water.

An essential requirement for life is water. Sadly, not all water is beneficial to human survival. Water from contaminated sources is the direct cause of a host of illnesses and premature deaths. Humans are forced to utilize water, even for drinking, from any source, whether it is pure or contaminated, because they require it to survive (Zeyede and Tesfaye, 2004).A disease that is connected to water supply and sanitation is referred to as a "water-associated disease."

2.8 Sanitation and Hygiene Practices

2.8.1 Utilization of Sanitation Facilities

The prevalence of diseases connected to water and sanitation can decline without improving water and sanitation infrastructure. Hygiene promotion strives to ensure the correct use and maintenance of facilities by encouraging individuals to modify their behavior. The installation of facilities must be coupled with their proper usage and maintenance to result in genuine improvements in health. Use of latrines properly extends well beyond structures. Using a toilet, washing your hands after using one, and keeping one clean enough are often more elements of attitude and habit than the presence of physical infrastructure (IRC 2004).

The technical and economic benefits of a particular latrine design will determine whether it is chosen. However, it has also been discovered that cultural aspects, local resources, and technological ownership have a greater impact on a community's adoption of specific technologies (Neupane, Sharma, & Thapa, 2002). According to (Jenkins, 1999) defecation and feces have long been universally connected with cultural taboos, pollution, and danger. This perception can limit the likelihood that a project will be successful. The viability of a sanitation system depends on the community's socioeconomic and cultural circumstances in addition to the physical factors of water supply, soil moisture, and groundwater levels (IRC 1997).

An individual's opinions have been demonstrated to be significantly influenced by their age of first exposure to latrines; exposure at a young age encourages acceptance of latrines. These variables are crucial for understanding the cultural and social importance of latrines, which has an impact on how a system is adopted. These can be used as a technique to gauge community members' level of awareness. This is crucial since successful adoption cannot happen if people are unaware of the design, use, and upkeep of latrines (Jenkins, 1999).

2.8.2. Diarrhea, Trachoma and ARIs

The Health Impact of Sanitation is based on an inference that is tenable and derived from the widespread sectoral acceptance of Esry's analysis15 of 144 research in 1991 and 1996, which was supported by Fewtrell's enlarged study in 2004. According to their analysis, the following health effects can be attained when sanitation and hygiene are improved and extensively used: The average incidence of diarrhea was reduced by 36% as a result of safe excreta disposal, and by up to 48% when sanitation and hygiene education were implemented.

2.8.3 Enhanced Well-being

Having a better toilet is regarded to provide a wide range of societal benefits, as shown by national and international knowledge, attitude, belief, and practice studies24. Dignity, comfort, privacy, social standing, security for women, increasing enrollment in school for girls, and a general sense of well-being all on the list. According to a woman from Arsi Woreda in the Oromia area, "The toilet completes my house." Health is frequently ranked low when addressing issues considered when discussing motivation to build or renovate toilets, as Jenkins and Scott concluded from one such study25 in Ghana. In general, it should be emphasized that research conducted outside of Ethiopia that highlight the need to better understand effect and results in the Ethiopian setting are mainly reflected in the list of advantages of enhanced hygiene and sanitation. Regional universities' ongoing verbal autopsy research offers vital insights into the causes of death that might be broadened to better understand the effects and results of various inputs, from health promotion to community outreach to sanitation marketing.

2.8.4 By drinking contaminated water either for drinking or food preparation

A person who is afflicted with various excreta-borne disease pathogens contaminates the water when they urinate in an open area. By drinking contaminated river water, washing in contaminated water, or coming into contact with contaminated water, a healthy individual can get the illness. Typhoid fever, bilharzias, and other infections are among those contracted (Ministry of Health, 2007).

2.8.5 Water Quality Index

The public's concern over river and stream pollution needs comments with a basic level of technical expertise (Haldar, Das, & Halder, 2016). WQI (Harkins, 1974) is one such method that provides a more comprehensible summary of the WQ data. In the United States, WQI debuted in

1965 (Horton 1965). A single number that describes the WQ status of a water body is produced from complicated data. Additionally, it assesses WQ trends and permits the preliminary classification of River water for a variety of approved uses, including agriculture, recreation, and other applications (Mont, et al., 2008). There are numerous WQI methods, though. Canadian Council of Ministers of the Environment (CCME) is one example. Among the different methods, there is not yet a single methodology that is universally acknowledged.

3. MATERIALS AND METHODS

3.1 Description of the Study

Dukem settlement is situated 37 kilometers to the southeast of Addis Ababa on the main route to Adama. The research area has a total area of 9630.6 hectares and is geographically located between latitudes 8045'25"N and 8050'30"N and longitudes 38051'55"E and 38056'5"E. It is situated at a typical elevation of 2100 meters above sea level.

Since a number of homes, businesses, services, and institutions have been built, the town has made progress. Due to its economic significance and proximity to the capital city Addis Ababa, the population is likewise growing quickly. Growing industrialization and population numbers have created a fierce rivalry for land resources.

The town is bordered by the towns of Bishoftu and Gelan in the southeast and most of the north, respectively. Four nearby peasant organizations of the A kaki district define the remaining eastern and western portions of the town.

Wajitu Dibdibe is the southern peasant organization that shares the most land with Dukem town. The Gogecha Peasant Association, located in the town's northern region, comes next. TedechaYatu lines up with the third largest section of Dukem town. Oda Nabe, in the northwest, is Dukem Town's neighbor with the smallest border. The peasant associations located in the north are the furthest away from the center of Dukem while the other peasant associations are located in the east and south, which are both closer to Dukem town.

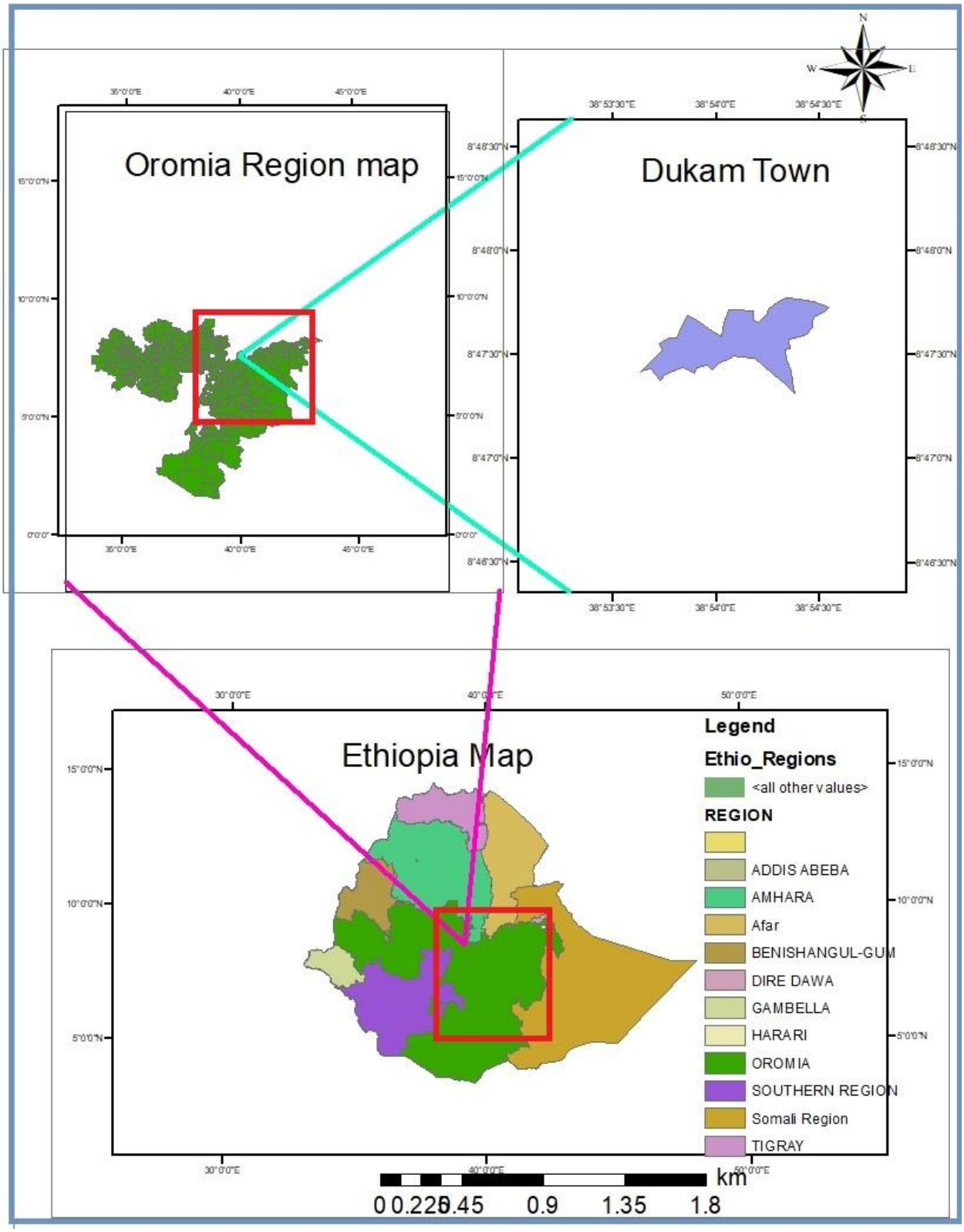


Figure 3.1: Dukem Town's map (source from GIS)

3.2. Study Design Period

Physio-chemical and bacteriological laboratory analysis in selected locations of Dukem town was conducted from February to July 2023.

3.3 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 in order to determine sample size. The actual difference between groups or the strength of the associations between variables that were observed in a study are referred to as the effective size. (WHO, 2011) suggested a population-based approach to sampling the minimum sample number for piped drinking water to conduct microbiological test in the distribution system. Therefore, for Dukem town with a population of 152,244 people, the sample size was 15 samples. (152,244/10000) +10). Additional 10 samples were added for end user and added 10 boreholes and 2 reservoirs, so that, the total water quality sample size was 37 but, one old reservoir was not provided service during this study period. Thus, the effective sample size became 36.

