ASESSMENT OF PHYSICO-CHEMICAL AND BACTERIOLOGICAL QUALITY OF DRINKING WATER SUPPLY, STATUS OF SANITATION AND HYGIENE PRACTICES: THE CASE OF BISHAAN GURRACHA TOWN, WEST ARSI ZONE, OROMIA REGIONAL STATE, ETHIOPIA.

M.Sc. THESIS

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A THESIS SUBMITTED TO THE
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REQUIREMENT FOR
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SCHOOL OF GRADUATE STUDIES

ADVISORS' APPROVAL SHEET

This is to certify that the thesis entitled "*Assessment of Physico-Chemical and Bacteriological Quality of Drinking Water Supply Status of Sanitation and Hygiene Practices: The Case of Bishaan Gurracha Town, West Arsi Zone, Oromia Regional State, Ethiopia*" is submitted in partial fulfillment of the requirements for Master of Science degree with specialization in Ecotoxicology and Environmental Health, the Graduate Program of the Department of Biology, and has been carried out by Matiyas Azage, Id Number PGEcEHW/0005/12 under our supervision. Therefore, we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis proposal to the department.

Name of Major Advisor	Signature	Date
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EXAMINERS' APPROVAL SHEET

We, the undersigned, members of the Board of Examiners of the final open defense by **Matiyas Azage Betane** have read and evaluated his thesis entitled ***"Assessment of Physico-Chemical and Bacteriological Quality of Drinking Water Supply Status of Sanitation and Hygiene Practices: The Case of Bishaan Gurracha Town, West Arsi Zone, Oromia Regional State, Ethiopia"***, and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree Master of Sciences in Ecotoxicology and Environmental Health.

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Final approval and acceptance of the thesis is contingent up on the submission of the final copy of the thesis to the School of Graduate Studies (SGS) through the Department Graduate Committee (DGC) of the candidate's department.

Stamp of the SGS

Date:______________________

Remark

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DECLARATION

I hereby announce that M.Sc. thesis entitled ***"Assessment of Physico-Chemical and Bacteriological Quality of Drinking Water Supply Status of Sanitation and Hygiene Practices: The Case of Bishaan Gurracha Town, West Arsi Zone, Oromia Regional State, Ethiopia"*** is my original work and that all sources of materials used for this thesis have been appropriately acknowledged.

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Date of submission: **June, 2024**

This M.Sc. thesis has been submitted for examination with our approval as thesis advisors.

Major Advisor: _______________

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Place and Date of submission: **June, 2024**

ABBREVIATIONS AND ACRONMY

EC	Electrical Conductivity
EPA	Environmental Protection Agency
FC	Fecal Coliform
FRC	Free Residual Chlorine
FC	Fecal Coliform
FS	Fecal Streptococci
HHs	Households
ISH	Improved Sanitation And Hygiene
SDG	Sustainable Development Goal
TC	Total Coliform
TDS	Total Dissolved Solids
UN	United Nations
UNICEF	United Nations International Children's Emergency Fund/ United Nations Children's Fund
WHO	World Health Organization
WASH	Water, Sanitation and Hygiene

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ABSTRACT

Access to safe drinking water and adequate sanitation is essential for safeguarding public health. This study aimed to assess the physicochemical and bacteriological quality of drinking water supply and evaluate sanitation and hygiene practices in Bishaan Gurracha town, located in the West Arsi zone of the Oromia region, Ethiopia. The methodology involved selecting water sources and households for sample collection, employing data collection instruments including household surveys, key informant interviews, focus group discussions, and direct observations. Laboratory analyses were conducted to measure various physicochemical parameters such as pH, turbidity, TDS, EC, alkalinity, nitrates, chlorides, free chlorine, heavy metals, and bacteriological indicators including total coliforms and fecal coliform. Sanitation coverage and hygiene practices were assessed using appropriate questionnaires to ensure data suitability for statistical analyses. The results indicated that most physicochemical water quality parameters met the standard values recommended by WHO/ESA, except for temperature and turbidity. Temperature ranged from 24.33°C to 26.17°C, and turbidity ranged from 5.62 NTU to 6.73 NTU. Total coliforms were present in all water samples from source water and household storage containers, with a significant number of samples also testing positive for fecal coliforms. The mean total coliform counts varied between 18 CFU/100ml to 101 CFU/100ml for source water and 16 CFU/100ml to 81 CFU/100ml for household storage water. These findings suggest potential deterioration in the untreated drinking water distribution system within Bishaan Guracha town, as the total coliform and fecal coliform counts exceeded the recommended standards set by national and WHO guidelines. Inadequate sanitation facilities in many homes pose significant health risks to the community in Bishaan Guracha town. The absence of proper toilets and improved sanitation systems increases the likelihood of fecal contamination, leading to the transmission of waterborne diseases such as diarrhea, cholera, and typhoid fever. Immediate interventions are therefore necessary, including decontamination of water sources, repair of distribution lines, expansion of sanitation infrastructure, and increased awareness of hygiene practices. It is recommended to regularly monitor water quality and encourage community participation in sustainable water, sanitation, and hygiene services.

Key Words: Bacteriological Water Quality, Bishaan Guracha ,Drinking Water Quality, Ethiopia, Hygiene Practices, Physicochemical Water Quality, Sanitation.

INTRDUCTION

1.1. Background of the Study

Water is one of the main important abiotic components of the environment. Approximately, 97% of the total water is found in oceans, which is not appropriate for drinking, and only 3% is considered as fresh water, out of which 2.97% is found as glaciers and ice caps. Only the remaining little portion, 0.03%, is obtainable as surface and ground water for human use (Muhammad *et al*., 2013). Harmless drinking water is a basic need for good health and it is a rudimentary right of humans (WHO, 2001). In addition, it is impossible to imagine clean and sanitary environment without water. Potable water is the water which is suitable for drinking and cooking purposes. Pot ability considers both the safety of water in terms of health, and its acceptability to the consumer, usually in terms of taste, odor, color, and other sensible qualities (Benignos, 2012).

Various health problems may occur due to inadequacy and poor drinking quality of water supply. Infant mortality rate is high due to unsafe water supply. Therefore, drinking water quality should be completely free from pathogenic microorganisms, physic-chemical element in concentration that causes health impact. It should be clear and aesthetically attractive, low turbidity and color recommended by WHO guide lines and should not be saline, contain any compounds that cause offensive and taste, should not cause corrosion scale formation, discoloring or staining and should not have a temperature unsuitable for consumption.

The quality of drinking water is an influential environmental determinant of health, management has been a key pillar of primary prevention for more than 150 years, and it continues to be foundation for the prevention and control of water borne diseases. Water is essential for life, but it can and does transmit disease in countries in all continents from the poorest to the wealthiest. The most predominant water borne disease, diarrhea, has an estimated annual incidence of 4.6 billion episodes and causes 2.2 million death every year (UNICEF/WHO, 2012). Access to safe drinking water and sanitation is a global concern.

Access to water and proper sanitation are major determinant of preventable disease in low income countries such as Ethiopia (World Bank, 2014). According to World Health Organization (WHO,2015), diarrhea remains the second leading cause of death in children under 5 years of age caused primarily by lack of safe drinking water, poor sanitation and hygiene.

However, developing countries like Ethiopia have suffered from a lack of access to safe drinking water quality and cause of human health problems due to water borne diseases. while, close to a billion people, most living in the developing world, do not have access to safe and adequate water (UNICEF/WHO, 2012). The World Health Organization (WHO) estimated that around 94% of the global diarrheal burden and 10% of the total disease burden are due to unsafe drinking water, inadequate sanitation, and poor hygienic practices (Covalan, 2006; Fewtrell *et al*., 2007; Doria, 2010).

One of the most important factors that affect drinking water quality through distribution and with sustainable use of town water supply systems is the quality of water the distributions systems deliver to the users (Brikke, 2002; Schoutern and Moriarty, 2003). If domestic water supply of any town is failed to meet acceptable drinking water quality standards (that is, physical, chemical and/or bacteriological) people may stop using the scheme and resort to unsafe sources; and were further exposed to acute and chronic illnesses (Karn and Harada, 2002). This were bringing challenge in meeting the Millennium Development Goals (MDGs) of ensuring environmental sustainability, improving health and eradicating extreme poverty of the rural and town majority living in the developing world (UN, 2005).

There are several variants of the fecal-oral pathway of water borne disease transmission. These include contamination of drinking water catchments (e.g.by human or animal faces), water within the distribution system (e.g. through leaky pipes or obsolete infrastructure) or of stored household water as result of unhygienic handling. Millions of people are exposed to unsafe levels of chemical contaminants in their drinking water. This may be due to a lack of proper management of urban and industrial wastewater or agricultural run-off water potentially giving rise to long-term exposure to pollutants, which can have a range of serious health implications.

Ethiopia is one of the participant countries that decided the millennium development announcement with its main impartial of poverty reduction. This resulted in prioritizing accessibility to improved drinking water quality. Therefore, to achieve these goals, drinking water quality concerns are often in terms of its physical, chemical, and bacteriological parameters (WHO, 2004). The most important component for measuring access to improved water supply sources and treatment distribution systems for the public. Acceptable water quality shows the safety of user community " perceptions of quality also carry great weight in their drinking water safety (Doria, 2010).

The people of Bishaan Gurracha town get their drinking water supply from protected Spring which is situated in Shasha Qaqelle near to Wondo Genet town. There could be a potential water pollution protected Spring due to problems of contamination of urban water distribution system are diverse. The major sources of water contaminants are mostly wasting from improper sanitation, institutional wastes, commercial wastes, Residential wastes, industrial wastes, Health care wastes , agricultural and other activities that make their way to the water distribution (Tabor, 2011).

Furthermore, breaking the distribution system, age and improper maintenance of the distribution system, and low level of chlorine usually compromise the integrity of the distribution system and quality of potable water. Therefore, this research attempts to assess the drinking water quality from the main existing drinking water system of Bishaan Gurracha town in terms of water quality parameters such as physic-chemical, bacteriological from source to household level. The ultimate result of this study is useful to address the main cause of public health problems related to deteriorated quality of drinking water, and to point out the way to produce a safe water for the population of the town.

1.2. Statements of the Problems

Water quality and associated health risks pose serious public health challenges in many developing nations such as Ethiopia (WHO, 2017). In Ethiopia, populations often obtain drinking water from natural water source such as wells, rivers or surface water and spring sources, as in Bishan Guracha Town. The people of Bishaan Gurracha town get their drinking water supply from protected spring which is situated in shasha qaqelle near to Wondo Genet town. Drinking water quality in the town may be compromised due to lack of proper water treatment, low level of residual chlorine in the distribution system, lack adequate sanitation infrastructure, lack of proper hygienic practice and waste management practices (Bishan Guracha Water Supply Office, 2022/2023).

Untreated domestic waste and inadequate water treatment can contaminate source waters with pathogens (Levin *et al*., 2021). Previous studies have detected bacterial indicators of fecal contamination such as *E. coli* in Ethiopia's water sources, highlighting widespread quality issues if left unaddressed (Gonfa *et al*., 2019). Furthermore, disease surveillance data from the Bishan Guracha Health Center (2022/2023) shows water-borne illnesses constitute some of the leading causes of morbidity in the area.

Conditions like pneumonitis (623), diarrhea (253), malaria plasmodium vivax (143), upper respiratory track disorder (101), malaria plasmodium falciparum (41), typhoid (196), giardiasis (22), and Amebiasis (13), feature prominently in local epidemiological profiles (Bishan Guracha Health Center, 2022/23). These indicators strongly suggest that the population in Bishan Guracha Town is likely experiencing adverse health effects due to poor drinking water quality and inadequate sanitation and hygiene practices. The presence of conditions such as Pneumonitis, Diarrhea, typhoid, Malaria, Upper Respiratory Track Disorder, Giardiasis, and Amebiasis in the local epidemiological profiles indicates the potential health impairments resulting from consuming contaminated drinking water. Additionally, the lack of proper sanitary systems and hygiene practices worsens the risks associated with poor water quality. Therefore, addressing both the issues of water quality and sanitation and hygiene practices is crucial to mitigate the health impacts on the population. Therefore, the aim of this study is to identify any potential deterioration in the quality of drinking water in Bishan Guracha Town by evaluating the physicochemical and bacteriological parameters of the water supply, as well as examining the sanitation and hygiene practices in the area. The findings will help inform appropriate interventions and strategies to ensure the provision of safe drinking water and mitigate the potential health risks.

1.3. Objectives of the Study

1.3.1. General objective

The general objective of this study is to assess the physico-chemical and bacteriological quality of the drinking water supply, evaluate the status of sanitation infrastructure, and examine hygiene practices in Bishaan Guracha Town.

1.3.2. Specific objectives

- ✓ To determine Physicochemical Quality of Drinking Water from Water Schemes and Stored Water in the selected Households in Bishan Guracha town;
- ✓ To appraise the Bacteriological Quality of drinking water from Water Schemes and Stored Water in the selected Households;
- ✓ To ascertain whether there are variations in the Mean Water Quality measurements among the Water Sources, and between the Water Sources and the Households;
- ✓ To evaluate the awareness of the community towards Water Quality, Sanitation, and Hygiene;

1.4 Research Questions

- ✓ Is the water sample from water schemes and stored water in Bishan Guracha safe for drinking in terms of its physicochemical parameters?
- ✓ Is the drinking water source from water schemes and stored water in selected households safe to drink with respect to bacteriological quality of drinking water?
- ✓ Are there variations in mean water quality measurements among different water sources, households, and between sources and households?
- ✓ What does the community awareness regarding water quality, sanitation, and hygiene in Bishan Guracha town look like?

1.5. Significance of the Study

The study has significant importance in several areas. Firstly, it provides insights into the potential risks to public health by identifying the quality of the drinking water supply and its impact on waterborne diseases in the community. This knowledge is crucial for implementing targeted interventions to improve overall health and well-being. Secondly, the study's findings have practical implications for policymakers and local authorities in terms of developing policies, regulations, and interventions to ensure safe drinking water and improved sanitation infrastructure. Thirdly, by assessing community awareness and knowledge about water quality, sanitation, and hygiene, the study empowers the community to actively participate in maintaining and enhancing their water and sanitation conditions. particularly in the Ethiopian context, and can be referenced by future researchers and practitioners. Finally, the study's alignment with sustainable development goals, particularly Goal 6, reinforces its significance in monitoring progress towards access to clean water and sanitation for all. Overall, this completed study provides valuable insights and recommendations for public health, policy development, community empowerment, research advancement, and sustainable development initiatives related to water, sanitation. and hygiene.

1.6. Scope of the Study

First, the administration boundary of Bishaan Guracha Town is the only border used for this study. So, the focus of this study was on Bishaan Guracha Town's water supply and sanitation and hygiene conditions as well as the variables that determine such conditions accessibility. From the source to the household tap connection, with selected kebeles and sampling points. It is conceptually confined to accessing the physicochemical characteristics of drinking water and the bacteriological quality of drinking water. Additionally, the study's scope included evaluating the effectiveness of sanitation and hygiene practice and water delivery systems as well as comparing current water quality against national and international standards. The research is conducted using a delimited cross-sectional descriptive research design that combines qualitative and quantitative techniques.

2. LITERATURE REVIEW

2.1. An Overview Water Supply and Sanitation

The transportation of water from source to the point of consumption with minimum losses is known as water supply. An effective water supply system is one which maintains a continuous, coherent, safe and regular supply of water. The supplied water should maintain a prescribed quality and quantity. Hence a good water supply system should be capable of the following such as; it should me*et al*l the necessary demands such as, domestic, industrial and trade, public, etc., it should maintain an adequate pressure under continuous consumption, it should convey the treated water up to the consumers with a prescribed degree of purity, it should also be capable to supply the necessary amount of water for the emergencies such as firefighting, it should also be reliable and safe against any future pollution and the system should be efficient with minimum losses.

The term water supply goes hand in hand with the term sanitation. Agriculture takes up the major portion of the supplied water. The remaining portion is utilized for domestic and industrial purposes. Domestic utilization is generally categorized as Drinking and Sanitary purposes. The drinking water constitutes of only a minor part of the domestic consumption in contrast to the household and sanitary purposes. Sanitation is the process of safe disposal of human, animal and other wastes without affecting the life on the earth. The various sanitary works include the following such as Collection works, Treatment works and Disposal works [Birdie and Birdie 2010].

2.1.1. Safe Drinking Water, Sanitation and Hygiene

Safe drinking-water

Improving access to safe drinking-water supplies may involve constructing or improving water supply systems or services such as provision of piped water on-site, public standpipes, boreholes, protected dug wells, protected springs or rainwater. It should also involve risk assessment and management approaches, such as water safety planning, to ensure the success and sustainability of the improvements put in place. Low-cost strategies to treat and safely store drinking-water at the point-of-use (e.g. filters, chlorine tablets, safe storage containers) can provide an intermediate solution while longer-term infrastructure improvements are being planned and implemented (WHO, 2019).

Sanitation

A safe sanitation system is designed and used to separate human excreta from human contact at all steps of the sanitation service chain from safe toilets and containment (in some systems with treatment in-situ) through conveyance (in sewers or by emptying and transport), to treatment and final disposal or end use. A holistic approach to addressing fecal risks from toilets to safe use or disposal is facilitated through sanitation safety planning. As a household moves away from open defecation towards use of better sanitation services, and ultimately to safely managed systems, health benefits increase (WHO, 2019).

