ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF GRADUATE STUDIES
DEPARTMENT OF CIVIL ENGINEERING
WATER SUPPLY AND ENVIRONMENTAL ENGINEERING STREAM

ASSESSMENT OF DRINKING WATER QUALITY IN MERCATO, ADDIS ABABA

By
Selamawit Mulugeta

A thesis submitted to the school of Graduate Studies of Addis Ababa University in Partial Fulfillment of the requirements of the Degree of Masters of Science in Civil Engineering (Water supply and Environmental Engineering Stream)

Advisor
Dr. Agezew Nigussie

Department of Civil Engineering
Addis Ababa University

August, 2012

ADDIS ABABA UNIVERSITY ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES CIVIL ENGINEERING DEPARTMENT

WATER SUPPLY AND ENVIRONMENTAL ENGINEERING STREAM

Assessment of Drinking Water Quality in Mercato, Addis Ababa

By

Selamawit Mulugeta

Approved by Board of Examiners:

________________	____________	______________
Chairman, Department Graduate Committee (DGC)	*Signature*	*Date*
______________	_______________	______________
Advisor	*Signature*	*Date*
___________________	___________	______________
Internal Examiner	*Signature*	*Date*
__________________	___________	_______________
External Examiner	*Signature*	*Date*

ACKNOWLEDGEMENTS

Above all I praise God for giving me his helping hands in all of my moves from the beginning up to the end.

I would like to thank my advisor Dr.Agezew Nigussie for his indispensable prompt help and invaluable effort in guiding and supervising during the course of this thesis. I treasure his advice which has contributed a great deal to the success of this work.

I have benefited a lot from AWSSA Central Laboratory; Therefore It gives me great pleasure to express my great gratitude to the personnel for their willingness to use all the equipments and reagents without any payment and to laboratory technicians.

It is difficult to express in words my special gratitude to my families, for their unlimited financial and moral support, and also to Ato Aklilu Getenet, Ato Gashaw Tesfaye, Ato Akalu M/Tsadik, and members of MK.

Table of content

LIST OF TABLES

LIST OF FIGURES

LIST OF ANNEXS

List of Acronyms

AAWSA…………………………………………....Addis Ababa Water and Sewage Authority

ANOVA………………………………………………………………..…Analysis of Variance

BGB…………………………………………………………...……………Brilliant Green Bile

BMPs…………………………………………………………..Best Management Practiceses

CFU……………………………………………………………………...Coloney Forming Unit

CSA ……………………………………………………………..…..Central Statics Agency

DPD……………………………………………………………..Diethyl-Phenylene-Diamine

EC…………………………………………………………………….....Escheria Coliform

ES………………………………………………………………………....Ethiopian Standard

FC…………………………………………………………….…..……..Fecal Coliform

FCR…………………………………………………………………...…Free Chlorine Residual

JMP…………………………………………………………………….…Statistical Software

KAP…………………………………………………………Knowledge, Attitude and Practice

NTU…………………………………………………………...…..Nepholometeric Turbidity Unit

R ……………………………………………………………….…………..…….Reservoir

TC………………………………………………………………….………....Total Coliform

TCR……………………………………………………………….……..Total Coliform Rule

TTC..……….Thermo Tolerant Coliform

WHO…………………………………………….………………World Health Organization

UNICEF………………………………………………………..United Nations Children's Fund

WQF……………………………………………………………………....Water Quality failure

ABSTRACT

While water is released from treatment plant for consumption purpose it does not embrace anything harmful and objectionable to human health. But due to the complex interaction of the distribution system with the environment quality of water may deteriorate. Bearing this in mind in the previous year's water quality assessment at different place within the distribution system was not the basic concern for many water sectors. Nowadays even though there are no documented and well organized studies about it water sectors know the above problem and its intended results.

The study was conducted in Mercato, Addis Ababa which is the largest market place in the country. Since the study area is very slum, crowded and serves as center for commercial activity the residents are forced to lead their day to day life activity in a small place. This phenomenon forced the dwellers to live in offensive environment. As an indication without considering the amount of waste failed to reach to the collection containers, from the total amount of waste collected in the sub-city only 74% is properly removed. The reaming was left to join rivers, streets, ditches and open spaces which facilitate health troubles and environmental disturbance.

In such living environment to maintain the health status of dwellers by having appropriate information on the level of safety of water regular examination of water quality for the presence of photogenic organisms, chemicals and physical parameters is mandatory.

Investigation under this study indicates the presence of significant level of water quality deterioration and existence of pathogens at consumers tap. For water quality assessment water samples were taken from treatment-plant, reservoirs, and consumer taps.

Key words: - Tap Water quality, Distribution system, Waterborne disease, Mercato, Addis Ababa, Ethiopia.

CHAPTER ONE

1 BACKGROUND

1.1 INTRODUCTION

Water quality is generally defined by a collection of upper and lower limits on selected possible contaminants in water. This is evaluated by using water quality indicators (parameters or classes) which can be classified into three broad categories: physical, chemical and biological. Within each class, a number of quality variables are considered. The acceptability of water quality for its intended use depends on the magnitude of these indicators and is often governed by regulations.

Water has the ability to dissolve solids and to absorb gases and other liquids. Hence, it is often referred to as the "universal solvent". Because of this solvent power, all natural water contains minerals and other substances in solution, which have been picked up from the air, the soil, and rocks through and over which it passes (Zeyede, Tesfaye, 2004).

A water quality failure (WQF) event is often defined as an excidance of one or more water quality indicators from specific regulations. To monitor the quality of water in the distribution system, physical, chemical and biological parameters are recorded from routine grab sampling, followed by an analysis in the laboratory. Some common water quality indicators used for water distribution system are alkalinity, dissolved oxygen, fluoride, nitrates, phosphate, residual disinfectant, specific organic compounds, temperature, turbidity and E-coli (Thomas & Andre van der, 2006).

The provision of piped water directly to the household has been associated with the improved hygiene and reduction in disease. However, as standards of living has raised and water infrastructures have aged, there has been growing recognition that water distribution systems are vulnerable to intrusion and contamination and may contribute to endemic and epidemic waterborne disease.(Milkiyas, etal, 2009)

According to WHO survey 80% of all illnesses in developing countries are water-associated. Diseases caused by contaminated water consumption and poor hygiene practices are the leading causes of death among children worldwide (Yves, 2004). Moreover, Lack of safe drinking water, absence of basic sanitation and hygienic practices are associated with high morbidity and mortality from excreta related diseases (WHO, 2003). Basically Water contaminated with pathogens, physical and chemical contaminants at the source and/or during distribution, transportation and handling in households or other working places may cause health risk unless used without treatment (Mark, 2004 and WHO, 1996). In addition, inadequate protection of water collection and storage containers and unhygienic conditions contribute to contamination at home (Nath and Johns, 2006).