Table 3.1: WHO Population-Based Approach

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

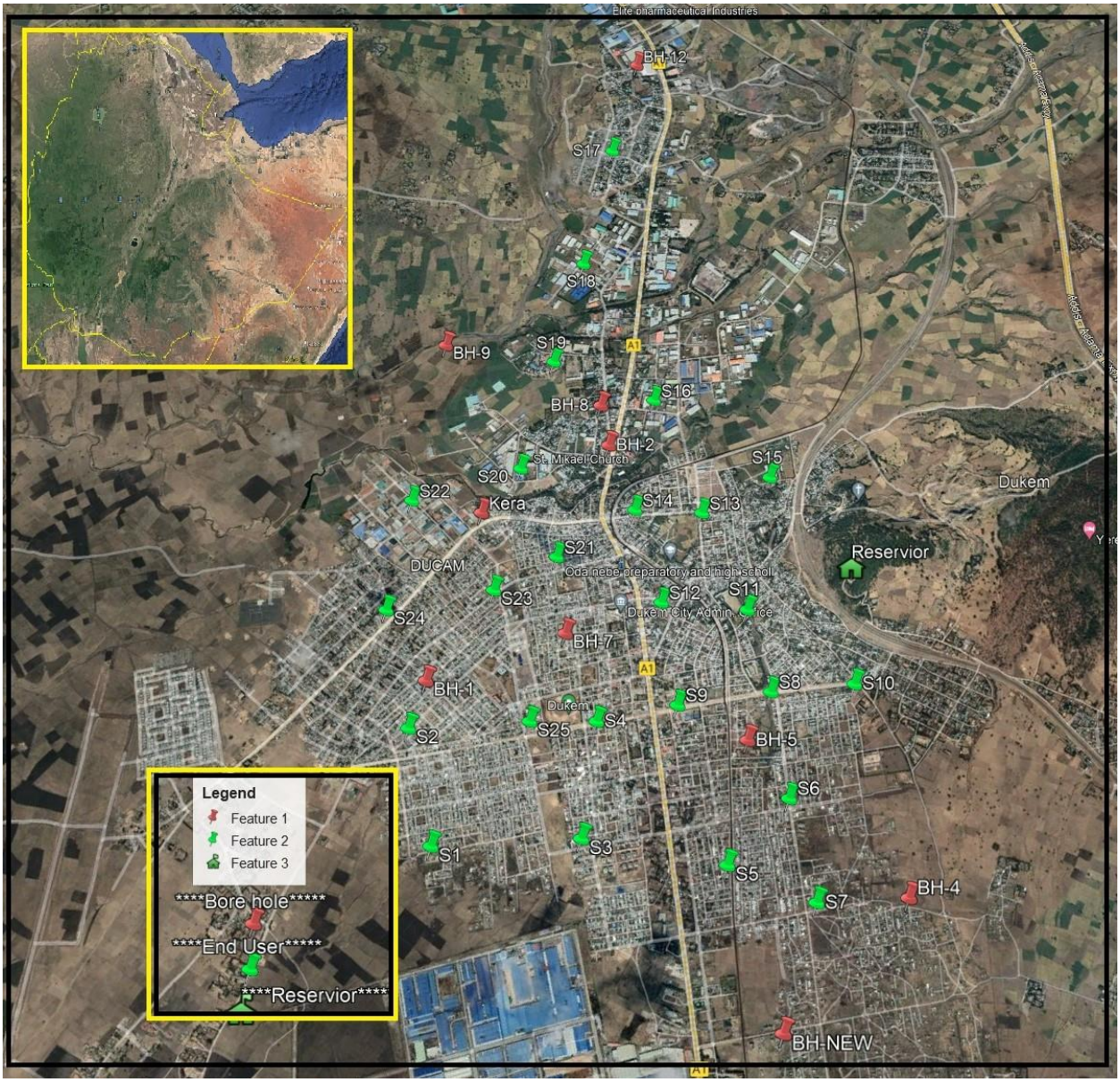


Figure 3.2: Location of sample points

3.4. 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.

3.5. 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.

3.5.1. Water Quality Calculation Data

The CCME WQI offers a mathematical framework for comparing current ambient water quality conditions to water quality recommendations. It is adaptable when it comes to the kind and number of water quality parameters to be tested, the time of application, and the type of water body (stream, river reach, lake, etc.) tested. Since these choices are left up to the user, they must be established before the index is computed.

3.5.2. Dukem Water Index Calculation

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

F1 and F2 can be calculated quite easily, while F3 needs a few extra steps. It has been discovered that the first term (F1) makes a larger contribution to the final CCME WQI score than do the other two terms.

F1 (Scope) represents the percentage of parameters that do not meet their guidelines at least once during the time

period under consideration (“failed parameters”), relative to the total number of parameters measured:

$$F1 = \left(\frac{\text{Numbers failed of parameters}}{Total\ Nubmer\ of\ parameters}\right) * 100 \quad \ldots\ldots\ldots\ldots\ldots 1$$

The frequency, or F2, indicates the proportion of individual tests (or "failed tests") that do not adhere to standards.

$$F2 = \left(\frac{\text{Number of failed Test}}{Total\ Nubmer\ of\ tests}\right) * 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots 2$$

F3 (**Amplitude)** reflects the deviation of failed test values from the target values. It calculates F3.

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

3(b) $\text{Excursion}_i = \left(\frac{\text{Objectivei}}{\text{failed test value i}}\right) - 1$

$$\text{nse} = \frac{\sum_{i-1}^{n} \text{Excursion i}}{\text{Number of test}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

$$F3 = \left(\frac{\text{nse}}{0.01\text{nse} + 0.01}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 5$$

$$\text{WQI} = 100 - \left(\frac{\sqrt{F1^2 + F2^2 + F3^2}}{1.732}\right) \quad \ldots\ldots\ldots\ldots\ldots 6$$

3.5.3. Source (Borehole)

For Dukem town water supply system was borehole so, all physico-chemical and bacteriological test was conducted. There are ten boreholes and sample was taken from all ten boreholes. Therefore, the total number of sample was ten. The sampling frequency for this research was two.

3.5.4. End User water quality

In order to evaluate the water quality situation between the source and the end user, the study assessed the end user's water quality. The samples were collected from end user taps, source (borehole) and from reservoir.

Sample Size Distributions at Reservoirs, Borehole and end user, based on the number of population Served										
no	Name	Capacity m	Ground level	Recived water from	Supplied to	Total population serving	Proportion of Water Sample to be Taken from Reservoir	Proportion of Water Sample to be Taken from borehole	Proportion of Water Sample to be Taken from End User	Remark
1	Reservoir-1	1500	2040	Reservoir-1		52000				
2	Tedecha BH-5				Tedecha kebele (03,	34000				
3	Tedecha BH-4			Reservoir, BH-	Melka Dukem(01)	10000				
4	Tedecha BH-2			5,BH-4,BH-2	partial	8500	1	3	14	
5	Condominium BH-1					5944				
6	Kera BH 10					6000				
7	Kona (qoonnaa) Magala BH-7			BH-1, BH-10 ,BH-	Dukem Koticha kebele (02)	6000	0	3	6	
8	Gogocha BH-8				Gogecha kebeke (04) and suurounding	9000				
9	Mendelo BH-12			BH-8, BH-12	mendelo	9300	0	2	6	
10	City park (BH –New)				Tedecha kebele	5000				
11	Dimitery BH-9			BH-9 and city park new BH	Gogecha kebeke and mendelo	6500	0	2	5	
	Total number of sample to be taken						1	10	25	

Table 3.2: sample Size Distribution

3.6. 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 taken into account separately while choosing sampling locations, however the following standard criterion was applied nonetheless. In discussed with Dukem town water, supply and sanitation utility, for this research, these criteria were selected considering the potential health risk scenarios.

- In order to ensure that the samples gathered are representative of the various water supply facilities, sampling stations were chosen carefully.
- The locations of the sampling points were chosen taking into consideration the population 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: in investigations, including surveillance, are routinely used. They are particularly helpful when findings need to be compared across

time, but they make it harder to spot regional issues like cross connections and contamination from faulty distribution systems.

Random or variable sites: have the advantage of being better at spotting local issues but are less effective at tracking changes over time. Each type of the above sampling site has certain advantages and disadvantages.

Therefore, for this research, random or variable sampling sites were selected in discussed with Dukem town water utility.

3.7. Sampling frequency

Considering the resource limitation in this research, a sample was taken for two times with one-month interval and for water quality Index three times.

3.8. Sampling Method

¬Duplicated water samples: was collected from one sample from each of outlet of source (borehole), out let reservoir and end user sampling points.

¬stratified random sampling method: 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.

¬Systematics Random sampling Method: was used to select representative samples from source (borehole) of ten water supply distribution network zones of 4 urban kebeles.

3.9. Data collection instruments and procedure

3.9.1. Sample Collection Technique (Instruments and physical)

3.9.1.1 PH Meter

In adequately cleaned and rinsed plastic bottles, water samples were obtained. The HQ440d multi pH meter, which has the appropriate electrodes, was used to measure PH on the spot. The measured parameters were shown on the instrument's LCD screen once these probes were submerged in the water sample.

3.9.1.2. Electrical Conductivity (EC) Meter

In adequately cleaned and rinsed plastic bottles, water samples were obtained. The HQ440d multi EC meter, which has the appropriate electrodes, was used to measure Electrical Conductivity (EC) on the spot. The measured parameters were shown on the instrument's LCD screen once these probes were submerged in the water sample.

3.9.1.3. Sample Collection Technique (Instruments and chemical)

Before collected any water samples, plastic hoses that were fixed in most of the end user out let taps were removed and the thoroughly washed with the tap water. Then, this collection points (taps) were properly disinfected using flame from alcohol. Following that, water samples were taken from each location using sterile bottles with a 500 ml capacity that included sodium sulphate to completely neutralize any remaining chlorine (1 ml of 10% $Na_2S_2O_3$). The bottles were labeled and maintained in an ice box while being transported to the laboratory in Koka.

DR-6000 UV Spectrophotometer is used to conduct the physico-chemical test. In a cylindrical cell, ml of prepared water sample is mixed with a reagent chemical before being left to react. The amount of the target element to be measured determines how intensely color develops. The Photometer is set to each element's specific maximum absorption wavelength (lambda). The sample cell allows light to enter so that light at the required wavelength can be absorbed. The results are shown as mg/l on the LCD screen in proportion to how much light at that specific wavelength was absorbed.

3.9.1.4. Bacteriological test (Membrane filter Technique)

To prevent the growth and/or demise of organisms in the samples, the biological test was carried out within 5 hours after sample collection (WHO, 2011).All biological test and physico-chemical parameters tests were conducted at Oromia water and energy laboratory center and Koka- Adama water treatment laboratory.

