JIMMA UNIVERSITY
JIMMA INSTITUTE OF TECHNOLOGY
FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING
ENVIRONMENTAL ENGINEERING CHAIR

ASSESSMENT OF DRINKING WATER QUALITY AT END USER IN CASE OF HIRMATA MERKATO AND HIRMATA MENTINA KEBELES OF JIMMA TOWN, SOUTH WESTERN OROMIA, ETHIOPIA.

By:

ALFARED ABDU ABAFOGI

A Thesis Submitted to Jimma University, Jimma Institute of Technology, Faculty of Civil and Environmental Engineering Environmental Engineering Chair in Partial Fulfillment for the Requirements of the Degree of Masters of Science in Environmental Engineering

Sep, 2022
Jimma, Ethiopia

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DECLARATION

I declare that this Msc thesis is my original work and all sources of material used for this study acknowledged accordingly.

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We the undersigned advisors agreed that this Msc thesis to be sumitted for examination:-

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ABSTRACT

Drinking water quality and water-related diseases are a serious public health problem in many developing countries including Ethiopia. The aim of the study was to assess the drinking water quality at end user tap water and it was assessed and analyzed for purposely selected kebeles of Hirmata Merkato and Hirmata Mentina of Jimma Town, South Western Oromia, Ethiopia. The physicochemical and bacteriological quality of drinking water was assessed via a laboratory-based experimental procedure and Knowledge, Attitude and Practice towards sanitary condition assessed using questionnaire. To analyze drinking water quality parameters, 18 sampling points were randomly selected from tap water. The main physio-chemical parameters analyzed for the study were Total Dissolved Solids (TDS), Temperature, Turbidity, Electrical conductivity (EC), pH, residual chlorine, and Microbiological parameters were (Total Coliform and coliform/CFU). Hence, for each assessment necessary reagents prepared and meters were calibrated. Turbidity meter, pH meter, conductivity meter, burrate and MPN methods were procedural used. Further, the result of some physio-chemical parameters like residual chlorine indicated in conformity with the standards. The residual chlorine levels obtained at end user tap water samples ranged from mean value of 0.087 ± 0.0001to 0.106 ± 1.150, which was less than the WHO recommended value to be equal or greater than 0.5m/l. The obtained results from bacteriological analyses showed that most of the sample points are greater than 18 MPN, i.e. the water sample contains an estimated 18 coli form per 100 mL. That indicate mainly inadequate chlorine disinfection and pipeline contamination can be a factor for deterioration on quality of drinking water and caused the result undesirable. The other obtained result via household survey compiled was around 93.0% of the respondent does not expect that their tap water could be contaminated this indicates their knowledge, attitude and practice gap on water quality deterioration and lack of appropriate awareness. Therefore, based on the assessed result the quality of drinking water at purposely selected Kebele households reflected positive result which need further attention. Also, chlorine residual showed under permissible limit during the study period. Generally, consistent monitoring and quality analysis of drinking water to utmost level required, and further studies that involve a wide scale laboratory analysis and an intensive survey suggested for better precise conclusion.

Keywords & phrases: Bacteriological, physicochemical, parameters, drinking water, attitude.

ACKNOWLEDGEMENT

The initial praise and thanks must go for almighty ALLAH, who made everything possible in my life. I express my heartfelt gratitude to my main advisor Dr. Yenealem Mehari (PHD) for her direction, committed way of advising approaches, leading how to write thesis and giving constructive comments patiently. I also, extend my deepest thanks to my Co-advisor Mr. Wondewosen Mekonin for assisting me via contributing important comments towards better output of my thesis.

Similarly, I appreciate DarAl-fiker for translation, publication and scientific research-Ethiopia who gave me budget assistance to attend my master program.

The last but not the least, I would like to express my special gratitude to my wife Letifa Abatemam for her demonstrative help to finalize my paper. Finally, I would like to extend my deep respect to all my friends for their support in each track towards my success.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

ACRONYM

BGB	Brilliant Green Bile
BMPs.	Best Management Practices
CFU	Coloney Forming Unit
CSA	Central Statics Agency
DPD	Diethyl-Phenylene-Diamine
EC	Electrical Conductivity
E.Colia	Escheria Coliform
EPA	Environmental Protection Authority
FC	Fecal Coliform
FCR	Free Chlorine Residual
HH	House Holds
JIT	Jimma Institute of Technology
JTWSSSE	Jimma Town Water Supply and Sewerage Service Enterprise
KAP	Knowledge, Attitude and Practice
NTU	Nepholometeric Turbidity Unit
PHCU	Primary Health Care Unit
PVC	Polyethylene and Polyvinyl Chloride
SDGs	Sustainable Development Goals
TC	Total Coliform
TCR	Total Coliform Rule
TDS	Total Dissolved Solids
TTC	Thermo Tolerant Coliform
UNICEF	United Nations International Children's Emergency Fund
WHO	World Health Organization

CHAPTER 1. INTRODUCTION

1.1 Background

Drinking water is indispensable for human existence. It is one of the most important of all-natural resources that exist on Earth. Access to safe drinking water is essential to health, a fundamental human right, and a component of effective policy for health maintenance. Every effort should be made to improve and address safe drinking water for better health. Drinking water quality should be completely free from any pathogenic microorganisms and physicochemical contaminants that can cause health impact (Desye *et al.*, 2021).

The Sustainable Development Goals (SDGs) coordinate international efforts toward improving the lives of people around the globe. SDG 6 broadly outlines "clean water and sanitation" while target 6.1 specifies: "By 2030, achieve universal and equitable access to safe and affordable drinking water for all. Yet achieving safe drinking water in developing countries and resource-poor environments requires sustained effort. In contribution, we demonstrate that current international standards around improved water have not properly specified standards around water quality. Without a stronger incorporation of water quality parameters, international targets risk focusing in improved basic water services means water free from contamination that merely supply users with non-potable, and contaminated water that would end up with non-functional. Water contaminated with thermotolerant coliforms (TTC) will not achieve the SDGs in the lives of people around the world (Gemeda *et al.*, 2021).

The study which was conducted in Jimma town, Oromia, south-west of Ethiopia on piped-water supply before entering the storage tanks and after leaving the water storage tanks which are found in Jimma. The study concluded that people think that piped water has a high quality, though it can be potentially deteriorated (biological and chemical) in distribution systems. Many microbial and chemical constituents of drinking water can potentially cause adverse impact on human health .Water storage tanks and reservoirs are critical component of distribution systems, yet can pose significant challenge for water utilities as they often have a negative impact on water quality. The study revealed that pH, temperature and turbidity of stored tap water in all storage tanks were within the WHO maximum permissible limit of drinking water. However, bacterial loads of total coliforms and faecal coliforms were detected in water samples analyzed before and after storage where increased numbers of coliforms were observed after storing the water. The positive results related to total coliforms and faecal might be due to both leakage and contamination in the distribution system or inadequate treatment (Chalchisa et al.,2018).

The people of Jimma town get their drinking water supply from Gibe River which is situated in the downstream side of the town. The water supply of the town is managed by JTWSSSE (Jimma Town Water Supply and Sewerage Service Enterprise). There could be potential water pollution at Gibe River due to expected effluents of waste water or storm water from domestic and agricultural fields generated from the upstream of the town. It is crucial to identify whether the water obtained from the river, along its various stages until it reaches the consumers, is safe with regard to water quality parameters(De Troyer *et al.*, 2016).

The sanitation and hygiene situation, particularly in purposely selected study area was poor. The poor sanitation systems and practices and the environmental pollution result in direct and indirect threats to the public health. As physical observed via transect walk some of visible water pipe lied on the ground was contaminated with waste in drainage channel. Even some drinking water pipe line passes through sludge removal ditch from Households. Hence, such inadequate management and lack of understanding towards drinking-water safety to consumers may cause common water borne diseases at end user.

So far, in Jimma town there was no drinking water quality assessment done specifically for end users. Hence, this needs investigation in order to assure safe drinking water production for human consumption. Recently, some damage in the distribution line and poor drinking water handling at house level observed as a problem, which needs study to identfy the existence of such gaps. Therefore, the study intention was to assess drinking water quality at end user of purposely selected kebeles wich are Hirmata merkato and Hirmata mentina kebeles of Jimma town. As far as some formerly investigated study has no more detail analysis of drinking water quality in Jimma town on particular area, it is important to conduct assessment of drinking water quality in piped-water supply of end user. Thus, this study determined the water quality aspects of drinking water in study area. The final outcome of the study aid to strengthen water quality monitoring and management at household levels. Therefore, the study analyzed quality of drinking water and determined the way of intervention to produce safe water for human consumption at study area.

1.2 Statement of the Problem

The quality of drinking water was a critical factor for human health. Accessibility of adequate drinking water was the most fundamental element in sustainable development. Drinking water which was free from disease causing microorganisms or toxic chemicals essential for food production, quality health and poverty reduction. Water quality and the risk of water-associated diseases are serious public health concerns in many developing countries like Ethiopia. This was mainly due to lack of proper study and subsequent monitoring of water quality parameters for most of the towns in Ethiopia. The population of Jimma town obtain their drinking water from Gibe River source, which is located on the downstream side of the town. Recently, in Jimma town there was no sustainable wide range experimental study done on the bacteriological and physicochemical status of drinking water quality at end user tap and as well as inquiry of knowledge, attitude and practices of the consumers at household level. In the report of Jimma town health sector water associated diseases are one of the top-ten diseases, perhaps this indicates poor drinking water quality. The other thing in Jimma town water supply distribution networks damage and storage duration in water tank could be a factor for water quality feature change. Further, conducting study to determining the bacteriological and physicochemical parameters of water quality in the selected study area was good approach to analyze drinking water quality status. Therefore, it was sensible to assess drinking water quality deterioration at end user in case of purposely selected kebeles of Hirmata merkato and Hirmata mentina of Jimma town.

1.3 OBJECTIVES

1.3 .1 General Objective

The main objective of this study was to assess drinking water quality at end user in case of Hirmata merkato and Hirmata Mentina of Jimma Town.

1.3.2 Specific Objectives

- To determine physicochemical analyses of drinking water quality at end user in Hirmata Merkato and Hirmata Mentina Kebeles.
- To determine bacteriological analyses of drinking water quality at end user in Hirmata Merkato and Hirmata Mentina Kebeles.
- To asses, Knowledge, Attitude and Practice (KAP) of study area community towards water quality at their home via organized questionnaires.

1.3.3 Reserch Questions

- Does the consumer at end user know drink water physicochemical parameters which could be health factor?
- How communities understand the cause of drinking water impurities by microbial ?
- Does respondent at end-user have adequate Knowledge, Attitude and Practice (KAP) towards drinking water ?

1.5 Significance of the Study

The main purpose of this study was to assess quality of drinking water according to WHO or national standard. The study added the value of drinking water quality which was crucial to the economic, health, and social well-being of the people. Further, assessing the quality of drinking water was very important to maintain reliable and safe water for community and help to eliminate the potential health risks related to water impurity. Therefore, this study identified the status of drinking water quality at purposely selected two kebeles of Jimma town in order to recommend priority area of intervention to produce safe drinking water for human consumption at study area.

1.6 Scope of the Study

A sample for analysis mainly focused on bacteriological and physicochemical investigation of drinking water quality and identifying the Knowledge, Attitude and Practice of community. The study was limited to purposely selected two kebeles of Jimma town to assess drinking water quality system at end users. To assess more analysis in the area it requires excess time, budget, materials and reagents, for this reason the study was limited. Hence, the assessment at end user of tap water was specifically focused only on the major water quality parameters of physicochemical and bacteriological analysis which are - Total Dissolved Solids (TDS), Temperature, Turbidity, Electrical conductivity (EC), pH, residual chlorine, and Microbiological parameters were (Total Coliform and coliform/CFU).

CHAPTER 2. LITERATURE REVIEW

2.1 General

Water is one of the most essential and valuable natural resources. It is important for the survival of living organisms from the simplest plant and microorganism to the most complex living system of the human body. Accessibility to potable drinking water is the most fundamental key factor in sustainable development. Water is essential for food production, quality health, and poverty reduction. Potable drinking water, free from disease- causing microorganisms or toxic chemicals, is important to life and a satisfactory safe supply must be made available for human consumptions. Public water supplier treats surface water and distributes the treated water to the various residential areas but in the course of transporting treated water to the various residences, it is sometimes exposed to contaminants before getting to the consumers as a result of leakages, corroded pipes, as well as deposits of contaminated dust on taps which have a physical, chemical and bacteriological effect on drinking water quality and when consumed can cause negative health effects. It is therefore important to monitor drinking water quality (Area, 2020).