In Ethiopia the problems related to water supply are attributed mainly to lack of maintenance of the previously constructed systems, lack of community involvement when the earlier water systems were built, lack of spare parts and local maintenance capabilities, etc (Asamnew, 2004). Southern Asia and sub-Saharan Africa still struggle with low coverage in sanitation 41 per cent and 30 per cent, respectively (WHO and UNICEF, 2010). As a result, Ethiopia is one of the countries in the world with the worst of all water quality problems. It has the lowest water supply and sanitation coverage in Sub-Saharan countries with only 68.5% and 56% for water supply and sanitation, respectively (MoWR, 2010)

Most of the population of Ethiopia does not have access to safe and reliable sanitation facilities. On top of these, majority of the households do not have sufficient understanding of hygienic practices regarding food, water and personal hygiene. As a result, over 75 % of the health problems in Ethiopia are communicable diseases which resulted from having unsafe and inadequate water supply, and unhygienic waste management, particularly human excreta (UN-WATER/WWAP, 2004).

The safety of drinking water can be monitored in a number of ways due to the constituents of drinking water (such as chemicals and microbes) which can compromise human health. The reason for monitoring drinking water quality is to determine whether the water supply system is being operating in accordance with national regulations, which means that the water is safe for drinking or not.

1.2 STATEMENT OF THE PROBLEM

Water quality deterioration is a big issue in many countries water supply system, which may be a result of many interconnected physical, chemical, and biological factors. It may or may not be at the source only rather it may happen after leaving the source, on the path from source to consumers tap. Moreover, it is also very difficult to identify strictly the cause as well as the place of pollution**.** Because of this by assessing water quality based on indicator parameters such as turbidity, BOD, pH, and faecal microorganisms different reports showed that significant level of water pollution both at sources and distributions systems. This indirectly determines the risk of ingesting pathogens and chemicals with polluted water (APHA, 1998). The reports also showed that water sources and distribution systems of towns and rural communities alike have serious water quality problems. Assessment of bacteriological and physico-chemical qualities of urban source water and tap water distribution systems in Akaki-Kalit sub-city of Addis Ababa (Mengestayehu,2007), Ziway town (Kassahun, 2008), Bahir Dar town(Getnet,2008), Adama town (Temesgen, 2009) showed contaminations of water by indicator bacteria such as total coliforms, fecal coliforms and/or fecal streptococci.

The problems of contamination of urban water distribution system are said to be diverse. According to (GTZ, 1995) wastes from improper sanitation (sewage) and agricultural and other activities make their way to the water distribution networks. Furthermore, break in the distribution system, inverse pumping of soil contaminants through interruption of the water supply, age and improper maintenance of the distribution system, low level of chlorine (treatment efficiency) usually compromise the integrity of the distribution system and quality of potable water (Muyina and Ngeakani, 1998; Phiro., 2005; Zambrlan *et al.*, 2007).

Beyond what has been stated, in places where liquid and solid wastes are not properly managed the probability of water quality deterioration is expected to be high and usage of this water may have a chance to cause waterborne diseases. In the study area, inappropriate liquid and solid waste management are the major problems and this greatly destructed the image of the area. As a result, if there is a possibility to join leaky pipes, this may contribute to deterioration of water quality in the distribution network. In addition, this can also be a major cause for existence of waterborne diseases. Health Office reports indicate that among the top ten diseases registered in the area waterborne disease take the higher ranks and among all typhoid, cholera, helminthiasis and diarrhea were the most rapidly occurring waterborne diseases (Sub-city report, 2003).

All in one come up with a holistic solution for the water and sanitation problems to conduct an applied research is a good approach. However, in Addis Ababa an integrated study has not been done on the bacteriological quality of water from source to yard or tap and as well on hygiene and sanitation practices of the consumers. Therefore to seal the gap of information on water quality starting from treatment plant up to place of usage and to assess the hygiene and sanitation practices of the community in the Mercato area this study was conducted.

1.3 OBJECTIVE OF THE STUDY

1.3.1 GENERAL OBJECTIVE

The general objective of this study was to contribute data for preparation of drinking water quality assessment database for Addis city sub-city especially for Wereda 1 and Wereda 8.

1.3.2 SPECIFIC OBJECTIVES

- To assess water handling practice and sanitary condition;
- To asses, knowledge, attitude and practice of the community towards water quality at their tap
- To assess the status of drinking water quality and its health impacts,
- To forward best management options if quality deterioration is noticed

CHAPTER TWO

2. LITERATURE REVIEW

2.1 WATER QUALITY AND ITS ASSOCIATED RISKS

Drinking water starts its journey within catchments, and is subsequently purified at treatment plants and delivered through distribution systems. Before deliver to distribution system it must meet the highest quality standards. To meet these quality standards, subsequent treatment processes must be done at place of treatment (Solomon, 2011). Drinking water quality has a strong impact on people's health because water is a vehicle for many pathogenic microorganisms and physico- chemical agents that cause waterborne diseases (Haworth, 1996).

2.1.1 WATER QUALITY

Water quality is a technical term that is based upon the characteristics of water in relation to guideline values of what is suitable for human consumption and for all usual domestic purposes, including personal hygiene. Components of water quality include microbial or biological, chemical, and physical aspects (EPA, 1999).

2.1.1.1 MICROBIAL (BACTERIOLOGICAL) WATER QUALITY

The presence of certain microorganisms in water is used as an indicator of possible contamination and an index of water quality (Hurst *et al*., 2002). Indicator organisms are selected to demonstrate the presence of human and animal wastes and hence the potential presence of pathogens in drinking water. Indicator organisms are usually of intestinal origin from humans and animals (Hurst *et al*., 2002; Brian, 2002; Mombal, *et al.,* 2006).

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 (ADWG, 1996; APHA, 1998; US EPA, 2012; WHO, 2008).