Hygiene

Hygiene interventions include promoting hand washing with soap at critical times. A broader definition may include food hygiene measures (e.g. washing, covering, cooking and storage of food), environmental hygiene (e.g. cleaning of surfaces), menstrual hygiene, or hygiene interventions specific to prevention and control of particular diseases (e.g. face washing for trachoma, shoe wearing for soil-transmitted helminths, and animal management for zoonotic diseases). (WHO, 2019)

Progress in Drinking Water and Sanitation Coverage

The proportion of the global population using safely managed services increased from 70% to 74%, urban coverage increased from 85% to 86%, and rural coverage increased from 53% to 60%. The number of people without safely managed services decreased by 193 million, decreasing by 225 million in rural areas but increasing by 32 million in urban areas. The number of countries with estimates available for SDG 6.1.1 increased from 96 to 138, and the proportion of the global population with data available increased from 34% to 45%. Latin America and the Caribbean recorded the biggest increase in data coverage. On average, use of safely managed services increased by 0.63 percentage points per year

(% points/year) at the national level, 0.89 % points/year in rural areas and 0.06 % points /year in urban areas. Achieving universal access to safely managed services by 2030 were require a 4x increase in current rates of progress (10x in least developed countries and 23x in fragile contexts). At current rates of progress, the world were only reach 81% coverage by 2030, leaving 1.6 billion people without safely managed services. i.e., drinking water from an improved source that is accessible on premise, available when needed and free from faecal and priority chemical contamination (UNICEF, 2021)

The proportion of the global population using sanitation safely managed services increased from 47% to 54%, rural coverage increased from 36% to 44%, and urban coverage increased from 57% to 62%. The population practicing open defecation decreased by a third, from 739 million people to 494 million. 85% of this drop occurred in rural areas. The number of countries with estimates available for safely managed services increased from 84 to 120, and the global population with data available increased from 48% to 81%. On average, use of safely managed services increased by 1.27 percentage points per year (% pts/yr) at the national level, 1.48 % pts/yr in rural areas, and 0.84 % pts/yr in urban areas. Achieving universal access to safely managed services by 2030 were require a 4x increase in current rates of progress (15x in least developed countries and 9x in fragile contexts). At current rates of progress, the world were only reach 67% coverage by 2030, leaving 2.8 billion people without safely managed service. (UNICEF, 2021)

2.2. Water and Public Health

Drinking water quality has a strong impact on people's health b because water is a vehicle of transmission for many pathogenic microorganisms that cause diarrhea diseases (Howard and Bartram, 2005).Waterborne disease out breaks usually involve, source contamination and the breakdown of the treatment systems, contamination of the distribution systems and the use of untreated water (WHO, 2004).drinking water quality has a strong impact on people's health because water is a vehicle of transmission for many pathogenic microorganisms that cause diarrheal diseases (Howard and Bartram, 2005).The term water borne disease is used to describe all infections whose etiologic agents are carried by water (OECD,2005).These are cholera, bacillary dysentery, enter hemorrhagic *Escherichia Coli*

(*E.coli*), viral hepatitis, shigellosis, typhoid fever, cryptosporidiosis, giardiasis (WHO,2001).

Generally, water borne disease out breaks usually involve, source contamination and the breakdown of the treatment systems, contamination of the distribution systems and the use of untreated water (WHO, 2004). The uses of polluted water from these sources are in criminated with most of the waterborne diseases (WHO, 2004). Water borne diseases can be controlled by different mechanisms. Fact sheet on Diarrheal diseases can be prevented through safe drinking water and disease is leading of child mortality and morbidity (WHO,2017). Improved sanitation could reduce diarrheal disease by32%, whereas hygiene education and promotion of hand washing was found to reduce by 45% (TID,2000).

The health of any community fully depends on the accessibility of adequate and safe water. Hence, water is predominantly essential for life, health and for human self-respect. Therefore, in addition to community health benefits, all people have the right to safe and adequate water retrieved in equitable manner for drinking, cooking, personal, and domestic hygiene. In this case, both adequacy and safety of drinking water are equally important to reduce the incidence of water-related and water borne health problems especially diseases like diarrheal (Bharti *et al*, 2011).

A possible contamination source that carries threats to drinking water quality are open field defecation, animal wastes, plants, economic activities (agricultural, industrial and businesses) and even wastes from residential areas as well as flooding situation of the area. Any water sources, especially older water supply systems, hand dug wells; pumped or gravity-fed systems (including treatment plants, reservoirs, pressure break tank, pipe networks, and delivery points) are vulnerable to such contamination. Particularly systems with casings or caps that are not watertight are most vulnerable. This is particularly true if the water sources are located close to surface runoff that might be able to enter the source. Additional way by which pollution reaches and enters a water supply system is through overflow or infiltration by floodwaters and inundation of waters commonly contain high levels of contaminants (Haylamichael *et al*., 2012).

The fitness of community extremely depends on the availability of safe and adequate water for drinking, domestic use, and personal hygiene. If public health is to be improved and maintained through provision of safe and adequate water supply the major five key elements are vital which includes quantity, quality, cost, coverage, and continuity. Most of the time the occurrence of communicable diseases in the country is related with water supply conditions in the locality. Infectious diseases affected by changes in the water supply condition are categorized as follows (Addisie, 2012).

Those spread through drinking water (water borne diseases, such as typhoid, cholera, gastroenteritis etc.). Those transferred through aquatic vectors (water-based diseases, such as schistosomiasis). Those spread by insects that depend on water (water related diseases, such as malaria and yellow fever). Those diseases produced by the lack of adequate water for personal hygiene (water washed diseases, such as scabies and trachoma. Based on the morbidity records, there is still a high incidence of communicable diseases which most of the time is related to water supply conditions in the country among which about 60% of the top ten diseases are relate to poor quality and scarcity of household water consumption (UNICEF, 2008).

2.3. Water Quality Parameters

Water quality parameters are classified in to three aspects such as physical, chemical, and biological characteristics of water in association to the set of standards. These parameters directly connected to the safety of the drinking water to human use. Water quality parameters deliver important information about the fitness of a water body. These limits are used to find out the quality of water for drinking purpose (Gupta and Saharan, 2009).

2.3.1. Physical aspects of drinking water quality

Physical aspects of drinking water quality mainly classified as; residual chlorine, temperature, color, odor, taste, turbidity, PH, electrical conductivity, and total dissolved solids and regards to examination of quality test categorized in to physiochemical and aesthetical parameters (WHO,2016)

a. Hydrogen Ion concentration (pH)

The pH of pure water refers to states of acidity and alkalinity of solutions with respect to hydrogen and hydroxide ions can be expressed by a series of positive numbers between 0 to 14. In general, water with a pH of 7 is considered neutral while lower than this referred acidic and a pH greater than 7 known as basic. Normally, water pH ranges from 6 to 8.5. It is noticed that water with low pH tends to be toxic and with high degree of pH, it is turned into bitter taste. According to the WHO standards, pH of water should be 6.5 to 8.5 It is significant to measure pH at the similar time as chlorine residual since the effectiveness of disinfection with chlorine is extremely pH dependent: where the pH exceeds 8.0, disinfection is less effective. To check that the pH is in the optimal range for disinfection with chlorine (less than 8.0), simple tests may be conducted in the field using comparators such as that used for chlorine residual. With some chlorine comparators, it is possible to measure pH and chlorine residual simultaneously (Muhammad *et al*., 2013).

b. Total Dissolved Solids (TDS)

Water has the aptitude to dissolve an extensive variety of inorganic and some organic mineral deposits or salts such as potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulfates etc.

These mineral deposits formed undesirable taste and diluted color in appearance of water. There is no contract have been developed on bad or optimistic effects of water that exceeds the WHO standard of maximum permissible level is 1,000 ppm. A total dissolved solid (TDS) in drinking water originates in numerous ways from sewage and urban industrial waste water etc. Hence, TDS test is mostly an indication to control the general quality of the water (Muhammad *et al*., 2013).

c. Electrical conductivity (EC)

Used to measure the ability of aqueous solution to carry an electric current such as; concentration of ions, mobility, valence and temperature. Clean water is not a good electrode of electric current rather a good heat proofing and increase in ions concentration improves the electrical conductivity of water. In general, the amount of dissolved solids in water concludes that the electrical conductivity. Electrical conductivity (EC) is really measures the ionic process of a solution that allows it to transmit current. Therefore, according to WHO standards EC value of drinking water quality should not exceeded 400 μS/cm and the conductivity of potable waters varies generally from 50 to 1500 μ mhos/cm (Gaur, 2008).

d. Turbidity

Turbidity is an expression for an optical property that causes light to be scattered and absorbed and it measures the degree of cloudiness or muddiness of water. It is impossible to correlate turbidity with the weight concentration of suspended matter because light scattering properties of the suspended particulate matter depends upon size, shape and refractive index of the particulates. It is caused by suspended matter such as clay, silts, finely divided organic and inorganic matter, soluble colored organic compounds, plankton, and other microscopic organisms. Turbidity touches both the acceptability of water to consumers, and the selection and competence of treatment processes, particularly the efficiency of disinfection with chlorine since it uses a chlorine demand, defends microorganisms, and may stimulate the growth of bacteria. In all procedures in which disinfection is used, the turbidity must always be low preferably lower than 1 NTU.

It is recommended that, for water to be disinfected, the turbidity should be reliably less than 5 NTU (John C.*et al*,2012) and preferably have a median value of less than 1 NTU (Nephelometric Turbidity Unity). Aesthetic limits are those obvious by the senses, namely turbidity, color, taste, and odor. They are important in monitoring public water supplies because they may cause the water supply to be disallowed and alternative (possibly poorer-quality) sources to be adopted, and they are simple and cheap to monitor qualitatively in the field.

E Color, Odor and tastes

Color is due to the presence of colored substances in solution, such as vegetable matter and iron salt. It does not necessarily have detrimental effects on health. Color intensity could be measured through visual comparison of the sample to distilled water. Colored water is not acceptable for drinking (Aesthetic as well as toxicity reasons). Therefore, drinking water should be colorless. Intended for the purposes of investigation of public water supplies, it is useful simply to note the presence or lack of observable color at the time of sampling. Changes in the color of water and the appearance of new colors serve as indicators that additional investigation is needed (WHO 2004).

Pure water is odorless; test less and color less hence; the presence of unwanted odor in drinking water is symptomatic of the existence of contaminants. Odor: should be absent or very weak for water to be satisfactory for drinking purposes. Tastes: pure water is tasteless; hence, the presence of unwanted taste in water shows the presence of contaminants. Taste problems relating to water could be indicators of changes in the water source or in the treatment process. Inorganic compounds such as magnesium, calcium, sodium, copper, and iron are usually detecting by the taste of water. Algae, decomposing organic matter, dissolved gases, and phenolic material may cause taste TSS (Gaur, 2008).

2.3.3. Chemical aspects of drinking water quality parameters

Chemical impurity of drinking water supply sources may be causes due to natural sources such as; certain industries and agricultural exercises. While toxic chemicals are present in drinking water, there is the risk that they may cause either acute or chronic health effects.

Chronic health effects are more common than acute effects because the levels of chemicals in drinking water are rarely high enough to cause acute health effects (Benignos, 2012).The major chemical or inorganic parameters of drinking water quality mainly classified as; hardness, calcium, magnesium, chloride, sulphate, fluoride, alkalinity, nitrate, phosphate and some toxic metals such as; copper, chromium, Iron, Manganese, etc**.**

I. Hardness

Hardness of drinking water is due firstly to calcium and magnesium carbonates and bicarbonates (which can be removed by boiling) and calcium and magnesium sulfate and chloride (which can be removed by chemical precipitation using lime and sodium carbonate). Hard water is mainly described with high mineral contents that are usually not dangerous for humans. It is frequently measured as calcium carbonate ($CaCO_3$) because it contains mainly calcium and carbonates which is the most dissolved ions in hard water. Public acceptability of the degree of hardness of water may be different considerably from one community to another. The taste threshold for the calcium ion is in the range of 100–

300 mg/l and maximum permissible concentration for total hardness of 500mg/l as $Caco_3$. According to World Health Organization (WHO, 2004) and according to National drinking water quality recommended for Ethiopia total hardness permissible limit is 300mg/l (Girmay *et al*, 2011).

II. Free Residual Chlorine

The fumigation of drinking-water supplies constitutes an important fence against waterborne diseases. Although numerous disinfectants may be used, chlorine in one form or another is the principal disinfecting agent employed in small communities in most countries. Chlorine residual has a number of advantages as a disinfectant, including its comparative cheapness, effectiveness, and comfort of measurement, both in laboratories and in the field. An important extra advantage over some other disinfectants is that chlorine leaves a disinfectant residual that assists in preventing recontamination throughout distribution, transport, and household storage of water. The absence of a chlorine residual in the distribution system may in certain circumstances, indicate the possibility of post-treatment contamination (Taylor andFrancis, 2007).

III. Alkalinity

The presence of acid substances is indicated by pH below 7.0 and alkaline substances by pH greater than 7.0. Acidic water is corrosive to metallic pipes. Alkalinity is the presence of one or more ions in water including hydroxides, carbonates, and bicarbonates. It can be define as the capacity to neutralize acid. Moderate concentration of alkalinity is desirable in most drinking water supplies to stable the corrosive effects of acidity. Alkalinity is a measure of the ability of water to absorb hydrogen ions without significant pH change. Simply stated, alkalinity is a measure of the buffering capacity of water and is thus a measure of the ability or capacity of water to neutralize acids. The major chemical constituents of alkalinity in natural water supplies are bicarbonate, carbonate, and hydroxyl ions. These compounds are mostly the carbonates and bicarbonates of magnesium, and calcium. These constituents originate from carbon dioxide (from the atmosphere) and occurring as a by-product of microbial decomposition of organic material or minerals primarily from chemical compounds dissolved from rocks and soil. The concentration of alkalinity varying from 5 to 125mg/l is expected, and extremes of these values are tolerated in water supplies. Titration with Sulfuric acid or other strong acids determine total alkalinity. According to the portability of drinking Water set by WHO standard guideline, the maximum permissible allowable limit should not be exceeded 200mg/l of CaCo3. However, excessive quantities may cause a number of damages. The WHO standards express the alkalinity only in terms of total dissolved solids (TDS) of 500 mg/l (Muhammad *et al*, 2013)

IV. Nitrate (NO^{-}_{3})

Nitrate is one of the extreme significant disease-causing parameters of drinking water quality, particularly blue baby syndrome in babies and has been used as an indicator for the presence of organics. Nitrates can cause methemoglobinemia at greater than 100 mg/l where a baby cannot take breaths enough oxygen (Roberts, 2006). The sources of nitrate are nitrogen cycle, industrial waste, nitrogenous fertilizers etc. The WHO guide lines maximum permissible values of nitrate in drinking water is 50 mg/l as NO^{-}_{3} for nitrate and 3mg/l as NO^{-}_{2} for nitrite (Alan *et al*., 2000). Nitrate (NO_3) is a compound of nitrogen and oxygen that is found in many everyday food items such as spinach, lettuce, beets, and carrots. There are usually low levels of nitrates that occur naturally in water but the majority run-off from, animal feedlots, wastewater and sludge, septic systems, and nitrogen fixation from the atmosphere by legumes, bacteria, and lightning. Nitrate in water is colorless, tasteless, and odorless. Therefore, it can only be detected using chemical analysis as previously explained in methodology section. Generally, the ground water has high nitrate concentration than surface water because of the percolating sewage, industrial waste, chemical fertilizers, leaches from solid waste landfills, septic tank effluents to the ground water. Whatever may be the reason the high concentration of nitrate is harmful to human beings, particularly for infants. The low acidity in the infant’s intestine permits the growth of nitrate reducing bacteria that converts the nitrate to nitrite that is then absorbed in the blood stream. The nitrite has a great affinity for hemoglobin than the oxygen and it replaces oxygen in the blood. The deficiency of oxygen causes suffocation. The color of the skin of the infants becomes blue so it is termed as blue baby disease. The medical name is „methemoglobinemia‟. This disease is a fatal disease and it takes place when the Concentration of nitrates is more than 50 mg/l according to WHO guideline.

V. Chloride

Chlorides are compounds of chlorine. They remain soluble in water, unaffected biological process, therefore, reducible by dilution. Their concentration at higher levels than adjacent waters is an indication of pollution (usually chloride concentration under 10mg/l is expected (De Zuane, 1996). High chloride concentration damage metallic pipes and structure as well as harms growing plants. According to WHO standards, the concentration of chloride should not exceed 250 mg/l.

VI. Fluoride

Fluoride is essential for human beings to fight against dental caries. The desirable concentration is 1 mg/l, if it is more than this it proves to be harmful. Fluoride concentration of more than 3mg/l is not allowed in potable water in any case. As per WHO, the fluoride concentration should not be more than 1.5mg/l. Actually, the higher concentration of fluoride leads to the discoloration of teeth known as dental fluorosis. The more dangerous is the deformation of the Skelton.

VII. Chromium

Chromium is a metallic element that occurs naturally in rocks, animals, plants, and soil (WHO, 2021). It exists in drinking water mostly in two oxidation states trivalent chromium [Cr (III) and hexavalent chromium [Cr (VI)]. Cr (III) is an essential nutrient and considered relatively non-toxic even relatively at high concentrations in drinking water (ATSDR, 2021). However, Cr (VI) is toxic and has been detected in drinking water sources near industrial and military sites where chromium-based chemicals are used (Isaac *et al*., 1997).

Long-term exposure to Cr (VI) through drinking water can cause digestive issues like diarrhea and stomach pain. Higher levels have been linked to damage of liver, kidney and immune system (Zhang *et al*., 2018). The EPA has set a maximum contaminant level (MCL) of 0.1 mg/L for total chromium in drinking water based on these health risks

(EPA, 2022). Monitoring data from municipalities in the US and other countries have reported Cr (VI) concentrations exceeding 0.1 mg/L at some locations (Sarwar *et al*., 2017; Ke *et al*., 2018). Improper disposal of chromium-laden industrial waste has contributed to groundwater contamination in these cases. In summary, while Cr (III) poses little risk even at elevated levels, Cr(VI) needs to be regulated and controlled in drinking water sources through source protection, water treatment and industrial waste management practices (WHO, 2021). Periodic testing is also important to safeguard public health from this toxic heavy metal.

VIII. Iron

Iron is commonly found naturally in drinking water sources around the world, including in Ethiopia (Fesseha, 2013). It typically occurs in two forms - ferrous iron (Fe^{2+}) and ferric iron (Fe^{3+}).

High iron concentrations can give water an undesirable metallic taste and red/orange color, though present no direct health risk at levels usually found (WHO, 2011). However, in some areas of Ethiopia groundwater sources contain iron levels exceeding the national guideline value of 0.3 mg/L (Alemayehu *et al*., 2015).

Long-term consumption of water with very high iron has been associated with occasional gastrointestinal effects like constipation and nausea (Saylor *et al*., 2022). Chronic excess intake may also increase risk of hemochromatosis - a rare condition where iron accumulates in organs (Lynch *et al*., 1997).

Further, high turbidity caused by suspended iron oxide particles can interfere with disinfection and allow bacterial regrowth in piped network systems (DHSS, 1998). This poses an indirect health risk to users. Various chemical and physical treatment methods have been explored for domestic wells with elevated iron in Ethiopia, with varying degrees of success (Gizaw and Getachew, 2020). Continuous monitoring and upgrades are required for sustainable access to palatable water meeting standards.

IX. Copper

Copper is a naturally occurring metal that is commonly present in drinking water sources at low concentrations. It originates from natural geological deposits contacted by water (WHO, 2008).

Copper is an essential nutrient for human health in small amounts. However, prolonged consumption of water with high copper levels can lead to gastrointestinal effects like nausea (EPA, 2019). The EPA has set the maximum contaminant level goal (MCLG) for copper at 1.3 mg/L, above which it may cause adverse health issues (EPA, 2022). Sources often exceed this limit near industrial sites where copper mining/processing takes place.