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 (Haylamicheal, 2012).

The production and supply of safe drinking water to consumers at all times constitutes a major challenge to water authorities. Nowadays, the quality of drinking water is degrading due to large scale application of agrochemicals, direct pollution by untreated sewage and infiltration of effluent from sewage treatment plants and storage pits .However, the efficiency of existing water treatment systems to remove potential pollutants from the above sources in different seasons were not clearly known. Conventional water treatment and bore hole are the dominant drinking water sources for urban settings in Ethiopia. But, studies are very limited and even the existing studies focused on springs and wells (Sisay et al., 2017).

As observed in the above authors finding the assessments of drinking water mostly exclude the piped water supply from treatment plant to end user. Thus, focusing to analysis drinking water quality in this area is very important to determine the quality compliance of drinking water with the WHO guideline and national standard.

2.2 Water Quality

Water quality is determined by physical, chemical and microbiological properties of water. The constituents of water quality should be monitored to evaluate potential risks to human health. According to the WHO, the major aspects of drinking water quality are chemical, microbiological, and radiological and those affecting water acceptability in appearance, taste, and odor (Tsaridou and Karabelas, 2021).

2.2.1 Bacteriologicalwater Quality

Securing the microbial safety of drinking-water supplies is based on the use of multiple barriers, from catchment to consumer, to prevent the contamination of drinking water or to reduce contamination to levels not injurious to health. Safety is increased if multiple barriers are in place, including protection of water resources, proper selection and operation of a series of treatment steps and management of distribution systems (piped or otherwise) to maintain and protect treated water quality. The preferred Strategy is a management approach that places the primary emphasis on preventing or reducing the entry of pathogens into water sources and reducing reliance on treatment processes for removal of pathogens (WHO, 2017a).

The most common and widespread health risk associated with drinking water is contamination, either directly or indirectly, by human or animal excreta, and with the micro-organisms contained in faeces. Monitoring of specific bacterial, viral and protozoan pathogens is usually complex, expensive, and time consuming, and may fail to detect their presence. In monitoring for microbiological quality, reliance is therefore placed on relatively rapid and simple tests for the presence of indicator organisms. The three common organisms used as microbial indicators are total coliforms (TC), thermotolerant coliforms (TTC) or alternatively E. coli and Enterococcus (APHA, 1998).

Total coliforms are a group of bacteria that are widespread in nature. All members of the total coliform group can occur in human feces, but some can also be present in animal manure, soil, and submerged wood and in other places outside the human body. Thus, the usefulness of total coliforms as an indicator of fecal contamination depends on the extent to which the bacteria species found are fecal and human in origin. For recreational waters, total coliforms are no longer recommended as an indicator. For drinking water, total coliforms are still the standard test because their presence indicates contamination of a water supply by an outside source. E. coli is a species of fecal coliform bacteria that is specific to fecal material from humans and other warm-blooded animals. EPA recommends E. coli as the best indicator of health risk from water contact in recreational waters; some states have changed their water quality standards and are monitoring accordingly (EPA, 2021).

In Kumasi one of city in Ghana, access to safe drinking water has been identified as a challenge. Access to treated piped water supplied directly to homes or public standpipes is estimated to be 95% (Appiah et al., 2021). But due to frequent and sometimes lengthy periods of interruption in the supply of treated piped water, many households rely on other sources of water such as wells, boreholes, springs and surface waters. Meanwhile, studies have reported high levels of microbial and metal contaminants in groundwater and surface water sources in Kumasi. Studies have shown that even improved water sources are not entirely free from contamination, and unsafe water storage and handling practices at the household (Appiah-Effah *et al.*, 2021).

In Bangalore city of India, The study investigated the concentration of pathogenic microbial flora and health risk in drinking water samples in households (Appiah et al., 2021). The samples were analyzed for microbiological and physico-chemical parameters. In the study, most probable number and heterotrophic plate count were used to assess the microbial load. The results of the study show that most of the household water samples were contaminated with the presence of coliform bacteria. The dominant bacterial species are Escherichia coli, Salmonella, Shigella, Klebsiella and Enterobacter. The bacteria belonging to the family Enterobacteriaceae showed maximum occurrence in water samples. The overall results of the study showed that the consumption of such contaminated drinking water at the end-user point may cause potential health hazards to the inhabitants (George et al., 2021).

The Assessment conducted at Adama Town, Oromia Regional State of Ethiopia for physico-chemical and bacteriological quality of drinking water at sources and household showed that out of 52 pipe water sample investigated, the turbidity of 12 (23.1%) water samples were above the standard and 40 (76.9%) within the WHO and National standard limits of < (Temesgen and Hameed, 2015).. All pipe water samples had pH levels within WHO and National standard limits of 6.5-8.0 and 6.5-8.5, respectively. The bacteriological test for the samples from water taps contains some fecal coliform and fecal streptococci. This is due to fact that the water treatment plant is far away from the town, mainly some kebele which are about 21 km away from treatment plant, so that the interconnections between the site of production and the tap, up to the home of the consumers may accumulate pathogenic organisms by formation of biofilms(Temesgen and Hameed, 2015).

In Wolaita Zone of Boloso Sore Woreda the study conducted showed that, the bacteriological quality analysis of household water samples of the study area shows that, of the total 75 households container, 91% had contaminated with E. coli. Among them 7 (9%), 38 (51%), 21 (28%), 3 (4%), and 6 (8%) had E. coli concentration range <1, 1–10, 11–50, 51–100, and >100, respectively(source). The E.coli detected in this study indicates that there might be higher human involvement in the contamination of water sources and poor sanitation of the water supply system. The household water contamination might be highly attributed to the low level of hygiene and poor water handling practices. This is supported by a finding from Bahir Dar, Ethiopia that reported coliform contamination of household water is associated with poor water handling practice(Gizachew *et al.*, 2020).

2.2.2 Physico-Chemical Water Quality Parameters

Drinking water quality acceptability is governed by limits of microbiological and physico-chemical parameters. Because changes in water chemistry tends to be longer-term, chemical testing is not undertaken as frequently as microbiological analysis. However, some of the physico-chemical parameters essential in water quality study discussed below. The Physico-chemical 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 physicochemical and aesthetical parameters (John De Zuane P.E., 1996).

Turbidity:-Turbidity is a measure of the degree of cloudiness or muddiness of water. It is an expression for an optical property that causes light to be scattered and absorbed. It is not possible 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 is important because it 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, et al, 2017).

Color: - Materials decayed from organic matter, namely, vegetation and inorganic matter such as soil, stones, and rocks impart color to water, which is objectionable for esthetic reasons, not for health reasons. 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 (Achparaki *et al.*, 2012).

Taste and Odor:-Taste and odor problems in source waters are primarily an aesthetic concern; taste and odor in water can be caused by foreign matter such as organic materials, inorganic compounds, or dissolved gasses. These materials may come from natural, domestic, or agricultural sources (Achparaki *et al.*, 2012).

Temperature:- Temperature affects both biological and chemical functions. Palatability, viscosity, solubility, odors, and chemical reactions are influenced by temperature. Thereby, the sedimentation and chlorination processes and biological oxygen demand (BOD) are temperature dependent. Most people find water at temperatures of 10–15°C most palatable (Achparaki *et al.*, 2012).

Nitrate: - Nitrates get into waterways from lawn fertilizer run-off, leaking septic tanks and cesspools, manure from farm livestock, animal wastes (including fish and birds), and discharges from car exhausts. Nitrates can be reduced to toxic nitrites in the human intestine, and many babies have been seriously poisoned by well water containing high levels of nitrate-nitrogen (WHO, 2004).

Chlorine residual: - Disinfection is a process designed for the deliberate reduction of the number of pathogenic microorganisms. While other water treatment processes, such as filtration, coagulation, flocculation and sedimentation, may achieve pathogen reduction, this is not generally their primary goal. A variety of chemical or physical agents may be used to carry out disinfection. Chlorine may be used as a disinfectant in the form of compressed gas under pressure which is dissolved in water at the point of application, solutions of sodium hypochlorite, or solid calcium hypochlorite. In areas where there is little risk of a waterborne outbreak, residual free chlorine of 0.2 to 0.5 mg/l at all points in the supply is recommended (Almahdi and Al-abed, 2020).

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 (Almahdi and Al-abed, 2020).

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 wastewater etc. Hence, TDS test is mostly an indication to control the general quality of the water (Almahdi and Al-abed, 2020).

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 (micro Siemens per centimeter) and the conductivity of potable waters varies generally from 50 to 1500 μ mhos/cm (Gaur, 2008).

2.2.3 WHO and Ethiopian standards of drinking water quality

Water is essential to sustain life, and a satisfactory (adequate, safe and accessible) supply must be available to all. Improving access to safe drinking-water can result in tangible benefits to health. Every effort should be made to achieve drinking-water that is as safe as practicable. Safe drinking water, as defined by the guidelines, does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages. In other direction, the nature and form of drinking-water standards may vary among countries and regions and there is no single approach that is universally applicable. In the development and implementation of standards it is essential to consider the current or planned legislation relating to water, health and local government and the capacity of regulators in the country. Additionally approaches that may work in one country or region will not necessarily transfer to other countries or regions (WHO, 2011).

The Compulsory Ethiopian Standard for Drinking Water Specification (CES- 58) outlines the physical, chemical, and bacteriological requirements of water for drinking and domestic purposes. Physical requirements (CES-58): Bacteriological & physicochemical Ethiopian drinking water standard and WHO must conform to the levels specified in Table below.

Table 1. Bacteriological & physicochemical standards

Bacteriological levels -Organism	ETH- Maximum permissible level	WHO (1993) standard
Total viable organisms, colonies per mL	Must not be detectable	0
Fecal streptococci per 100 mL	Must not be detectable	0
Coliform organisms, number per 100 mL	Must not be detectable	0
E. coli, number per 100 mL	Must not be detectable	0
Physical Characteristics	**Maximum permissible level**	
Odor	Odor Unobjectionable	
Taste	Taste Unobjectionable	
Turbidity, NTU 5	5	<5 at disinfection point
Color, TCU 15	15	
Chemical characteristic	**Maximum permissible level**	
Total hardness (CaCO3)	300	
Total dissolved solids mg/L	1,000	1000
Total Iron (Fe) mg/L	0.3	
Manganese (Mn) mg/L	0.5	
Ammonia (NH3+NH4+) mg/L	1.5	0
Residual free chlorine mg/L	0.5	0.2-0.5 at distribution point
Magnesium (Mg) mg/L	50	
Calcium (Ca) mg/L	75	
Copper (Cu) mg/L	2	
Zinc (Zn) mg/L	5	
Sulfate (SO4) mg/L	250	
Chloride (Cl) mg/L	250	
Total alkalinity (CaCO3) mg/L	200	
Sodium (Na) mg/L	200	
Potassium(k) mg/L	1.5	
pH value, units	6.5 to 8.5 (permissible range)	6.5-8
Aluminum (Al) mg/L	0.2	

Source: Compulsory Ethiopian Standard for Drinking Water Specification (CES- 58) - 2013

2.2.4 Health Risks Associated With Water

The greatest risk to public health from microbes in water is associated with consumption of drinking-water that is contaminated with human and animal excreta, although other sources and routes of exposure may also be significant. Waterborne outbreaks have been associated with inadequate treatment of water supplies and unsatisfactory management of drinking water distribution. For example, in distribution systems, such outbreaks have been linked to cross-connections, contamination during storage, low water pressure and intermittent supply. Water borne outbreaks are preventable if an integrated risk management framework based on a multiple barrier approach from catchment to consumer is applied (WHO, 2017b).

Water-associated disease can be defined as a disease in relation to water supply and sanitation. There are four categories which are listed in table 2 below following table with examples.