- **Total Coliform**: - Total coliform (TC) bacteria comprise many members of the family Entero-bacteraceae. TC bacteria are those that can grow in selective media at 35°C and ferment lactose or possess a B-galactosidase enzyme, as an indicator of fecal contamination. they are not useful as an index of fecal pathogens, but they can be used as an indicator of treatment effectiveness and to assess the cleanliness and integrity of distribution systems and the potential presence of biofilms (WHO, 2008).On the one hand, the Total Coliform group of bacteria is unreliable indicators of fecal contamination because many members are capable of growth and long term persistence (having a non-fecal origin) in many environments, including water distribution systems. On the other hand, there are more TC bacteria in untreated fecal waste than any of the other fecal indicators or indicator groups, making the TC test the most sensitive of all indicator tests. Because of this sensitivity, the TCR (total coliform rule) relies on the TC bacteria test as the initial test to detect the possible presence of fecal contamination in delivered water, as well as to assess water treatment effectiveness and the integrity of the distribution system. Distribution system. Water from a distribution system that is free of TC bacteria should have no or minimal levels of pathogens.

- **Fecal Coliform**: - Under the TCR, if the TC test result is positive, that sample is then further tested for the presence of fecal coliform (FC) bacteria. Since it is difficult to monitor disease carrying microorganisms directly we use the count of FC bacteria as a standard measure and indicator of disease potential. The presence of FC bacteria in water indicates that fecal material from mammals or birds is present, so organisms that cause water born diseases may be present as well. The FC group of organisms is a subset of the TC group that can grow in selective media at 44.5°C and ferment lactose, majority of FC bacteria are E. coli (UNICF, 2011).
- **Enterococcus**: - Enterococci are facultative organisms, *i.e.*, they are capable of cellular respiration in both oxygen-rich and oxygen-poor environments. Though they are not capable of forming spores, enterococci are tolerant of a wide range of environmental conditions: extreme temperature (10-45°C), pH (4.5-10.0) and high sodium chloride concentrations (Pelletier, 1996).

2.1.1.2 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 investigation are discussed hereinafter.

- **Turbidity*:*** - the optical property of a water sample that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample. In simple terms, turbidity answers the question, how cloudy is the water? Moreover Light's ability to pass through water depends on how much suspended material is present. Turbidity may be caused when light is blocked by large amounts of silt, microorganisms, plant fibers, sawdust, wood ashes, chemicals and coal dust. Any substance that makes water cloudy will cause turbidity. Additionally, the most frequent causes of turbidity in lakes and rivers are plankton and soil erosion from logging, mining, and dredging operations (EPA, 1999).

Electronic turbid-meter, a device that used for the most accurate way of determining water's turbidity, has a light source and a photoelectric cell that accurately measures the light scattered by suspended particles in a water sample. The results are then reported in units called Nephelo-metric Turbidity Units or NTUs. (Bartram, 2000)

Color:-color is derived from the backscatter of light passing through the water, and is influenced by the dissolved or suspended constituents in the water. Color can be the result of natural factors (e.g., dissolution of iron from iron-rich minerals, and dissolved humic materials) or factors that result from human-based activities such as effluent discharge from industrial activities. The source of the color may influence the toxic effects of other contaminants.

- **Taste and Odor**:-Taste and odor problems in source waters are primarily an aesthetic concern; however, they can undermine consumer confidence in water supplies, and result in millions of dollars annually in treatment costs to the water industry.
- **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 (Atnaf, 2006**).**). Temperature also affects the concentration of dissolved oxygen and can influence the activity of bacteria in a water bodies (Olson, 2004).
- **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) in order to check the concentration of nitrate it can be measured at Point of entry, Reservoir inlets/outlets the end of distribution network (tap).

- **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.
- **PH**:-The balance of positive hydrogen ions (H+) and negative hydroxide ions (OH-) in water determines how acidic or basic the water is. Notice the ' + ' and ' - ' in the chemical symbols above they indicate that these chemical forms are 'ions' they have a positive or negative electrical charge. This means the molecule in question is either missing an electron or has an extra electron. Since electrons have a negative charge, an extra one in the OH molecule makes it OH-, and a missing one in the H molecule gives it a "missing-minus" charge in other words, positive and makes it H+. When analysts measure pH, they are determining the balance between these ions. The pH scale ranges from 0 (high concentration of positive hydrogen ions, strongly acidic) to 14 (high concentration of negative hydroxide ions, strongly basic). In pure water, the concentration of positive hydrogen ions is in equilibrium with the concentration of negative hydroxide ions, and the pH measures exactly 7 (Gaur, 2008).
- **Ammonia** Pure ammonia is a strong-smelling, colorless gas. It is manufactured from nitrogen and hydrogen or is produced from coal gas. In nature, ammonia is formed by the action of bacteria on proteins and urea. Ammonia makes a powerful cleaning agent when mixed with water. For this reason, it is one of the most common industrial and household chemical. The formula for ammonia, NH3, means it consists of one atom of nitrogen and three atoms of hydrogen. Ammonia is rich in nitrogen so it makes an excellent fertilizer. In fact, ammonium salts are a major source of nitrogen for fertilizers. Like nitrates, ammonia may speed the process of eutrophication in waterways (Edzwald, 2001). In the presence of certain dissolved constituents in water, each of the disinfectants may react and transform to less biocide chemical forms. In the case of chlorine, these principally involve reactions with ammonia. This typically occurs in drinking water treatment when ammonia is embraced in the water system along with, immediately before, or after the addition of chlorine or hypochlorite. In the presence of ammonia nitrogen ion, free chlorine reacts in a stepwise

manner to form chloramines, Ammonia concentration is measured at Point of entry, Reservoir inlets/outlets the end result is important to develop baseline data for prediction of the onset of nitrification. Degradation of nitrogenous organic matter, industrial and municipal waste discharges are typical sources of ammonia (Rasheed, 1999).

2.1.2 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). For this work WHO and Ethiopian guidelines values for drinking water are presented in Table 2.1

Table 2.1 WHO and Ethiopian guide line values of drinking water

Number	Parameter	WHO (1993) standard	Ethiopian (1998) standard
1	pH	6.5-8	6.5-8
2	Turbidity(NTU)	<5 at disinfection point	<5
3	Free chlorine residual(mg/L)	0.2-0.5 at distribution point	0.1-0.2
4	Fecal coliform(CFU/100mL)	0	0
5	Total coliform (CFU/100mL)	-	0
6	Nitrate (mg/L)	0.5	0.5
7	Ammonia (mg/L)	-	0.5

Source http://www.lenntech.com

2.1.3 HEALTH RISKS ASSOCIATED WITH WATER

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

Usage of quality deteriorated water may be a cause for the existence of water born, water washed water based and water related diseases. The term water associated disease is used to describe all infections whose causing agents are carried by water (OECD, 2005).These are cholera, bacillary dysentery, Escherichia Coli(E.coli), viral hepatitis A, shigellosis, typhoid fever, cryptosporidiasis, giardiasis(WHO,2001). Generally, waterborne disease outbreaks usually involve, source contamination and the breakdown of the treatment systems, contamination of the distribution systems and the use of untreated water (WHO, 2004).