When water has high copper and is delivered through copper piping, even more of the metal can leach in over time (Health Canada, 2012). This is due to corrosion of household plumbing systems. To mitigate risks, treated water is required to maintain optimal pH and hardness levels which reduce corrosively (Health Canada, 2012). Proper corrosion control practices ensure prolonged compliance with standards.

X. Sodium (Na^+)

Sodium is a silver white metallic element and found in less quantity in water. Proper quantity of sodium in human body prevents many fatal diseases like kidney damages, hypertension, headache etc. In most of the countries, majority of water supply bears less than 20 mg/l while in some countries the sodium quantity in water exceeded from 250 mg/l (WHO, 1984). According to WHO standards, concentration of sodium in drinking water is 200 mg/1.

XI. Potassium (k^+)

Potassium is silver white alkali which is highly reactive with water. Potassium is necessary for living organism functioning hence found in all human and animal tissues particularly in plants cells. The total potassium amount in human body lies between 110 to 140 g. It is vital for human body functions like heart protection, regulation of blood pressure, protein dissolution, muscle contraction, nerve stimulus etc. Potassium is deficient in rare but may led to depression, muscle weakness, heart rhythm disorder etc. According to WHO standards the permissible limit of potassium is 12 mg/1.

2.3.4. Bacteriological aspects of drinking water quality

A diversity of microorganisms can be present even in very good quality domestic waters. Most of these microorganisms are harmless but if the water is, polluted pathogens may be present (KasrilsandMSimang, 2001).

Pathogens are disease-causing microorganisms such as those causing cholera, gastro enteritis, hepatitis, etc. (Pathogen from the Greek words pathos, meaning suffering and gen, meaning to give rise to). It is difficult to determine the presence of all the different pathogenic organisms and therefore the presence of certain indicator organisms are used to give an indication of the possible presence of pathogens. There are different types of indicator organisms. The most common indicator organisms used for domestic water quality assessment are total coliforms and fecal coliforms.

I. Coliform Bacteria

Total coliforms are the ones that are commonly measured as indicator bacteria for drinking water quality (Brian, 2002, Hurst *et al.,* 2002). They are defined as aerobic and facultative anaerobic non-spore forming bacteria that ferment lactose at 35 to 370C with the production of acid and gas within 24-48 hours (WHO, 1985; Hurst *et al.,* 2002). Coliform bacteria belong to the family enterobacteriace and include *Escherichia coli* (*E. coli*) as well as various members of the genera Nitro bacteria, Klebsiella and Citrobacter (Hurst *et al.,* 2002).

II. Fecal Coliforms (Thermo tolerant Bacteria)

Apart from the fact that the fecal coliform *E. coli* is considered as one indicator of fecal contamination of water (Stephen and Gundry, 2004), some strains such as enter-hemorrhagic and entroinvasive have become serious causative agents of emerging waterborne diarrhea disease (Nold, 2008). The presence of coliform bacteria in potable water indicates unsuitable sanitation practices (; Garcia-Armisen and Servais, 2006). Such occurrences may be a result of poor water treatment systems, leakages in the pipelines, and or regrowth in the distribution system (Geldreich, 1996)

2.4. Sampling Methods and Location of Sampling Points

2.4.1. Location of sampling points

Any significant difference between the two has important implications for remedial measures. Samples must be taken from locations that are representative of the water source, storage facilities, distribution network, points at which water is delivered to the consumer, and points of use. In selecting sampling points, each locality should be considered individually; Sampling points should be selected such that the samples taken are representative of the different sources from which water is obtained by the public or enters the system but by this research, case was considered only one source (WHO, 1997). These points should include those that yield samples representative of the conditions at the most unfavorable sources or places in the supply system, particularly points of possible contamination

Such as raw water, loops, reservoirs, ends of the system, etc. Sampling points should be uniformly distributed throughout a piped distribution system, considering population distribution; the number of sampling points should be proportional to the number of links or branches. There should be at least one sampling point directly after the clean-water outlet from each treatment site (WHO, 1997).

2.4.2. Sampling frequency amounts

The most important tests used in water-quality surveillance or quality control in small communities are those for microbiological quality (by the measurement of indicator bacteria) and turbidity and for free chlorine residual and pH where chlorination is used. These tests should be carried out whenever a sample is taken, regardless of how many other physical or chemical variables are to be measured. The recommended minimum frequency of critical measurements in minimum sample numbers for piped drinking water in the distribution system is shown in table 2-1 below (WHO, 1997)

Table 2.1 Minimum sample numbers for piped drinking-water in the distribution system based on WHO standard.

Population served	No. of monthly samples
< 5,000	1

5,000–100,000	1 per 5,000 population
>100,000	1 per 10, 000 population, plus 10 additional Samples

2.4.3. Bacteriological quality of drinking water

The frequency of bacteriological testing for public water supplies depends on the size of the population served and the disease caused by water related microorganisms is divided into four main classes;

Water-borne diseases: it is caused by water that to be contaminated by human, animal or chemical wastes. Examples include cholera, typhoid, meningitis, dysentery, hepatitis and diarrhea. A host of bacterial, viral, causes diarrhea and parasitic organisms most of which can be spread by contaminated water (WHO,2006). Poor nutrition resulting from frequent attacks of diarrhea is the primary cause for stunted growth for millions of children in the developing world (Addisie, 2012).

Water-related vector diseases: diseases that transmitted by vectors, such as mosquitoes that breed or live near water. Examples include malaria, yellow fever, dengue fever and filaria. Malaria causes over 1 million deaths a year alone (WHO, 2006). Stagnant and poorly managed waters provide the breeding grounds for malaria-carrying mosquitoes.

Water-based diseases: Parasitic aquatic organisms referred to helminthes cause that and to be transmitted through skin dissemination or contact. Examples include Guinea worm disease, filarial, paragonimia, clonorchiasis, and schistosomiasis (WHO, 2006)

Water-scarce diseases: These diseases flourish in conditions where freshwater is scarce and sanitation is poor. Examples include trachoma and tuberculosis

2.4.4. Physicochemical quality of drinking water

Number of chemical contaminants have been to cause adverse health effects in humans because of prolonged exposure through drinking water. These include, both organic and inorganic chemicals including some pesticides. Some of them are toxic to humans or affect the aesthetic quality of water. In this regard, the WHO has put forward guideline values that set limits for many of the contaminants in drinking water. Ethiopia has also ready its own drinking water quality specification in line with the international norms and values. The Quality and Standards Authority of Ethiopia have stipulated legally binding drinking water quality specifications (ES 261:2001) in 2001. According to Girma (2011), the Ethiopian standard ES 261:2001 set limits for not only the physic-chemical parameters but also for Microbiological and radiological parameters.

2.5. Standard of Drinking Water Quality Guide Fulfillment Criteria

2.5.1. Physical requirements

Table 2.2 physical characteristics of drinking of water quality

S.no	Characteristics	Permissible level	Method
1	Odor	Un objectionable	ES605
2	Test	Un objectionable	
3	Turbidity	<5	ES ISO 7027
4	Color (TCU)	15	ES ISO 7887

Sources: National Drinking Water Quality monitoring and surveillance strategies, 2011

2.5.2. Chemical requirements

Characteristics that affect the delicious properties of drinking water quality shall be conforming to the level specified in table 2.3

Table 2.3 chemical characteristics of drinking of water quality

S.no	Characteristics	Permissible level	Method
1	Total hardness (as caco3) mg/l	300	ES607
2	Total dissolved solids mg/l	1000	ES 609
3	Total iron (as Fe) mg/l	0.3	ES ISO 6332
4	Manganese (as Mn) mg/l	0.5	ES ISO 6333
5	Ammonia (NH3+NH4+) mg/l	1.5	ES ISO 7150-2
6	Residual free chlorine mg/l	0.5	ES ISO 7393
7	Anionic surfactants mg/l	1	ES ISO 7875-1
8	Magnesium (as Mg) mg/l	50	ES ISO 7980
9	Calcium (as Ca) mg/l	75	ES ISO 7980
10	Copper (as Cu) mg/l 2 ES ISO 8288	2	ES ISO 8288
11	Sulfate (as So4)	250	ES ISO 9280
12	Chloride (as Cl) mg/l	250	ES ISO 9297
13	Total alkalinity (as Caco3	200	ES ISO 9963-1
14	Potassium (as K), mg/l	1.5	ES ISO 9964-2
15	PH value, units	6.5 to 8.5	ES ISO 10523
16	Phosphate	0.5	ES ISO 2007
17	Electrical conductivity (μS/cm)	250-400	WHO

Sources: National Drinking Water Quality monitoring and surveillance strategies, 2011

2.5.3. Bacteriological analyses of drinking water quality

Drinking water experts are concerned with water supply and water purification through a treatment process. In treating water, the primary concern, of course, is producing potable water that is safe to drink (free of pathogens) and has no accompanying unpleasant characteristics, such as a foul taste or odor. To achieve this, the drinking water practitioner must possess a wide range of knowledge. In short, to correctly examine raw water for pathogenic microorganisms and to determine the type of treatment necessary to ensure that, the quality of the product potable water meets regulatory standards.

Absolutely the most serious public health risk associated with drinking water supplies is microbial contamination. Pathogens; bacteria, viruses and parasites, then can cause a wide range of health problems when consumed in drinking water, but the primary concern is infectious diarrhea disease transmitted by the faecal-oral route. It is unpractical to analyze water for every individual pathogen, some of which can cause disease at very low doses. As an alternative, since most diarrhea causing pathogens are faecal in origin, it is more practical to analyze water for indicator species that are also present in faecal matter. The most commonly used indicator species are coliform bacteria, which include a wide range of bacteria, all of which can ferment lactose and produce gas at 37°C. Many but not all coliforms are faecal in origin, so the presence of total coliforms in water is not a good indicator of poor water quality. Coliforms that come from faecal matter can tolerate higher temperatures than most environmental coliforms, so those that ferment lactose and produce gas at 44°C are called thermo tolerant coliforms, or faecal coliforms. These are more closely associated with faecal pollution than total coliforms.

The most specific indicator of faecal contamination is Escherichia coli (E. coli), which unlike some faecal coliforms never multiplies in the aquatic environment (UNICF, 2008). When evaluating faecal contamination, it is suggested to measure turbidity along with E. coli (or faecal coliforms), since pathogens can adsorb onto suspended particles, and to some extent be shielded from disinfection. When water has been disinfected, it is also important to measure chlorine residual and pH. These four parameters (E. coli/faecal coliforms, turbidity, disinfectant residual chlorine and pH) are considered the minimum set of “essential parameters” required to assess microbiological quality of drinking water (WHO, 2006). Therefore, bacteriological analysis mainly includes estimation of faecal coliform and total coliforms.

Total coliforms**:** The coliform organisms were better referred to as total coliforms to avoid confusion with others in the group, are not an index of fecal pollution or of health risk, but can provide basic information on source water quality. Total coliforms have been long utilized as a microbial measure of drinking water quality, largely because they are easy to detect and enumerate in water. Traditionally they have been defined by reference to the method used for the group’s enumeration and hence there have been many variations dependent on the method of culture. In general, definitions have been based around the following characteristics; gram-negative, non-spore forming, road shaped bacteria capable of growth in the presence of bile salts or other surface-active agents with similar growth inhibiting properties, oxidize-negative, fermenting lactose at 35-37^{o}C with the production of acid, gas, and aldehyde within 24-48 hours according to Assessing Microbial Safety of Drinking Water (2002)

Faecal coliforms:The term 'fecal coliforms‟, although frequently working, is incorrect. The correct terminology for these organisms is "thermo tolerant coliforms‟. Thermo tolerant coliforms were defined as the group of total coliforms that are able to ferment lactose at 44-45^{0}C. The genus Escherichia comprise to a lesser extent, species of Klebsiella, Entero-bacter, and Citrobacter. Of these organisms, only *E. coli* was considered to be specifically of fecal origin, being always present in the faeces of humans, other mammals, and birds in large numbers and rarely, if ever, found in water or soil in temperature climates that has not been subject to fecal pollution (Fujioka *et al*., 1999). The danger of coliform presence can rest on the health or sensitivity of the user. The risk of E. coli presence, rather than WHO Guideline is zero count per 100ml that may be of only low or intermediate risk. According to risk classification presence or absence of thermo tolerant coliforms or E. coli (Michael, 2006) of rural water supplies is shown.

3. MATERIALS AND METHODS

3.1. Description of The Study Area

3.1.1. Geographical location of study area

Bishan Guracha Town is located in the Oromia Regional state in the southern edge of the west Arsi Zone. It is situated approximately 266 km south of Addis Abeba and 16 km south of the Zonal capital town, Shashemene. The town is also about 4 km north of Hawassa City. Bishan Guracha town is approximately located between 07^{0}08' North latitude and 38^{0} 48' East longitudes (Alemayehu Addunya, 2005).

Bishan Guracha has developed into one of the important urban centers in Oromia since the 1950s. Its socio-economic development originated from small-scale formal as farmer association and informal settlements which are migrants.The name "Bishan Guracha" is derived from the Afan Oromo words "Bishan" (water) and "Guracha" (black), referring to the color of the river that flows from the Wondo highlands to Lake Hawassa, bounding the town from the eastern area. With an area of 997.58 hectares, Bishan Guracha is classified as a second-grade town in the region. It is bordered by Shashemene Woreda, the Sidama Regional state, Wondo Genet, and Shala Woreda to the south, north, east, and west respectively.

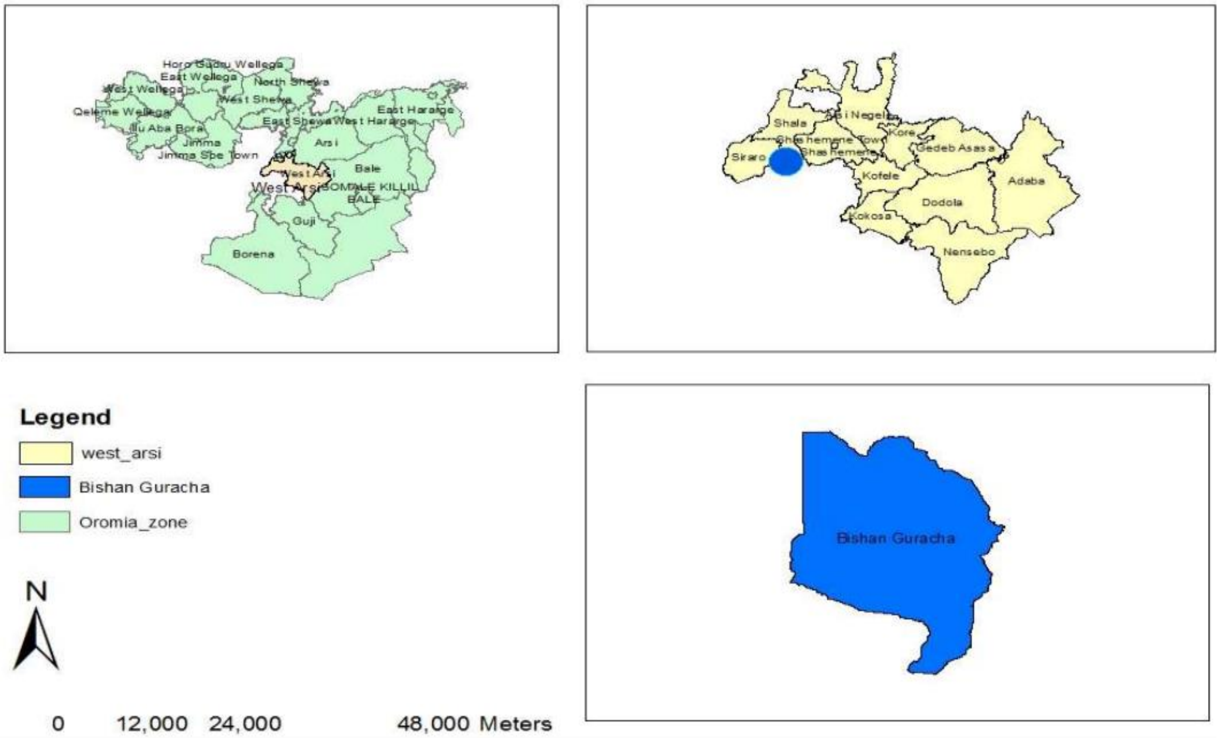

Figure 1.The study area Administrative map

3.1.2. Climate and Topography

Bishan Guracha town is located at the center of the Great East African Rift Valley, and the topography of the area consists of a hot and humid flat landscape, characterized by gentle slopes that descend towards Lake Hawassa (Addunya, 1995). This geographical feature enables the efficient drainage of floodwaters, directing them either into the Bishan Guracha River or Lake Hawassa. The elevation of the land gradually decreases towards the east, south, and southwest directions. The highest point in the region reaches slightly above 1,508 meters, while the lowest point measures approximately 1400 meters above sea level (Tegenu, 2021). Overall, the majority of the area can be classified as a flatland surface, except for a few scattered plateaus in the west-central part.

In terms of climate, Bishan Guracha shares similar characteristics with Hawassa City. It falls within the tropical climatic region, renowned for its warm temperatures, high levels of rainfall, and humidity (Tegenu, 2021). The town experiences an average annual rainfall of 1735.8mm, based on historical data.

3.1.3. Water Supply Schemes, Status of Sanitation, and Hygiene Practices

Based on the information provided by the Bishan Guracha town administration office and feedback from respondents, the provision of clean and accessible drinking water, as well as proper sanitation facilities, is still lacking in meeting the needs of the community. There are different sources of water supply in the study area for household and animal use.

In Bishan Guracha town, the community relies on different water public tap water that has been installed in the area. These water point obtain their supply from the water distribution system. However, the amount of water available from this source is insufficient to meet the current demands of the town. On the sanitation front, the existing conditions are at a lower level. Although the coverage of sanitation facilities exceeds 70%, the town community is still exposed to various diseases due to poor hygiene practices and the lack of safe drinking water.

3.2. Research design

This study employed a descriptive cross-sectional study with experimental investigations conducted in a laboratory setting. The main objective was to achieve a thorough understanding of the topic under investigation by employing both quantitative and qualitative data approaches.

To evaluate the quality of the drinking water samples obtained from different sources, quantitative data approaches were utilized. These approaches involved assessing the physical, chemical, and bacteriological properties of the collected samples. Through rigorous laboratory analysis, the researchers were able to quantitatively measure and quantify various parameters related to the drinking water, enabling them to draw objective conclusions about its quality and suitability for consumption.