Table 2. Water associated disease

Category	Description	Example
Waterborne	Enteric infections spread through faecal contamination of drinking water.	Typhoid, Campylobacter, giardiasis, Cryptosporidium, Cholera, Enter hemorrhagic and Enterotoxigenic , E.coli, norovirus, etc.
Water washed	Infections that spread in communities that have insufficient water for personal hygiene.	Trachoma, scabies, Shigella
Water based	Diseases where the causative organism requires part of its lifecycle to be spent in water.	Schistosomiasis, dracunculiasis
Water related	Vector-borne disease where the insect vector requires access to water.	Mosquito(malaria), tests fly(sleeping sickness)

Source: Water Supply and Health: doi: https://doi.org/10.1371/journal.pmed.1000361.t002

2.2.5 Link Between Water, Sanitation And The Environment

Water and sanitation are environmental issues to their very core, and together constitute one of the top drivers of development. Managing water supplies so they become neither depleted nor polluted, and providing good sanitation, are central to the health of communities and the environment on which they depend. Poor water and sanitation provision can affect entire communities: one person's bad sanitation is another's contaminated food or water. Even piped systems, if poorly managed, can concentrate any "downstream" problems such as pollution in rivers, lakes and seas and further degrade wildlife habitats and contribute to human health problems. Where water and sanitation deficiencies are severe, there are likely to be a range of serious public health hazards. Water and sanitation as key factors in environmental health. It's supremely ironic that water the source of life is also the ideal breeding ground or vehicle for some of the most devastating diseases known, if correct environmental management techniques are not employed. Because water flows downstream, whatever happens to it as it makes that journey will determine the quantity and quality available for human use. Wastewater disposal or sanitation practices can introduce pollutants into water used for bathing, washing or fishing. (Environment, Water and Sanitation, unpublished)

It is important to understand the relationship between disease and environmental risk factors because interventions must target risk factors properly. Contaminated water and poor sanitation are linked to transmission of diseases such as cholera, diarrhea, dysentery, hepatitis A, typhoid, and polio. Absent, inadequate, or inappropriately managed water and sanitation services expose individuals to preventable health risks (WHO, 2019).

Top ten diseases recorded in Jimma Town Health office in 2020GC and specifically total Case reported at Higher Two Primary Health Care Unit which found at Hermata Merkato Kebele data's presented in the following table.

Table 3. Top ten disease recorded in Jimma town health Office 2020GC

N	Diseases	Total Case Reported at Jimma Town Higher Two PHCU at Hermata Merkato Kebele	Total Case Reported In all Jimma Town PHCU under Town health Office
1	Pneumonia (Pneumonia Unspecified)	550	5936
2	Urinary Tract Infection (Urinary Tract Infection Site Not Specified)	530	12266
3	Dyspepsia (Inability To Swallow)	255	7374
4	Respiratory Infection (Acute Upper Respiratory Infection Unspecified)	240	9691
5	Tonsillitis (Acute Pharyngitis Unspecified)	231	3481
6	Diarrhea (Functional Diarrhea)	172	7174
7	Helminthiasis (Intestinal Helminthiasis Unspecified)	172	2649
8	Infection (Bacterial Intestinal Infection Unspecified)	119	1152
9	Typhoid Fever	26	6721
10	Pneumonia (Bacterial Pneumonia Unspecified)	10	3719

Source: - Jimma Town Health Office HMIS report 2020GC

2.3 Distribution System Water Quality Deterioration Factors

In water distribution systems both physicochemical and microbiological can affect the quality of drinking water. There are a lot of factors that have an effect on secondary contamination of water that can be supplied to consumers. Chemical and microbiological stability of water in distribution systems is affected by the raw water quality and reliability of treatment processes. Therefore, the main problem of all water supply systems is the loss of water stability during the transmission from water treatment plant to customer (Jachimowski, 2017).

The principal factors that affect water quality during distribution are the system's structure, its operation, and water quality factors (Logsdon, 1991).

- **Structural Factors**

In the case of operational factors an operating perspective, system operating conditions such as slow water speed, switching on and off the supply source, and the length of time the system stores water and water pressure significantly affect water quality measurements. Water pressure along the distribution system can cause water pipes to rupture along the distribution network, which affects the quality of drinking water by absorbing unpleasant substances from the environment in the absence of water supply. Any of these factors can cause residual chlorine to disappear, leading to microbial growth in the network. In addition, hydraulic conditions can drive sedimentation, accumulation and serve as a habitat and disinfectant for microbial growth. Many storage facilities are full to make the system better prepared for emergencies. However, a long residence time leads to reduced water quality (Logsdon, 1991).

- **Operational Factors**

From an operations standpoint, network operating conditions such as slow water velocities, supply sources going on and off-line, and the amount of time that systems store water greatly affect water quality. Any of these factors can cause chlorine residual to fade, and, thus, allow microbial growth in the network. Further, hydraulic conditions can cause sediment to deposit, accumulate, and serve as both habitat and protection from disinfectants for microbial growth. What's more, many storage facilities are kept full so that the system can be better prepared for emergency conditions. However, the long detention times result in degraded water quality (Logsdon, 1991).

- **Water Quality Factors**

In addition to the above aspects some of the factors that provide optimal conditions for microorganisms to multiply include long water retention times in reservoirs and pipelines, adequate nutrient levels and warm temperatures. Furthermore, research has shown that the level of degradable organic matter in the distribution system severely influences the growth of bacteria and hosts opportunistic pathogens. The deterioration of drinking water supply infrastructure is one of the leading causes of loss of drinking water quality and quantity in consumer faucets (Logsdon, 1991). Generally, mentioned water quality deteriorating factors in distribution system to be well managed through combination protection of raw water, treatment processes, transmission and distribution systems and handling of water at household level.

2.4 Sanitary Inspection

A sanitary survey of a water supply system is the complete, extremely careful and detailed investigation of the entire water supply system, from source to end users, in order to detect the presence of actual or potential sources of contamination. The sanitary survey report of the water supply system is the single reliable and practical source of information for ascertaining the portability of the water supply. Sanitary inspection and acknowledging the status is very important to minimize pollution. Sanitation as defined by the WHO (World Health Organization); generally refers to the provision of facilities and services for the safe disposal of human urine and feces. Inadequate sanitation is a major cause of disease world-wide and improving sanitation is known to have a significant beneficial impact on health both in households and across communities (Naughton and Mihelcic, 2019).

Basic sanitation – refer to facilities are defined as being used by only one household and may empty on-site or are connected to a sewer system that may or may not be followed by treatment. Many sanitation facilities are however shared in both urban and rural settings. One key goal of sanitation is to safely reduce human exposure to pathogens. Pathogens are excreted by infected individuals and if not properly contained or treated, may present a risk to humans who come in contact with them. These individuals can also be exposed to pathogens through drinking water or eating food contaminated with pathogens found in human excreta

(Naughton and Mihelcic, 2019). As stated in the above statement safely managed drinking water must be free from fecal contamination.

Environmental sanitation - is a set of actions or a fundamental process of collecting and safely disposing all kinds of waste within the environment with the intention of protecting and promoting the individual health and quality of life of communities (WHO, 2017b). This leads to the improvement of health, well-being and economic productivity and benefits the individual, household and community through the provision and practice of adequate sanitation, good hygiene and the use of safe waters (WHO, 2004). The situation of Jimma town solid waste and wastewater management may contribute to environmental factor that links to disease transmission.

2.5 Knowledge, Attitude and Practice (KAP) Towards Drinking Water Supply

According to the assessment done In Arsi Nagele Town, South Eastern Ethiopia, to assess knowledge, attitude and practice of Arsi Nagele town inhabitants on water supply, sanitation and hygiene at household level. Result Four out of ten (43.8%) respondents know private taps are safe for drinking and domestic use while 116(40.4%) shared taps are safe. Moreover, 31(10.5%) know hand pump are safe and 16(5..3%) know unprotected well are safe for any domestic purpose. The majority of the respondents 260(90.5%) had positive attitude whereas 21 (7.1%) of the respondents negative and 8(2.5%) neutral attitude to the issue that in proper disposal of solid and liquid waste may contribute to the transmission of disease. While 241 (83.9%) of the respondent had positive attitude while 32(10.8%) and 16(5.2%) of the respondents had negative and neutral attitude to the view that human waste disposal is not a problem in that area. Conclusion The majority of respondent 250(87.1%) had good practice in case of cover the water storage container during the time of visit while 39(12.9%) of the respondent had bad practice. This calls urgent action to create awareness on health education and hygiene household be promoted to influence the resident's attitude that target personal, household and community hygiene and sanitation (Mako , et.al, 2019).

Based on this finding it has been evident that the majority of respondents were knowledgeable about water supply, sanitation and hygiene; however it was not adequate as water supply, sanitation and hygiene is one of the basic elements and human right of the health living of human being, and most of the residents were expected to acquire high level of knowledge. Whereas as majority of respondents were not practice what they have known. Greater part of the respondents had favorable attitude to water supply, sanitation and hygiene but there was some in consistencies on resident's attitude. These variations might be due to lack of knowledge and information, or existence of weak social norms in the value system of the community concerning WASH. Majority of the residents of Arsi Nagele town did not take actions to improve environmental sanitation in their living area. This indicated that they were not as such sacrificing their personal interest for the sake of WASH. This lack of action might be the weakness of the communities and other stakeholders to do different practical activities in group in order to maintain urban environmental sanitation. (Mako , et.al, 2019).

The study conducted in Northwest Ethiopia indicated that four in five (80%) of HHs used pipe water and one-third (34%) of the respondents practiced HH water treatment , and a study conducted in 16 small towns in Ethiopia reported that 79% of the HHs used pipe water . On the other hand, a study conducted in Nepal showed that 53.4% of the total population has access to pipe water . Nearly, nine in ten, 659 (87%), of the HHs spend less than or equal to 30 minutes to fetch water which is similar to a study done in India. An average consumption of water by HHs is less than 20 liters per person per day for nearly nine in ten, 668 (88.4%), of respondents. In line with this, a study in East Shoa Zone, Ethiopia, re-ported that three in four, 74%, of the HHs consume less than 20 liters per person per day . Behavioral factors are important in determining the uptake and sustainable adoption of water, sanitation, and hygiene technologies and practices. Hence, behavioral variations across the different areas may have an impact on the difference in WASH practices. Inappropriate waste collection, waste disposal, and housing environment cleanliness were observed in 60%, 93%, and 61% of the HHs respectively (Berhe *et al.*, 2020).

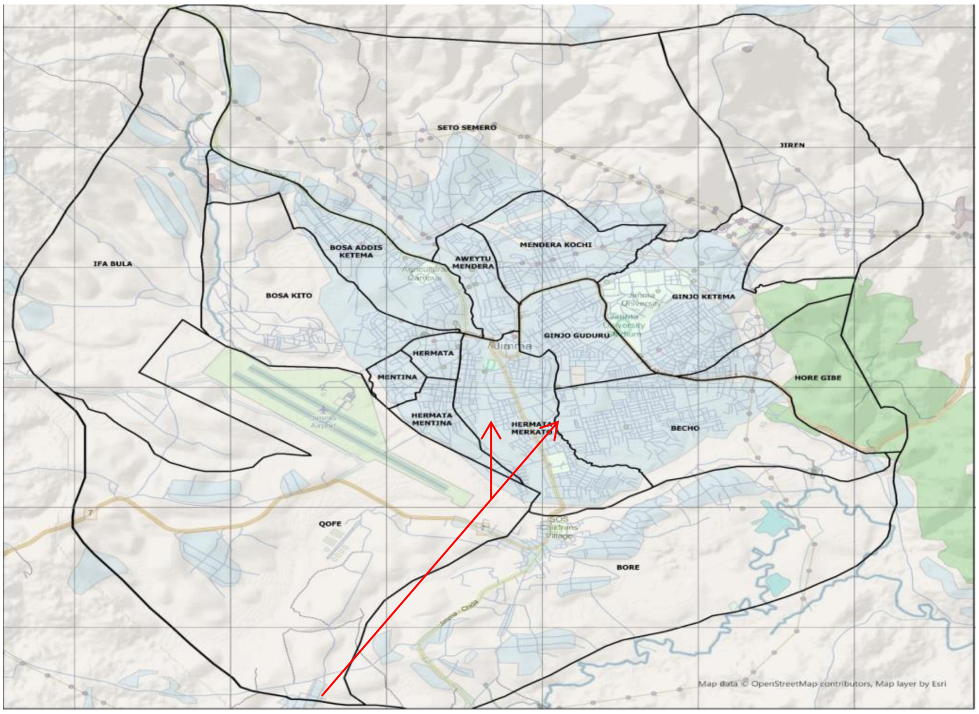
Access to safe water, sanitation, and hygiene (WASH) facilities is a basic necessity for human livelihood, survival, and well-being. Adequate WASH facilities provision is a critical issue to most developing countries around the world including Nigeria. Knowledge, attitudes, and practices regarding WASH are integral to effective and sustainable WASH facilities provision. This study assessed the level of knowledge, behavior, and practices towards water, sanitation, and hygiene in Kaduna state, Nigeria, with a view to ensuring sustainable WASH facilities intervention in the region. Data collection tools included spot check observation and questionnaire involving 854 participants, selected from five local government areas (LGAs): Chikun, Kajuru, Soba, Kachia, and Zango Kataf. From the results, major drinking water sources were surface waters (52.5%) and unprotected hand dug wells (44.8%); only 46.2% treated their water supply and few (16.6%) used chlorination method. Pit latrine toilets were the major (76.5%) excreta disposal means, and open defecation practices were widespread (41.4%). Level of personal and environmental hygiene understanding was fairly good in all the local government areas, and 65.4% claimed to use water and soap for washing hands after defecation. Incidence of water related diseases is generally low in the area. Despite the commendable findings in the study areas, communities are still at risk due to lack of safe water supply and poor practices of home treatment and excreta disposal. Therefore provision of WASH facilities and WASH education is fundamental for ensuring public health in the study area (Sandar *et al.*, 2019).