Using membrane filters with a pore size of 45 m, water samples were collected aseptically in pre-sterilized plastic bags. The filters were incubated at 37°C for faecal coliforms and 44°C for total coliforms in sterile aluminum Petridishes with m-Coli Blue24 broth absorbent pads in a (Name) field incubator. After 24 hours, the filters were checked for bacterial development.

3.9.1.5. Laboratory Analysis

Water sampling and analysis, which require specialist knowledge and experience was mainly done by experts in Oromia water and energy office and Koka laboratory. Then each analysis result was compared with the national standards and WHO guide lines.

3.10. Sampling procedure and analysis

In taking the sample from the source a sterilized plastic bag of 200ml has been used after wearing 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 camp where another incubation unit called Pot lab is used. The former incubation unit has only one temperature adjustment option to grow bacteria: either 37^0C or 44^0C; whereas the latter has both options at a time since it has two compartments to place the Petri dish and set the temperature separately at 37 and 44^0C. The prepared samples have been incubated for 24 hours before opening and examining for bacterial growth.

3.11. Sanitary Inspection

Concerning to sanitary inspection all Bore Holes are good in sanitary condition except, two of them sources Kera & Condominium BHs are not in good sanitary condition. Therefore, DWSSE should be given attention and to be corrected. To assure and sustain the drinking water quality, WSP (risk assessment and risk management) from source to end user should be implemented.

3.12. Interpretation

The results of the analysis have been compared with different standards and guide lines: WHO and National (Ethiopian Drinking Water Standard).Under normal condition protected water sources should be free from contamination indication bacteria, particularly Faecal coliform that shows the contamination from human or animal faeces. In this analysis, selected sampling points have been conducted for Faecal and total coliform. Additionally, both sources and private outlet tap have been analyzed for selected physico-chemical &Faecal and total coliform.

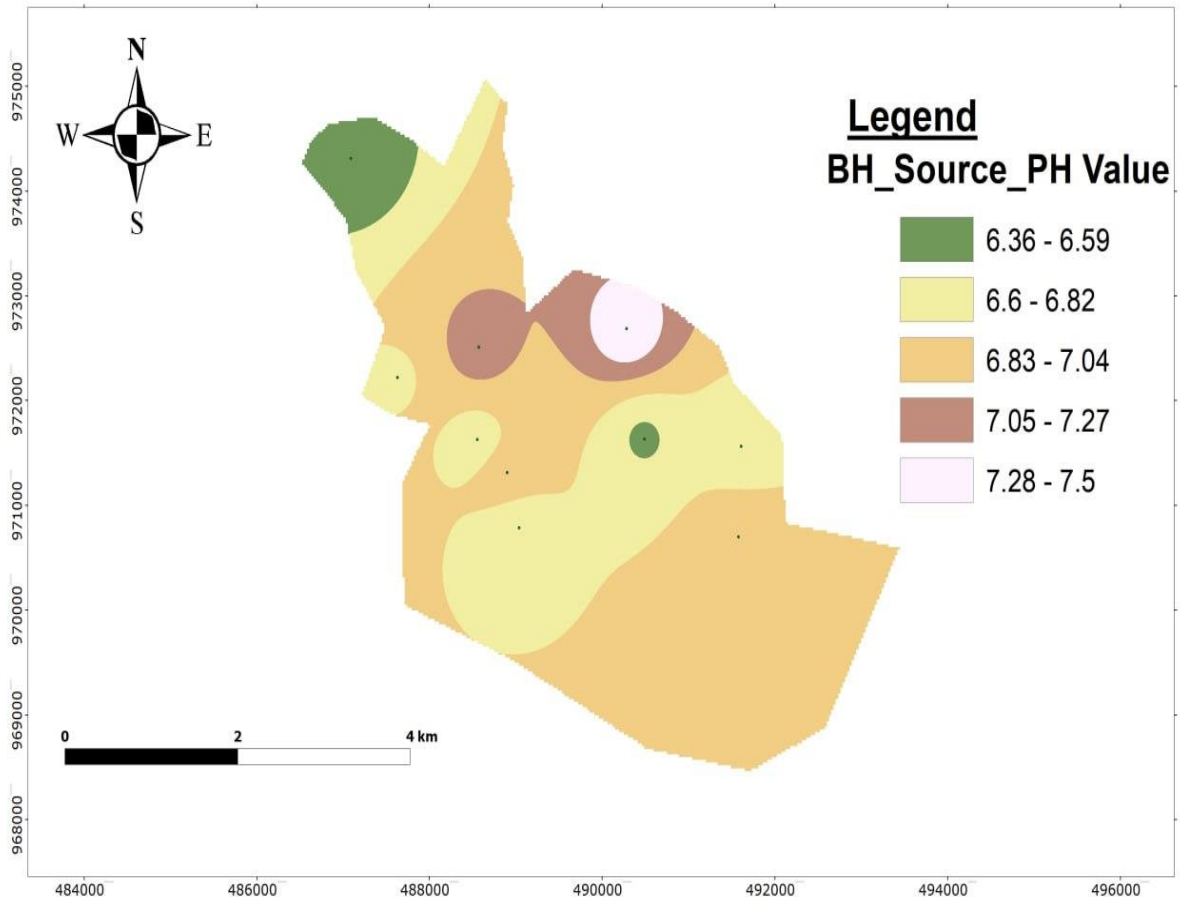
4. RESULT AND DISCUSSION

4.1 At Borehole

Table 4.1.1: Compliance with National Standard and WHO Guide Lines for pH @ Borehole with two Sampling Frequency.

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	Significance
B1	6.63	6.46	6.545	6.5-8.5	6.5-8.5	ES ISO 10523	Yes	Yes	Aesthetic & indirect Health
B2	6.73	6.57	6.65	"	"	"	Yes	Yes	
B3	6.71	6.69	6.7	"	"	"	Yes	Yes	
B4	6.88	6.56	6.72	"	"	"	Yes	Yes	
B5	6.87	6.57	6.72	"	"	"	Yes	Yes	
B6	6.99	6.85	6.92	"	"	"	Yes	Yes	
B7	7.02	7.4	7.21	"	"	"	Yes	Yes	
B8	6.52	6.2	6.36	"	"	"	Yes	Yes	
B9	7.19	6.84	7.015	"	"	"	Yes	Yes	
B10	7.16	6.42	6.79	"	"	"	Yes	Yes	
A.R	6.87	6.656	6.763						
	A requirement level whose non-fulfillment would disqualify the water for drinking and domestic use because of its probable hazard to health								

The pH reading at the source or borehole water was 6.87, 6.66, 6.7 in the first, second and average reading respectively. It was a clear and have fallen within the WHO guide line and national standard range.



4.1 PH Spatial Map for Borehole

4.2 At Reservoir

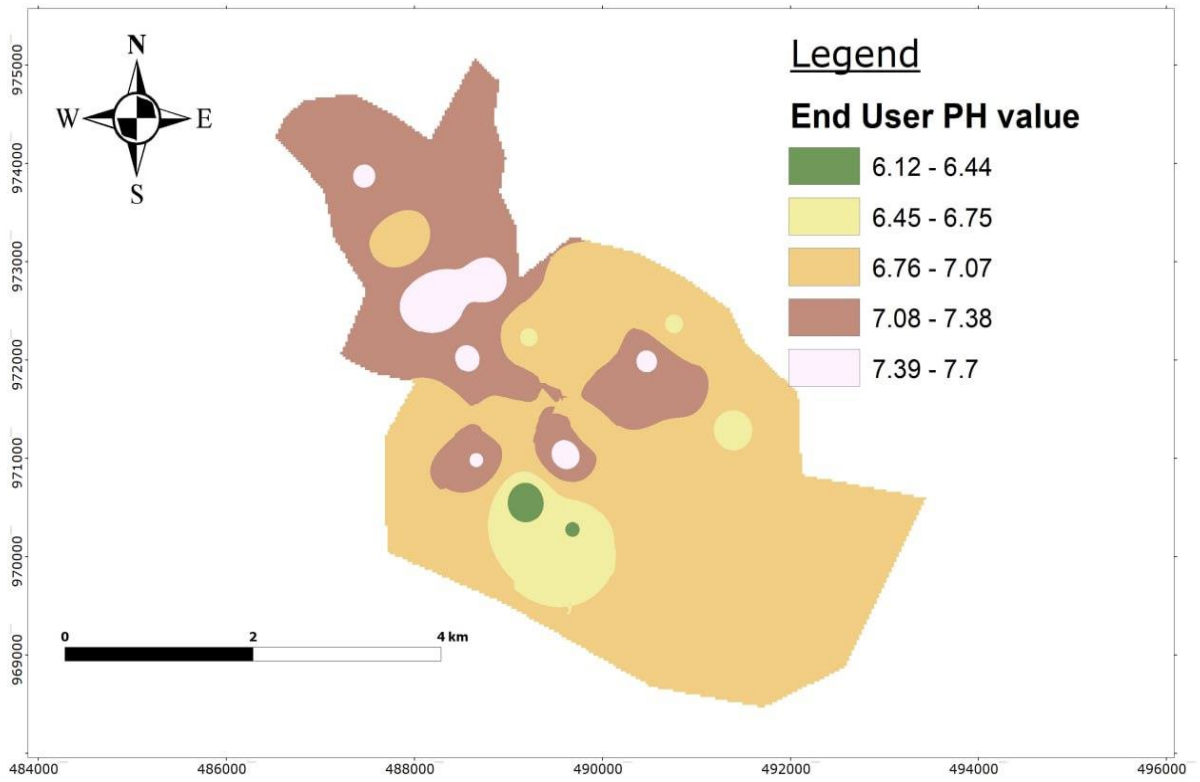
The pH data observed in the reservoirs also similar to the borehole. Therefore, when the water reached at reservoir, it was met both WHO guideline and national standard ES ISO 10523.

4.3. at End User

Table 4.3.1: Compliance with National Standard and WHO Guide Lines for pH @ End User with two Sampling Frequency.

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	Significance
S1	6.32	6.5	6.41	6.5-8.5	6.5-8.5	ES ISO 10523	Yes	Yes	
S2	6.04	6.2	6.12	"	"	"	Yes	Yes	Aesthetic & indirect Health
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	
AR	7.074	7.0084	7.0412						
A requirement level whose non-fulfillment would disqualify the water for drinking and domestic use because of its probable hazard to health									

From Table 4.3.1 the end user average observation data indicated that, the pH level kept on very closely similar data with borehole and reservoir the water data. So that, from this finding, it could suggest that, there was no observation in the end user system that could impact to change the pH level. Therefore, the pH level was complied with WHO guide line and national standard ES ISO 10523.