In addition to the quantitative assessments, qualitative approaches were employed to gain insights into the water handling practices at the household level. This involved conducting interviews, making observations, and administering surveys to individuals. By gathering subjective information about individuals' habits, attitudes, and behaviors regarding water usage and management, the researchers aimed to obtain a more holistic understanding of the factors influencing water-related practices in the studied population.

3.3. Sampling Procedure

3.3.1. Water Sampling for Physicochemical and Bacteriological Analysis.

The sample size for the physicochemical and bacteriological analysis in Bishan Guracha town was determined based on the need to obtain representative data for the study. A total of 57 water samples (triplicated) were collected from source water which comprises various raw water sources, including spring 1, spring 2, reservoir 1, reservoir 2, the main distribution line, and 14 tap (private or public tap)water sources from the three kebeles (7 water samples from 01 kebele, 5 water samples from 02 kebele and 2 samples from 03 kebele).

In addition to tap water samples, 48 water samples (triplicated) were collected from the household storage containers from three kebeles. The number of household storage samples collected was proportional to the total sample size of households selected for the survey in each kebele. A total 16 households were selected for water sample collection from the household storage containers, with 8 households from kebele 01, 6 households from kebele 02, and 2 households from kebele 03.

The limited number of households selected for water sample collection (16 out of 321 households) was due to various reasons such as financial constraints, lack of logistical infrastructure, time limitations, and a shortage of laboratory technicians to support the data collection process, and also based on the recommendations from previous studies, including the Center for Affordable Water and Sanitation Technology (CAWST, 2013), which suggests a sample size of 5-10% when the total number of households exceeds 100.

3.3.2. Selection of the Study Kebeles

The selection of sampling kebeles in Bishan Guracha town was carried out in a sequential and correct manner. The town consists of three kebeles, and the water supply is distributed from a source located approximately 13 km away from these kebeles. All three kebeles were included in the study, and water samples were collected from public tap water sources, community facet and household containers at different locations within each kebele. The selection of public tap water sources was based on the number of beneficiaries who collected water from them.

3.3.3. Sample procedure and sample size determination for survey Method

The total number of households is 8,304 in the town who lived in three kebeles 01,02 and 03 the so called Geda tokuma from this 4100 are found in kebele one (1), 3150 are found in kebele two (2) while the rest is 1054 are found in kebele three (3) and the total household residence, sample population was determined by using the following statistical formula (Cochran,1977).

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

Where: n(i) – sample number of household

N – Total number of households

P – Proportion (70%)

Q = (1-p)

W = (5%)

Z = 95% confidence interval (1.96)

$$n(i) = \frac{8,304*(1.96)^2*0.7*0.3}{(0.05)^2*(8,304-1) + 1.96^{2*}0.7*0.3} = 292 + 10\% \text{ (non-respondents)} = 321$$

Therefore, the sample size for this study is 321 households. With regard to the sample households a total of 321 households were selected have a chance to drawn for a data collection by using systematic sampling as shown in table below 3.4.

The appropriate sample from the three kebeles of the town was taken by using proportional allocation in the following way:

$n1 = \frac{n \times p}{N}$ where n1 = is the sample size of each kebeles

P = is the number of households in selected kebele

N = is the total number of households in three kebeles

Samples from kebele one was taken as;

$n1 = \frac{321 \times 4{,}100}{8{,}304}$ = 158 respondents, in similar way of calculation for 02 is 122 respondents and for kebele 03 is 41 respondents.

Table 3.4 Number of sample of households from those three kebeles

Selected sample kebele	No of Households	Sample Households	
		Frequency	Percentage (%)
Kebele 01	4100	158	49
Kebele 02	3150	122	38
Kebele 03 Geda tokuma	1054	41	13
Total	8304	321	100

3.3.4. Data collection instruments

To obtain the essential information needed to meet the objective of the study, both primary and secondary data collection techniques were employed. The primary data collecting procedure includes recording experimental results, personal observations, household survey and key informant interview. Secondary data gathering method was document review on water quality, status of sanitation and hygiene practice of Bishan Guracha town and other related journals, articles, newspapers, and from internet.

A. Household survey

To evaluate sanitation condition, an interview was accompanied with structured questionnaire. Accordingly, data associated to sanitation and hygienic condition like availability of relevant toilet, hand washing practice after toilet and appropriate disposal of waste, accessibility of water and quality of water was collected from the households mainly from women and men HHs heads.

B. Key informant Interview

Key informants' interviews were employed to gather background evidence on institutional Set up, operation, and maintenance of water points, sanitation situation status of Bishan Guracha town residents. They were selected by using non-probabilistic purposive sampling method. The interview was held with selected individuals of Bishan Guracha Town heath office, Bishan Guracha Town municipality, town administration office and Bishan Guracha Town water supply service enterprise, who were believed to have good knowledge about the subject matter and experience.

Table 3.5 Selection of key informants from differents offices

No	Office from where the key informants were selected	No of selected key informants	Method of selection
1	Bishan Gurach town office	2	Purposive
2	Bishan Gurach town Municipality	2	Purposive
3	Bishan Gurach town Water supply service enterprise	3	Purposive
4	Bishan Gurach town Health office	3	Purposive
	Total	10	

C. Personal observation and site visits

Personal observation was employed to observe and record the status of sanitation condition at water sources and storages. Photographs were part of the assessment instruments to pick up the status of different water supply schemes and latrine condition. Field observations using structured checklists and unstructured interview administered. Data for the observation include mainly protection mechanism like presence of fence, guard, problems related with service structures, presence of latrine and its situation.

3.4. Physicochemical Analysis of Water Sample

In this study, the physicochemical properties include: Temperature, pH, Turbidity, Total Dissolved Solids (TDS), Free Residual Chlorine (FRC), cupper, Iron, Chromium, Nitrate Sodium, Potassium, Fluoride ,Alkalinity and Except for nitrate, cupper, Iron, Chromium, Sodium, Potassium, Fluoride ,Alkalinity and all physical parameters were analyzed at the site. Temperature and pH was analyzed using portable digital pH meter. The pH meter was calibrated just before analysis using PH 4.0 and PH 7.0 and it were runs with distilled water from one sample to the other following the Jenway pH meter operation manual (Jenway,2003). Total dissolved solids (TDS) and electrical conductivity were analyzed using portable digital conductivity meter (CC-401, Poland. This instrument was used to cross check the temperature of the water samples using waterproof oxygen meter (CO-411, Poland). Free residual chlorine test was made for all chlorinate samples. The tests were performed using N, N-diethyl-1, and 4- phenylenediamine (DPD-1) reagent with digital portable Calorimeter, were used for measurement free residual chlorine. Nitrate, cupper, Iron, Chromium, Sodium, Potassium, Fluoride, were measured using HACH DR/6000 spectrophotometer following HACH instructions manual (HACH, 2012) and Alkalinity were measured by volumetric titration method using sulfuric acid (0.02N) as titrant.

3.5. Bacteriological Analyses of Water Samples

With regard to bacteriological parameters, samples were analyzed using membrane filtration (MF) method for water quality to determine the degree of contamination (WHO, 2006; APHA, 1998). All samples we reanalyzed for the presence of total coliforms (TC), and faecal coliforms (FC). One hundred milliliter of water sample for each test were filtered through a sterile cellulose membrane filter with a pore size of 0.45µm to retain the indicator bacteria. The filtration apparatus was sterilized before use and re-sterilized between samples using methanol when analyzing water samples (OXFAM, 2004). The cellulose membrane filter was transferred from filtration apparatus to a sterilize aluminum Petri-dish containing absorbent pad soaked with 24 bronth agar (Wagtech, England) for both total coliforms (TC) and feacal coliform (FC). The Petri-dishes were inverted and incubate at 37ºC for 18-24 hours for TC and 44±0.5ºC for 18-24 hours for FC and FS.

3.6. Materials, Chemicals and Reagents

The materials that were used in this study are: Conductivity meter, autoclave, pH meter, Digital Calorimeter, Digital turbidity meter, UV-Vis Spectrophotometer DR/6000 and Titration Apparatus. The chemicals and reagents that were used in this study are:

Potassium Chloride (KCl), indicators, Potassium Nitrate (KNO3), Sulfuric Acid (H2SO4), Sodium Hydroxide (NaOH), Hydrochloric Acid (HCl) and Potassium Hydroxide (KOH).

3.7. Statistical Analysis

All water quality parameters: physical and chemical as well as bacteriological data were analyzed using MS EXCEL Version 2019 and SPSS software such as Version 20. At the end, the results were compared with different national and international standards. Data were entered, cleaned and analyzed using SPSS software such as Version 20. One-way ANOVA were used to test if there are statistical differences in the tested parameters among the water sources. Spearman's correlation was used to check if there is correlation between bacteriological and physicochemical parameter. The results of bacteriological and physicochemical analyses were compared with national and WHO guidelines for drinking water. P-value < 0.05 was considered to indicate statistically significant association.

3.8. Data quality assurance

To reduce the probability of getting biased information and variables, all the original questionnaires were prepared in English and translated into "Afaan Oromo language,'' the local language to make it simple to understand and administer for both interviewers and interviewees. The latter version was translated back to English to ensure its consistency. The interviewers were first given short orientation and training on how to distribute questioner, and how to fill it by themselves (in case of uneducated household) before they are involving in to the processes. The whole processes of data collection were supervised by researcher.

3.9. Ethical Considerations

During the data collection process, the research purpose was informed to the respondents and other concerned bodies and they were convinced in order to collect relevant data and information from them after they are willing to respond for the questionnaires and interview to be asked for the study purpose. With regard to data collection at the household level, the aims of study were clearly explained to the households. Each household was expressed that the information provided would be confidential and used only for the study purpose.

4. RESULT AND DISCUSSION

4.1. Physicochemical Water Quality

4.1.1. The Physicals water quality of different water sources

Table 6 provides an analysis of the physical water quality parameters, namely temperature, turbidity, total dissolved solids (TDS), and electrical conductivity (EC), for various types of water sources. The data presented in the table includes mean values for each parameter, as well as the standard deviation (SD) and the comparison with the standards set by the Ethiopian Standards Agency (ESA, 2013) and the World Health Organization (WHO, 2017).

I. Temperature

The temperature values across the different water sources range from approximately 24.33°C to 26.17°C. The average temperature for the springs is 25.64°C, while the reservoirs, distribution line, and taps exhibit slight variations around this average. The value of temperature for all water sources were beyond the acceptable range for water quality standards which is less than 15^0C.

In fact, similar studies in Ethiopia such as Bahir Dar (Kassahun, 2008), Gondar zone (Damite *et al*., 2014), Adaa woreda (Daba, 2016), Nekemnte (Duressa *et al*., 2019) and Kobo town (Baye and Molla, 2021), the temperature records have been higher than the standard limit, even in water systems where pollution level was very low. This could mean that variation in water temperature may not be caused by problem associated to water pollution but, other factors such as climatic influences in Ethiopia can contribute to elevated temperatures in distributed drinking water (Tesfaye *et al*., 2021). The country experiences high ambient air temperatures year-round in many regions particularly in this area, with average temperatures often exceeding 25°C. This warm environment allows for substantial heat gain through water pipes that are exposed above ground or buried shallowly near the hot surface (Tadesse *et al*., 2018). Such heat exchange is exacerbated where distribution systems consist of long transmissions mains stretching for kilometers without adequate shade or insulation (Assefa *et al*., 2017). Additionally, Ethiopia's varied landscape means some areas rely on gravity-fed pipelines that maintain spring water at higher temperatures as they flow long distances down from highland sources. Prolonged heat absorption from the surroundings along these gravity pipelines can deliver warmer water to the last taps. Generally, Ethiopia's characteristic warm climate and vulnerabilities in current piped water infrastructure to the sun may contribute to unduly high delivered drinking water temperatures experienced (Mekonnen and Kebede, 2018).

High temperature by itself may not cause series problem. However, high water temperature enhances the growth of microorganisms and may increase problems related to taste, odor and corrosion (WHO, 2017). Thus, maintaining temperatures within appropriate limits are crucial for ensuring water safety.

II. Turbidity:

Turbidity measurements indicate the clarity of water by measuring the presence of suspended particles. The value of turbidity was within the range of 5.62 NTU (Nephelometric Turbidity Units) to 6.73 NTU across the different water source. Water samples obtained from tap water (Tap14) from 03 kebele exhibited the highest average turbidity of 6.73 NTU, while Tap1 (from kebele 01) had the lowest average turbidity of 5.62 NTU. The turbidity values for all water sources exceeded the WHO standard of less than 5 NTU. The reason for this result could be due to the presence of suspended particles, such as sediment, organic matter, or microorganisms, in the water. These particles can make the water appear cloudy or turbid.

Similar result was reported in Jimma town, where 60% of water samples analyzed for turbidity were above permissible limit of WHO and national standard value for turbidity (Yasin *et al*., 2015). The current result of turbidity deviates from the values reported from previous study of Baye and Molla (2021) for drinking water quality of Kobo town Northern Ethiopia, which reported, the range of turbidity was 0.61 to 3.87 NTU and which was within acceptable limit of Ethiopian and WHO standards. Likewise, Daba (2016) conducted similar research in Ada’a Woreda and reported turbidity level of water samples ranged from 0.47-2.54 NTU which fits WHO permissible limit.

III. Total Dissolved Solids (TDS) of Source Water:

Total Dissolved Solids (TDS) represents the concentration of dissolved inorganic and organic substances in water, providing an indication of water quality and its impact on the aesthetic value of drinking water, including turbidity (ESA, 2013). The compulsory Ethiopian Standard recommends a TDS range of <1000 mg/l.

In the present study, the TDS range in spring water samples varied from 169.93 mg/l to 180.83 mg/l, all falling below the maximum permissible limit. Reservoir water samples had an observed TDS value of 181.87 mg/l, also below the recommended limits. The TDS value for water sampled from the distribution line was 179.97 mg/l. Tap water in Bishan Guracha town had a TDS range of 173.83 to 178.77 mg/l, well within acceptable limits. These findings indicate that the health risks associated with TDS are insignificant, as the values are much lower than the maximum limits set by Ethiopian and WHO standards. A similar result was reported by Daba (2016), where TDS values in Aada Woreda ranged from 212 to 357 ppm.

IV. Electrical Conductivity (EC):

The quantity of dissolved solids in water particularly concentration of ions resulted from dissociation of inorganic minerals general determines the electrical conductivity of given water sample. According to Ethiopian and WHO standards, EC value should not exceed 500µS/cm. In this study, the average values of EC for spring, reservoirs, distribution line and tap water were 265.50 ± 24.28 µs/cm, 284.67 ± 0.00 µs/cm, 281.33 µs/cm and 276.50 ± 2.53 µs/cm respectively. The values of all water samples for electrical conductivity were within the acceptable range (<500) of WHO and compulsory Ethiopian standard value (ESA, 2013; WHO, 2017). Similar Researches done in Arbaminch town (Haile, 2016), in Kobo town (Sitotaw and Nigus, 2021), In Sidama district (Belachew, 2013) and in Wogeda town (Sitotaw *et al*., 2021) reported that the mean value of EC for water samples were below 500 µS/cm, which is similar to the present study. This could be due to water treatment methods like sedimentation, filtration, and desalination that are used to remove minerals and ions from source water lower its dissolved solid content and ability to conduct electricity (Doe *et al*., 2001). Additionally, the increasing use of plastic distribution pipes instead of metal pipes means fewer ions are leached from pipe materials into the drinking water, as plastics do not corrode like metal (Smith *et al*., 2016). Aging infrastructure with corroded old metal pipes has been shown to deposit scale inside over time, which prevents further ion exchange between the stationary water and piping network (Jones, 2005). Some original water sources such as springs from granite and sandstone aquifers tend to be softer with naturally lower dissolved ion levels, providing less dissolved contents to start with (Brown *et al*., 2017). Longer distribution systems increase water-pipe contact surface area but also retention times, allowing more precipitates to form scale deposits on pipe walls rather than dissolving out into the flowing tap water (Wilson *et al*., 2014).

Table 4.1. The Physicals water quality of different water sources.

Type of water source		Temperature	Turbidity	TDS	EC
Spring 1	Mean	26.17	5.89	169.93	248.33
Spring 2	Mean	25.10	5.62	180.83	282.67
	Mean ± SD	25.64 ± 0.76	5.76 ± 0.19	175.38 ± 7.71	265.50 ± 24.28
Reservoir 1	Mean	25.33	5.85	181.87	284.67
Reservoir 2	Mean	25.33	6.00	181.87	284.67
	Mean ± SD	25.33 ± 0.00	5.93 ± 0.11	181.87 ± 0.00	284.67 ± 0.00
Distrubtion Line	Mean	24.63	5.87	179.97	281.33
Tap1 (public)	Mean	24.87	6.25	175.80	274.67
Tap2 (Private)	Mean	25.00	6.03	177.50	277.33
Tap3 (public)	Mean	25.10	6.33	177.47	277.33
Tap4 (public)	Mean	25.17	6.01	176.40	275.67
Tap5 (Private)	Mean	24.90	6.20	173.83	271.67
Tap6 (public)	Mean	25.13	6.07	178.37	278.67
Tap7 (Private)	Mean	25.17	6.07	178.77	279.33
Tap8 (Public)	Mean	24.33	6.05	177.47	277.33
Tap9 (Private)	Mean	25.07	6.05	178.37	278.67
Tap10 (public)	Mean	25.23	6.35	175.80	274.67
Tap11 (Private)	Mean	24.83	6.01	177.50	277.33
Tap12 (public)	Mean	25.10	6.33	177.47	277.33
Tap13 (Private)	Mean	24.90	6.20	173.83	271.67
Tap14 (Private)	Mean	25.10	6.73	178.77	279.33
	Mean ± SD	24.99 ± 0.23	6.19 ± 0.20	176.95 ± 1.63	276.50 ± 2.53
ESA (2013) standard Value		< 15	< 5	< 1000	< 500
WHO (2017) standard value		< 15	< 5	<1000	< 500

Note: “Tap” represents Private or public Pipes

4.1.2. Chemicals Water Quality of differnt Water Sources

I. The pH of source water

The pH levels of the different water sources were assessed to determine their suitability for drinking. The springs exhibited pH values of 7.13 (Spring 1) and 7.2 (Spring 2), with a mean pH of 7.1±0.05, all falling within the recommended range of 6.5-8.5 of ESA (2013) and WHO (2017). Similarly, the reservoirs displayed pH values of 7.3 for both Reservoir

1 and Reservoir 2, resulting in a mean pH of 7.3, which also fell within the recommended range. The tap pH values ranged from 6.73 to 7.53, with an average pH of 7.05±0.2 which was also fell in the range of suggested standard value for pH.