CHAPTER 3. MATERIALS AND METHODS

3.1 Description of the study area

Jimma town is located in Oromia National Regional State in the South-Western part of Ethiopia, at a road distance of 352 km from Addis Ababa. Jimma is the largest city in South-Western Oromia Region and it is found in Jimma Zone at latitude and longitude of 7°40′N 36°50′E. Jimma town is divided in to 17 Kebeles of which 3 of them are rural added kebele to the administrative boundary of Jimma town. Among these Kebeles the study focuses on two Kebeles in the middle of the town which are densely populated in congested area which are Hirmata Merkato and Hirmata Mentina which embraces a total population of 10,153 and 15,780 respectively according to CSA, 2020 projection. JTWSSSE 2020 annual report stated seven reservoirs have been supplying water to the community of Jimma town; the raw water source is from Gibe River and the treatment plant found at Boye area of the town. So, the study areas purposely selected due to congested settlement in the middle of the town with some dwellers are with less coverage of basic environmental services, including water supply provisions.

Location of the study area - Jimma Town



Location of Study Area Kebeles
Source: Sanitation Situation Assessment Report of Jimma Town (2021).

Figure 1: Location of sampling points at selected kebeles of Jimma town

3.2 Study design and period

Both descriptive and experimental study designs was conducted to determine the drinking water quality compliance applied for the achievement of the study objectives. Descriptive study design applied to examine the sanitary condition of the study area, and to assess Knowledge, Attitude and Practice of the people. While Experimental study design was applied for assessing physicochemical and bacteriological quality of drinking water at consumers tap. The sanitary conditions of the study area assessed using questionnaire. The study conducted at Hirmata Merkato and Hirmata Mentina to examine physico chemical and bacteriological quality of drinking water. For the study, these two Kebele administrations selected by purposive sampling technique and assessed from beginning of April 2022 to end of May 2022.

3.3 Materials

3.3.1 Source of data

Primary data obtained from study area observation, questionnaires and laboratory results was organized and interpreted. Water sample collected from selected sampling site for microbiological and physico-chemical water quality analysis. Collected water sample analyzed for different parameters at JIT laboratory and main campus of JU. Subsequently parameters examined for quality status of drinking water compared to the Ethiopian and WHO guideline values. Secondary data collected and organized from different literatures.

3.3.2 Equipments

WHO Guidelines cover microbiological, chemical and physical qualities. However, it was stressed that microbiological quality was the most important since it was the biggest cause of illness and death around the world. In the laboratory quantitative spectrophotometer techniques, comparator or colorimeter method and pH meter used for chemical water quality inspection. Microbiological analysis undertaken in the same laboratory accordingly, using Multiple tube (Most probable numbers (MPN)- multiple tube fermentation technique. The main procedure was incubating sample water in media which selectively promote growth of total coliform bacteria, fecal coliform and the prominent pathogenic contamination indicator, Escherichia coli. Sampling bottle, taste tubes, diurnal tubes, Knife/spoon, distilled water, incubation machine, sterilization machine, refrigerator, spectrometer, pH meter, pipet expected to be used when microbiological and physico-chemical water quality analysis conducted.

Microbiological Testing Equipment:

Multiple tube (Most probable numbers (MPN) this method involves the addition of measured volumes of the sample to sets of sterile tubes or bottles each holding a suitable liquid medium(containing lactose). Thermo tolerant coliform organism (E,coli) produce acid and gas when incubated at $44^{O}C$ for 48 hours. They need to be incubated for longer period for confirmative tests (Equipment and Addresses -unpublished).

Membrane filtration- This method involves filtering a measured volume of the sample through a membrane filter with a pore size of 45μm. Microorganism is retained on the surface of filter. The filter is then placed on an absorbent pad which has been soaked in a suitable selective growth medium (containing lactose) in a petri dish and then incubated at 45 ^{O}C for 24 hours. Bacteria growth into colonies on the filter paper and can be counted visually.

Table 4. Advantage and Limitation of Testing Equipment

Multiple tube (Most probable numbers (MPN)	**Membrane filtration**
Advantages	**Advantages**
Can be used for turbid water	Results are quicker than from multiple tube method
Good for the detection of small number of organism	Uses less consumables than the multiple tube method
Limitation	**Limitation**
Result take a long time	It is suitable for use with turbid waters containing small numbers of desired organisms, as they and thee undesirable bacteria grow on the same medium
Large volume of consumables	Training is required to carry out the test
Training is required to carry out the test	There are many opportunities for contamination

https://ec.europa.eu/echo/files/evaluation/watsan2005/annex_files/WEDC/ews/section5.pdf

Wagtech Potatest and Oxfam-Delagua Test Kits

The kit is designed for use in the field, but may also be used in a laboratory or other permanent location. The kit can be supplied with a range of accessories that will increase the scope of water quality monitoring programs. Operating instructions detail all the necessary procedures for a complete bacteriological analysis.

<table>
<tr><td>Wagtech Potatest</td><td>Oxfam-Delagua</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Figure 2: Wagtech Potatest and Oxfam-Delagua Test Kits
Test type
• E. coli, total coliforms using membrane filtration
• Multiple physical and chemical parameters including pH, turbidity, chlorine
• Flexible chemical testing options: comparator allows further testing of over 30 chemical parameters if required (Wagtech only).
Necessary Equipment
• Pressure cooker or portable sterilizer or access to an autoclave (e.g. in a hospital)
• Methanol (approx 2 ml per test)
• Distilled water
• 1 litre measuring cylinder or beaker
• Lighter</td></tr>
<tr><td>Wagtech International Wagtech Court
Station Road Thatcham Berkshire
RG19 4HZ - United Kingdom
export@wagtech.co.uk-www.wagtech.co.uk</td><td>Robens Centre for Public and
Environmental Health - University of
SurreyGuildford, GU2 5XH - United
Kingdom- sales@delagua.org
www.delagua.org</td></tr>
</table>

Source: Introduction To Drinking Water Quality Testing, A CAWST Training Manual, June, 2009 Edition, Center For Affordable Water And Sanitation Technology.

3.4 Methods

3.4.1. Data Collection Techniques

In order to achieve the objectives of this study a comprehensive literature review was collected from published sources and community Knowledge, Attitude and Practice (KAP) assessed through questionnaire by enrolling competent data collectors. The study objectives clearly explained to each selected household in order to assure that the information provided kept confidential. Additionally some photos collected through observation at study area. For the laboratory analysis the water samples collected from each selected house hold as per the procedures to characterize the quality of drinking water at the end user.

3.4.2 Sample size determination for assessment of KAP

According to CSA Jimma branch, 2020 projection report the population of Hirmata Merkato and Hirmata mentina are 10,153 and 15,780 respectively. Subsequently, to convert population to HHs number, the conversion factor (4.8) applied as per Jimma town health office clue. Therefore, those purposely selected study area kebeles which are Hirmata Merkato and Hirmata mentina calculated to be 2115 HHs and 3287 HHs respectively. Then, the total of both Kebeles become 5402 HHs. To determine sample size for household survey the following statistical formula applied (Cochran, 1977).

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

n (i) ……………….sample household N………total number of sample house hold
P………………………………. proportion (50%)
Q…………………………………1-P
Z………………………95%confidence interval (1.96)
W………………………………………5%

$$\mathbf{n(i)} = \frac{5402*(1.96)^2*0.5*0.5}{(0.05)^2*(5402-1) + (1.96)^2*0.5*0.5} = \mathbf{358\ household}$$

To assess Knowledge, Attitude and Practice of sanitary survey expected questionnaires divided proportionally as below for each Kebele expectation:

$$\text{HHs proportion of H/ Merkato} = \frac{\text{H/Merkato} * n(i)}{\text{Total of both kebele HHs}} = \frac{2115HH * 358HH}{5402\ HHs} = 140HH$$

$$\text{HHs proportion of H/ Mentina} = \frac{\text{H/Mentina} * n(i)}{\text{Total of both kebele HHs}} = \frac{3287\ HH * 358HH}{5402\ HHs} = 218HH$$

After sorting house-number in ascending order the first house will be selected by lottery means and the next was selected by interval of 20 HH to complete the proposed questionnaires.

3.4.3 Sample selection for water quality analysis

Based on WHO sample collection for drinking water analysis; the Physicochemical and Bacteriological parameters of the water, WHO advises that samples taken from intended locations at end user points at which water is delivered to the consumer (Tegomejech et al, 2016). Based on this, the sample for this study collected from house hold water taps. For water quality analysis 5% of total sample house hold was taken as representative. That means; 358HHs * 5%= 18HH sampling points collected for water quality assessment. Therefore, total of 18 sampling points carefully analyzed and laboratory analysis done in triplicates steps following the procedures. The summarized numbers of samples used for questionnaire and laboratory water quality analysis organized for result compilation. .

3.4.4 Sample handling and reagents used

3.4.4.1 Reagents

For microbiological water quality assessment (total and feacal coliform) the following reagents used for each consecutive stage: macconkey broth, EMB agar media for analysis. For physico- chemical water quality determination the following Physcio-chemical test protocol: Palintest-Photometer-7100 instrument, which is product of Wagtech™ Potatech using photometer method is used to test the pH and free residual chlorine (FRC), and

Palintest-turbimeter used for turbidity measurements. For testing pH 3310 meter, free residual chlorine, diethyl-phenylene diamine (DPD) and for turbidity TDS meter used.

3.4.4.2 Sampling time, storage and transportation

Water samples collection started on 7 April 2022 and repeated each fifteen days to make triplet sample during morning hours. Water samples collected by safe procedures for both microbiological and physico-chemical water quality analysis. The collected samples safely handled and reached to laboratory within less than 8 hours.

3.4.4.3 Bacteriological analysis

The principal risk associated with water supplies in small-community is that of infectious disease related to faecal contamination, the microbiological examination of drinking-water emphasizes assessment of the hygienic quality of the supply. This requires the isolation and enumeration of organisms that indicate the presence of faecal contamination. In certain circumstances, the same indicator organisms may also be used to assess the efficiency of drinking-water treatment plants, which is an important element of quality control (WHO, 2011).

Table 5. MPN value reference

MPN values per 100 ml of sample and 95% confidence limits for various combinations of positive and negative results (when one 50-ml and five 10-ml test portions are used)

No. of tubes giving a positive reaction		MPN (per 100 ml)	95% confidence limits	
1 of 50 ml	5 of 10 ml		Lower	Upper
0	0	<1	—	—
0	1	1	<1	4
0	2	2	<1	6
0	3	4	<1	11
0	4	5	1	13
0	5	7	2	17
1	0	2	<1	6
1	1	3	<1	9
1	2	6	1	15
1	3	9	2	21
1	4	16	4	40
1	5	>18	—	—

https://microbeonline.com/probable-number-mpn-test-principle-procedure-results/16June2022 For treated (unpolluted) water the following procedures followed for MPN value justification:

1. Take 1 tube of single strength (50mL) and 5 tubes of double strength (10mL) for each water sample to be tested.
2. Using a sterile pipette add 50 mL of water to the tubes containing 50 mL single strength medium.
3. Similarly, add 10 mL of water to 5 tubes containing 10 ml double strength medium.
4. Incubate the tubes at 37°C for 24 hrs. If no tubes appear positive re-incubate up to 48 hrs.
5. Compare the number of tubes giving a positive reaction to a standard chart and record the number of bacteria present in it.

   For example, a water sample tested shows a result of 1-4 (1 × 50 mL positive, 4 × 10 mL positive) gives an MPN value of 16, i.e. the water sample contains an estimated 16 coliforms per 100 mL.

3.4.4.4 Data analysis

After collecting all necessary data collected for the study the results summarized by Microsoft excel, SPSS Statistics 20 and Online Calculators Soup used for standard deviation conversion of sample data and analyzed to determine the significance differences. Finally the analyzed results compared with WHO guideline values and Ethiopia Guidelines.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Basic sanitation observation of study area

The critical situation assessed at purposely selected kebles of Hirmata Merkato and Hirmata Mentina was environmental sanitary conditions. As per the observation the residents were dumping out the waste materials along the roads and on open spaces which was mismanaged and wastes randomly disposed. In the study area drinking water contamination factors; like solid and liquid waste generation and management practice of the community along distribution pipe to house hold was neglected. The other observed situation was the entire latrine in the study area was in very poor sanitation condition. Some of drinking water pipes in the study area sewage lines were not positioned at an appropriate distance. The other thing was drinking water pipe is not lined in a safe and sound manner or it was not away from any potential source of visible pollution in the vicinity of water supply pipes.