Water-associated disease can be defined as a disease in relation to water supply and sanitation. There are four categories (Salvato, 2003) this are:-

1. Waterborne disease
2. Water-washed disease
3. Water-based disease
4. Water-related disease

1. Waterborne diseases

Several infections enteric or intestinal diseases of man are transmitted through water contamination by fecal matter.

Pathogens excreted in water by an infected person include all major categories such as bacteria, viruses, protozoa and parasitic warms. In this category water acts as a passive vehicle for the infectious agent. Some water born disease and their disease causing micro-organisms are presented in Table 2.2

Table 2.2 water born disease and their disease causing organism

Diseases	Disease causing organism	Species	Source
Typhoid	Salmonellae typhus	Bacteria	Human feces
Cholera	Vibrio-cholera	Bacteria	Human feces
Amoebic dysentery	Entamoeba-histolitica	protozoa	Human feces
Giardiasis	Giardia-lamblia	protozoa	Human or animal feces

2. Water-washed diseases

These comprise diseases linked to a lack of water for personal hygiene. Example is presented in Table 2.3

3. Water-based diseases

These are diseases caused by infectious agents that are spread by contact with water. The essential part of the life cycle of the infecting agent takes place from an aquatic animal. Example is presented in Table 2.3

4. Water-related diseases

These are diseases transmitted by insects that live close to water. Example is presented in Table 2.3

Table 2.3 water associated disease

Water associated disease	Example
Water born	Typhoid, cholera, Amoebic dysentery
Water washed	Trachoma, scabies
Water based	Schistosomia, Guinea worms
Water related	Mosquito(malaria), tests fly(sleeping sickness)

2.1.4 LINK BETWEEN DISEASE AND ENVIRONMENT

Unlike genetic diseases, which individuals are predisposed to, acquiring water, sanitation and hygiene related diseases are controllable and preventable. The spread of these diseases depends on environmental conditions and behavior in the household and community.

The majority of these preventive measures are related to environmental conditions: appropriate shelter and site planning, clean water, good sanitation, vector control, personal protection (such as insecticide-treated nets), personal hygiene and health promotion. These measures address conditions in the environment, known as 'risk factors' because they can cause disease. It is important to understand the relationship between disease and environmental risk factors because interventions must target risk factors properly. The summery is presented in Table 2.4.

Table 2.4 overview of diseases and environmental risk factors

Disease	**Symptoms**	**Environmental risk factors**	**Health hazards**
Acute upper Respiratory tract infections	All symptoms of the common cold, fever and heavy coughing. Chest pain and pain between shoulder blades in pneumonia	Crowding, poor hygiene	Influenza and pneumonia may cause severe complications, especially in groups at risk
Diarrhea	Watery stools at least three times a day, with or without blood or slime. Might be accompanied by fever, nausea or vomiting	Contaminated drinking water or food, or poor sanitation	Dehydration, especially in children, shown by dark coloration of urine, dry tongue or leathery skin
Cholera	Modest fever, severe, but Liquid diarrhea (rice water stools),abdominal spasms,	As for diarrhea	As for diarrhea

	vomiting, rapid weight loss and dehydration, rapid deterioration of condition		
Meningococcal meningitis	Infected persons may show no symptoms for a considerable time. When an epidemic is in progress, headache, fever and general malaise will suggest the diagnosis, which must be confirmed by lumbar puncture	Crowding	Often fatal if untreated at an early stage; neurological problems in survivors
Shigella dysentery	Diarrhea with blood in the stools, fever, vomiting and abdominal cramps	Contaminated drinking water or food, or poor sanitation, poor hygiene	Case fatality rate may be High
Typhoid fever	Starts like malaria, sometimes with diarrhea, prolonged fever, occasionally with delirium	As for diarrhea, and contaminated Foods	Without appropriate medical care, including antibiotics and surgery, may lead to fatal complications in a few weeks
Measles	A disease of early childhood, characterized by fever and catarrhal symptoms, followed by maculopapular rash in mouth	Crowding, poor hygiene Very contagious	Severe constitutional symptoms, high case fatality rate
Viral hepatitis	Nausea, slight fever,	Poor hygiene,	Long-term disabling

A	palecoloured stools, dark colored urine, jaundiced eye whites and skin after several days	contaminated foods and water	Effects
Diphtheria	Inflamed and painful throat, coughing	Crowding, poor hygiene	A secretion is deposited in the respiratory tract, which can lead to asphyxiation

Source: - Public Health Guide for Emergencies, 2000

2.1.5 HEALTH EFFECTS OF DRINKING WATER CONTAMINANTS IN THE STUDY AREA

Chemicals in drinking water which are toxic may cause either acute or chronic health effects. An acute effect usually occurs almost immediately and it is easy to obtain the source as well as the possible solution. Ten top diseases occurred in 2003 Ethiopian working calendar are presented in Table 2.5.

Table 2.5, 10 top diseases in the sub-city

Number	Disease	Number of peoples		
		Male	Female	summation
1	Acute upper Respiratory tract infections	15,944	21,480	37,424
2	Typhoid	5,968	8,652	14,620
3	Diarrhea	5,620	4,892	10,512
4	Urinary system disorder	2,976	6,560	9,536
5	Diaspesiya	3,276	5,912	9,188
6	Trickia disorder	4,284	4,492	8,776
7	Skin disorder	2,900	3,720	6,620
8	Helimintisiyas	1,876	2,184	4,060

9	Trauma	2,088	1,444	3,532
10	Attitus	1,320	1,452	2,772

Source: - Sub-city Health Office report, 2003

The following five elements are vital on the water supply service if health is to be improved & maintained: - (*National environmental service center, 2011)*

- **Quantity:** Enough water for everyone to drink, cook & bath, e.g. 30-100 liters/person/day
- **Quality:** The water will not cause disease in those who drink or use it
- **Cost:** The cost of sufficient water for basic needs is within everyone's reach
- **Coverage:** Water must be available to everyone in the community.
- **Continuity:** Water is available all day, every day

2.2 DISTRIBUTION SYSTEM WATER QUALITY DETERIORATION FACTORS

A distribution system's pipes and storage facilities constitute a complex network of uncontrolled physical, chemical, and biological reactions that can produce significant variations in water quality. The principal factors that affect water quality during distribution are the system's structure, its operation, and a number of water quality factors (Lahlou, 2002).