Unlike the present findings, the study conducted in Bona district revealed that the 20% of spring water samples tested for pH had the value < 6 (Berhanu and Hailu, 2015). Generally, the samples from all water sources in present study met the pH guidelines specified by the World Health Organization (2017) and the Ethiopian standard Agency (2013) which is considered safe for drinking water.

II. Free Chlorine

The analysis of water samples from springs, reservoirs, distribution pipes, and taps reveals important insights regarding the presence of free chlorine. Springs representing untreated raw water sources, exhibit no detectable free chlorine (<0.00 mg/L). In contrast, the reservoirs, distribution pipe and tap water samples show varying levels of free chlorine, ranging from 0.03 to 0.20 mg/L, indicating the addition of chlorine during water treatment and distribution processes. According to the World Health Organization (WHO) guideline, a disinfectant residual of 0.2 - 0.5 mg/L free chlorine is recommended for treated water, and most tap samples do not meet this level, suggesting effective disinfection is taking place. While the spring sources do not have chlorine added due to levels below detection, the presence of chlorine in reservoirs, distribution pipe and tap samples indicates that it is introduced at some point after the raw water sources. Notably, there is greater variability in chlorine levels across individual tap samples compared to the raw water sources, implying that the consistency of chlorine dosing may decrease during distribution. The higher chlorine readings in some tap samples (e.g., distribution pipe at 0.20 mg/L) compared to others (e.g., some taps at 0.03 mg/L) could indicate the loss of chlorine residual during distribution before reaching certain taps. In summary, the analysis confirms the addition of chlorine for water treatment and distribution, as evidenced by detectable free chlorine in distributed waters that meet health guidelines. However, the variability in chlorine levels across the distribution system highlights the potential loss of disinfectant residual prior to reaching all tap locations.

III. Nitrate

Nitrate levels were analyzed across spring, reservoir and tap water sources and, the level of nitrate ranging from 10.27 to 10.67 mg/L which fell well below the WHO/ESA guideline of 50 mg/L. Specifically, spring nitrate levels averaged 10.67 mg/L with little variability between the two springs sampled. Reservoir nitrate levels were consistently 10.33 mg/L. Tap water nitrate ranged from 10.27 to 10.67 mg/L with an average of 10.55 mg/L. These nitrate concentrations were very stable between sources. The analyzed levels indicate nitrate contamination is not a health concern according to WHO and ESA drinking water standards, as all sources contained nitrate far below the 50 mg/L safety limit. The consistent readings also suggest the water treatment process is reliably maintaining low nitrate quality across the distribution system from springs to taps. Similar studies conducted somewhere else in Ethiopia also showed the nitrate record as Nekemte town (1.8 mg/l), Bahirdar Dar town, (12.9 mg/l) and Wondogenet district (12.7 mg/l) (Kassahun, 2008; Haylamicheal and Moges, 2010; Duresa *et al*., 2019), all values fell much below the suggested value for nitrate in drinking water.

IV. Alkalinity Levels

The water samples obtained from springs and reservoirs show consistent alkalinity levels averaging around 92.5 mg/L and 92 mg/L respectively. This stability indicates the underlying geology is contributing a consistent buffering capacity without much variability between sources. Alkalinity is largely unaffected by the source, with levels well below the WHO and ESA guideline value of 200 mg/L, demonstrating a moderately alkaline water quality.

The treatment and distribution processes also do not seem to significantly influence alkalinity levels. The distribution pipe sample taken after treatment but before distribution has an alkalinity reading of 91.33 mg/L, aligning with the raw water concentrations. Most tap samples also cluster closely around 92–93 mg/L alkalinity. This consistency in alkalinity levels after treatment and throughout the distribution network suggests the water treatment process is not altering the alkalinity chemistry. It also implies that piping materials and infrastructure are not leaching or solubilizing additional alkalinizing compounds that could raise values. Similar study by Mengistie *et al* (2023) in Hawassa city water supply system reported the mean alkalinity level of 196.39 mg/L which below the maximum suggested value.

The stable, uniform alkalinity concentrations both before and after treatment point to predominant control of this parameter by the underlying geology and original groundwater chemistry, rather than external inputs from water system processes. Alkalinity appears well buffered and managed through all stages to distribution to consumers. This stability indicates alkalinity levels are predominantly based on natural mineral contents, without significant influence from water treatment or distribution infrastructure variables.

V. Fluorides

Remarkably, minimal variation in fluoride concentration was observed across all sources, ranging only from 1.12 to 1.13 mg/L. Springs exhibited an average fluoride level of 1.13 mg/L, while reservoirs consistently measured 1.13 mg/L. Tap water samples displayed a range of 1.12 to 1.13 mg/L, with a mean concentration of 1.13 mg/L. Importantly, these concentrations fell below the drinking water guideline of 1.5 mg/L for fluoride set by the World Health Organization (2017) and the National standard agency (2013). This could be due to the sampled water source was spring in which the fluoride level expected to be lower compared to ground water sources which contain high concentration of fluoride.

In contrast to the findings of the present study, previous research conducted in the Rift Valley region of Ethiopia has consistently indicated elevated levels of fluoride in groundwater. Several studies have reported a high prevalence of dental fluorosis in this specific region, where the fluoride concentration surpasses the recommended acceptable value of 1.5 mg/L (Wondwossen, 2004; Tekle-Haimanot *et al*., 2005; Christpher *et al*., 2018).

VI. Chlorides

The raw water sources (springs) had very low chloride concentrations with the mean value of 10.84±.23 mg/L, indicating minimal naturally occurring chlorides. However, chlorides are commonly used as part of the water treatment process for disinfection and corrosion control, with targets above these baseline levels. The distribution pipe sample taken after treatment but before distribution has chloride levels at 11.33 mg/L, only slightly higher than the raw waters and potentially indicating treatment is not sufficient.

Water samples taken from tap water ranged from 9.67-12.67 mg/L with many on the lower end of this spectrum, suggesting chlorides are not being consistently dosed to the desirable levels through treatment. Below target chloride residuals post-treatment could mean disinfection and corrosion protocols within the distribution system may be inadequately applied, jeopardizing water quality. The generally lower chloride concentrations in distributed waters compared to expectations therefore point to potential insufficient treatment that fails to properly adjust chloride chemistry for safe, regulated drinking water.

Table 4.2. Chemicals water quality of different water Sources.

Type of water source	pH	Free Chlorine	Chloride	Nitrate	Alkalinity	Fluoride
Spring 1	7.13	.00	11.00	10.67	94.33	1.12
Spring 2	7.2	.00	10.67	10.67	90.67	1.13
Mean ± SD	7.1±.05	0.00±.0	10.84±.23	10.67±.00	92.50±2.5	1.13±.01
Reservoir 1	7.3	.20	10.67	10.33	92.00	1.13
Reservoir 2	7.3	.10	10.67	10.33	92.00	1.13
Mean ± SD	7.3±0	0.15±.07	10.67±.00	10.33±.00	92.00±.0	1.13±.0
Distrubtion Pipe	7.33	.06	11.33	10.27	91.33	1.13
Tap1 (public)	7.17	.05	12.67	10.60	92.33	1.13
Tap2 (Private)	7.53	.03	9.67	10.60	92.33	1.13
Tap3 (public)	7.43	.05	10.00	10.63	92.67	1.13
Tap4 (public)	7.33	.04	10.33	10.33	92.67	1.13
Tap5 (Private)	6.83	.03	11.33	10.63	92.33	1.13
Tap6 (public)	6.87	.04	10.67	10.60	92.67	1.13
Tap7 (Private)	6.87	.03	10.00	10.60	93.67	1.12
Tap8 (Public)	7.07	.03	10.67	10.60	93.67	1.13
Tap9 (Private)	6.87	.03	10.67	10.67	92.67	1.13
Tap10 (public)	6.73	.03	10.00	10.60	92.67	1.13
Tap11 (Private)	6.83	.05	10.00	10.33	95.33	1.13
Tap12 (public)	7.43	.05	10.00	10.63	92.67	1.13
Tap13 (Private)	6.83	.03	11.33	10.63	92.33	1.13
Tap14 (Private)	6.93	.04	10.67	10.27	93.33	1.12
Mean ± SD	7.05±.2	.04 ± .01	10.57±.79	10.55±.13	92.95±.8	1.13±0
ESA (2013)	6.5-8.5	0.2 to 1	250	<50	200	1.5
WHO (2017)	6.5-8.5	0.5	250	<50	200	1.5

4.1.3. Physicochemical quality of household storage water

Table 9 bellow demonstrates physicochemical quality of drinking water sampled from household storage container of three kebeles in Bishan Guracha town. All the physicochemical quality parameters tested for water samples collected from household's storage remained within the suggested standard value of WHO/ESA with the exception of temperature and free chlorine. The value of temperature for all water samples was slightly beyond the maximum recommended value for temperature whereas the value of for all water sample was below minimum recommended value. This could be due to climatic condition of the area rather than pollution of water sample. Generally, there is no health risks associated to physicochemical water quality of water from household storage container as the value of all water quality parameters fell within the suggested value for drinking.

Table 4.3. Physicochemical quality of household storage water

Source	Kebele	Temp	pH	E.C	Free Chlorine	Cl^-	NO_3^-	Alkalinity	F
HHS1	01	25.1	7.47	274.67	.04	11.3	10.60	91.33	1.13
HHS2	01	24.7	7.27	277.33	.03	8.67	10.60	93.33	1.13
HHS3	01	25.1	7.47	271.33	.03	12.6	10.63	95.67	3.40
HHS4	01	23.7	7.30	281.00	.02	10.6	10.33	92.33	1.12
HHS5	01	25.0	7.23	282.67	.04	9.3	10.63	92.00	1.13
HHS6	01	24.6	7.33	278.67	.04	9.3	10.6	93.33	1.13
HHS7	01	24.7	7.03	275.33	.03	9.3	10.6	93.33	1.13
HHS8	01	25.0	7.23	277.33	.04	11.3	10.6	92.33	1.13
HHS9	02	24.9	7.43	274.67	.03	9.3	10.6	94.67	1.12
HHS10	02	24.8	7.57	279.33	.05	11.3	10.6	92.33	1.13
HHS11	02	25.0	7.47	277.33	.03	10.0	10.6	92.67	1.14
HHS12	02	24.8	7.57	271.67	.05	10.0	10.3	91.67	1.13
HHS13	02	25.0	7.53	279.33	.05	11.6	10.2	92.67	1.13
HHS14	02	24.6	7.33	278.67	.04	9.33	10.6	93.33	1.13
HHS15	03	24.7	7.0	275.3	.03	9.33	10.6	93.33	1.13
HHS16	03	25.0	7.23	277.33	.04	11.33	10.60	92.33	1.13
Mean ± SD		24.8	7.3	277.0	0.0	10.3	10.5	92.9	1.3
ESA (2013)		<15	6.5-8.5	<500	0.2-1	250	<50	200	1.5
WHO (2017)		<15	6.5-8.5	<500	0.5	250	<50	200	1.5

4.2. Bacteriological Quality and Some Heavy Metals Contents of Source and Household Storage Water.

4.2.1. Bacteriological quality and some heavy metals contents of source water

4.2.1.1. The level of Total coliforms in source water

Total coliform (TC) bacteria were tested in various water sources as part of routine water quality monitoring. TC are commonly used as indicators of water quality and potential pathogens. Springs had the lowest mean TC of 19.5 CFU/100mL, indicating minimal exterior contamination reaching these protected sources. Spring 1 and 2 values were similar, suggesting consistent quality. Even though the levels of TC in springs does not met WHO standards, and could possibly cause risk to consumers.

On other hand, the reservoirs showed higher and more variable TC than springs, with a mean of 46 CFU/100mL and range of 27-65 CFU/100mL. This may be due to elevated surface water exposures like runoff, sediment disturbance and wildlife likely contributed to increased TC bacteria. The Values for reservoirs also exceeded the maximum standard value suggested by WHO as well as national standard level.

The count value of TC for distribution line was 85 CFU/100mL before decreasing in taps. However, mean tap TC of 50.6 CFU/100mL was substantially above springs and reservoirs. These points to potential post-treatment contamination increase through cracks in aging pipes. Some individual tap readings like Taps 13 and 14 exceeded 100 CFU/100mL, breaching standards. Remedial actions are needed to safeguard distributed water quality.

Generally, the recorded value for TC across all water sources in the Bishan Guracha town indicated deteriorating untreated drinking water distribution. Similar studies conducted in the different areas of Ethiopia such as Kobo town (Baye and Molla, 2021), Bahirdar Dar town (Tabor *et al*., 2011), Dire Dawa (Amenu *et al*., 2013), Bona district (Berhanu and Hailu, 2015) and Wogeda town (Baye *et al*., 2021) have shown similar results where the level of coliform was beyond the permissible limit of world health organization and National standard. Higher levels pose greater risk to consumers and demand improved environmental and infrastructure protections. Regular sampling should continue across the full supply chain to pinpoint hotspots requiring upgraded maintenance or rehabilitation. Proper disinfection alongside distribution network revitalization are thereby recommended to reliably protect public health.

4.2.1.2. Fecal coliforms level in Source water

Fecal coliform (FC) testing supplements total coliform analysis by specifically identifying excreta-derived bacteria. This provides greater indication of recent fecal contamination and associated pathogens.

In current study, the highest mean FC count (38.0±1.4 CFU/100ml) was observed in water sampled from springs that used as water supply to distribute in the study area. The same study in North Gonder zone indicated the water samples collected from springs were positive for *E. coli* (Abera *et al*., 2011). So that, it is more likely to cause water borne diseases such as intestinal infections, dysentery, hepatitis, typhoid fever, cholera and other illnesses unless treated effectively with disinfectants (Emmanuel *et al*. 2009). High level contamination of spring water with fecal coliforms in this study could be due to human and animal waste entering the water source, and/ or inadequate infrastructure for waste management, animal grazing near the springs, or surface water runoff carrying FC from nearby agricultural or urban areas.

On the other hand, the distribution line and most tap water samples showed no FC contamination. However, some individual taps recorded levels between 1-2 CFU/100mL FC. As FC are not normally present in potable waters, this signals potential post-treatment contamination entry. FC positive taps were scattered throughout the network rather than clustered. This implies localized intrusion points rather than systemic issues. Aging infrastructure like leaks or cracks allow infiltration that possibly resulted in observation of FC in tap water sample. Unlike current study, the studies conducted in Tigray (Eastern Zone) indicated all water source were positive fecal coliforms (Aderajew *et al*., 2019).

Absence of FC from natural sources was expected and reinforce their purity. Detection within some taps but not others point to discrete rather than widespread contamination breaches requiring remediation. Ongoing infrastructure upgrades and water quality surveillance are essential to maintain distributed water safety. Targeted remedial actions guided by incident mapping can prevent human health consequences benefitting from such water sources.

4.2.2.3. Iron, Chromium, Sodium and Potassium concentration in source water

The potassium (K) levels in the water sources showed consistent patterns. Springs exhibited uniform K levels around 6.25 mg/L, whereas reservoirs had slightly higher concentrations ranging from 6.33 to 7.33 mg/L. The distribution and taps maintained a steady K concentration of 6.27 to 6.33 mg/L. Notably, the variations in K levels were minimal. These findings suggest that the water sources naturally contained stable potassium concentrations that remained unchanged during the treatment and distribution processes. Consequently, the presence of potassium in the water sources did not pose any health concerns.

In terms of sodium (Na^+), all tested water sources consistently reported nearly identical levels. The sodium content ranged from 27.10 to 27.25 mg/L across the various sources, including springs, reservoirs, and the delivery systems. Importantly, these measured values remained consistently low and significantly below the World Health Organization's (WHO) limit of 200 mg/L. The uniformly low sodium content across all tested water sources suggests that sodium is naturally present without significant additional contributions. Consequently, the sodium levels observed in the water sources did not approach the safety guidelines set forth by the WHO.

Concerning iron, Springs and reservoirs had similar low Fe levels of 0.22 mg/L, meeting the standard of ≤0.3 mg/L. However, Distribution line and taps showed slightly higher Fe at 0.21-0.22 mg/L, still within standard value suggested by WHO for iron in consumption water. Slightly elevated Fe in distribution could be due to corrosion of iron pipes. However, all sources had negligible Fe levels posing no risks.

With regard to chromium all water sources had chromium levels ≤0.03 mg/L, significantly below the standard of ≤0.05 mg/L. The concentrations of chromium were consistent with no notable variations between different points in the system. Minimal chromium detected demonstrates lack of contamination from industrial sources. Levels were uniformly low with no safety concerns for any of the water sources based on chromium.

Table 4.4. Bacteriological quality and some heavy metals concentration in source water

Source of water	TC	FC	Na^{+}	Fe	K	Cr^{6+}	Cu^{2+}
Spring 1	18.00	37.00	26.47	.22	6.17	.00	.02
Spring 2	21.00	39.00	27.10	.22	6.33	.01	.04
Mean ± SD	19.50±2.2	38.0±1.4	26.79±.4	0.22±0	6.25±.1	0.01±.01	0.03±.01
Reservoir 1	27.00	.00	27.10	.22	6.33	.01	.03
Reservoir 2	65.00	.00	27.10	.21	7.33	.02	.05
Mean ± SD	46.00±26	0.00±0	27.10±0	.22±.01	6.83±.07	.02±.01	.04±.01
Distrubtion Line	85.00	.00	27.10	.22	6.37	.02	.04
Tap1(public)	30.00	.00	27.10	.21	6.33	.03	.06
Tap2 (private)	43.00	.00	27.10	.21	6.27	.02	.05
Tap3 (public)	45.00	.00	27.10	.21	6.30	.02	.04
Tap4 (public)	46.00	1.00	27.10	.21	6.33	.02	.05
Tap5 (private)	49.00	.00	27.10	.21	6.33	.02	.05
Tap6 (public)	39.00	.00	27.25	.22	6.30	.02	.05
Tap7 (private)	45.00	.00	27.13	.21	6.33	.03	.06
Tap8 (public)	55.00	1.00	27.10	.21	6.30	.02	.05
Tap9 (private)	47.00	.00	27.17	.21	6.33	.02	.05
Tap10 (public)	37.00	1.00	27.10	.21	6.27	.02	.06
Tap11 (private)	33.00	.00	27.10	.21	6.33	.02	.06
Tap12 (public)	41.00	.00	27.10	.21	6.30	.02	.04
Tap13 (private)	101.00	.00	27.10	.21	6.33	.02	.05
Tap14 (private)	97.00	1.00	27.10	.22	6.33	.02	.06
Mean ± SD	50.57 ±21.5	.29 ±.4	27.12 ±.04	.21 ±.0	6.31 ±.02	.02 ±.0	.05 ±.01
ESA (2013)	0	0	-	0.3	-	0.05	1
WHO(2017)	0	0	200	0.3	-	0.05	2

4.2.2.4. Risk category of source water samples analyzed for Escherichia Coli

Generally, in this study area, only 68% of water samples are safe for consumption interims of fecal coliform even if all water points were positive for total coliforms, whereas the rest 32% were known to be under intermediate risk category (Table 10). Similar study in Bona district showed that all of the protected springs examined had risks ranging from low to high risk category (Berhanu and Hailu, 2015). The results in this study clearly reveals that raw water source (springs) were polluted with human and animal fecal material so that it needs efficient treatment before delivering the water in to distribution networks for consumption.