According to the study by Tizita and Wondessen (2009) drinking water pipe must be placed at a distance of 20-50 meter away from any potential source of contaminant or pollutant. But the above mentioned case indicates the community lives with potential hazardous area that can harm the health status of residents. Hence, economic constraint, lack of awareness, negligence of sanitation and hygiene and less attention of stakeholders obtained from observation as factors in the study area.

Good sanitation and safe drinking water are fundamental for the well-being of the people. Evidence shows that Sub-Saharan African countries have very low water and basic sanitation coverage. The 2015 MDG final report outlines that, although five developing regions met the access to drinking water target, Sub-Saharan Africa (SSA) fell short of meeting the target. However, the region had a 20% point increase in the use of improved sources of drinking water during the MDG monitoring period. The Ethiopian Demographic and Health Survey (EDHS) (CSA and ICF, 2016) reported that 97% of urban households in Ethiopia have access to an improved source of drinking water, with nearly universal access to improved water, and rural areas, with only 57% improved water access, are rare in Ethiopia. Nevertheless, no reliable information is available on the readability of drinking water quality reports (Geremew, 2022).

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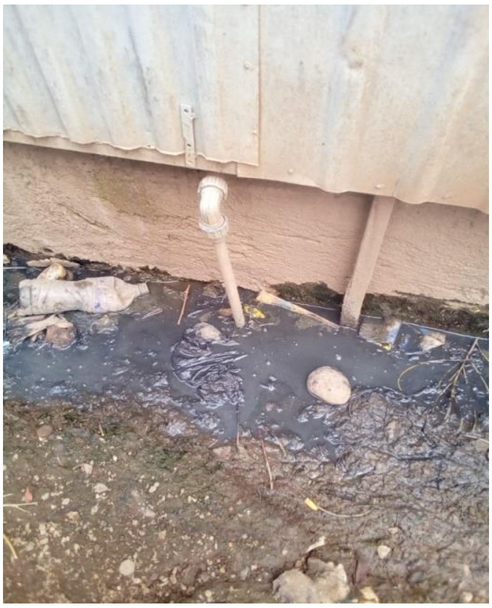


Hirmata Mentina

Hirmata Merkato

Figure 3 : Drinking water lied pipe status at study area

4.2 Physicochemical and bacteriological quality of drinking water

The Physicochemical and Bacteriological parameters directly related to the safety of the drinking water to human consumption. Those water quality parameters provide important information about the health of a water to find out the quality of water for drinking purpose. During water quality analysis the following physicochemical and bacteriological parameters were assessed using experimental procedures of laboratory. Totally from purposely selected two kebeles of Hirmata Merkato and Hirmata Mentina in Jimma town eighteen samples were effectively analyzed. The physicochemical and bacteriological water quality parameters analyzed in the laboratory were Turbidity, pH, , Temperature(O^C), Total Dissolved Solids (TDS), Conductivity (EC), Chlorine residual, Total coliform and Faecal coliform.

Hence, management of drinking water from distribution systems to house hold tap which was primarily involves maintaining water quality, and minimizing the risk of contamination and deterioration of quality during transport. However, such drinking water quality was not given attention accordingly in some area of distribution line contamination.

The study assessed in Southwest Ethiopia to determine drinking water quality and the efficiency of treatment plants stated that: Eighty four water samples were collected from the sources to household taps during dry and rainy seasons. A pre-tested and calibrated multi-parameter probe and turbidity meter were used to measure on the spot. Samples were transported at 4 °C and analyzed according to standard methods and procedures. The majority (87.4%) of physicochemical parameters were in compliance with the WHO standard. However, free residual chlorine, coliform and fluoride were not within the recommended limits (Sisay, Beyene and Alemayehu, 2017).

Table 6. Physicochemical analyses of Drinking Water Quality at household water taps

	Mean value of triplet samples ± SD						
Kebeles	**Sample Sites**	**Turbidity (NTU)±SD**	**pH ± SD**	**Temp(Oc) ± SD**	**TDS(mg/l) ± SD**	**Conductivity (µS/cm) ± SD**	**Chlorine residual**
Hirmata Merkato	S1	0.32 ± 0.005	7.55 ± 0.001	16.73 ± 0.115	94.67 ± 0.577	138.63 ± 0.115	0.087 ± 0.0001
	S2	0.37 ± 0.057	7.66 ± 0.001	16.33 ± 0.115	93.67 ± 0.577	138.53 ± 0.115	0.087 ± 0.0001
	S3	0.14 ± 0.057	7.66 ± 0.001	18.33 ± 0.115	93.00 ± 2.64	140.53 ± 0.115	0.087 ± 0.0001
	S4	5.18 ± 0.068	7.68 ± 0.001	17.07 ± 0.115	94.67 ± 1.15	141.43 ± 0.115	0.087 ± 0.0001
	S5	0.63 ± 0.005	7.66 ± 0.001	17.73 ± 0.115	95.67 ± 1.15	141.63 ± 0.115	0.087 ± 0.0001
	S6	0.15 ± 0.005	7.66 ± 0.001	19.17 ± 0.5	93.33 ± 1.52	140.20 ± 0.73	0.087 ± 0.0001
	S7	0.32 ± 0.01	7.66 ± 0.001	18.80 ± 0.05	94.67 ± 2.3	141.40 ± 0.115	0.087 ± 0.0001
	S8	0.33 ± 0.015	7.65 ± 0.001	19.80 ± 0.17	94.00 ± 1.7	141.53 ± 0.115	0.087 ± 0.0001
	S9	0.27 ± 0.015	7.61 ± 0.001	18.73 ± 0.115	94.33 ± 2.8	141.97 ± 0.57	0.087 ± 0.0001
Hirmata Mentina	S1	0.92± 0.011	7.67 ± 0.001	20.27 ± 0.05	97.33 ± 0.57	142.77 ± 0.57	0.106 ± 1.150
	S2	0.25 ± 0.011	7.67 ± 0.001	19.73 ± 0.15	96.40 ± 0.34	142.33 ± 0.115	0.106 ± 1.150
	S3	1.52 ± 0.015	7.69 ± 0.001	20.17 ± 0.05	95.00 ± 1.7	141.70 ± 0.173	0.106 ± 1.150
	S4	0.41 ± 0.011	7.70 ± 0.001	20.13 ± 0.05	94.33 ± 1.15	141.43 ± 0.115	0.106 ± 1.150
	S5	2.30 ± 0.086	7.71 ± 0.001	20.57 ± 0.115	94.67 ± 1.15	141.43 ± 1.15	0.106 ± 1.150
	S6	0.68 ± 0.011	7.66 ± 0.001	20.80 ± 0.17	93.67± 2.3	141.80 ± 0.173	0.106 ± 1.150
	S7	0.33 ± 0.028	7.66 ± 0.001	20.63 ± 0.115	95.47 ± 0.25	142.43 ± 0.115	0.106 ± 1.150
	S8	2.30 ± 0.264	7.62 ± 0.001	21.07 ± 0.05	96.17 ± 0.115	141.43 ± 1.15	0.106 ± 1.150
	S9	0.65 ± 0.02	7.69 ± 0.001	21.63 ± 0.115	96.10 ± 0.17	143.33 ± 0.115	0.106 ± 1.150

4.2.1 Physico- chemical parameters

Turbidity : Turbidity is a very critical and widely used water quality physical parameter that can provide the most important data throughout the water treatment process. The mean value of turbidity was found in the range between 0.15 ± 0.005 to 5.18 ± 0.068 in the drinking water assessed from purposely selected two kebeles of house hold taps. According to WHO (1996) Turbidity of 0.5 NTU is recommended for effective disinfection in drinking water treatment. However, up to 5 NTU is considered acceptable to the consumers. As a result, from the study sample sites 5% indicated slight increment of turbidity in one of sample site at Hirmata Merkato 5.18 ± 0.068 which was supposed to be pipe leak which causes the result change. Hence, other 95% of sample analyzed from tap water in the study area was below the WHO permissible limit of 5 NTU for drinking water.

pH: The majority of analyzed of drinking water from selected tap were found within the recommended limits of drinking water guideline values of 7.55 to 7.71 in both study area. The pH values more than 8 are not suitable for effective disinfection with chlorine while values less than 6.5 enhance corrosion in water pipes and household water system(WHO,1996). Therefore, pH in selected study area was safe for drinking purpose.

Temperature:-Temperature affects both biological and chemical functions. Chemical equilibrium constants, solubility's, and the rates of chemical reactions are all temperature dependent. High water temperature enhances the growth of microorganisms and may increase taste, odor, and color problems of drinking water . Temperature also affects the concentration of dissolved oxygen and can influence the activity of bacteria in a water bodies . In analysis of the physical quality of pipe water samples, temperature is considered as a critical parameter. It has an impact on many reactions, including the rate of disinfectant decay and by product formation (Kassa, 2020).

It is desirable that the temperature of drinking water should not exceed 15^{o}C because the palatability of water is enhanced by its coolness(WHO, 2017a).In addition to cool water tasting better than warm water, temperatures above 15 degrees Celsius can speed up the growth of nuisance organisms such as algae, which can intensify, taste, odor, and color problems. In case of temperature if nutrients are available, the microbial activity as measured by high performance computing practic increases significantly at water temperatures above 15^{o}C, in the absence of a disinfectant residual.(WHO,2004). The mean value of obtained temperature from study area was found in the range between 16.33 ± 0.115 to 21.63 ± 0.115 in the drinking water assessed from purposely selected two kebeles of house hold taps. Most sampled sites temperature varies at the time of water sample collection from taps and this characteristic did not meet the WHO requirement of 15 degrees celsius.Thus the obtained result was exceed the acceptable limit.

Figure 4 : TDS Meter

Total Dissolve Solids (TDS): Major contribution to total dissolved solids in water is due to the natural contact with rocks and soil; minor contribution to TDS is from pollution including runoff. The TDS tests are considered to determine the general quality of water. The mean value of total dissolved solids (TDS) in mg/L of the tap water samples from the study area ranged from 93.00 ± 2.64 to 97.33 ± 0.57. Thus, the TDS values obtained in this study area was safe since the acceptable range of TDS for drinking purpose permissible limit from (50 to 350mg/l).

Electrical Conductivity (EC):. The conductivity of potable waters varies generally from 50 to 1500 µmhos/cm. According to WHO standards the EC value of drinking water supply should not be exceeded 400 µS/cm. The result depicts that the EC mean values of study area water supply varies from 138.53± 0.115 to 143.33 ± 0.115 µS/cm, which is below the WHO maximum permissible limits. These results indicate that the water in the systems are characterized by low ionized and has the low level of ionic concentration activity due to low concentrations of dissolved solids.

Figure 5 : Conductivity meter

Residual chlorine: is a chemical that is used to disinfect water prior to it being discharged into the distribution system. It is used to ensure the water quality is maintained from the water source to the point of consumption. Active chorine should be present at each stage of water distribution. The residual Chlorine at the consumers end should be 0.2mg/l. Presence of excessive chlorine gives bad odor and taste that is harmful. It may lead to cancer, skin and eye irritation, to avoid excess chlorination water sample need to be boiled before the domestic use.(IS:3025 Test procedure Ethiopia ,2003).Bacterial growth may occur in distribution systems when very low levels of chlorine are encountered. Therefore, it is important to make sure there is enough chlorine to efficiently disinfect even at the far ends of the distribution system. Chlorination can kill many pathogenic, disease-causing microorganisms such as E-coli, but others, like Cryptosporidium and Giardia, are very resistant to chlorine and require other measures to properly remove them. The World Health Organization guidance level for drinking water supply recommends maximum residual chlorine 0.5mg/L (www.Safewater.Org) in the distribution systems of any water supply. However, the study area have shown that the residual chlorine levels drop below recommendations, several water quality problems can occur. It is important to note that, although chlorination has been the most common method of disinfection for over many years. It expected to be enough chlorine to make sure drinking water is properly disinfected. However, as shown the laboratory results of the study area were high loss of chlorine in the system. The study area water taps consists mean value of 0.087 ± 0.0001to 0.106 ± 1.150 of disinfection which was less than the standard that indicate inefficiency of disinfection in the distribution system and require an excessive disinfectant.