- **Structural Factors**

Drinking water distribution systems are typically thought of as the underground network of interconnecting mains or pipes. This mainly includes oversized pipelines and storage facilities and interconnection of drinking water pipes with sewer line. By considering an area's future drinking water needs. Oversized facilities result in long detention times, loss of chlorine residual, taste and odor concerns, and other water quality problems. Furthermore, some of the material designers choose to install water infrastructures that create suitable environments for microorganism growth. Materials, such as cast or ductile iron, asbestos cement, or pressurized concrete, can pit and make way for microorganisms to colonize. In addition, oxidant-resistant microorganisms settle on pipe surfaces and produce a complex microenvironment known as biofilm. Biofilm form when organisms enter the distribution system and become entrapped in slow-flow areas, line obstructions, or dead-end sections. They usually appear as a patchy mass in pipe sections or as a uniform layer along the inner walls of a storage tank. And interconnection with sewer line results in water quality deterioration in cases when available space is not given between drinking water pipes with sewers.

In addition Pipe materials can cause water quality to deteriorate through pipe corrosion and reaction with water. For example, unlined or exposed ferrous materials in pipelines can corrode and cause red or rusty-colored water. Now-a-days to avoid corrosion problems, systems are turning to plastic materials, such as polyethylene and polyvinyl chloride (PVC).

- **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 and water pressure greatly affect water quality. The pressure of water along the distribution system may result breaks of water pipes along the distribution network which affect the quality of drinking water by soaking of any objectionable matter from the surrounding in cases where there is no water supply. 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. 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.

- **Water Quality Factors**

Some of the factors that provide optimal conditions for microorganisms to multiply include long water-detention times in tanks and pipes, adequate nutrient levels, and warm temperatures. In addition, research has shown that the level of biodegradable organic matter in the distribution system strongly affects bacterial re-growth and harbors opportunistic pathogens. An opportunistic pathogen can be any disease-causing organism, bacterium, virus, helminthes, or protozoan that slips through the treatment processes or enters the distribution system during pressure loss and finds the opportunity or favorable circumstances to lodge or reproduce in organic material, bacterial slime, or other material that it finds attractive. A number of other conditions also can affect water quality. For example, disinfectants may react with organic and inorganic compounds and cause taste and odor problems or form disinfection by-products. Also, particulate re-suspension may cause increased turbidity, (*National environmental service center, 2011*).

Diagnostic contamination risk in water distribution systems is a difficult task due to the following:-

- ✓ Water distribution system may comprise (depending on the size of the water utility) thousands of kilometers of pipes of different ages and materials;
- ✓ Operational and environmental conditions under which these pipes function, may vary significantly depending on the location of the pipes within the system;
- ✓ Since the pipes are not visible, it is relatively difficult and expensive to collect data on their performance and deterioration, and therefore indeed little field data are available;
- ✓ Some factors and processes affecting pipe performance are not completely understood; and
- ✓ It is often difficult to determine or validate an exact cause for water contamination or waterborne disease outbreak because such episodes are often investigated after the occurrence has ended. For these reasons, high uncertainties are inherent in any risk measure that may be assigned to the distribution system (National research council, 2012).

The deterioration of drinking water distribution infrastructure is among the main causes for the loss of quality and quantity of drinking water at the consumers tap. However, since a major portion of the distribution infrastructure is underground, its deterioration does not present the same visual urgency as other visible infrastructure. Since deterioration of the distribution infrastructure adversely impacts the water quality, public water systems cannot justify the costs and efforts of treating water to potable levels and then transmitting them through deteriorating distribution systems. (twort, Ratnayaka & Brandit, 2006)

The quality of drinking water may be controlled through a combination of:-

- Protecting of water sources
- Controlling of treatment processes
- Management of transmission and distribution systems and
- Handling of water at household level

2.3 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 potability 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. The word sanitation also refers to the maintenance of hygienic conditions, through services such as garbage collection and wastewater disposal. For this study the term "sanitation" comprises only the following basic concepts:

- **Basic sanitation** - refers to the management of human feces at the household level. The combination of human feces and urine can be termed as Excreta which is the principal vehicle for the transmission and spread of a wide range of communicable diseases. Some of these diseases rank among the chief causes of sickness and death in societies where poverty and malnutrition are ubiquitous. Diarrheas, for instance, are together with malnutrition, respiratory disease and endemic malaria-the main causes of death among small children and infants in developing countries. Cholera, whether endemic or epidemic in form, is accompanied by numerous deaths in all age groups-although under endemic conditions, it is children who suffer the most fatalities. These diseases, and the many others, start their journey from an infected individual to a new victim when the causative agent is passed in the excreta. Therefore the collection, transport, treatment, and disposal of human excreta are of the utmost importance in the protection of the health of any community. Feces not only are malodorous and considered esthetically offensive in most societies, but they may contain an array of pathogenic viruses, bacteria, cysts of protozoa, and eggs of helminthes (the collective term for worms parasitic to man) that may cause disease in a new host. Feces are therefore the beginning of the transmission routes of the diseases, so the objective of improving excreta disposal facilities is to intercept these routes at their point of origin. (Richard, 1983)
- **Environmental sanitation** - Activities aimed at improving or maintaining the standards of basic environmental conditions affecting the well-being of people. These conditions include clean and safe water supply, clean and safe ambient air, efficient and safe animal, human, and industrial waste disposal, protection of food from biological and chemical contaminants, and adequate housing in clean and safe surroundings. As shown in fig 2.1the real situation may contribute to the Control of environmental factors that forms link in disease transmission. Subsets of this category

are solid waste management, water and wastewater treatment, industrial waste treatment and noise and pollution control.

Fig 2.1 unsanitary disposal of solid waste to the Environment

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 STUDY DESIGN

Both Descriptive and Experimental study designs were applied for the completion of the study. Descriptive study design was 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 used for assessing physicochemical and bacteriological quality of drinking water at sources, reservoirs and consumers tap. The sanitary conditions of the study area were assessed using questionnaire. The survey questionnaire were adopted from WHO 1996 and modified to the objectives of the study. The study was conducted in Mercato area, from January 1st 2012-mid of June 2012.

3.2 DESCRIPTION OF THE STUDY AREA

Addis Ababa, the capital city of Ethiopia has ten sub-cities. Addis city sub-city is one of them which consist of 10 Weredas. Among this the study focuses only on two Weredas, Wereda 1 & Wereda 8, which embraces a total of 9,434 residential units according to CSA, 2010. Number of residents, number of shops and number of Verenda and Medebe found in each Wereda is presented in Table 3.1.