Table 4.5. Risk category of water source samples analyzed for Escherichia Coli Bacteria.

WHO (2017) suggested values	*E. coli* leve	Risk Category	Type of water source									
			Springs (n=2)		Reservoir (n=2)		Distribution line (n=1)		Tap (n=14)		Total (N=19)	
			No	%	No	%	No	%	No	%	NO	%
All drinking water should have zero CFU per any 100 ml sample	0	No/Low	-	-	2	100	1	100	10	71	13	68
	1 – 10	Intermediate	-	-	-	-	-	-	4	29	6	32
	11 - 100	High risk	2	100	-	-	-	-	-	-	-	
	> 100	Very high risk	-	-	-	-	-	-	-	-	-	

4.2.2. Bacteriological quality and some heavy metals contents of household storage water

Table 11 depicts the result of bacteriological parameters and some heavy metals of water sampled from storage container of the households in Bishan Guracha town. The measured value of TC ranged from 14 CFU/100ml to 81 CFU/100ml. The highest (81 CFU/100ml) count value for total coliform was recorded in water sampled from household eleven (HH11) benefitting from public tap located at 02 kebele in the study area, whereas the lowest (14 CFU/100ml) count value was recorded in water sampled from household 12 benefitting from the same water source.

With regard to fecal coliforms, with exception of three water samples, all other water samples were positive for fecal coliforms. This result clearly indicates that almost all water samples were probably contaminated with bacterial pathogens as coliforms were noticed in all of the samples (total coliform counts 100%, fecal coliform 81%) and found to be beyond the suggested values in the WHO and national standards. Similar studies from Eastern Tigray zone showed higher percentage (91%) for fecal coliforms in water collected from household Storage water (Gebrewahd *et al*., 2019). Similarly, study conducted at Farta woreda indicated 100% of household samples were positive for E. coli (Genet, 2017).

With respect to heavy metals analyzed in the water samples, the value for all remained below the maximum suggested value of WHO/ESA. Therefore, there is no health effects related to the concentration of sodium, iron, potassium, chromium and copper in the study area.

Table 4.6. Some heavy metals and bacteriological quality of household storage water.

Water source	Kebele	TC	FC	Na^{+}	Fe	K^{+}	Cr^{6+}	Cu^{2+}
HHS1	01	16.00	6.00	27.10	.21	6.30	.02	.05
HHS2	01	21.00	11.00	27.25	.21	6.33	.02	.05
HHS3	01	27.00	.00	27.13	.21	6.27	.01	.06
HHS4	01	17.00	1.00	27.10	.21	6.27	.01	.04
HHS5	01	48.00	15.00	27.17	.21	6.30	.02	.06
HHS6	01	43.00	5.00	27.10	.21	6.33	.02	.06
HHS7	01	46.00	4.00	27.10	.22	6.33	.02	.05
HHS8	01	37.00	5.00	27.10	.21	6.30	.02	.05
HHS9	02	49.00	22.00	27.10	.21	6.33	.02	.05
HHS10	02	39.00	19.00	27.10	.22	6.30	.02	.04
HHS11	02	81.00	.00	27.25	.21	6.33	.02	.05
HHS12	02	14.00	1.00	27.13	.22	6.27	.02	.04
HHS13	02	21.00	8.00	27.10	.21	6.33	.02	.05
HHS14	02	33.00	.00	27.10	.21	6.33	.02	.06
HHS15	03	32.00	1.00	27.10	.22	6.33	.02	.05
HHS16	03	34.00	12.00	27.10	.21	6.30	.02	.05
Mean		34.9	6.9	27.1	0.2	6.3	0.0	0.1
ESA (2013)		0	0	200	0.3	-	0.05	1
WHO (2017) standard value		0	0	200	0.3	-	0.05	2

4.3. Comparison of Bacteriological Water Quality

4.3.1. Comparison of bacteriological water quality between source and house hold storage

The level of water contamination with TC and FC was compared between household storage water samples and water sampled from tap water, using independent sample T-test (Table 12). The analyzed result shows, the level of water contamination with TC in source water was significantly higher than the level of water contamination of household storage water samples. In contrast, the water samples collected from household storage containers had significantly high fecal contamination level (p=0.02) than the water samples collected from tap water. This result is in line with previous finding of Baye *et al*. (2021) in Wogeda town where samples collected from household storage containers had higher level of contamination compared to the source water. This strongly suggests a lack of awareness about the quality of water they have been using and poor potable water handling practice at the household level.

Table 4.7. Comparison of bacteriological water quality between source and house hold storage

Parameters	Source of water	N	Mean	Std. Deviation	Std. Error Mean	Sig. (2-Tailed)
Total	Source water	14	50.57	21.51	5.74	0.03
coliforms	HH storage	16	34.87	16.89	4.22	
Fecal	Source water	14	0.28	0.46	0.12	0.02
coliforms	HH storage	16	6.87	7.06	1.76	

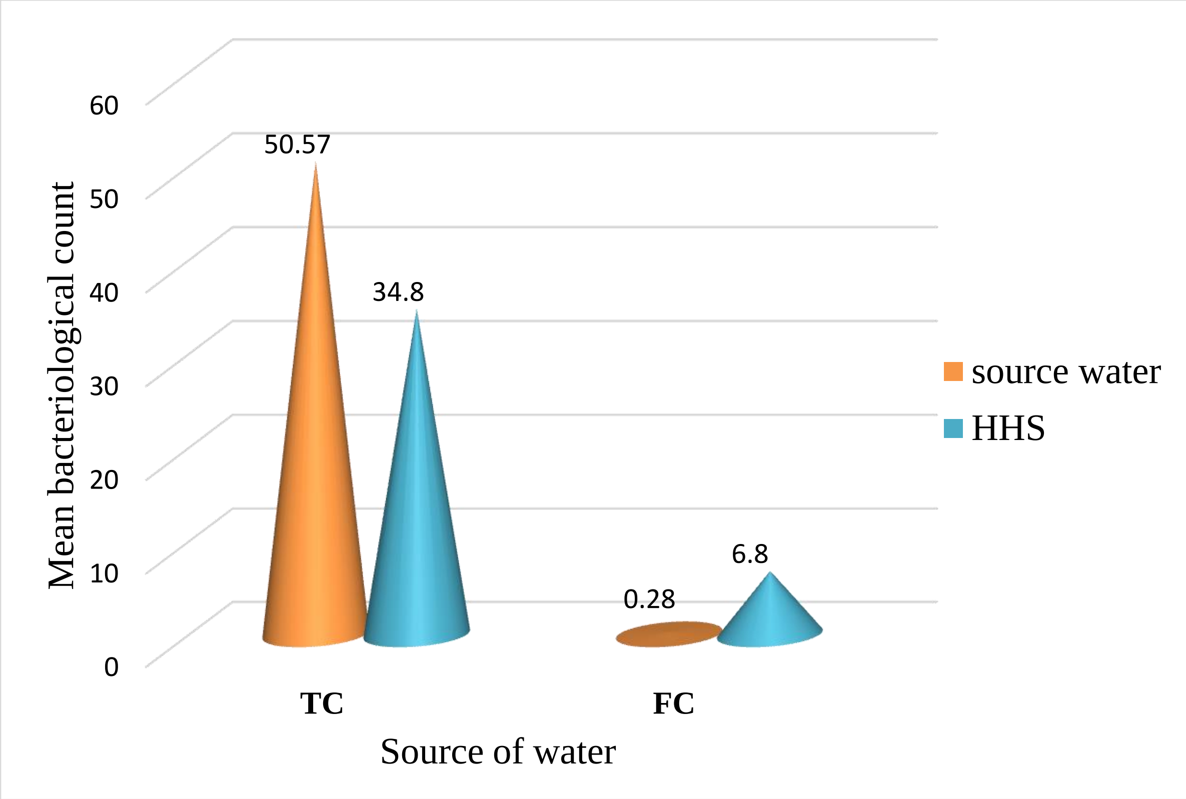

Figure 2.Distribution of total coliforms and fecal coliforms in water sampled from source and household storage (count value/100ml CFU)

4.3.2. Comparison of bacteriological water quality across three sampled kebeles households.

A one-way ANOVA was conducted to evaluate bacterial contamination level of water samples across three water sample collected kebeles. The result of ANOVA indicated that there is no statistically significant difference in contamination level of water with fecal coliforms across three kebele ($p>0.05$). However, total coliforms were not similarly distributed across three kebeles ($p<0.05$). The post hoc test was conducted for total coliforms to compare the mean contamination level and, the result indicated that significantly high (66 CFU/100ml) and low (36.8 CFU/100ml) of TC contamination level was observed 03 kebele and 01 kebele respectively (Fig. 3). The variation among three kebeles could be possibly associated to the inconsistency in water handling practice and sanitary condition of individuals that handling water from the point of collection to the consumption.

Table 4.8. Comparison of bacteriological water quality Across three sampled kebeles

		Sum of Squares	df	Mean Square	F	Sig.
Total coliforms	Between Groups	2721.491	2	1360.745	3.902	.032
	Within Groups	9415.309	27	348.715		
	Total	12136.800	29			
Fecal coliforms	Between Groups	15.218	2	7.609	.194	.825
	Within Groups	1059.582	27	39.244		
	Total	1074.800	29			

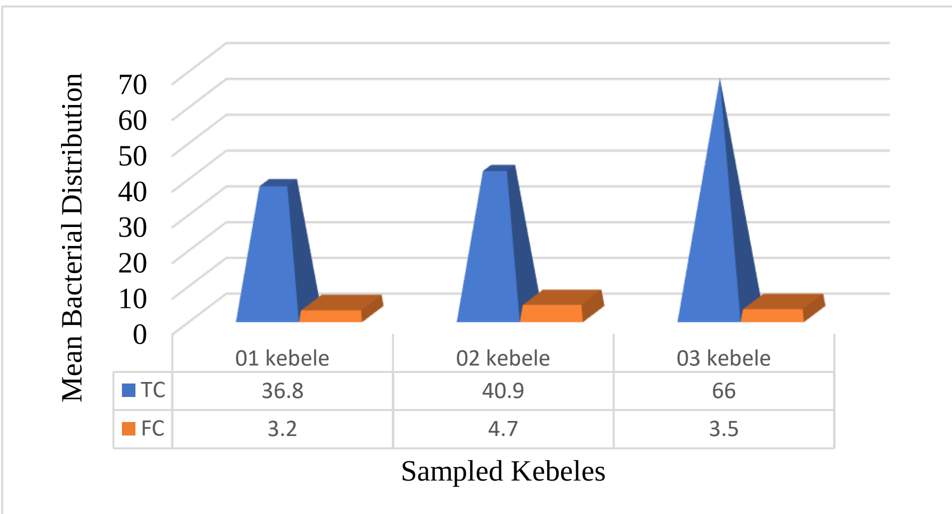

Figure 3.Bacterila distribution across three sampled kebeles

Table 4.9. Tukey's post hoc

Variable	Sampling kebele		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Total coliforms	01 kebele	02 kebele	-4.10909	7.41276	.845	-22.4884	14.2702
		03 kebele	-29.20000*	10.50840	.026	-55.2547	-3.1453
	02 kebele	01 kebele	4.10909	7.41276	.845	-14.2702	22.4884
		03 kebele	-25.09091	10.90322	.073	-52.1245	1.9427
	03 kebele	01 kebele	29.20000*	10.50840	.026	3.1453	55.2547
		02 kebele	25.09091	10.90322	.073	-1.9427	52.1245

*. The mean difference is significant at the 0.05 level.

4.4. Association Between Physicochemical Parameters and Microbial Loads of Source Waters

Total coliform positively correlated to turbidity (r=0.12), temperature (r=0.17) copper (r=0.16) and nitrate (0.13), whereas negatively correlated to free chlorides (-0.23), fluorides (-0.14), pH (r=-0.35) electrical conductivity (r = -0.01). Similarly, fecal coliform positively correlated to temperature, pH, TDS, EC and iron while negatively correlated to chlorides, fluorides and chromium (Table 15). Similar result was reported by Yasin *et al*. (2015) in Jimma town where correlation analysis indicated that bacteriological load was positively correlated with Turbidity (r = 0.721) and total suspended solids (r = 0.718) and negatively correlated with pH (r = -0.829), EC (r = -0.845) and TDS (r = -0.813).

Table 4.10. Association b/n bacterial load and physicochemical parameters

		Temp.	pH	Tur	TDS	EC	Fe	Cr^{6+}	Cu^{2+}	Cl^-	F^-	Free Cl	Nitrate	TC	FC
Temp		1.000													
	R														
	P														
pH	R	-.049	1.000												
	P	.798													
Turb	R	.044	-.042	1.000											
	P	.819	.825												
TDS	R	-.215	.058	.049	1.000										
	P	.255	.759	.797											
EC	R	-.213	.059	.050	1.000**	1.000									
	P	.257	.757	.792	.000										
Fe	R	.006	-.197	.105	-.113	-.112	1.000								
	P	.974	.298	.580	.551	.554									
Cr^{6+}	R	.348	-.257	.110	.053	.055	.000	1.000							
	P	.059	.171	.564	.779	.772	1.000								
Cu^{2+}	r	.231	-.426*	.188	.058	.053	.024	.273	1.000						
	p	.219	.019	.321	.762	.781	.900	.145							
Cl^-	r	.158	.013	-.097	-.298	-.300	-.138	-.062	.014	1.000					
	p	.403	.946	.610	.109	.107	.468	.745	.944						
F	r	.164	.185	-.153	-.364*	-.367*	.022	-.509**	.240	.422*	1.000				
	p	.387	.329	.421	.048	.046	.907	.004	.201	.020					
FreeCl	r	.280	.258	.153	.147	.149	.010	.335	-.099	.183	-.261	1.000			
	P	.134	.168	.421	.438	.432	.957	.070	.602	.334	.164				
Nitrate	R	.180	-.063	-.042	-.149	-.150	-.002	.175	.048	-.086	.112	-.344	1.000		
	P	.340	.740	.826	.431	.428	.993	.354	.802	.653	.557	.063			
TC	R	.179	-.359	.123	-.015	-.012	.185	.141	.169	-.030	-.140	-.236	.133	1.000	
	P	.345	.052	.517	.939	.949	.328	.458	.373	.874	.459	.209	.483		
FC	R	.018	.360	.139	.233	.235	.150	-.015	-.118	-.135	-.118	-.138	.149	-.135	1.000
	P	.925	.051	.463	.216	.210	.428	.936	.534	.478	.535	.468	.433	.478	

*. Correlation Is Significant At The 0.05 Level (2-Tailed).

**. Correlation Is Significant At The 0.01 Level (2-Tailed).

4.5. Drinking Water Handling, Sanitary and Hygienic Conditions at Source and Storage in the Study Area

A survey was carried out to understand household's drinking water handling practice, as well as to evaluate the sanitary and hygienic conditions at source and storage. The data and findings of this survey are depicted and described below.

4.5.1. Demographic characteristics of the respondents

A total of 321 households were participated in the study and among them 245 (76%) were females and the rest 76 (24%) were males. In terms of occupational status, approximately 46% of the household heads were employed by the government, 38% were involved in merchant activities, and the remaining 16% were farmers. Among the household heads, 53% reported generating a monthly income between 4001 and 6000 Ethiopian Birr, while 13%, 28%, and 6% earned up to 2000, 2001 to 4000, and above 6000 Ethiopian Birr, respectively. Only about 3% of the respondents were uneducated, while the rest 97% were able to read and write or had higher levels of education. The age range of the majority of respondents (54%) fell between 31 and 45 years old, and the average family size was 2 individuals (Table 11).

Table 4.11. Demographic information of respondents

Characteristics		Frequency	Percent (%)
Gender of Respondents	Male	76	24
	Female	245	76
Age of Respondents	18-30	62	19
	31-45	172	54
	46 Years and Above	87	27
Educational Level	Uneducated	9	3
	Read and Write	21	7
	Primary	52	16
	Secondary	68	21
	College and Above	171	53
Occupation of Household	Government Employee	147	46
	Merchant	122	38
	Farmer	52	16
Income Level Per Month	Up To 2000	41	13
	2001-4000	89	28
	4001-6000	172	53
	6001 And Above	19	6
Total		**321**	**100.0**

4.5.2. Drinking water handling practice associated to water supply, collection and transportation

The majority of respondents (61.9%) were found to collect water from private pipes, while 38.1% collected water from public tap water sources (Table 17). Approximately 65.4% of study participants used jerry cans, while the remaining 34.9% used plastic buckets to collect water from the source. Respondents explained that they preferred jerry cans because they were readily available at affordable prices in local markets, easy to carry, and came in various capacities that could be managed by small children. However, those using buckets mentioned that they preferred them for collecting water from pipes due to their wide openings, which facilitated efficient collection without water wastage. A similar study conducted in Bona district also indicated that most respondents used jerry cans or plastic buckets for water collection and storage (Berhanu and Hailu, 2015).

A large percentage (96%) of the respondents reported covering their water containers during transportation to prevent water outflow. This finding demonstrates a higher value compared to the study conducted in Bona district, where 74.7% of respondents covered their water collection containers (Berhanu and Hailu, 2015). It is also consistent with a study conducted in Tehulader District, North Ethiopia, where 92.7% of respondents covered their containers during transportation (Tiku *et al*., 2003). These results suggest that the communities in Bishan Guracha town and Tehulader District have better water handling practices during transportation compared to the community in Bona district. This difference could be attributed to more effective awareness training provided to the communities by health extension workers.