In areas where there is little risk of a waterborne outbreak, residual free chlorine of 0.2 to 0.5 mg/l at all points in the supply is recommended (Muhammad, 2013).

To determine the lab finding of residual chlorine the following steps completed.

$$\text{Residual chlorine} = \frac{\text{Volume of sodium thiosulphate} * N * 35.45 * 1000 \text{(for converting ml to L)}}{\text{Volume of sample taken}}$$

N= Normality of sodium thiosulphate = (0.01) ; For instance volume of sodium thiosulphate from one of burret reading of sample taken was 0.05, Hence the residual chlorine determined:

$$\text{Residual chlorine} = \frac{0.05 * 0.01 * 35.45 * 1000}{200\text{ml}}$$, which was equal to 0.0886mg/l

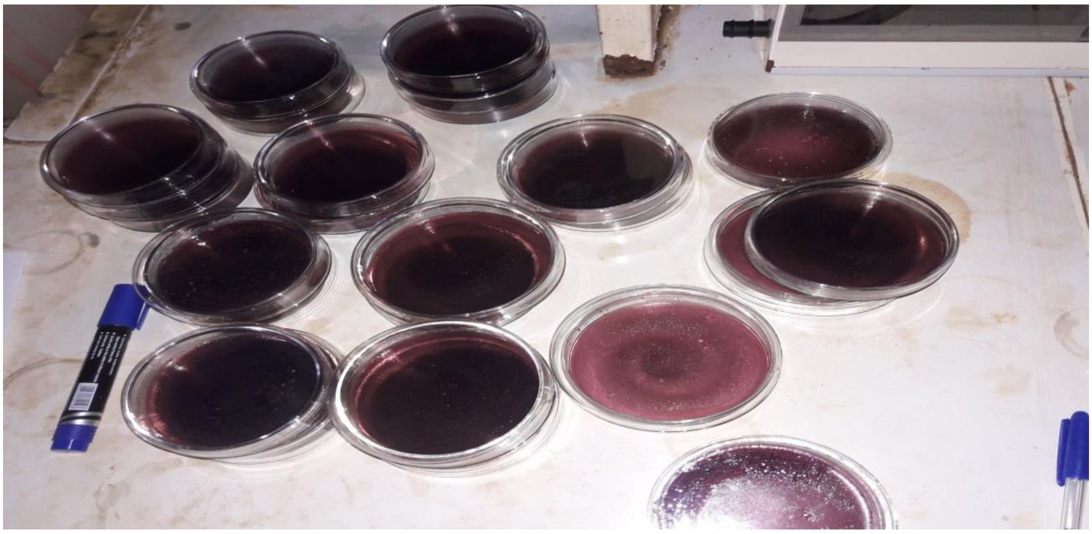
In Ethiopian drinking quality standard also recommends the residual chlorine in drinking water should be 0.5 mg/l. However, In this study, the mean free residual chlorine concentration of water samples from the tap was 0.0886 mg/l, the values were less than the maximum concentration set by WHO and ES. This indicates that the water can be recontaminated and there is no reserved chlorine that can disinfect it which may lead the consumer to water related disease. That means the result obtained indicates inadequate disinfection observed which was below WHO standard and needs a great attention.

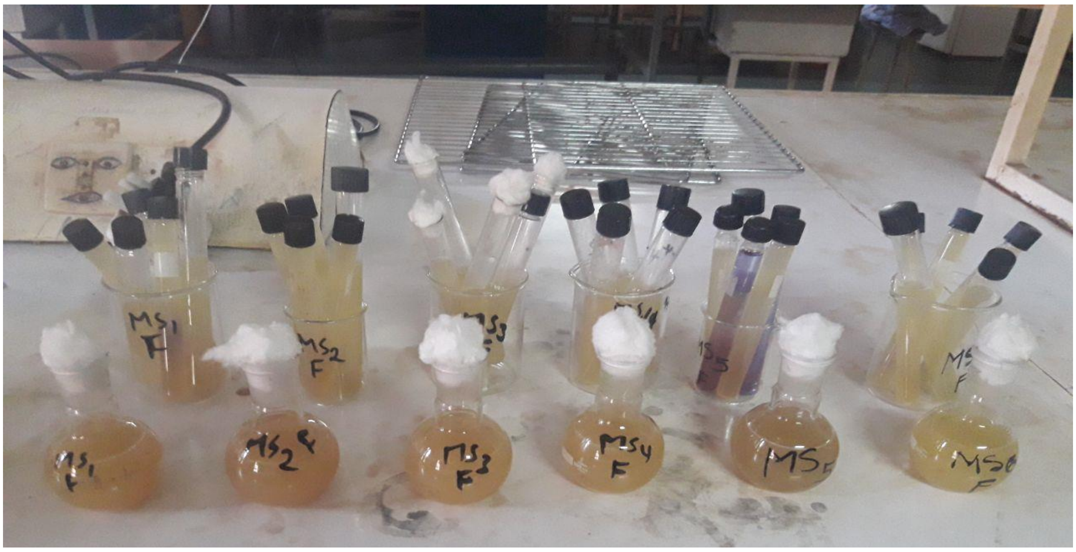
4.2.2 Bacteriological Parameters

Table 7. Bacteriological examination of drinking water tap at household by MPN method

Bacteriological analyses of Drinking Water Quality at household water taps							
Triplet samples reproducible and one representative data represented below							
Kebeles	**Sample Sites**	**Total Coliform**			**Faecal coliform**		
		1 of 50 ml	**5 of 10 ml**	**MPN index per 100 ml**	**1 of 50 ml**	**5 of 10 ml**	**MPN index per 100 ml**
Hirmata Merkato	S1	1	5	>18	1	5	>18
	S2	1	5	>18	1	5	>18
	S3	1	5	>18	1	5	>18
	S4	1	5	>18	1	5	>18
	S5	1	5	>18	1	5	>18
	S6	1	5	>18	1	5	>18
	S7	1	5	>18	1	5	>18
	S8	1	5	>18	1	5	>18
	S9	1	5	>18	1	5	>18
Hirmata Mentina	S1	1	5	>18	1	5	>18
	S2	1	5	>18	1	5	>18
	S3	1	5	>18	1	5	>18
	S4	1	5	>18	1	5	>18
	S5	1	5	>18	1	3	9
	S6	1	5	>18	1	5	>18
	S7	1	5	>18	1	5	>18
	S8	1	5	>18	1	5	>18
	S9	1	5	>18	1	5	>18

MPN (Most Probable Number): Method Bacteriological examination of water for total coliform and E.colia count was done by MPN method for drinking water. The presumptive coliform count by MPN method was shown in Table-above had total coliform counts indicated greater than 18 MPN/ 100 ml except one site which was indicated 9 MPN/100 ml, out of 18 were contaminated with E.coli. The presence of indicator organism Escherichia coli isolates for faecal contamination was confirmed by the production of greenish metallic sheen on EMB media as shown in Figure below. The results for confirmed test of MPN method were presented above**.**


A)


B)

F igure 6 :A) EMB agar media and B) Characterization tests for Escherichia coli isolation

In the study, Multiple Fermentation Tube or Most Probable Number (MPN) method used according to focus analysis of drinking-water with satisfactory results. The results for the presence of coliform bacteria are represented as a most probable number (MPN) index that would give the results shown by the test and not a count of the actual number of indicator bacteria present in the sample. This study was conducted with the aim to find out the bacteriological contamination of tap drinking water in accordance with the results of the acceptable limit. The objectives of the study were to enumerate fecal indicator bacteria by the most probable number (MPN), to estimate the level of contamination in the water sample in the presence of indicator coliform Escherichia coli. After 48 hour incubation at 37ºC, the number of positive tubes was recorded from each set and compare with standard chart to give presumptive coliform count per 100ml water sample (Sander et al., 2019).

Hence following all the above procedures the obtained lab finding at purposely selected kebeles of study area indicates the sample collected contains an estimated greater than 18 coliforms per 100mL.Which need detail investigation and analysis to protect the health of public. According to the World Health Organization**,** a zero count of E. coli per 100 ml of water is considered safe for drinking. A count of 1–10 MPN/100 ml is regarded as low risk; 11–100 MPN/100 ml is medium risk. Finally, an *E. coli* count greater than 100 MPN/100 ml is adjudged high risk (Odonkor and Mahami 2020).

As per water quality index calculation of drinking water done in southwest Ethiopia towns, the index showed that, Jimma water quality was classified as poor, and Agaro and Metu were in the good category. Therefore, water supply sector needs strict evaluation of the water quality in the rainy season, particularly in Jimma and Agaro towns. The overall efficiency of treatment plants were 73.6%, 48.4% and 74.1% effective in overall pollutant removal in Jimma, Agaro and Metu town, respectively. The study concluded that the treatment plants were still technologically appropriate to deliver safe water to the public, but giving attention on technical skills on water quality monitoring may improve the observed negative findings on bacteriological quality and free residual chlorine(Sisay et al, 2017).

In Ethiopia studies conducted in Dire Dawa and Jimma revealed 83.34% and 87.5% of water sample were positive for bacterial indicators respectively. Additionally, a study done in North Gondar showed that springs (35.7%), protected wells (28.6%), and water lines (50%) had Escherichia coli. Quality and safety of drinking water is challenging due to contaminants from man-made and natural disasters. Many of the diseases in communities are caused by microorganisms carried in drinking water. The contaminated drinking water is not only due to fecal contamination but also growing in piped water distribution systems (Wolde et al. ,2020).

Table 8. Obtained result comparison with WHO and Ethiopian standard

Physicochemical and bacteriological parameters of drinking water	WHO standard	Ethiopian Maximum permissible level	Obtained study result
Total Coliform, per 100 mL	0	0	>18 MPN index per 100 ml
E. coli, number per 100 mL	0	0	>18 MPN index per 100 ml
Turbidity, NTU 5	<5	5	5.2
pH	6.5-8	6.5-8.5	7.63
Temperature(O^c)	<15	15	>15
Total Dissolved Solid (mg/L)	1000	1000	96.7
Conductivity (µS/cm)	400	1000	141
Residual free chlorine mg/L	0.5	0.5	0.087

WHO guideline recommends that drinking water quality should be routinely monitored at the end user taps of water supply system. At the very least, water temperature and disinfectant residual should be monitored every day as simple rapid tests result as indicator of possible problem identification. Other basic parameters that should be regularly monitored, if possible, include pH, conductivity, turbidity, color and Escherichia coli (coliforms). Routine sanitary inspection of a temporary water supply by the appropriate sector is very important. If any problem related to water quality arises, remedial actions should be taken promptly. As summarized above some obtained result not fulfilled the required standard. Hence, it needs some attention and detail analyses.

4.2.3 Knowledge, Attitude And Practice Towards Drinking Water Quality

As illustrated in the following table the reaction of respondent gathered via questionnaire compiled that around 93.0% of the respondent does not expect that their tap water would be contaminated. This was due to their inadequate knowledge on water quality deterioration and lack of appropriate awareness from stakeholders. Additionally 89.2% respondents have no better understanding about water borne diseases that cause health problem. This was due to respondents' less expectation that tap water drinking water has no quality deterioration problem. Therefore, 81.4% of respondent said that the water fetched from tap drinking water has a good quality. However, only 2.9% of the respondent with no separate water containers for storing drinking water at household level in comparison. From the study area only 11.0% of respondents have a good awareness towards factors that cause water quality deterioration with in the distribution pipe; cross connection with sewers, Interconnection with toilet, pipe corrosion and pipe breakage and invisible entrance of contaminants in to the distribution.

From the obtained respondent result lack of knowledge on tap water contamination via piped drinking water from each kebele observed. Poor hygienic practices, inadequate water supply and poor sanitary conditions play a major role in the spread of diseases. Lack of knowledge, attitude and practices (KAP) on water sanitation was one of the most imperative causes for transmission of infectious diseases. At the period of survey 5 respondents testified water borne disease occurrence in their home in the recent six months ago and the other 3 respondent faced the disease before six months ago. Poor waste disposal, interconnection of drinking water pipes with sewer and presence of leaky pipe which result cross contamination with the surrounding seem to contribute bacterial contamination of drinking water in the distribution systems. of leakage detection and reported repair in drinking water pipe line. This needs emphasis on routine water quality supervision and monitoring.