4. 2 PH Spatial Map for End use

4.4 At Reservoir

Electrical conductivity (EC) was used to calculate the total dissolved salts (TDS). It establishes whether the water is drinkable and appropriate for rehydrating dehydrated people.

However, the conductivities in industrial waste fluids may exceed 100,000 mhos/cm. The WHO and national guidelines state that the EC value of drinking water supplies should not be higher than 400 S/cm. The outcome demonstrates that the EC values of Dukem Town's water supply twice between 389 and 386 and on average 387.5 S/cm are both within the range of the WHO and national standard maximum acceptable limits.

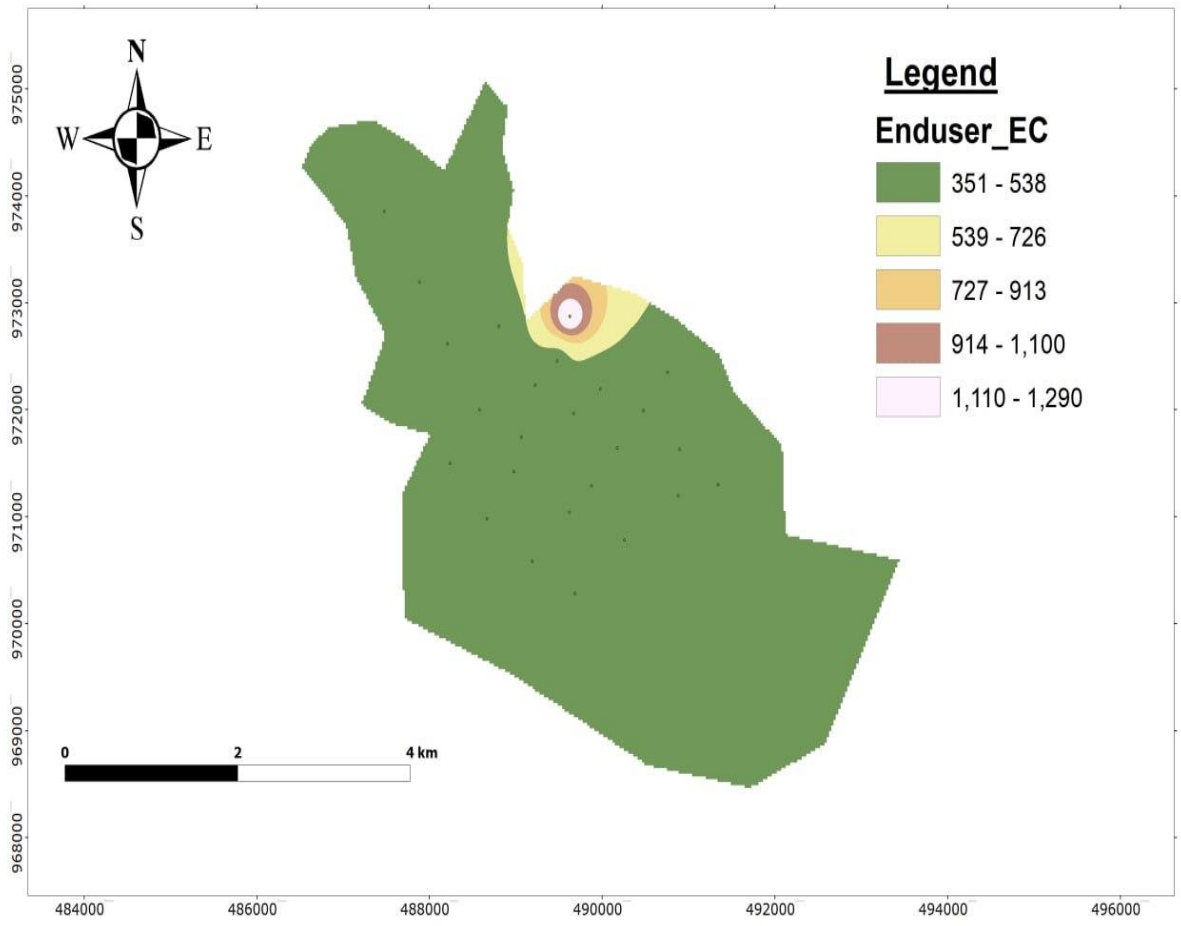
4.5 At End User

Table 4.5.1: Compliance with National Standard and WHO Guide Lines for Electrical conductivity (E.C) @ End User with two Sampling Frequency.

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	Significance
S1	369	375	372	400	400	field	Yes	Yes	palatability & indirect health
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	
A.R	455.24	456.36	455.8						

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

The first, second, and average readings of the EC at the end-user water 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 to have a higher level of ionic concentration activity. As a result, it effectively conducts electrical current.



4. 3 Electrical Conductivity Spatial Map for End use

4.6 At Borehole

Table 4.6.1: Compliance with National Standard and WHO Guide Lines for Electrical conductivity (E.C) @ Borehole with two Sampling Frequency.

NO code	Laboratory Result Frist Round	Laboratory Result second	Average	WHO Standard	National Standard	National Standard Test Method	Compliance with WHO Guide Lines	Compliance with National Standard	Significance
B1	436	450	443	400	400	field	No	No	
B2	358	363	360.5	"	"	''	Yes	Yes	indirect health
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	
A.R	581.6	540.6	561.1						

These results from the source or borehole provide unmistakable proof that the study areas' water was heavily ionized and had a higher level of ionic concentration activity as a result of an abundance of soluble solids. It is a good conductor of electrical current as a result. However, sampling point S8 exhibits extremely high electrical conductivity as a result of dissolved salts and other inorganic chemicals that act as electrical conductors; conductivity rises as salinity rises.

4. 4 Electrical Conductivity Spatial Map for Borehole

4.7 At Reservoir

Sewage and industrial effluents are two common and man-made 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.

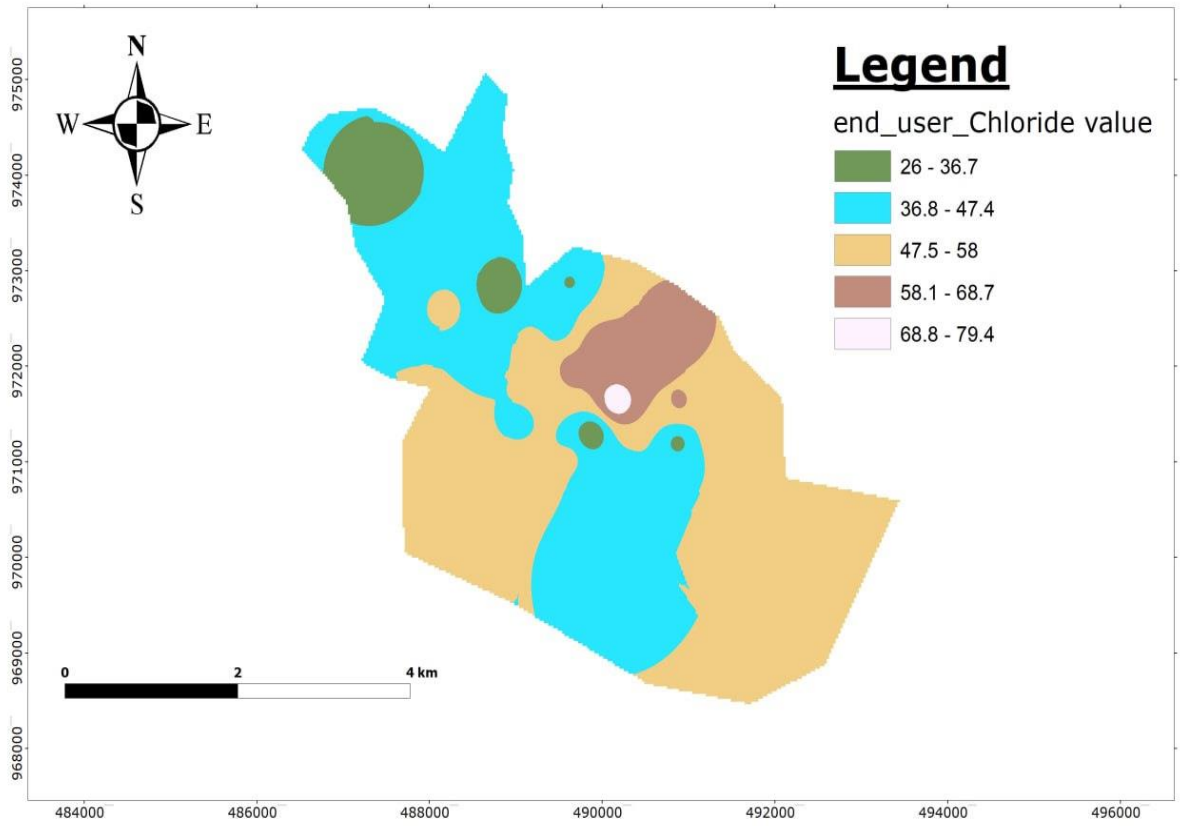
They are still soluble in water, unaffected by biological activity, and reducible via dilution. High chloride levels are bad for pipelines and metallic buildings as well as growing plants. According to national regulations and WHO recommendations, chloride concentrations shouldn't be more than 250 mg/l. 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.

4.8 At End User

Table 4.8.1: Compliance with National Standard and WHO Guide Lines for chloride @ End User with two Sampling Frequency.