The maximum distance traveled by respondents to collect water from public taps was up to 100 meters. Respondents explained that the long distances were not due to a lack of nearby water availability but rather because water distribution sometimes ceased in certain areas, necessitating the collection of water from other kebeles (administrative subdivisions) where water was available at that time. This result is in line with the study conducted in 2021 which reports that, the distance from the water source takes a minimum of 5-10 minutes to fetch water in Bishan Gurach town (Tariku, 2021)

Table 4.12. Drinking water handling practice associated to collection and transportation

Variables		Kebeles of households			Total	
		01 kebele	02 kebele	03 kebele	No	(%)
Source of drinking water	Private pipe	97	71	31	199	61.9
	Public tap	61	51	10	122	38.1
	Other	0	0	0	0	0.0
How much water is collected each day in liter?	Up to 20 L	27	51	4	82	25.5
	Above 20 L	131	71	37	239	74.5
How far you travel to fetch drinking water from public tap water?	Not at all	90	70	41	201	62.6
	Up to 50 m	54	49	0	103	32.1
	51-100 m	14	3	0	17	5.3
	Above 100 m	0	0	0	0	0.0
Type of container used to fetch water	Jerry cans	81	102	27	210	65.4
	Bucket	77	20	15	112	34.9
Cover container during transportation	Yes	147	122	39	308	96.0
	No	11	0	2	13	4.0

4.5.3. Drinking water handling practice associated to storage and use

Approximately 68% of the individuals surveyed reported using the same container for collecting water from the source and storing it at home, while the remaining 32% stored water in a separate container at home. This finding is consistent with a study conducted in the rural communities of Aada woreda, where a majority of respondents (56.6%) used the same container for both water collection and storage (Daba, 2016).

According to this study, 14.6% of respondents mentioned that they did not wash their water storage containers before refilling them, as they believed that the containers would not become contaminated if continuously filled with fresh water. In contrast, 87.9% of respondents reported cleaning their drinking water storage containers. The cleaning frequencies reported were as follows: daily (33%), weekly (49.5%), monthly (12%), and rarely (4.4%). These results align with studies conducted in Jimma town (91%) and Bona district (77.5%), where respondents washed their water storage containers before refilling them (Teklu and Kebede, 1998; Berhanu and Hailu, 2015). They are also similar to a study conducted in Dire Dawa rural communities, where 55.5% of participants cleaned their containers before transferring water from collection to storage (Desalegn *et al*., 2013).

Among the respondents who stored water in separate containers, an average of 72.6% poured water out of the container, while 27.4% dipped their containers and kept the dipping material inside since it was easily accessible and did not require frequent cleaning for multiple water withdrawals. This result is lower than the findings reported in the study conducted in Bona district, where 97.2% of respondents used the pouring method to draw water from the storage container, which is considered a better practice to minimize water contamination (Berhanu and Hailu, 2015). Thus, Bona district communities showed better water transfer practices compared to Bishan Guracha. Similarly, a study conducted in Wogeda town reported that 56.7% of participants drew water by dipping cups into the storage container (Baye *et al*., 2021).

On average, 7.5% of respondents in the surveyed area treated drinking water at the household level before consumption, while 92.5% used untreated water. This finding is similar to the study conducted in rural communities of Dire Dawa, where only 13% of respondents treated drinking water at the household level (Desalegn *et al*., 2013). The reasons for this may include the perception that the water they have been using is safe to drink or a lack of information and awareness about household-level water treatment practices, potentially due to insufficient training on this aspect by public health officers or rural health extension workers (Table 18).

Table 4.13. Drinking water handling practice associated to storage and use

Variables	Answer by respondents	Kebeles of households			Total	
		01 kebele	02 kebele	03 kebele	No	(%)
Keep water in separate container	Yes	51	22	30	103	32.1
	No	107	100	11	218	67.9
Clean water storage container	Yes	132	101	49	282	87.9
	No	26	21	0	47	12.1
If yes, how often the container is cleaned?	Every day	7	76	23	106	33.0
	Every Week	118	24	17	159	49.5
	Every Month	19	19	1	39	12.1
	Rarely	11	3	0	14	4.4
Days water remaining in container	A day and below	43	65	11	119	37.1
	For Two Days	98	45	30	173	53.9
	3 Days and Above	17	12	0	29	9.0
Cover storage container	Yes	154	112	38	304	94.7
	No	4	10	3	17	5.3
Water withdrawal method	Pouring	132	80	21	233	72.6
	Dipping	26	42	20	88	27.4
Stored water treatment	Yes	12	12	0	24	7.5
	No	146	110	41	297	92.5

4.5.4. Water sources condition, functionality and protection level

Throughout the survey period, an assessment was conducted to evaluate the overall state of each water source. Despite the fact that piped water systems were implemented and extended to cover significant areas, certain challenges related to functionality and maintenance were observed, and no immediate measures were taken to address them. Consequently, the water infrastructure suffered from a lack of proper upkeep and failed to reach all sections of the town, resulting in insufficient access to water for certain residents. Additionally, the condition of water collecting containers was a cause for concern, as some of the observed containers were inadequately cleaned, posing potential health risks to those utilizing them for water storage.

4.5.6 Existence of latrines in study area

The results presented in this section based on household survey and personal observation. The results revealed that 90.9% (292) of the respondents that are included in this survey reported the existence of latrine in the household compound. However, this does not mean that the sanitation coverage mostly and successfully achieved. Although the latrine coverage is 90.9 %, sanitation problems like poor awareness on sanitary and hygienic practices, lack of using hand-washing facility after defecation and lack of pour-flush to piped sewer system, septic tank pit latrines and ventilated improved pit latrines. The results of household survey and personal observation revealed that the public toilets also available in some parts of Bishan Guracha town are dirty and filled with faces.

Table 4.14. Existence of latrines in study area

Variables	Answer by respondents	Kebeles of households			Total	
		01 kebele	02 kebele	03 kebele	No	(%)
Do you have a latrine at home	Yes	153	111	28	292	90.9
	No	5	11	13	29	9.03

4.5.7 Types of latrines constructed

In the study area, three types of latrine commonly constructed; pit latrine with walls but without roof, pit latrine with closed wall and roof and open pit latrine without house. On the average, 70.72 % (227) of the households had latrines with a wall and roof; 16.51 % (53) of the respondents had pit latrines with closed walls but without roof, 12.77 % (41) of the households had open pit latrines. The sanitation technologies said to improve if those sanitation facilities prevent humans, animals and insects from coming in contact with human excreta (UNICEF, 2008). However, such improved technologies not mostly been observed in the study area. The sanitation condition is not pleasing as some of the toilets are simply made of local materials without any facilities. Therefore; lack of proper access to sanitation is the major cause of potable water quality problem and spreading of diseases in in community, which are harmful to human life. This finding agreed with previous study by Tegegn M. (2009) in twenty villages of Ethiopia and Joseph (2013) in WA, Ghana.

Table 4.15. Types of pit latrines constructed

	Kebeles of households respondents			Total	
Variables	01 kebele	02 kebele	03 kebele	No.	(%)
Pit latrine with walls but without roof	20	23	10	53	16.51
Pit latrine with walls and roofs	126	83	18	227	70.72
Open pit latrine without house	12	16	13	41	12.77

4.5.8 Materials used for washing hands after defecation

More than 116(36.14 %) of respondents in all the study area don't use water at all for hand washing after defecating (Table 4.13). 128(39.88 %) of the respondents were using water only, 28(8,72%) of the respondents were used water and ash and the remaining respondents were used water and soap 49 (15.26%) for hand washing after attending toilet. The number of respondents who do not use water at all after attending toilet was the somewhat similar in the three kebeles. This result is different from the finding of Tehuledere woreda, northeast Ethiopia, i.e. is most of the households 141(73.4%) rinsed their collection containers and wash their hands 123(64.1%) before and after water collection and after defection (Seid *et al*., 2013).

Table 4.16. Materials used for washing hands after defecation

	Kebeles of households respondents			Total	
Variables	01 kebele	02 kebele	03 kebele	No.	(%)
Water only	58	52	18	128	39.88
Water and ash	12	10	6	28	8.72
Water and soap	26	18	5	49	15.26
Don’t use water at all	62	42	12	116	36.14

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The present study assessed the physicochemical and bacteriological quality of drinking water supply from sources to household tap connections and sanitation practices in Bishaan Gurracha town. The findings revealed that the microbial quality of water progressively deteriorated from source to household tap. The water sources and distribution network were prone to fecal contamination mainly due to poor sanitation practices in the catchment areas for source water and pipe leakages in the distribution system. All the physicochemical parameters were within the standard value of the national and international standards except for temperature, turbidity and free residual chlorine which making the water suitable for drinking purposes without prior treatment with respect to them. Sanitation facilities were also found to be inadequate in most households. The results presented here will serve as baseline information to design appropriate urban water supply and sanitation improvement programs.

5.2. Recommendations

The local municipal water authority should:

- Construct sanitary seals/fences around water sources and repair pipeline leakages to protect water quality.
- Establish water testing laboratories and assign water quality monitoring responsibilities.

The health department should:

- Conduct community awareness campaigns on water safety and hygiene practices.
- Promote household latrine construction and solid waste management.

The water and infrastructure development bureau should:

- Fund projects to improve water sources, treatment and distribution infrastructure like chlorination systems.

The regional environmental protection agency should:

- Monitor and ensure enforcement of regulations regarding source protection and wastewater management.
- Provide technical support and resources for ongoing surveillance of water quality.
- Regular multi-stakeholder coordination led by the municipal government is important for effective planning, implementation and sustainability of recommended water supply and sanitation improvements.

Researchers and NGOs should:

- Carry out comprehensive assessments of the local water supply and sanitation systems. This should include evaluating the current infrastructure, water quality, accessibility, and management practices. Utilize scientific methods and collaborate with local authorities to gather reliable data.
- Facilitate regular dialogues and workshops with diverse stakeholders, including community members, local government, and service providers. This multi-stakeholder engagement is crucial for understanding community needs, identifying barriers, and co-creating sustainable solutions.
- Offer technical expertise and resources to support the planning, implementation, and monitoring of water supply and sanitation improvements. This can include training local personnel, developing operational guidelines, and providing access to innovative technologies.
- Leverage research findings and community insights to advocate for policy reforms that strengthen regulations, enforcement, and resource allocation for water and sanitation services. Work closely with policymakers and local authorities to ensure that recommended measures are integrated into development plans.

6. REFERENCES

A. Melaku, (2006). Assessment of bacteriological quality of drinking water supply at the sources and point of use at home in Wore babu District, South Wollo, M.S, thesis, Addis Ababa University, Addis Ababa, Ethiopia, 2006.

A. U. Muhammed, G. Nicolas, and V. B. Joachim, (2016.) The Impact of Drinking Water Quality and Sanitation Behavior on Child Health: Evidence from Rural Ethiopia, ZEF–Discussion Papers on Development Policy No. 221, *Center for Development Research*, Bonn, Germany.

Abebe Berhanu and Dejene Hailu (2015). Bacteriological and physicochemical quality of drinking water sources and household water handling practice among rural communities of Bona District, Sidama zone-southern, Ethiopia. *Science Journal of Public Health*. **3(5):**782-789.

Abebe Beyene, Tamru Hailu, Kebede Faris, and H. Kloos (2015). Current state and Trends of access to sanitation in Ethiopia and the need to reviseindicators to monitor progress in the Post-2015 era, *BMC Public Health*, vol. **15(1)**, 2015.

Addisie, M. (2012). Assessment of drinking water quality and determunats of house hold potable water consumption in Sidima District, Ethiopia. un published.

Aderajew Gebrewahd, Gebre Adhanom, Gebremedin Gebremichail *et al*. (2019). Bacteriological quality and associated risk factors of drinking water in Eastern zone, Tigrai, Ethiopia. *Tropical Disease, Travel Medicine and Vaccine*, 6-15.

Admasu M,Mamo W,Baye G . A survey of bacteriological quality of drinking water in **18**, 113-115.

Alan C., T., Don D., R., and Malcolm J., B. (2000). Water Supply. (5.edition, Ed.) TOKYO: Published.

Alemayehu, E., Belyazid, S., and Hesaraki, S. (2015). Groundwater quality mapping in the eastern highlands of ethiopia: A GIS-based approach. Hydrology, **2(1)**, 1-20. https://doi.org/10.3390/hydrology2010001 .Accessed,18,November, 2022.

APHA (American Public Health Association) (2005). Standard Methods for the Examination of Water and Wastewater. American Public Health Association, Washington, D .C.USA,2005.

APHA (American Public Health Association) (1998).Standard Methods for the Examination of Water and Wastewater, American Public Health Association, Washington, DC, USA, 20th edition, 1998.

ATSDR (Agency for Toxic Substances and Disease Registry) (2021). Toxicological Profile for Chromium.

Baye Sitotaw and Molla Nigus (2021). Bacteriological and physicochemical quality of drinking water in Kobo town, Northern Ethiopia. *Journal of Water, sanitation and Hygiene for Development*, 2-10.

Baye Sitotaw, Eshetie Melkie and Denekew Temesgen (2021). Bacteriological and Physicochemical Quality of Drinking Water in Wegeda Town, Northwest Ethiopia.

Benignos, A. (2012). Rural Water Supply Manual Design (Vol. Volume I). Malina:

Bharti, N., and Katyal, D. (2011). Water quality indices used for surface water vulnerability assessment. Volume2

Birdie,G.S., and Birdie, J.S. (2010). Water Supply and Sanitary Engineering. Dhanpat Rai publishers, ISBN:81-87433-31-0.

BM, Obi CL. (2006).Safe drinking water stills a dream in rural areas of South Africa. Case Study: The Eastern Cape Province. Water SA.2006;32: 715-722.

Brikke, F. (2002). Operation and maintenance of rural water supply and sanitation systems: A training package for managers and planners. World Health Organization, Geneva.

Corvalan, C. (2006) Preventing Disease through Health Environments. Towards an Estimate of the Environmental Burden of Disease. WHO, Geneva.

Cochran, W. G.1977. Sampling techniques (3rd ed.). New York: John Wiley and Sons.

Debasu. Damite, Mengistu Endris, Yifokir Tefera .(Assessment of microbial and physic-chemical quality of drinking water).*e.t al*. (2014). in North Gondar Zone, Northwest Ethiopia, *Journal of Environmental and Occupational Science*, **(3)4**, 170

Desta. Kassa, (Bacteriological and physicochemical quality assessment of drinking water supply from source to taps) (2009). in Debreziet town, Ethiopia, M.S. thesis, Addis Ababa University, Addis Ababa, Ethiopia

Daba Desisa .(Quality assessment of drinking water supply schemes from source to point of use in Adaa Woreda, Oromia Regional State of Ethiopia). (2016). Addis Abeba University.

Dagne, W. T., Assefa, D., Woldemariam, G. (Assessment Drinking of Water Quality in the federal Republic of Ethiopia.Federal Democratic republic of health). (2007). Department. Country report. Addis Ababa, 19-67. 2007.

De Zuane J. (1996). Hand Book of Drinking Water Quality. Published

Debasu Damite, Mengistu Endris, Yifokir Tefera *et al*. (2014). Assessment of microbial and physic-chemical quality of drinking water in North Gondar Zone, Northwest Ethiopia, *Journal of Environmental and Occupational Science*, **(3)4**, 17

Desalegn Amenu, Sissay Menkir and Tesfaye Gobena (2013). Assessment of water handling practices among rural communities of Dire Dawa administrative council, Dire Dawa, Ethiopia. *Science, Technology and Arts Research Journal*, **2(2)**, 75-82.

DHSS (Department of Health and Social Security). (1998). Iron in Drinking Water.

Doria, M. (2010). Fators influencing public perception of drinking water quality. Water policy12, 1-19.

Emmanuel, E., Pierre, M.G., Perrodin, Y. (2009). Groundwater contamination by microbiological and chemical substances released from hospital wastewater and health risk assessment for drinking water consumers, *Environment International Journal*, **3(5)**, 718-726.

EPA (United States Environmental Protection Agency) (2022). Basic Information about Copper in Drinking Water. https://www.epa.gov/dwreginfo/copper-drinking-water.Accessed,28,November, 2022.

EPA (United States Environmental Protection Agency). (2022). Basic Information about Chromium in Drinking Water. https://www.epa.gov/dwreginfo/chromium-drinking-water Accessed ,28,November, 2022.

Ethiop J Health Develop.(2004). African Health Sciences Vol 13 Issue 4 December 2013 1152in Abeokuta, Nigeria. Afr J Biome Res.2008;11: 285 – 290.

Ethiopian Standards Agency (ESA) (2013). Drinking Water Specifications, *Compulsory Ethiopian Standards, CE58*, Ethiopian Standards Agency, Addis Ababa, Ethiopia, 1st edition, 2013.

Ethiopian Standards Agency (ESA), (2013) Drinking Water Specifications, Compulsory Ethiopian Standards, CE58, Ethiopian Standards Agency, Addis Ababa, Ethiopia, 1st edition, 2013.

Fesseha, G. (2013). Water quality: Ethiopia. In R.L. Nussbaum (Ed.), Global Issues in Water, Waste, and Climate (pp. 75-78). New York: Britannica Educational Publishing.

Fewtrell, L., Pruss-Ustun, A., Bos, R., Gore, F., and Bartram, J. (2007). Water sanitation and hygiene: quantifying the health impact at national and local levels in countries with incomplete water supply and sanitation coverage. WHO, Geneva.

G. Kassahun, "Physicochemical and bacteriological drinking water quality assessment of Bahirdar town water supply from source to yard connection, North western Ethiopia," M.S. thesis, Addis Ababa University, Addis Ababa, Ethiopia, 2008.

Garcia, A. and Servais (2006). Respective Contribution of Point and Non-Point Sources of *E. coli* and Enterococci in ALarge Urbanized Watershed (The Seine River, France)

Genet Gedamu Kassie (2017). Assessment of water handling and sanitation practice among rural communities of Farta woreda, Northwest Ethiopia. *American Journal of Health Research,* **5(5)**:119-124

Gizaw, B., and Getachew, A. (2020). Performance evaluation of iron removal techniques applied in rural water supply wells of Ethiopia: A review. Water Science, (**34)**(3), 193-210. https://doi.org/10.1016/j.wsj.2020.03.003

Gonfa Duressa, Fassil Assefa and Mulissa Jida (2019).Assessment of Bacteriological and Physicochemical Quality of Drinking Water from Source to Household Tap Connection in Nekemte, Oromia, Ethiopia. *Journal of Environmental and Public Health*, **7**: 10-14

Gurmessa Oljira (2015)., Investigation of Drinking Water Quality from Source to point of distribution ,The Case of Gimbi Town, In Oromia Regional State Of Ethiopia). Addis Ababa University School of Graduate Studies Addis Ababa Institute of Technology, Addis Ababa, Ethiopia

HACH (2012). DR/6000 Spectrophotometer User manual. *Hach company*, Edition 2,USA.

Haruna R, Francis E, Edmond K K. (2005).The quality of water from protected springs in Katwe and Kisenyiparishes, Kampala city ,Uganda. Africa Health Sci. 2005; 5: 14 –20.