Table 9. Assessed KAP towards drinking water quality

Figure 9..1 Case summary of Yes Respondant

Case Summary						
	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
$Yes[a]	354	98.9%	4	1.1%	358	100.0%

a. Dichotomy group tabulated at value 1

$Yes Frequencies

	Varabiles	Responses N	Percent of Cases
$Yes[a]	Private piped water in yard connection	354	100.0%
	Is the water fetched from tap transported to your house with covered containers	344	97.2%
	In your house water for drinking is stored in a separate container from water intended for other purposes?	348	98.3%
	Do you know about water borne diseases that cause health problem?	52	14.7%
	Do you think that drinking water you fetch from your tap has a good quality and healthy?	288	81.4%
	Do you think drinking water can polluted in the distribution system?	39	11.0%
	Do you think the conditions you mentioned above exist in your area?	15	4.2%
	Have you faced water borne diseases recently in your home?	28	7.9%

a. Dichotomy group tabulated at value 1.

Table 9. 2 Case Summary of No Respondant

Case Summary						
	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
$No[a]	343	95.8%	15	4.2%	358	100.0%

a. Dichotomy group tabulated at value 2.

$No Frequencies

Varabiles		Responses N	Percent of Cases
$No[a]	Private piped water in yard connection	4	1.2%
	Is the water fetched from tap transported to your house with covered containers	14	4.1%
	In your house water for drinking is stored in a separate container from water intended for other purposes?	10	2.9%
	Do you know about water borne diseases that cause health problem?	306	89.2%
	Do you think that drinking water you fetch from your tap has a good quality and healthy?	70	20.4%
	Do you think drinking water can polluted in the distribution system?	319	93.0%
	Do you think the conditions you mentioned above exist in your area?	343	100.0%
	Have you faced water borne diseases recently in your home?	330	96.2%

a. Dichotomy group tabulated at value 2.

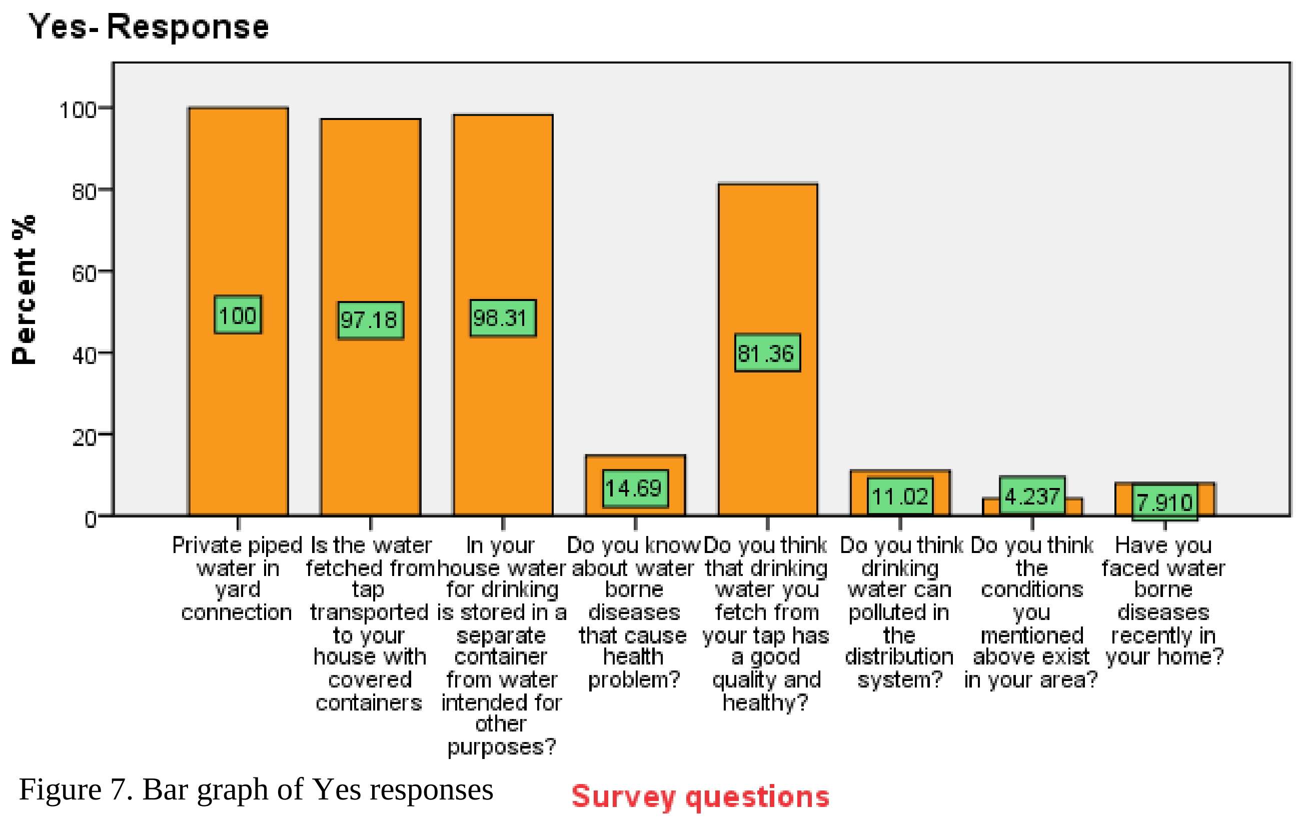


Figure 7. Bar graph of Yes responses

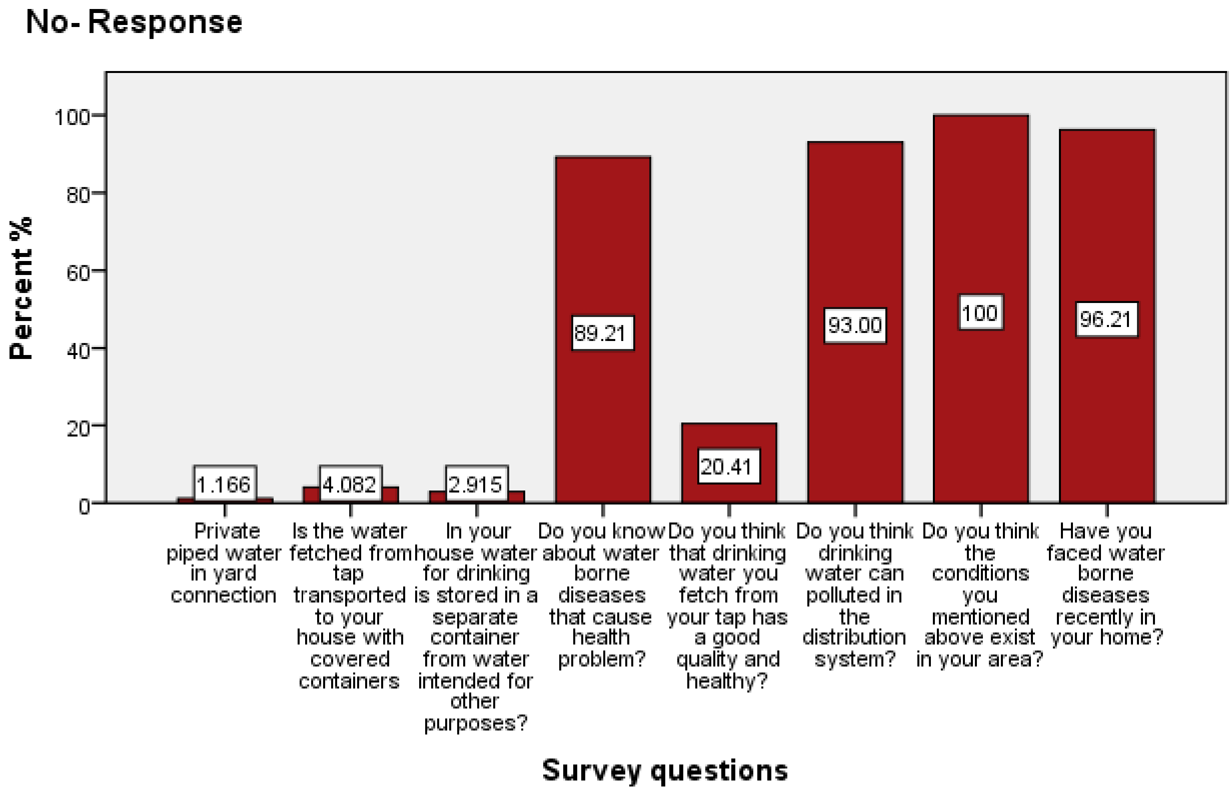


Figure 8. Bar graph of No responses

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The drinking water quality parameters and the effects of residual chlorine in drinking water tap purposely selected kebeles of Jimma town investigated through laboratory experiments for analyses of drinking water quality parameters from total of 18 randomly selected representative samples of water from different households. Comparison of the water quality parameters with the permissible limit of the WHO guidelines (2012) and with that of the Ethiopian recommended values in Compulsory Ethiopian Standard for Drinking Water Specification (CES- 58) – 2013);regarding safe and acceptable level of drinking water for customers.

The main physico-chemical parameters considered for investigation include turbidity, pH, electrical conductivity, total dissolved solids, and residual chlorine. Bacteriological tests such as faecal coliforms and total coliforms were analyzed in relation to the health prevalence of water-associated diseases. The laboratory results have shown that except for, residual chlorine, the remaining all parameters were found within the permissible limit. The mean value of residual chlorine was in the range of (0.087 ± 0.0001 and 0.106 ± 1.150) were found unacceptable range of WHO permissible limit. WHO guidelines and Ethiopian recommended values concerning acceptability level of residual chlorine (CES- 58) – 2013); for end users could be equal or greater than 0.5 mg/l. The desired temperature for drinking water should not exceed 15^{o}_{C} , however the obtained result during assessment indicate above $15^{o}_{C.}$ The results of bacteriological analyses have shown greater than 18 MPN/100ml, i.e. the water sample contains an estimated 18 coliforms per 100 mL. Mainly inadequate chlorine disinfection and invisible pipe leakage was a factor for deterioration on quality of drinking water and caused the result undesirable.

Generally, concerning some of the physico-chemical parameters, the water seems to be safe. However, further studies that involve a wide scale laboratory analyses and an intensive necessary data collection suggested for precise and ultimate conclusions. Therefore, concerned stakeholder, in close collaboration with sector of water supply, should develop a strong interest in monitoring water quality for the town beneficiaries. Also environmental awareness must initiated towards drinking water safety at home, proper water storage practices and water related risks in order to limit water pollution for safe consumption. Consequently the result from house hold survey assessment of drinking water in the study area showed that the respondent have a gap of knowledge, attitude and practice towards tap water impurities that need effort for improvement. Hence, consistent drinking water quality analysis required at purposely selected study area as well as other areas in the town in order to rectify public health problems.

5.2 Recommendation

Regular inspection of sanitary and hygienic aspects with appropriate management of the distribution pipe for prevention of contamination must be done and pipes along the distribution system must be replaced. Solid and liquid wastes must be managed properly and frequency of apporiparate waste removal must be increased and private involvement to be appreciated. Public awareness and Involvement must be practiced towards drinking water safety management at home. Water handling practice and sanitary condition of the people must be improved. So, all concerned bodies should be react cooperatively and in integrated manner for promoting peoples understanding on the causes of contaminants and how to use home water treatment mechanisms. The result of this study depicted that, the amount of residual chlorine in the distribution system was below the limiting value. This indicates there might be recontamination of drinking water which leads to health problem of consumers. Therefore, sufficient amount of chlorine should be added in the reservoir to have adequate residual chlorine which is safe to end user. The status of the water quality vary with in season due to different factors. This research was done in summer season due to research schedule. Therefore, further research should be done by considering different season and routine monitoring of the water supply system is necessary to verify suitability of drinking water quality for end uses.