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	Significance
s1	38	40	39	250	250	ES ISO 9297	Yes	Yes	palatability & indirect health
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	"	"	"	''	''	
A.R	48.52	48.68	48.6						

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. 5 Chloride Spatial Map end use

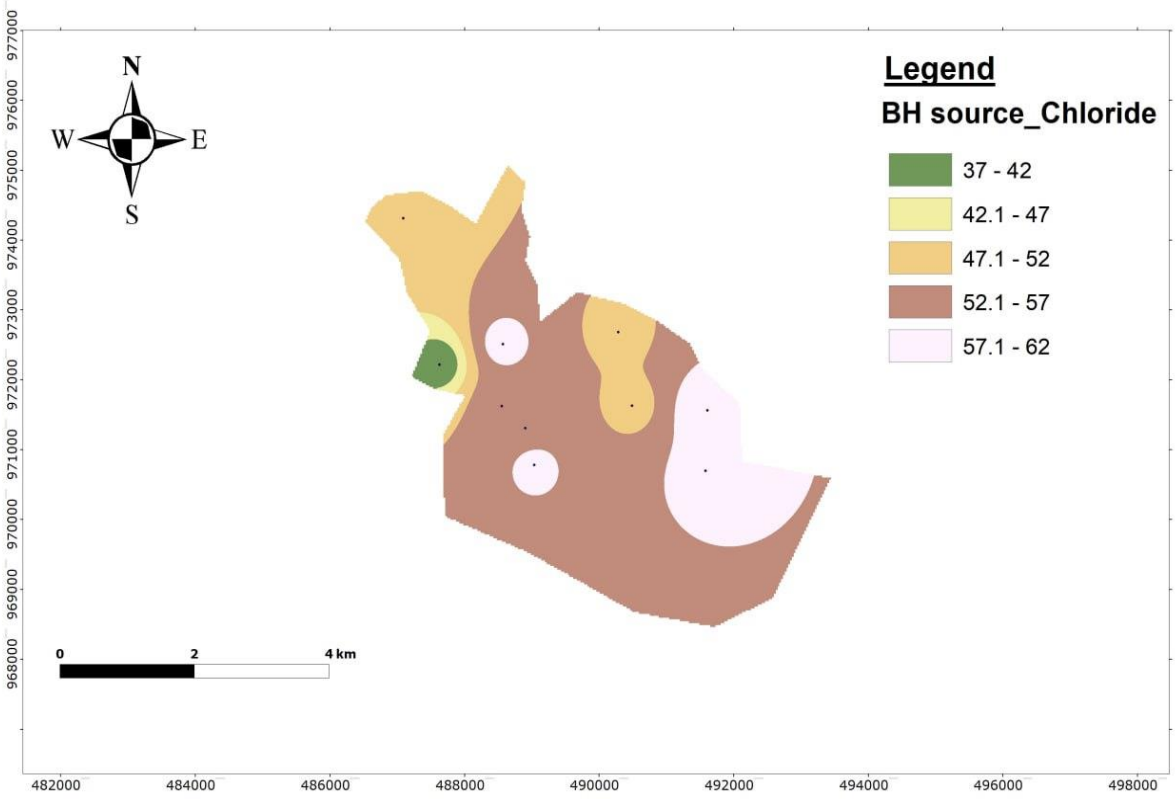
4.9 At Borehole

Table 4.9.1: Compliance with National Standard and WHO Guide Lines for chloride @ Borehole with two Sampling Frequency.

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	Significance
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	"	"	"	"	"	
A.R	53.4	53.5	53.45						

Although the taste of water may be discernible at high chloride concentrations (e.g., NaCl, KCl, and CaCl2), 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. 6 Chloride Spatial Map for Borehole

4.10 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 (Caco3), gypsum (CaSo4.2H2O), fluorite (CaF2), hypochlorite (Ca (ClO) 2), and nitrate (Ca (NO3)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. 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.

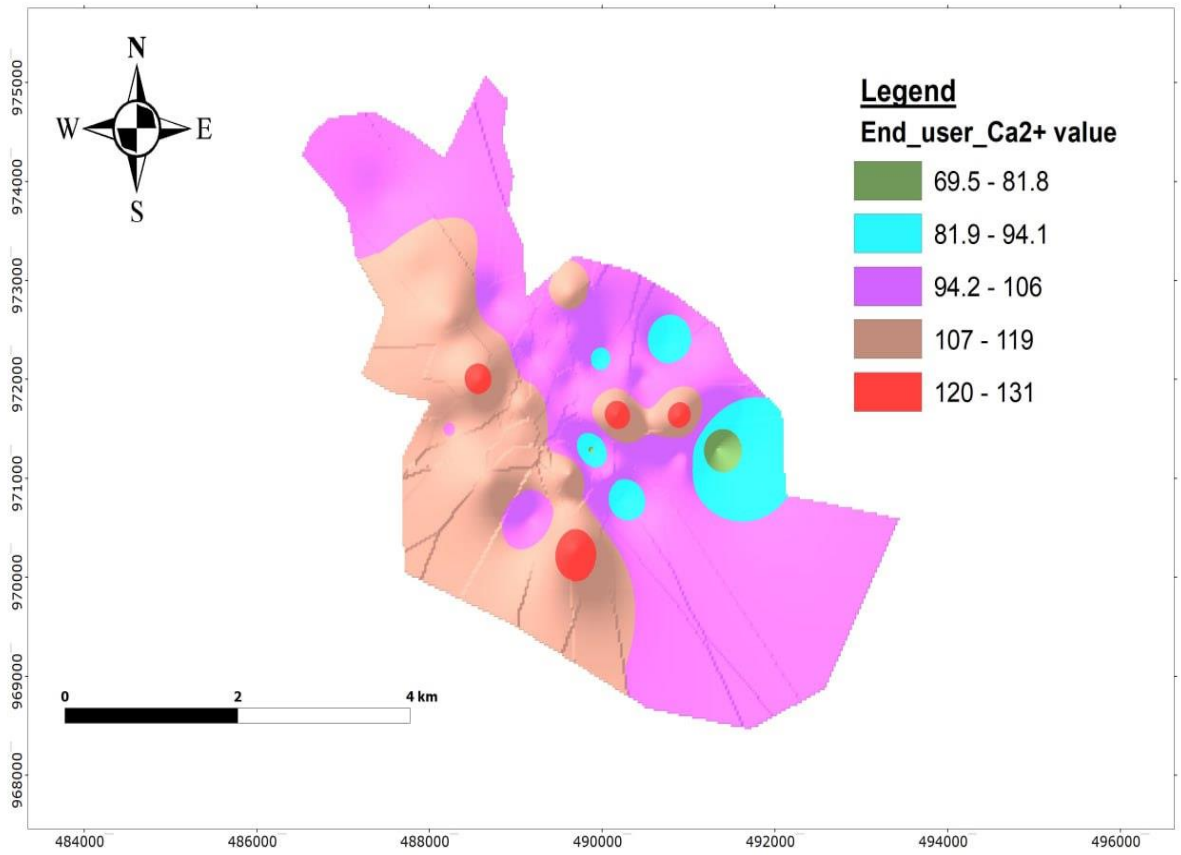
The average result was higher than the WHO and national standard, which is the maximum allowable limit not established by WHO guidelines and national standard level. This shows that the community's health is being impacted by the almost mild hardness of the water in the reservoir.

4.11 At End User

Table 4.11.1: Compliance with National Standard and WHO Guide Lines for calcium C2+ @ End User with two Sampling Frequency.

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	Significance
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	
S8	96	93	94.5	"	"	''	No	No	
S9	130	132	131	"	"	''	No	No	
S10	88	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	Health Significance
A.R	104.08	104.52	104.3						

At the End User calcium C2+ also there above the WHO guideline and national standard. All the laboratory results indicated that the calcium C2+ level in Dukem town the end user water was not complied with WHO guide line and national standard and health effect on the community (ES ISO 7980).



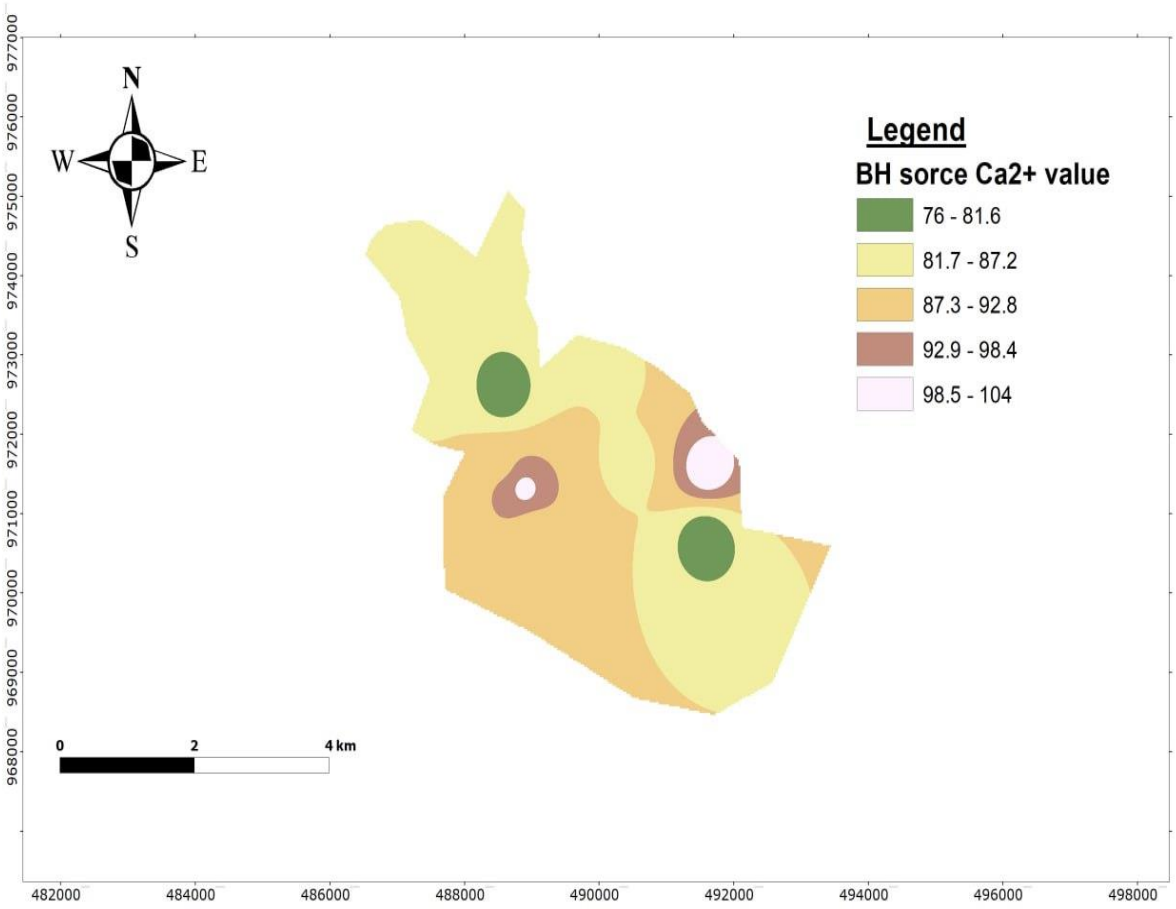
4. 7 Calcium Spatial Map for end use

4.12. At Borehole

Table 4.12.1: Compliance with National Standard and WHO Guide Lines for calcium C2+ @ Borehole with two Sampling Frequency.