Haylamichael Isreal, and Moges, Awdenegest. (Assessing water quality of rural water supply schemes as a measure of service delivery sustainability: A case study of Wondo Genet district, Southern Ethiopia) .(2012). *African Journal of Environmental Science and Technology*, 229-236

Health Canada (2012). Guidelines for Canadian Drinking Water Quality: Guideline Technical Document Copper. https://www.canada.ca/en/health-canada/services/publications/healthy-living/guidelines-canadian-drinking-water-quality-guideline-technical-document-copper.html Accessed ,8,November, 2022.

Howard AG. (2002).Water supply surveillance: reference manual. WEDC, Loughborough University,UK.2002.

Howard G ,Pedley S, Barrett M, Nalubeg (2003).a microbiological contamination of shallow ground water in K ampala, Uganda. Water Res.2003; 37: 3421–3429. https://web.archive.org/web/20150904002113/http://www.dhsspsni.gov.uk/phsa/iron.htm International Journal of Humanities and Social Science (**3**)(15); Accessed 10, December, 2022

Isaac, R. A., Gil, L., Sznopek, J. L., Cawthon, D. L., and Upp, Jr. S. R. (1997). Chromium and nickel levels in Illinois groundwater and their relationship to water quality characteristics. Bulletin of Environmental Contamination and Toxicology, (**58**)(4), 612–619. https://doi.org/10.1007/s001289900368

Israel Deneke Haylamicheal and Awdenegest Moges (2010). Assessing water quality of rural water supply schemes as a measure of service delivery sustainability: A case study of Wondo Genet district, Southern Ethiopia. *African Journal of Environmental Science and Technology*, **6(5)**: 229-236. *Journal of Environmental and Public Health.*

J Water Prac Tech. (2006) ;1:1-9.T , Carter RC, T yrrel SF , We bster J . An assessment. Physico-chemical and bacteriological quality drinking water supplies and influence of communities in Benue State, Nigeria.

John C. Crittenden, R.Rhodes TrusseII, David W.Hand, Kerry J.Howe, and George Tchobanoglous. (2012). MWH's Water Treatment: Principles and Design Third Edition. Hoboken, New Jersey: Published by John Wiley and Sons, Inc

Joseph (2013), Latrines And Household Well Water Quality in WA, Ghana.

K. Bedane, (2008) Assessment of physicochemical and bacteriological quality of drinking water in Central Rift Valley System, Ziway town, Oromia regional state, M.S. ,thesis, Addis Ababa University, Addis Ababa, Ethiopia, 2008.

Karn, S., and Harada, H. (2002). Field survey on water supply, sanitation and associated health influences in urban poor communities. Mumbai City, India

Kassahun, G. (2008). Physicochemical and bacteriological drinking water quality assessment of Bahirdar town water supply from source to yard connection, North western Ethiopia," M.S. ,thesis, Addis Ababa University, Addis Ababa, Ethiopia.

Ke, Q., Vega, E. R., Quiñonez, A., Qiang, L., and Deng, N. S. (2018). Chromium pollution in groundwater of El Paso, Texas. Journal of Environmental Management, 217, 280-290. https://doi.org/10.1016/j.jenvman.2018.03.071 Accessed 16, December, 2022

Lloyd B ,Bartman J .Sur veillance solutions to microbiological problems in water quality control in developing countries. W aterSci of Kampala, Uganda. Appl Environ Microbiol.1999; 66: 864-868.

Lynch, S. R., Cook, J. D., and Abdalla, H. (1997). Mapping of iron overload. Annals of the New York Academy of Sciences, 813(1), 248-261. https://doi.org/10.1111/j.1749-6632.1997. Accessed 26, December, 2022

M, Genthe B, Moyo S.,(2006). Contamination of drinking water between source and point-of use in rural households of South Africa and Zimbabwe: implications for monitoring the Millennium Development Goal for water.

Mengistu Admassu, Mamo Wubshet, and Baye Gelaw, (A survey of bacteriological quality of drinking water in Gondar). (2004) .*Ethiopian Journal of Health Development*, (**18**).(2), 112–115, 2004.

Mohammed Yasin, Tsige Ketema, and Ketema Bacha, (Physico-chemical and bacteriological quality of drinking water of different sources, Jimma zone, Southwest Ethiopia), (2015) . BMC Res Notes, (**8**)(1), 541.

Mekonnen, M. M., and Kebede, E. (Water balance of Ethiopia). (2018). Hydrology and Earth System Sciences, 22(8), 4193-4211. DOI: 10.1016/j.scs.2018.03.005

Memon, M., Soomro, M. S., Akhtar, M. S., and Memon, K. S. (2011). Drinking Water Quality Assessment in Southern Sindh (Pakistan). Environmental Monitoring and Assessment, 177, 39-50.

Mengistu Birhanu, (2007) Assessment of physicochemical and microbiological quality o rural drinking water supply at the sources and selected communities of Akaki-Kality Sub-City, Addis Ababa City administration, M.S. ,esis, Addis Ababa University, Addis Ababa, Ethiopia, 2007.

Michael, H. Drinking water quality assessment and treatment and treatment in east Timor a case study; Tangkae, the University of East Timor. . (2006). Published.

Milkiyas Tabor, Mulugeta kibret and Bayeh Abera (2011). Bacteriological and physicochemical quality of drinking water and hygiene-sanitation practices of the consumers in Bahirdar city, Ethiopia. *Ethiop Journal Health Science*, **21(1)**:19-26.

Miller, G. T. Jr. (1997). Environmental Science: Working with the Earth. (6th Ed.). California: Wadsworth Publishing Company, (Chapter 11).

Mohammed Yasin, Tsige Ketema and Ketema Bacha (2015). Physicochemical and bacteriological quality of drinking water of different sources, Jimma zone, Southwest Ethiopia, *BMC Res Notes*, **8(**541).

Moges Tariku Tegenu. Assessment of Water Supply and Sanitation in Bishan Guracha Sub-City in West Arsi Zone. (2021). Civil and Environmental Research, (**13)**(4):124

Momba MB, Tayfa a Z, Makala N, Brouckaert M, Johal K. (1991).Risk factors contributing to 25. Gundry SW , Wright JA, Conroy R, DuPreez Technol.1991;24:61-75.

Muhammad, M., Samira, S., Fayal, A., and Farrukh, J. (2013). Assessment of Drinking Water Quality and its impact on Residents Health in Bahawalpur City. International Journal of Humanities and Social Science, (**3**)(15).

Muyima N,Ngcakani F .(1998).Indicator bacteria and regrowth potential of the drinking water in Alice, Eastern Cape. Dep J Biochem Microbiol.1998, 24: 29-34.

N. D. Troyer, S. T. Mereta, P. L. M. Goethals, and P. Boets, (2016).Water quality assessment of streams and wetlands in a fast growing East African city, vol. 8, no. 4, p. 123, 2016.

OECD (2005), Measuring Sustainable Development, OECD Statistics Brief.

PSQCA.(2002). Drinking Water.Pakistan Standards and Quality Control Authority (PSQCA), Karachi, Pakistan.Published.

Roberts, E. A. (2006). Drinking Water Quality Control Hand Books. (s. Edition, Ed.) New York Chicago San Francisco Lisbon London Madrid Mixeco: published

Solomon Aberra, Ahame Zeyinudin, Burktawit Kebede *et al*.,(Bacteriological analysis of drinking water sources), (2011) . *African Journal of Microbiology Research,* (5),(18), 2638–2641.

Saddozai, A. A., Khalil, S., and Hameed, T. (2009). Microbial Quality of Food Snakes and Drinking Water in Islamabad Schools and Colleges. Pakistan Journal of Agricultural Research, 22(3-4), 144-149.

Saylor, A., Shohan, D., Sen, S., and Denniston, K. (2022). Gastrointestinal effects of excess iron ingestion. Current Gastroenterology Reports, 24(3), 1-8. https://doi.org/10.1007/s11894-022-00950-6

Seid Tiku, Worku Legesse, Hailu Endale and Kebede Faris (2003). Factors affecting drinking water quality from source to home in tehuledere woreda, northeast Ethiopia. *Ethiop Journal Health Science*, **13(2)**: 95-106.

Sisti M, AlbainoA,Brandi G . Bacteriological effect of chlorine on motile Aeromonas spp.in

Soomro, Z. A., Khokhar, M. I. A., Hussain, W., and Hussain, M. (2011).Drinking Water Quality Challenges in Pakistan. World Water Day April-2011, 17-28.

T. Eliku and H. Sulaiman, (2009). Assessment of physco-chemical and bacteriological quality of drinking water at sources and household in Adama Town, Oromia, Ethiopia, *African Journal of Environmental Science and Technology*, **(9)** 5, 413–419.

Tadesse, G., Eugene, E., and Kidane, A. (2018). Mapping impact of climate change on freshwater resources for the sustainable management and environmental protection in Ethiopia. Water, 10(2), 256. DOI: 10.3390/w10020256

Tanwir, F., Sabbor, A., and Shan, M. H. (2003). Water Contamination, Health Hazards and Public Awareness: A Case of the Urban Punjab. International Journal of Agricultural Biology, 5, 460-462.

Taylor, and Francis Group,LLC. (2007). Handbook of Water Analysis. Boca Raton London New York: Published.

Tegegne M. Tarekegne (*2009*) Sustainability of rural water supply and sanitation services in *Ethiopia*: A case study of *twenty villages* in *Ethiopia*.

Teklu Mulugeta and Kebede Faris (1998). Survey on practice of water handling and level of contamination in Jimma town. *Ethiopian Journal of Health Science*. **8(1):** 29-34.

Terngu. J, Oluma A, Hyacinth O A,Sha'Ato R.J Anal Environ Chem.(2010); 11: 73-78. and limits of correlation with microbial indicators. Ground Water.2011;49;4-11. water in Manonyane community: Maseru District (Lesotho). Afr. Health Sci. 2011; 11: 474

Tesfaye, M., Abebe, A. T., and Melesse, A. M. (2021). Assessment of climate change impacts on temperature and precipitation extremes in Ethiopia. Water, **13**(2), 454. DOI: 10.3390/w13020454 Accessed 12 december,2022.

TID (2000). Basic Diagnostic Imaging Report.

UN,(2005). Transforming Our World: the 2030 Agenda for Sustainable Development, UN,NewYork,NY,USA,2015,https://sustainabledevelopment.un.org/post2015/transformingourworld. Accessed 22 december,2022.

UNEP GEMS/Water programed.(2008). Water Quality for Ecosystem and Human Health.(2nd Ed.). Ontario: United

UNEP.(1999). Global Environment Outlook (2000). New York and London: United Nations Environment programmed (UNEP).

UNICEF and Meta-Meta. (2009). Provision of Safe Drinking Water for All, Water Safety Plans for Rural Water Supply.

UNICEF /WHO. (2012). Progress on drinking water and sanitation.

UNICEF, W. a. (2021). progress on household drinking water ,sanitation And hygiene: 2015-2020. Geneva: BY_NC_SA 3.0IGO.

UNICEF/WHO, (2012) Joint Monitoring report: Progress on Drinking Water and Sanitation: Special Focus on Sanitation. UNICEF, New York and WHO, Geneva, 2008.

UNICF. (2008). UNICEF Handbook on Water Quality. New York: Published

United Nations. (2005). the millennium development goals report. UN, New York.

WHO (2017). Millennium Development Goals. Available from: *http://www.who.int/topics/millennium_development_goals/en*, Accessed,2 December 2022).

WHO (World Health Organization). (2011). Iron in drinking-water. Background document for development of WHO Guidelines for Drinking-water Quality. https://www.who.int/water_sanitation_health/dwq/chemicals/iron.pdf

WHO Edition 4th. (2004). Acceptability aspects: Taste, odor and appearance. Published.

WHO, (2006).Guidelines for Drinking Water Quality, 1st Addendum to the 3rd Edition Vol. Recommendations, World Health Organizations, Switzerland, Geneva, 2006.

WHO, 2. (2001). Water health and human rights, World Water Day 2001.Avaliable online athttp://www.worldwaterday.org/thematic/hmnrights.html#n4.published. Accessed 26,December 2022).

WHO,(1997).Guidelines for Drinking-Water Quality, Surveillance and Control of Community Supplies, World Health Organizations, vol. 3, 2nd edition, 1997.

WHO. (1984). Guidelines for Drinking Water Quality. Health Criteria and Other Supporting Information, Vol. 2, Geneva: World Health Organization (WHO).

WHO. (2002). Global Strategy for Food Safety: Safer Food for better Health. Geneva: World Health Organization (WHO).

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

WHO. (2010). Water for health, WHO Guidelines for Drinking-water Quality, WHO Geneva, Switzerland 2010.

WHO. (2019). water, sanitation and hygiene And health a primer for health. Geneva: BY-NC-SA 3.0IGO. BY-NC-SA 3.0IGO.

WHO.(1996). Guidelines for Drinking Water Quality. Recommendation, Vol. 1, Geneva: World Health Organization (WHO).

WHO.(2004). Guidelines for Drinking-Water Quality (3rd Ed., Vol. 1). Geneva: World Health Organization (WHO)

WHO.(2011).Guidelines for Drinking-water Quality ,Fourth edition. WHO, Geneva, Switzerland ,2011.

WHO/UNICEF, (2009).Diarrhea: Why Children are Still Dying and What Can Be Done, World Health Organization (WHO) and United Nations Children's Fund (UNICEF), Geneva, Switzerland, 2009.

WHO/UNICEF. (2000) Global Water Supply and Sanitation Assessment 2000 Report, Switzerland,2000.

WHO/UNICEF.(2010) Rapid assessment drinking water quality in the Federal Democratic Republic of Ethiopia, Country Report of Pilot Project and UNICEF, New Y ork,2010.

World Bank,(2014). Ethiopia Poverty Assessment *2014* ; Published. 2015-01.

World Health Organization,(2001). *APA. International classification* of functioning, disability, and health : ICF. (2001).

World Health Organization.(2006). In Water, Sanitation and Health World Health Organization. Published.

Yirdaw Meride and Beamlaku Ayenew, (Drinking water quality assessment and its effects on residents health in Wondo genet campus, Ethiopia),(2016). *Environmental Systems Research*, (**5**) (1).

Yami, M., Ejeta, G., and Mequaninte, T. (2016). Impacts of urban green infrastructure development as an adaptation measure against climate change in Addis Ababa, Ethiopia. Land use policy, 50, 203-213. DOI: 10.1016/j.landurbplan.2016.03.010

Yirged Antehun Mengstie, Wendesen Mekonin Desta, and Esayas Alemayehu (2023). (Assessment of Drinking Water Quality in Urban Water Supply Systems: The Case of Hawassa City, Ethiopia), *International journal of Analytical Chemistry,* 23(1):20-23.

Zinabu Assefa Alemu, Kirubel Tesfaye Teklu, Tsigereda Assefa Alemayehu *et al*., (Physicochemical quality of drinking water sources in Ethiopia and its health impact: a retrospective study) (2015), Environmental Systems Research, (**4**) (1).

Zamxaka, M, ,Pironcheva G, Muyima NYO. (2004). Microbiological and physic-chemical assessment of the quality of domestic water sources in selected rural communities of the Eastern Cape Province, South Africa. Water SA.2004; 30: 333-340.

7. APPENDICES

Appendices 1

Questionnaire used for thesis writing

This survey questionnaire is planned to assess the water handling practice at house level in Bishaan Gurracha Town. The objective of the questions is study on challenges of quality drinking water, handling practice of tapes, storage and containers at house hold level. Dear respondent first I appreciate your politeness to participation this study questionnaires. All the required information fulfilled by yourself through interview and group discussion system; and you requested to give truly information without any restriction. Finally, I thank you very much for your time and cooperation for genuinely answering the questionnaire which has valuable contribution to my study.

Thank you!

Date

Name of house hold owners ________________________________

Region ____________________________________

Zone ________________________________

Woreda ____________________________________

Keble ________________________________

Part one: Hose hold characteristics

Gender :- 1. Male 2. Female

Age :-

No	Category	Frequency
1	18-30 years	
2	31-45 years	
3	46 years and Above	

Educational level of house hold

No.	Educational level	Frequency (n)
1	Un educated	
2	Read and Write	
3	Primary School	
4	Secondary School	
5	College and Above	

Occupational Status of household

Occupational Status :-	Frequency (n)
Government Employee	
Merchants	
Farmer	

Average monthly income of house hold in (birr):

1. Up to 2000 2. 2001 -4000 3. 4001 – 6000 4.6001 and Above

Part Two: House hold water supply status of, Sanitation and hygiene practices

What is your household's current source of drinking water?

1. Private pipe water 2. Public tap or Bono water 3.other

How much water is collected by family per jerry can for domestic purpose?

Estimate ___________liters. 1. Up to 20L 2. Above 20L

How far you travel to fetch drinking water from public tap?

1. Not at all 2. Up to 50 meters 3. 51 – 100 meters 4. Above 100 meters

How long do you store drinking water in container?

1. A day and below 2. For two days 3.For three days and above

Do you cover the container when storing water at home?

Category	Frequency (n)
Yes	
No	

What method do you use to draw the water from storage container?

Pouring 2. Dipping

Do you clean water storage container?

Category	Frequency (n)
Yes	
No	

If your answer for question above is yes, how often the container is cleaned?

1. Every day 2. Every week 3. Every month 4. Rarely

Do you treat stored water at home?

Category	Frequency (n)
Yes	
No	

Do you have a latrine at home?

Category	Frequency (n)
Yes	
No	

What types of latrines constructed do you have?

Types pit latrines	Frequency (n)
Pit latrine with walls but without roof	
Pit latrine with walls and roof	
Open pit latrine without house	

What Materials used for washing hands after defecation?

1. Water only 2. Water and ash 3.Water and soap 4. Don’t use water at all

Thanks for your responding interview questions!!

Appendix-2

Interview Guideline

Interview with different officials

Background: age________________, sex______________, education_______________.
________________________Year of service, in other place and current kebele.

1. What strategy is set by your office to provide improved water and sanitation facilities the urban dwellers?

2. Do you think unsafe drinking water and sanitation have negative impact on the economic
welfare of the community members? If 'yes' in what way?

3. Which types of diseases are the most prevalent – water-borne, water washed or water related?

4. Are the diseases are related to unsafe drinking water and poor sanitation?

5. Do you contribute to creating awareness about using safe water?

6. What are the challenges in providing improved water services to the urban residents?

Appendices -3

Picture 1: Laboratory works for Physico chemicals and Bacteriological

Picture 2: On site test

Picture 3: Protected Spring Source