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Annex 1. Questionnaire For Household Survey To Assess The Knowledge, Attitude And Practice Of Study Area On Drinking Water Quality

HOUSEHOLD SURVEY OF ______________________KEBELE Date: ___________

1. Main source of drinking water for your household -Circle all where you have more than one answer and specify for what purpose you use it. (Observation).

   a) Private piped water in yard connection b) Shared piped water in yard connection

   c) Piped public/communal tap d) Protected well/spring

   e) Unprotected well/spring f) River

   h) Other specify__________________

2. Is the water fetched from tap transported to your house with covered containers?

   Yes _________ No__________

3. In your house water for drinking is stored in a separate container from water intended for other purposes? Yes _________ No__________

4. Do you know about water borne diseases that cause health problem?

Yes _________ No__________

4.1 If yes, what do you guess the source of water borne diseases?___________________

5. Do you think that drinking water you fetch from your tap has a good quality and healthy?

   Yes _________ No__________

If no what limitations do you think it has? _______________________________

6. Do you think drinking water can polluted in the distribution system? Yes _____ No______

6.1 If yes, what are the factors that cause water quality deterioration with in the distribution system?____

7. Do you think the conditions you mentioned above exist in your area?

Yes _________ No__________

7.1 If yes, what type of appropriate measures you suggest to resolve it?____________

8. Have you faced water borne diseases recently in your home? Yes____ No____

8.1 If yes in what frequency _______________________

8.2 If yes, what measures do you take to solve such problem?_________________

Annex 2 :Assessed Knowledge, Attitude And Practice Towards Drinking Water Quality

No	Survey questions	Number of respondent in %	
		Yes (%)	No (%)
1	Main source of drinking water for your household?		
	a) Private piped water in yard connection	99	
	b) Shared piped water in yard connection	1	
2	Is the water fetched from tap transported to your house with covered containers?	96	4
3	In your house water for drinking is stored in a separate container from water intended for other purposes?	97	3
4	Do you know about water borne diseases that cause health problem?	14	86
4.1	If yes, what do you guess the source of water borne diseases?	Contamination and poor hygiene of drinking water container at home	
5	Do you think that drinking water you fetch from your tap has a good quality?	81	19
5.1	If no, what limitations do you think it has?	Sometimes taste and color change observed	
6	Do you think drinking water can be polluted in the distribution system?	11	89
6.1	If yes, what are the factors that cause water quality deterioration with in the distribution system?	Pipe leakage contaminated by waste, Exposure with toilet, Pipe corrosion and Invisible pipe breakdown	
7	Do you think the conditions you mentioned above exist in your area?	4	96
7.1	If yes, what type of appropriate measures you think to resolve it?	Calling the utility workers for visible leakage repair	
8	Have you faced water borne diseases recently in your home?	8	92
8. 1	If yes in what frequency?	In the period of recent six months	Before six months ago
		5 respondents	3 respondents
8.2	If yes, what measures do you take to solve such problem?	Looking for medication	

Annex 3: Procedures In Laboratory

Determination of pH

Reagent prepared

Instrument calibrated

Sample taste result obtained through each procedures

Turbidity

First the reagents was prepared

Turbidity meter calibration checked

Check the reading in turbidity meter, wit until to get stable reading.

Obtained result of water sample tabulated in sequence of test.

Residual Chlorine in Water

Procedure

Measure 200ml of water sample

Add 5ml of acetic acid

Add 1gm of potassium iodide

Titrate against sodium thiosulphate till the color turns to yellow

Add 2ml of starch till the color turns to blue

Continue the titration till the color turns to colorless.

Conductivity

Reagent prepared

Instrument calibrated

Sample taste result obtained through each procedures

Records tabulated and calculated

Biological parameter (total coliform and fecal coliform)

Sampling from a tap

A) Clean the tap: Remove from the tap any attachment that may cause splashing. Using a clean cloth, wipe the outlet to remove any dirt.

B) Open the tap: Turn on the tap at maximum flow and let the water run for 1-2 minutes. In this case the tap will not be sterilized in order to obtain results which way will provide information on the quality of the water as consu med.

c) Open the sterilized bottle: Take out a bottle and carefully unscrew the cap or pull out the stopper.

F) Fill the bottle: While holding the cap and protective cover face downwards (to prevent entry of dust, which may contaminate the sample), immediately hold the bottle under the water jet, and fill.

In the Lab: Presumptive test functions: (MPN) Multiple fermentation tubes used)

I. MacConkey broth and EMB agar used for lactose fermentation for the presence of the indicator bromocresol purple.

II. The inverted Durham's tube is used for the detection of gas formation by Gram negative coliform bacteria.

III. The color changes of media into yellow and on collection of gas in Durham's tube can be assumed that coliform bacteria are present in these samples.

IV. 5 of 10ml of water samples were inoculated into each of 10ml of presumptive broth (double strength).

V. 1 of 50ml water sample was added to a tube containing 50ml of presumptive broth (double strength).

VI. After 48 hour incubation at 37ºC, the number of positive tubes was recorded from each set and compare with standard chart to give presumptive coliform count per 100ml water sample.

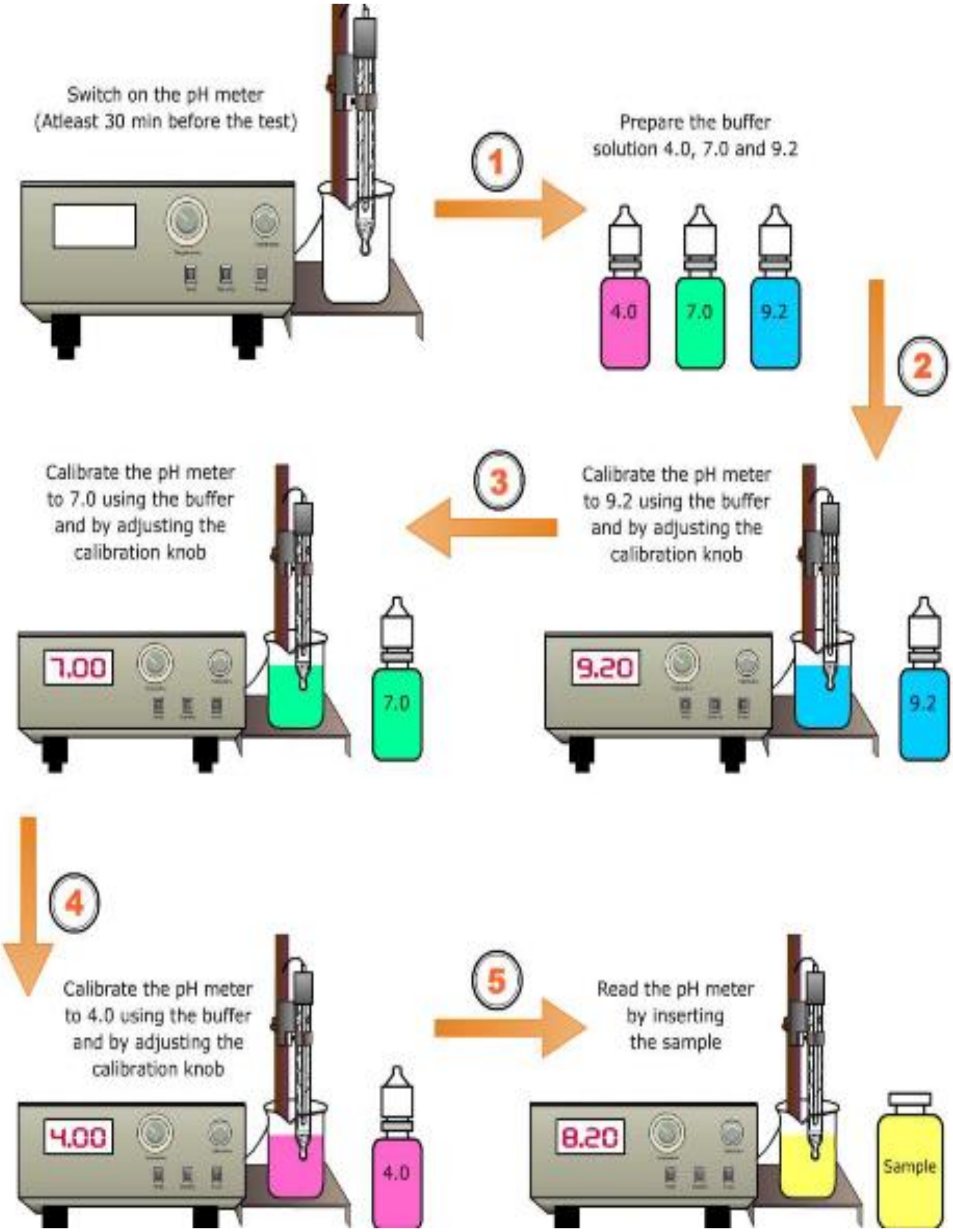
VII. After 24 hour incubation at 44ºC. The color change from purple to yellow.

Annex 4 : Coordinate sampling points of selected kebeles

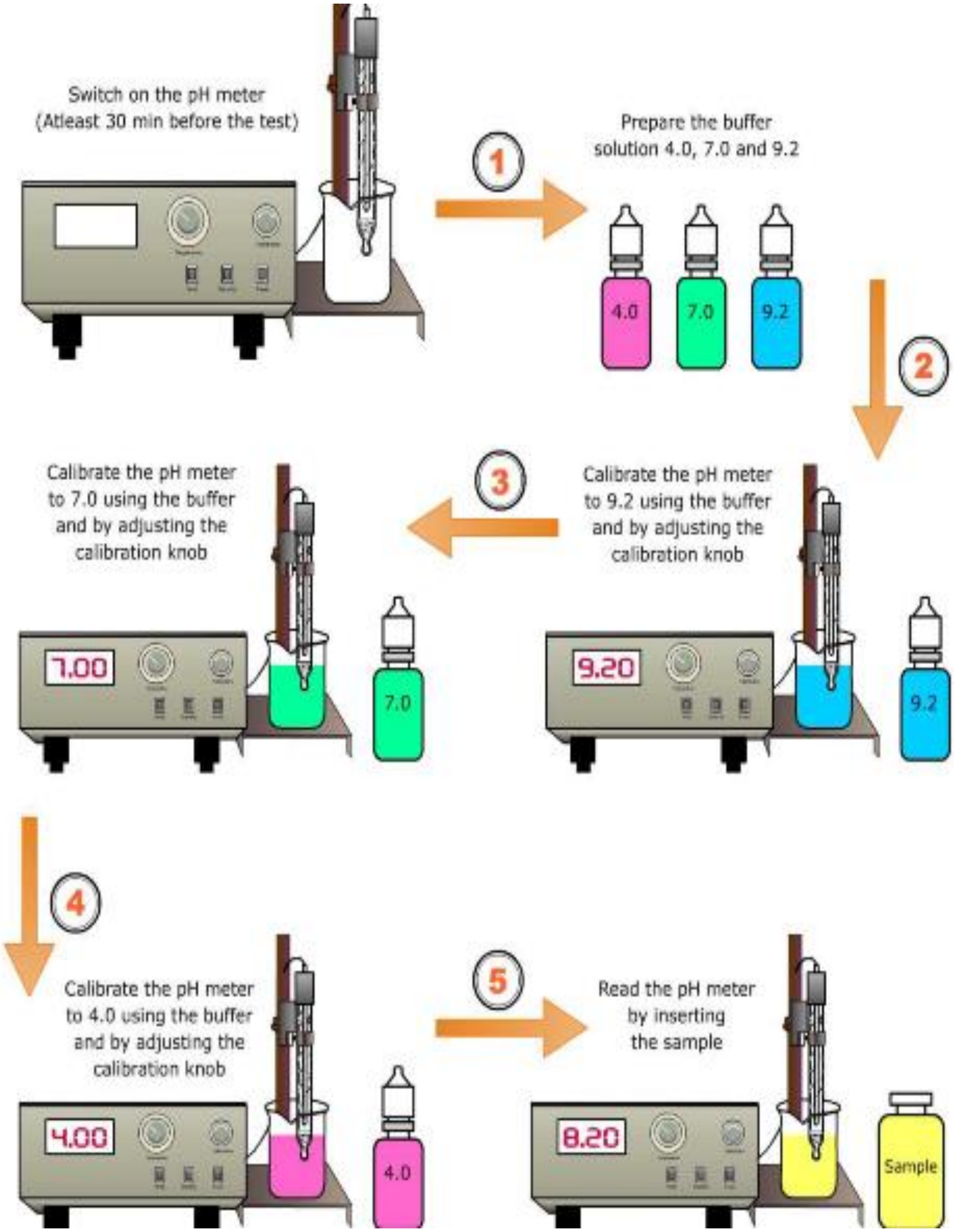
Kebele	Sample points	
	X	Y
Hirmata Merkato	261250	848248
	261244	848239
	261238	848183
	261235	848180
	261211	848191
	261208	848193
	261038	848131
	260411	848721
	261054	848047
Hirmata Mentina	260880	848083
	260865	848076
	260850	848045
	260786	847711
	260787	848061
	260757	848065
	260721	848091
	260721	848103
	260824	847999

Annex 5 : Some Lab Illustrative Procedure Chart

A. pH determination



B. Turbidity


Switch on the pH meter
(Atleast 30 min before the test)
1
Prepare the buffer
solution 4.0, 7.0 and 9.2
4.0
7.0
9.2
2
Calibrate the pH meter
to 9.2 using the buffer
and by adjusting the
calibration knob
9.20
9.2
3
Calibrate the pH meter
to 7.0 using the buffer
and by adjusting the
calibration knob
7.00
7.0
4
Calibrate the pH meter
to 4.0 using the buffer
and by adjusting the
calibration knob
4.00
4.0
5
Read the pH meter
by inserting
the sample
8.20
Sample

C. Determination of residual chlorine