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	Significance
B1	79	90	84.5	75	75	ES ISO 7980	No	No	Significance
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	
A.R	87.6	87.2	87.4						

At the Source (Borehole) calcium C2+ also there above the WHO guideline and national standard. All the laboratory results indicated that the calcium C2+ level in Dukem town the Borehole water was not complied with WHO guide line and national standard and health effect on the community (ES ISO 7980).



4.8 Calcium Spatial Map for Borehole

4.13. 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.

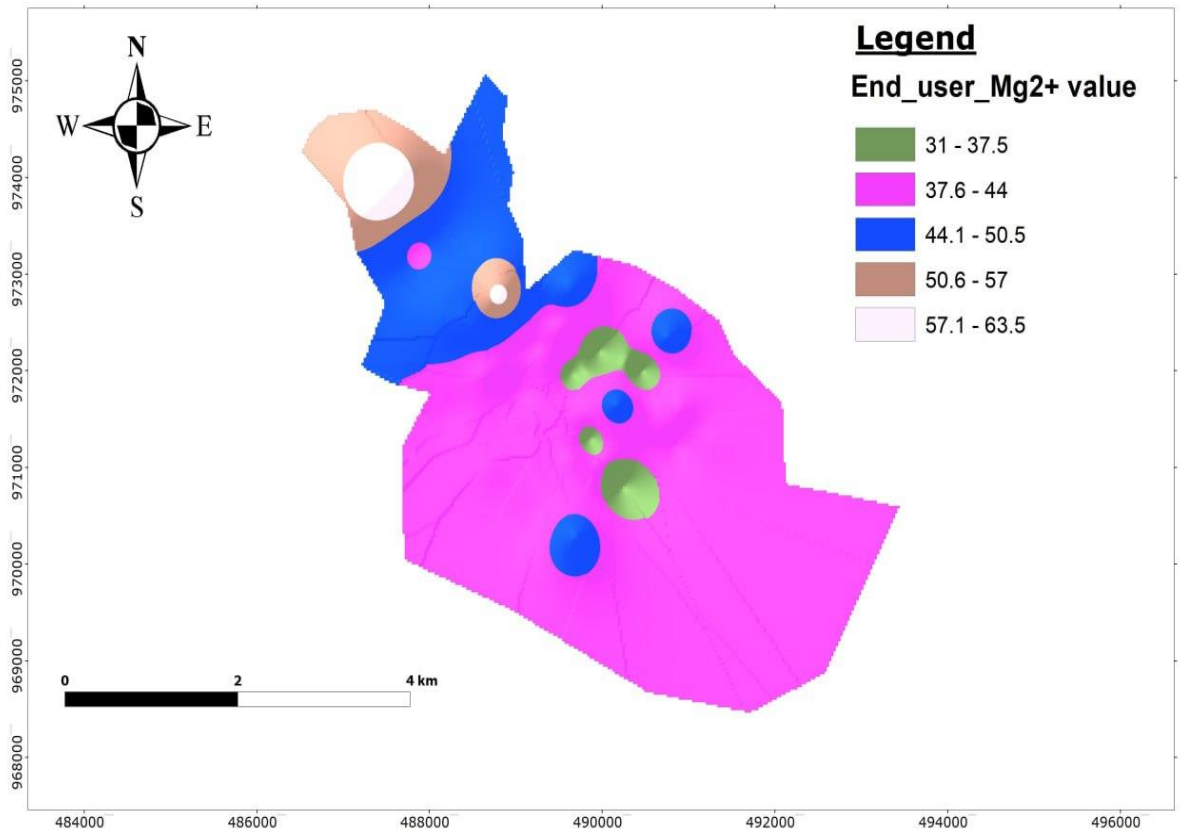
4.14.at End User

Table 4.14.1: Compliance with National Standard and WHO Guide Lines for magnesium 2+ @ end user with two Sampling Frequency.

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	Significance
s1	48	49	48.5	50	50	ES ISO 7980	Yes	Yes	Health Significance
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	
A.R	42.6	42.56	42.58						
	A requirement level whose non-fulfillment would disqualify the water for drinking and domestic use because of its probable hazard to health								

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 Dukem Town 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.



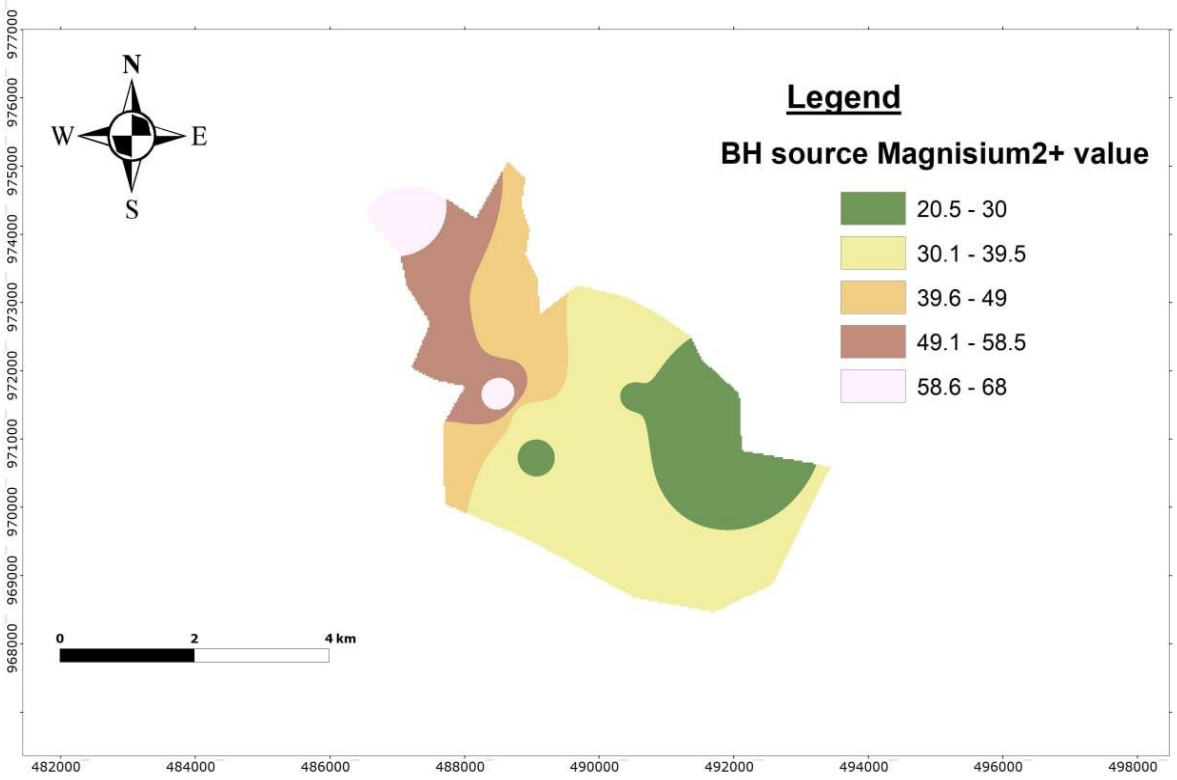
4. 9 Magnesium Spatial Map for end use

4.15. At Borehole

Table 4.15.1: Compliance with National Standard and WHO Guide Lines for magnesium 2+ @ Borehole with two Sampling Frequency.

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	Significance
B1	29	30	29.5	50	50	ES ISO 7980	Yes	Yes	Health Significance
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	
A.R	40	39.2	39.6						

At the Borehole magnesium 2+ also there above the WHO guideline and national standard. The laboratory results indicated that the magnesium 2+ level in Dukem town the Borehole s5, s8, s10, sample water was not complied with WHO guide line and national standard and health effect on the community and the remain result water was complied with WHO guide line and national standard (ES ISO 7980).



4.10 Magnesium Spatial Map for Borehole

4.16. 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.

The maximum allowable limit of overall hardness should not exceed 300mg/l as CaCo3, according to WHO guidelines and national standards. The Dukem Town Water Supply laboratory test results for the first, second, and average readings of CaCo3 were 119 mg/l, 121 mg/l, and 120 mg/l, respectively. Therefore, the World Health Organization and National regulations classify the Dukem Town water supply at reservoir's level of hardness as moderately soft water, which is not harmful to consumers.

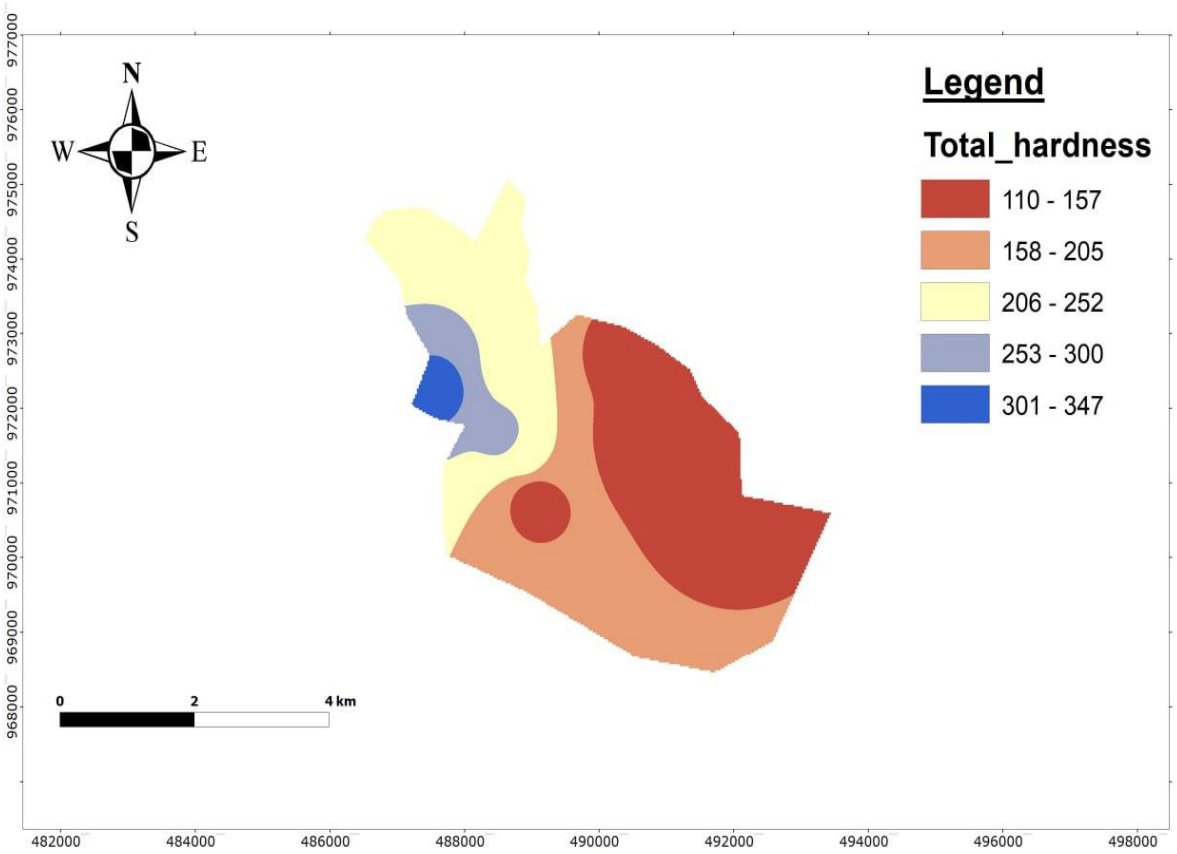
4.17 At Borehole

Table 4.17.1: Compliance with National Standard and WHO Guide Lines for Total hardness @ Borehole with two Sampling Frequency.