There are two reservoirs that supply water to the community; which receive their water from Geffersa water treatment plant. But due to economic insufficiency most of the people in the study area are using basic services like drinking water tap and toilet in shared. So the area can be considered as slum settlement with poor coverage of basic environmental services. Map of the study area is presented in Fig 3.1.

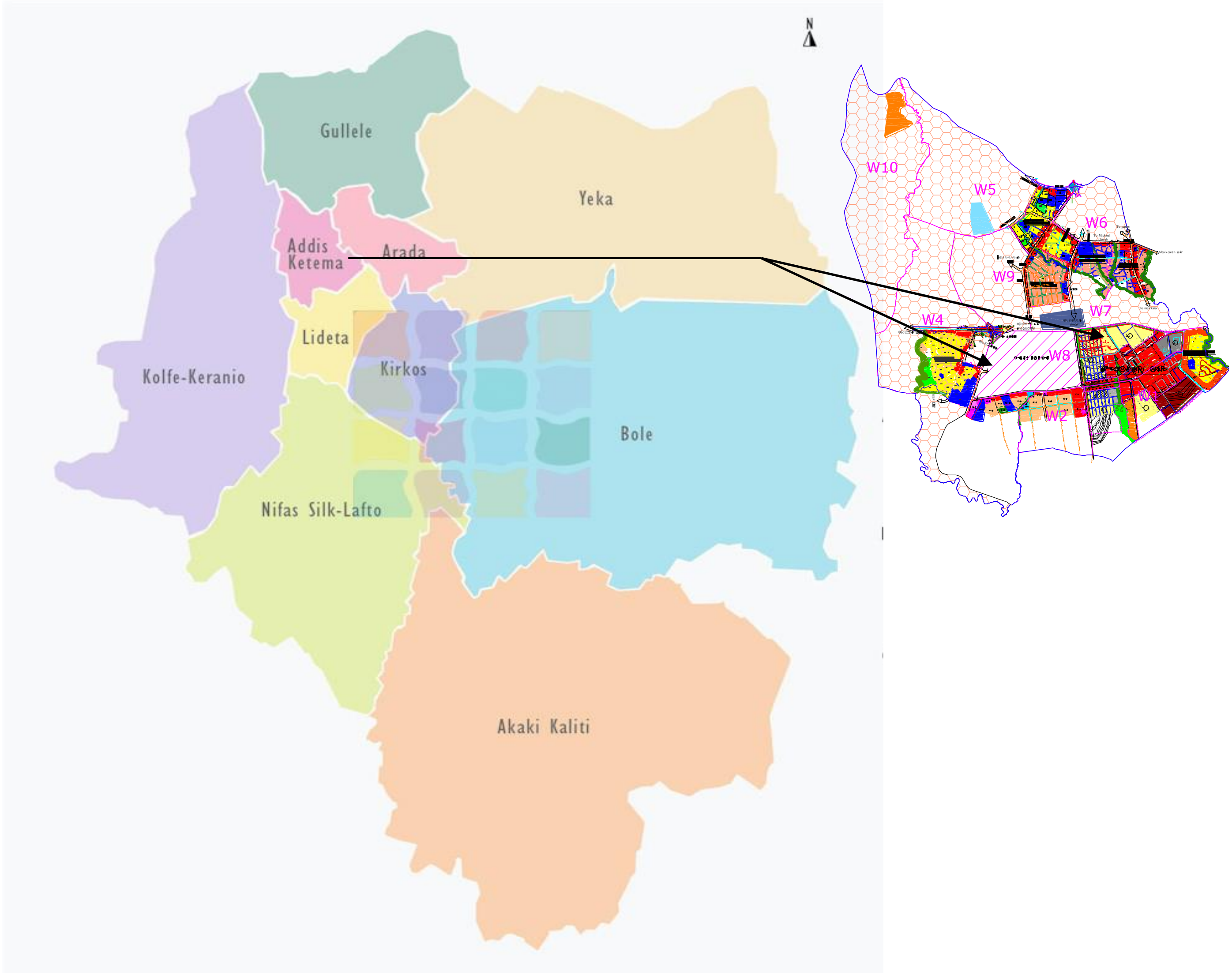


Fig 3.1: map of the study area

Source: Addis city sub-city Administration

Table3.1 Area coverage of Addis city Sub-city with its detail

Wereda	Area(ha)	Number of residential units	Number of shops	No.of "Verenda and medebe"
Wereda1	77	5028	4657	1112
Wereda2	38	3297	209	0
Wereda3	89	2698	142	1
Wereda4	120	1511	349	282
Wereda5	127	1269	153	0
Wereda6	62	3245	207	52
Wereda7	49	2973	501	1
Wereda8	100	4406	3883	201
Wereda9	78	3286	342	0
Wereda10	125	611	10976	1890

Source: Addis city sub-city, 2003

3.3 MATERIALS

3.3.1 SOURCE OF DATA

Primary data was obtained from field observation, checklists, questionnaires and laboratory results. Water sample was taken at selected sampling site for microbiological and physico-chemical water quality analysis. Water sample collected was analyzed for different parameters at Addis Ababa Water and Sewage Authority central laboratory. After checking parameters which indicate quality status of drinking water it was compared to the Ethiopian and WHO guideline values. Secondary data were collected from published and unpublished literatures and from the sub-city reports.

3.3.2 EQUIPMENTS USED

AAWSA laboratory was used for aesthetic and chemical contents analysis; quantitative spectrophotometer techniques, comparator or colorimeter method and pH meter were used for chemical water quality inspection. Microbiological analysis was also undertaken in the same laboratory, using validated 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, Distiled water, Incuabation machine, Sterilization machine, Referagarator, Spectrometer, pH meter, Pipet were used when microbiological and physico-chemical water quality analysis were done.

3.4 METHODS

3.4.1 DATA COLLECTION

3.4.1.1 DATA COLLECTION TECHNIQUES

In order to achieve the objectives of this study a comprehensive literature review was collected from published and unpublished sources and the community knowledge, attitude and practice (KAP) was assessed through questionnaire and informal discussion by enrolling ten data collectors. Five were volunteers and the reaming were data collectors which were paid 40 birr per day. Additionally, Household head means the person who plays the main role in the decision-making process of a family were selected to answer the questionnaire and in absence of the household head, the second-important adult member of the family was selected. In doing so, the study objectives were clearly explained to the households and each household was assured that the information provided would be kept confidential. Beside this, Information was also collected through photographic observation.

In addition laboratory analysis of water samples were done to characterize the quality of drinking water in the study area.