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	Significance
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	
	193.6	193.7	193.65						
	A requirement level whose non-fulfillment would disqualify the water for drinking and domestic use because of its probable hazard to health								

CaCo3 concentrations range from 110 mg/l to 142 mg/l according to the laboratory test results for the Dukem Town Water Supply at Source or borehole samples (s1, s2, s3, s4, s9). As a result, the water supply in Dukem Town can be classified as moderately soft at the source, which is safe for users by national and World Health Organization criteria. The values of CaCo3 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 and the World Bank, 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 result of 10 and more than 300 mg/l, is harmful to consumers.



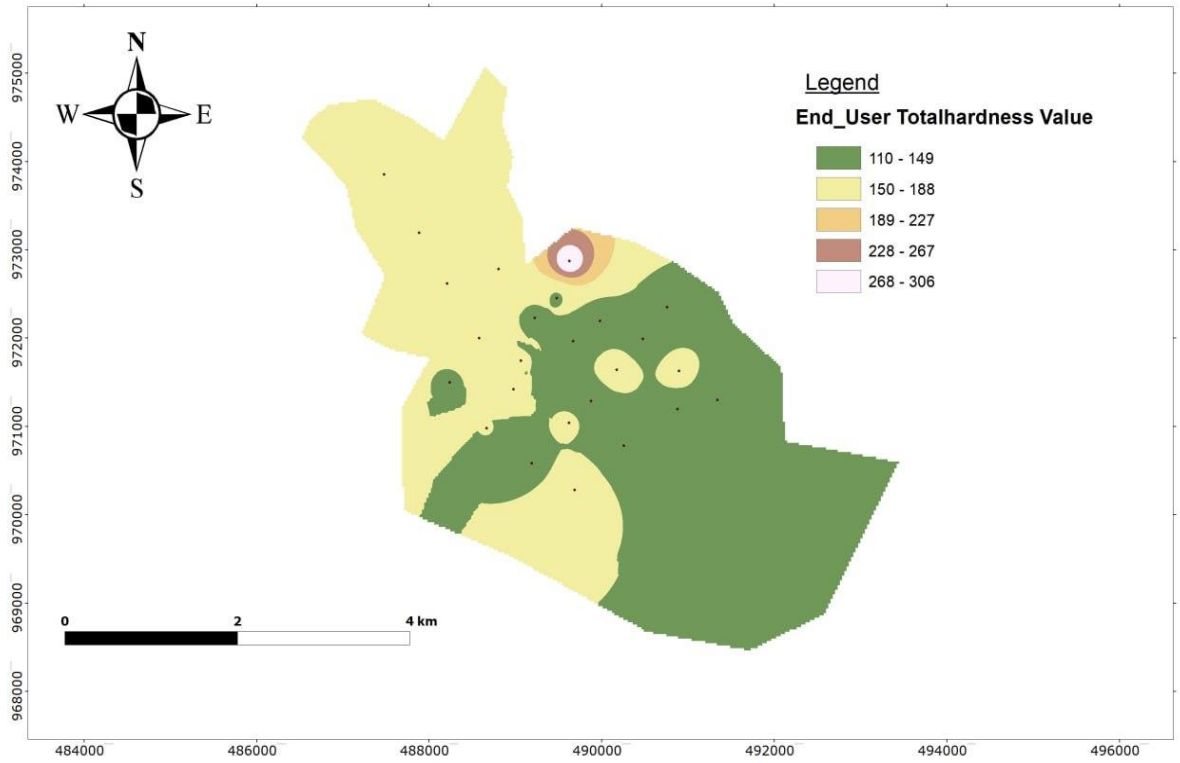
4. 11 Total hardness Spatial Map for Borehole

4.18 At End User

Table 4.18.1: Compliance with National Standard and WHO Guide Lines for Total hardness @ End User with two Sampling Frequency.

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	Significance
s1	178	177	177.5	300	300	ES ISO 607	Yes	Yes	Health Significance
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	
A.R	146.6	158.28	152.44						
	A requirement level whose non-fulfillment would disqualify the water for drinking and domestic use because of its probable hazard to health								

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



4. 12 Total hardness Spatial Map for end use

4.19 At Borehole

Table 4.19.1: Compliance with National Standard and WHO Guide Lines for Average Total Coliform (TC) (no/100ml) @ Borehole with Two Sampling Frequency.

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	Significance
B1	0	0	0	0/100 ml	must not be detectable	ES ISO 9308-1	Yes	Yes	Health Significance
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	
A.R		0	0						
	A requirement level whose non-fulfillment would disqualify the water for drinking and domestic use because of its probable hazard to health								

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

None detected per 100 mL is what the WHO and National Standard state, which indicates that for every 100 ml of drinking water tested for total coliforms, there must be none. So that, the TC reading at Source or borehole was zero and complied with WHO guide line and national standard ES ISO 9308-1.

4.20 At Reservoir

With respect to Total Coliform Test at reservoir the water samples are positive or zero result for Total coliform. So that, the TC reading at Source or reservoir was zero and complied with WHO guide line and national standard ES ISO 9308-1.

4.21 At End User

Table 4.21.1: Compliance with National Standard and WHO Guide Lines for Average Total Coliform (TC) (no/100ml) @ End Use with Two Sampling Frequency.

No	Laboratory result 1st round(no/100ml)	Laboratory result 2nd round (no/100ml)	average	WHO Standard 0/100 ml	National Standard	National Standard Test Method	Compliance with WHO Guide	Compliance with National Standard	Significan
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	TNTC	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	Health Significance
A.R	3.56	0.24							
A requirement level whose non-fulfillment would disqualify the water for drinking and domestic use because of its probable hazard to health									

When the water left the reservoir and borehole, it went through the distribution system with carried on total coliform bacteria. Out of 25 sampling location (double frequency) in the end user system, only fifteen samples location were found free from total coliform bacteria. In the

remaining 10 samples, bacteria were obtained in the laboratory result. So that, 40% of the End User addressed in this research were not complied with WHO guideline and national standard ES ISO 9308-1 related to total coliform.

4.22 At Borehole

Table 4.22.1: Compliance with National Standard and WHO Guide Lines for Average Escherichia Coli (E-Coli) (no/100ml) @ Borehole with Two Sampling frequency.

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	Significance
B1	0	0	0	0/100 ml	must not be detectable	ES ISO 9308-2	Yes	Yes	Health Significance
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	"	''	"	''	"	
A.R	0	0	0	"	''	"	''	"	
	A requirement level whose non-fulfillment would disqualify the water for drinking and domestic use because of its probable hazard to health								

In all Borehole, there is no E. coli finding in the water, all laboratory result was zero E. coli/100 ml of water. Therefore, the zero E. coli concentration result continued in the Borehole. The water was complied with WHO guide line and national standard of ES ISO 9308-2.

4.23 At Reservoir

In Reservoir, there is no E. coli finding in the water, laboratory result was zero E. coli/100 ml of water. Therefore, the zero E. coli concentration result continued in the reservoir. The water was complied with WHO guide line and national standard of ES ISO 9308-2.

4.24 At End User

Table 4.24.1: Compliance with National Standard and WHO Guide Lines for Average Escherichia Coli (no/100ml) @ End User with Two Sampling frequency.

No	Laboratory 1st Samples (no/100ml)	Laboratory 2nd Samples (no/100ml)	Laboratory average (no/100ml)	WHO Standard 0/100 ml	National Standard	National Standard Test Method	Compliance with WHO Guide Lines	Compliance with National Standard	Significance
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	
A.R	0.9	0	0.45						
	A requirement level whose non-fulfillment would disqualify the water for drinking and domestic use because of its probable hazard to health								Health significance

From 25 total samples taken in the End User, E. coli was detected in two of them. E. coli has direct health related risk. Especially the presence of E. coli in the End User has high health risk. Because end user would have addressed all family. Even though, 92% of this research finding was free from E. coli, WHO guide line and national standard ES ISO 9308-2 clearly indicated that. Coli must not be detectable at any point of the water supply system from source up to end house hold user. In the second-round sample test result, zero E. coli laboratory result reading was found. But, in a few locations, the pressure main was eroded with flood and delicate for contamination. Therefore, in general, the End User didn't comply with WHO guide line and national standard ES ISO 9308-2.

4.2 The Dukem Water supply WQI

The gathering, evaluation, and dissemination of data on water quality (WQ) is a crucial part of managing water resources (WR). It is frequently necessary to communicate inherently technical WQ data to a variety of audiences. When the general public is the target audience, communicating WQ data can be particularly difficult.

Water quality data are not of significant relevance to the majority of participants, including the general public. Instead of being concerned in the information that the WQ data gives, they are more interested in the knowledge that arises from the information.

However, when the information is translated into the understanding that the pH 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 in order to be communicated.

4.2.1 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.

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

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.

$$F_2= \left(\frac{Number\ of\ failed\ tests}{Total\ number\ of tests}\right) * 100$$

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:

$$\text{Excursion}_i = \left(\frac{failed\ test\ value\ i}{Objective\ \ j}\right) - 1$$

When the test value must not fall below the objective:

$$\text{Excursion}_i = \left(\frac{Objective\ j}{failed\ tests\ value\ i}\right) - 1$$

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).