3.4.1.2 FIELD OBSERVATION AND SANITARY SURVEY

Primarily field observation and sanitary survey was done from 1st February up to 1st March through observation using checklists. A checklist having 9 questions was prepared for assessing the sanitary services, handling system of wastes, placement of drinking water pipes in relation with solid and liquid waste and other basic environmental condition on the study area. With the help of results gained from the checklists the study dwellings were grouped in to two. This are

- ✓**Most vurnuable for contamination:-** for this study those dwellings having more than or equal to 5 negative answers from the checklist,
- ✓**Less vurnuable for contamination:-** if less than or equal to 4 negative answers were recorded from the checklist.

The total number of household units that are catagorized under each group is presented in Table 3.2

Table 3.2 household categorization for each wereda

Level of vulnerability	Number of household	
	Wereda 1	Wereda 8
Most vulnerable	3429	3005
Less vulnerable	1599	1401

3.4.1.3 SAMPLE SIZE DETERMINATION FOR ASSESSMENT OF KAP

Total number of residence in the two Wereda's was 9434; from this total population sample population was determined by using the following statistical formula (CochranWG, 1977).

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

n (i) ………………sample household

N…………………….…total number of house hold

P……………………………… proportion (50%)

Q…………………………………1-P

Z……………………..95%confidence interval (1.96)

W……………………………………..5%

$$\mathbf{n\,(i) = \frac{9434*1.96^2*0.5*0.5}{0.05^2*(9434-1) + 1.96^2*0.5*0.5} = 370\ household}$$

Since people Knowledge, Attitude and Expectation are different the total number of sample household was used to fill the questionnaires. By using proportion a total of 197 household units from Woreda 1 and total of 173 household sampling points from Woreda 8 were used. After sorting house-number in ascending order the first house were selected by lottery means and the next were elected by interval of 25. This work was started at mid March and end up at mid April. During this 20 household units were covered within one day.

3.4.1.4 SAMPLE SELECTION FOR WATER QUALITY ANALYSIS

For water quality analysis from a total sample 5% was taken as a representative sample. As the basic assumption that Water quality may not vary at a nearby distance (WHO, 1999).

Sample size =5%*370residences=18.5

From this total of 19 household sampling points were used for water quality assessment. Additionally water sample from the nearby reservoirs represented by sampling code of R_1 and R_2 were taken. So total of 21 sampling points were selected then laboratory analysis was done in triplicates. The summerized number of samples used for questionnare and laboratory water quaity analysis is shown in Table 3.3.

Table 3.3: sampling code to each wereda

Wereda	Group	No.of H.H for laboratory work	Sampling code	No.of H.H for questionnare
1	Total	10	Pt_1-pt_{10}	197
	Most vulnurable	7	Pt_1-pt_7	134
	Less vulnurable	3	Pt_8-pt_{10}	63
8	Total	9	Pt_{11}-pt_{19}	173
	Most vulnurable	6	Pt_{11}-pt_{16}	118
	Less vulnurable	3	Pt_{17}-pt_{19}	55
Reservoir		2	R_1 and R_2	

All the nessary procedures, questionaries and checklist used for this categoraization are attached on the annex part (Annex1 and Annex 2).

the number of household used for laboratory and questionare for each wereda as shown in table 3.2 was determined by proportion. And the first sampling point were taken by lottery means but the rest were taken with mechanism similar to questionnary survey.

3.4.2 SAMPLE HANDLING AND REAGENTS USED

3.4.2.1 REAGENTS USED

For microbiological water quality assessment (total and feacal coliform) the following reagents were used for each consecuitive stages

- ✓ Lactose broth,used for analysis of total coliform at the presumptive stage
- ✓ BGB(Brilliant green bile) used for fecal coliform analysis at conformative stage and

Fig3.2 A) Lactose broth used for total coliform count B) BGB fecal coliform count

For physico chemical water quality determination the following reagents were used

- ✓ Nitrate and nitrite reagent for determination of nitrate concentration
- ✓ Nessler was used for determination of ammonia
- ✓ DPD(Diethyl-Phenylene-Diamine) for determination of free residual chlorine

3.4.2.2 SAMPLING TIME, STORAGE AND TRANSPORTATION

Water samples were collected starting from mid April up to first of May, during morining hours. Residual chlorine analysis were taken at time of sampling by taking water sample directly from tap to the sampling tubes in the comparator.For other parameters, water samples were collected by using water sampling kit from AAWSA for microbiological parameters and using plastic bottles for physico-chemical water quality analysis. The collected samples were made to reach to laboratory within less than 8 hours.Following the procedure in Fig.3.5 micrbiological water analysis were done.