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

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.

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

The WQI is then calculated as:

$$\text{WQI} = 100 - \left(\frac{\sqrt{F1^2 + F2^2 + F3^2}}{21.732}\right)$$

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.

4.2.2 How the CCME WQI is influenced by varying measurements scales and ranges of exceedances.

Analyses of water quality often use a variety of measurement scales. Pesticides, for example, may have an impact on the ecosystem at ng•L-1 ranges, whilst other compounds have an impact at mg•L-1 ranges. These data can be combined in the same multivariate index formulation by using a guideline-oriented approach because the comparison of the measured data to its guideline is the important metric.

This method also gets around the issue of 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. The detection limit should be regarded as the guideline if it occurs to be greater than the recommendation, as is frequently the case for cadmium, for instance.

Table 4.25: Physico-chemical parameter sample collected for WQI

Each value represents the average of three assessments.

Code	pH	EC	chloride mg/l	mg2+ mg/l	ca2+ mg/l	Total Hardness mg/l
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
s13	6.1	414.3	55.7	41.3	94.3	138.0
s14	6.9	413.7	42.7	33.7	87.3	122.0
s15	6.8	386.3	24.7	35.0	82.3	117.3
s16	6.9	491.0	33.0	36.7	97.3	134.7
s17	7.3	454.3	57.3	40.3	126.7	169.0
s18	6.7	389.7	51.0	39.3	69.7	110.7
s19	7.4	414.3	59.7	33.7	94.7	121.7
s20	7.2	395.7	78.0	48.7	130.0	182.0
s21	6.7	453.7	64.7	49.0	89.0	136.3
s22	6.8	357.7	66.7	31.0	90.3	122.3
s23	7.0	480.3	63.0	34.7	95.7	135.3
s24	7.1	478.0	39.3	42.7	102.7	145.3
s25	6.6	358.3	50.7	40.3	101.3	141.7
s26	7.0	1297.3	35.7	48.3	108.0	257.7
s27	7.6	379.3	27.7	58.3	99.0	159.7
s28	7.4	389.3	28.3	61.7	94.7	159.0
s29	6.9	436.0	45.0	42.3	108.0	152.3
s30	7.6	490.0	49.3	46.7	115.0	159.0
s31	7.4	490.0	41.0	43.3	124.0	167.3
s32	7.2	348.7	48.3	39.3	110.7	151.7
s33	6.7	378.0	52.3	39.3	103.0	148.3
s34	6.8	457.0	43.3	40.0	109.7	149.7
s35	7.4	373.3	56.7	41.7	114.0	152.0
s36	7.7	480.0	48.0	37.7	116.7	155.0
WHOG	**6.5-8.5**	**400.0**	**250.0**	**50.0**	**75.0**	**300.0**

Three metrics (EC, mg2+, and ca2+) out of a total of six parameters do not fulfill standards. Therefore:

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

There were 59 tests that did not adhere to the rules, and there were 216 tests overall.

$F_2 = \left(\frac{59}{216}\right) * 100 = 27.3$

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)

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

$= \frac{37.37}{216} = \underline{\mathbf{0.173}}$

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

$= \left(\frac{0.173}{0.01 * 0.173 + 0.01}\right)$

$= \frac{0.173}{0.01173}$

$= \underline{\mathbf{14.75}}$

$\text{WQI} = 100 - \left(\frac{\sqrt{F1^2 + F2^2 + F3^2}}{21.732}\right)$

$100 - \left(\frac{\sqrt{27.3^2 + 50^2 + 14.75^2}}{1.732}\right) = \underline{\mathbf{89}}$

According to the CCME WQI, the water quality in Dukem was good. This location's environmental factors can be deemed favorable for the preservation of aquatic life.

4.3 WATER SANITATION PRACTICE AND ITS RELATIONSHIP WITH PUBLIC HEALTH

Table 4.26: Disease Registration of two years in Dukem Health Center

Summary of - Disease Registration two years | Hospital, Health center, Health post, Clinic | Dukam Health Center				
Code	**Disease**	**2014**	**2015**	**Total**
ESV-ICD11 ME05.1	**ESV-ICD11 ME05.1 - Diarrhoea**	**168**	**501**	**669**
	Male, < 1 year	20	72	92
	Male, 1 - 4 years	36	126	162
	Male, 5 - 14 years	15	16	31
	Male, 15 - 29 years	12	37	49
	Male, 30 - 64 years	3		3
	Female, < 1 year	17	58	75
	Female, 1 - 4 years	25	89	114
	Female, 5 - 14 years	10	24	34
	Female, 15 - 29 years	30	79	109
ESV-ICD11 1A07	**ESV-ICD11 1A07 - Typhoid fever**	**103**	**559**	**662**
	Male, 5 - 14 years	7	15	22
	Male, 15 - 29 years	26	237	263
	Male, 30 - 64 years	19	34	53
	Male, >=65 yr		12	12
	Female, 5 - 14 years	13	24	37
	Female, 15 - 29 years	25	212	237
	Female, 30 - 64 years	13	15	28
	Female, >=65 yr		10	10
ESV-ICD11 1A0Z	**ESV-ICD11 1A0Z - Bacterial intestinal infections, unspecified**	**59**	**83**	**142**
	Male, < 1 year		2	2
	Male, 1 - 4 years	4	11	15
	Male, 5 - 14 years	7	4	11
	Male, 15 - 29 years	3	7	10
	Male, 30 - 64 years	11	6	17
	Male, >=65 yr	1	2	3
	Female, < 1 year		8	8
	Female, 1 - 4 years	4	9	13
	Female, 5 - 14 years	5	7	12
	Female, 15 - 29 years	19	21	40
	Female, 30 - 64 years	5	6	11

Source (Dukem Health Office)

Everyone's health can be improved by using water sanitation practices properly. Improved water sanitation, especially hand washing at key times, has been empirically shown to lower by one third the likelihood that people would contract diseases like diarrhea, which are frequently brought on

by a lack of or incorrect water sanitation practices. Additionally, a sufficient supply of clean water combined with good water sanitation can cut diarrhea by one fifth and by three quarters.

A better water supply also cuts down on the time and effort needed to collect water, especially for women and girls. People who drink clean water and wash their hands frequently will save money since they won't have to pay for the diseases' medical expenses. Additionally, they will be able to attend class or work on the days they would have been absent.

4.3.1. Water Quality and sanitation practice

4.3.2 Safe collection, handling and storage of water

Water that is safe to drink is typically clean and clear, but just because it is transparent does not guarantee that it is safe. When we consume certain poisons and microorganisms, we risk contracting diseases that we cannot see. The new water sources built as part of the initiative will have their water quality tested to ensure that they are delivering safe water for drinking. Water that is safe at a public tap or well needs to be taken care of in order to maintain it safe from the source to the consumer's mouth.

Water must be collected and stored in clean containers, and anything used in the containers to stop water from spilling must likewise be clean. To prevent dirt or dust from getting into any water held in the house, it must be covered. When pouring water for drinking, care must be taken to prevent the introduction of dirt. If a scoop is used to remove water for drinking from a large container, it should be kept clean and off the ground. Additionally, the person collecting the water should have clean hands and ideally not touch the water with them.

Everyone should always wash their hands after going to the bathroom and before handling any food. Although the majority of individuals do not wash their hands frequently enough, hand washing should be made as simple as possible by keeping hand washing water and the cleaning agent outside the kitchen or eating area or near the restroom.

Table 4.27: Result of Sanitary Inspection of End User

No	Household (End User) (n=25)	Category (Yes / No	
		Yes	NO
1	Is the water tap in your compound safeguarded (fenced) properly?	56% (n= 14)	44% (n=11)
2	Do you have a practice of washing hands with or without soap before and after having a meal as a family?	48% (n= 12)	52 (n=52)
3	Do you think the consumption of unclean water from your tap has ever caused you diarrheal diseases?	60% (n= 15)	40% (n= 10)
4	Is the water supply system to your tap flows spontaneously or not?	36% (n=9)	64% (n= 16)
5	Do you have a practice of storing water for later use as a household?	68% (n= 17)	32% (n= 8)
6	Is the storage utility used in your household safe to store the water?	56% (n = 14)	44% (n = 11)
7	Are there any frequent leaks in the household pipe?	72% (n = 18)	28% (n = 7)
8	Is there the water tap area clean and good looking?	64% (n = 16)	36% (n = 9)
9	Do you use the stored water by boiling or not for drinking purpose?	12% (n = 3)	88% (n = 22)
10	Is the household's waste disposal far enough from the tap area?	68% (n= 17)	32% (n= 8)

4.4. Health Benefits Water Sanitation practices

It is evident that proper and adequate water sanitation from its very production, storage, distributions and along making its way to the end user, have a directly proportionality with the health of the end user. The better the sanitation, the better the health. The poorer the water sanitation the worsen the health it would be. Having saying so, let's see some of the health benefits of an applied water sanitation practices among many others.

The major benefit goes to improved water quality which could be depicted in its good odor, color and look of water. For its true that, the more the water is good in odor, look clean, the better it is healthy and safer to be drunk. This benefit can go to even for general cleanliness and for other in compound activities in the garden.

The other benefit that could not be diminished would be the fact that, it Saves time and energy in collection. The better the water sanitation at the production as well as in its storage and its distribution, the better it saves time and energy of the end user to go through extensive sanitation practices.

5. 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 Dukem town 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. And the water distribution system needs checking up the status within same time in Dukem town 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 from 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 Dukem drinking water supply and it should be search for multiple barriers to avoid contamination.

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APPENDICES A

I. Questionnaire

1. Is the water tap in your compound safeguarded (fenced) properly?

   Yes □ No □

2. Do you have a practice of washing hands with or without soap before and after having a meal as a family?

   Yes □ No □

3. Do you think the consumption of unclean water from your tap has ever caused you diarrheal diseases?

   Yes □ No □

4. Is the water supply system to your tap flows spontaneously or not?

   Yes □ No □

5. Do you have a practice of storing water for later use as a household?

   Yes □ No □

6. Is the storage utility used in your household safe to store the water?

   Yes □ No □

7. Are there any frequent leaks in the household pipe?

   Yes □ No □

8. Is there the water tap area clean and good looking?

   Yes □ No □

9. Do you use the stored water by boiling or not for drinking purpose?

   Yes □ No □

10. Is the household's waste disposal far enough from the tap area?

    Yes □ No □

APPENDICES B

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