3.4.3 LABORATORY ANALYSIS PROCEDURES FOR BIOLOGICAL PARAMETERS

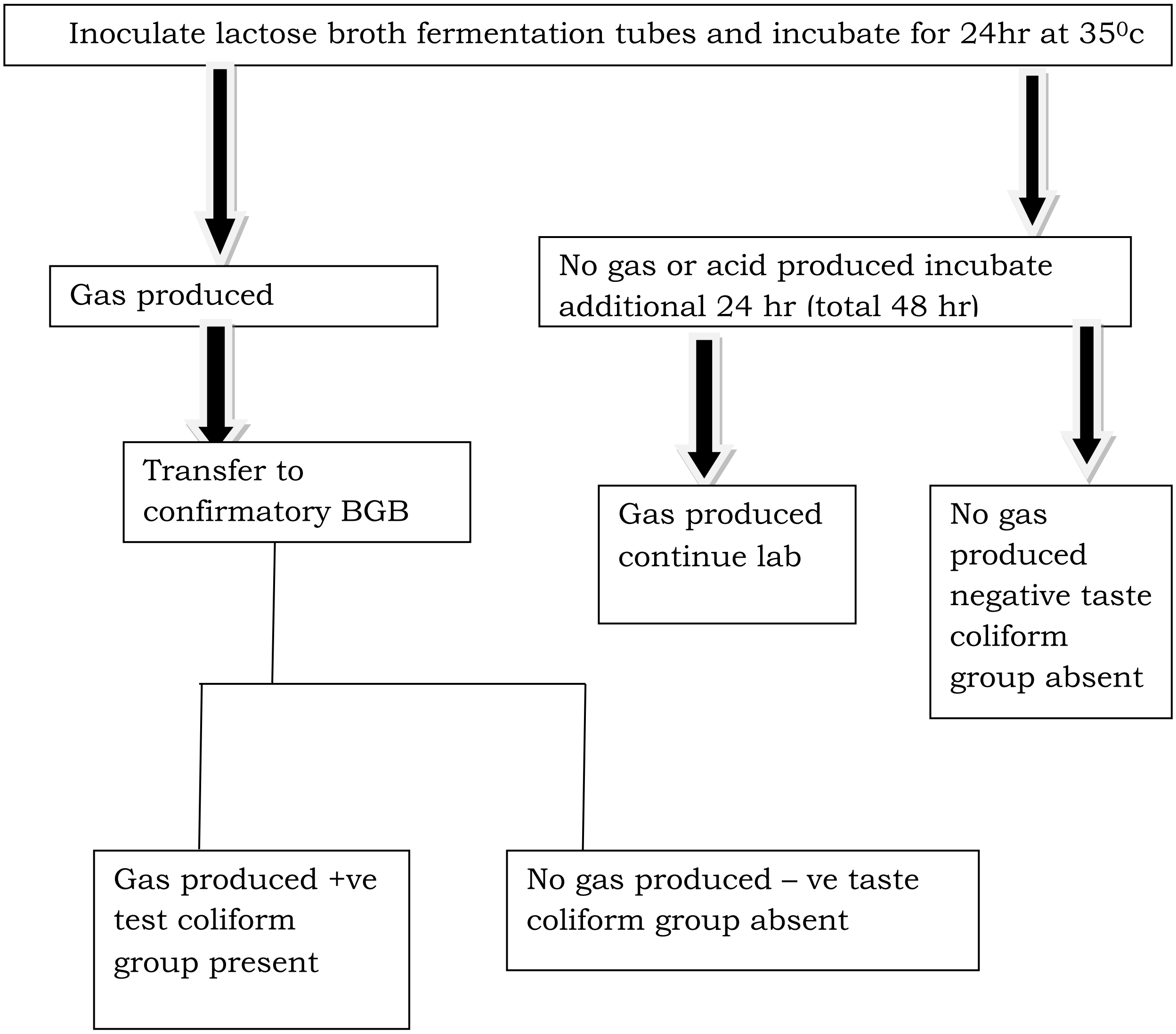


Fig3.3 sample analysis procedure for determination of total and fecal coliform

positive tubes are identified by simple observation of taste tubes that means if there are microorganisms they eat the food for their growth and release carbondioxide (Co_2) gas, this can be easly seen by observing the diurnal tube and as well dark light color is observed.

3.4.4 STATISTICAL DATA ANALYSIS

After collecting all necessary data concerning each study parameters and environmental conditions from checklist, laboratory and observation results were summarized by Microsoft Excel and analyses of variance (ANOVA) at 95% confidence level were used to determine the significance differences by using JMP programme version5.

3.4.5 HEALTH IMPACT ASSESSMENT

Based on the criteria shown in Table 3.4 impact assessment was done.

Table 3.4 criteria used for Appraisal of health impacts **(**Espinoza, 2002)

Character (C)	Negative (-1)	Neutral (0)	Positive(1)
Significance (S)	High (3)	Medium (2)	Low(1)
Disturbance(D)	Important$^{(3)}$	Regular$^{(2)}$	limited$^{(1)}$
Occurrence(O)	Very probable$^{(3)}$	probable$^{(2)}$	unlikely$^{(1)}$
Extension(E)	regional$^{(3)}$	local$^{(2)}$	specific$^{(1)}$
Duration(D)	permanent$^{(3)}$	Medium-term$^{(2)}$	Short-term$^{(1)}$
Reversibility(R)	Irreversible$^{(3)}$	Partial$^{(2)}$	Reversible$^{(1)}$
Total	18	12	6

Positive character: - that represent environmental benefits

Negative character: - that causes harm or deterioration to a component

Disturbance: - refers to change in average environmental condition that causes a pronounced change in an eco-system. This characteristic can be classified as important, regular and limited.

Occurrence: - This shows the probability of happening and can be classified as very probable, probable and unlikely probable.

Extension: - Refers to area of influence it may be regional, local or specific.

Duration: - which refers to the behavior of predicted environmental impacts in time either permanent, medium term or short term.

Reversibility: - the possibility difficulty or impossibility of returning to the situation prior to the action or project. So based on this impact may be Irreversible, Partially reversible or Reversible.

Reversible: - if human assistance is not required, partially reversible:-if human assistance is required and Irreversible: - if a new environmental condition needs to be created.

Significance: - is the superiority of the affected environment, and was determined with the help of Table 3.5.

Table 3.5 Appraisal of impact significance

Extension	Specific	1
	Partial	2
	Extensive	3
Time of occurrence	Immediate	3
	Medium-term	2
	Long-term	1
Persistence	Temporary	1
	Permanent	3
Reversibility	Impossible	4
	Long-term	3
	Medium-term	2
	Short-term	1

High……………………………………….≥ 9

Medium………………………………….. 5- 8

Low………………………………………..≤ 4

Based on this environmental risk is done by the following categorization

Total impact=C* (S+D+O+E+D+R)

Negative (-)

Sever………………………………….≥ (-) 15

Moderate……………………………… (+) 9- (+) 15

Compatible……………………………≤ (+) 9

Positive (+)

High……………………………………≥ (+) 15

Medium……………………………… (+) 9- (+) 15

Low…………………………………≤ (+) 9

Based on the above described procedure the impact of using this water for consumption purpose on the community health was assessed.

CHAPTER FOUR

4. RESULTS AND DISCISSION

4.1SANITARY INSPECTION

Results of sanitary inspection on the water source or Geffersa water treatment plant and on the study area presented under:-

4.1.1 GEFFERSA WATER TREATMENT PLANT

The study areas receive its water from Geffersa, so this discussion gives attention only to Geffersa water treatment and supply system. Its schematic representation is presented in Fig 4.1. Even though detailed survey were under taken from the reservoirs up to place of consumption or up to consumers tap for this study rough observation of treatment plant was also made. Potential sources of pollutants such as agricultural and floricultural runoff, animal husbandry, etc exists in close proximity from the treatment plant. Due to this, the under listed activities were planned to be accomplished by AAWSA:-

- Source water protection is the first phase to ensure safe drinking water. Many of the pollutants that enter the drinking water system are removed through municipal water treatment plants, addressing the source of pollution through source water protection is both safer and less expensive than treating raw water (Ontario 2009).
- Control of treatment plant by running pre-chlorination, coagulation and sludge blanket flocculation by using Alum, clarification, gravitational sand filtration, post-chlorinating, final pH adjustment by adding Lime. And
- Management of distribution systems which primarily involves maintaining water quality, and minimizing the risk of contamination and deterioration of quality during transport. But this activity was not given attention as the above mentioned ones.

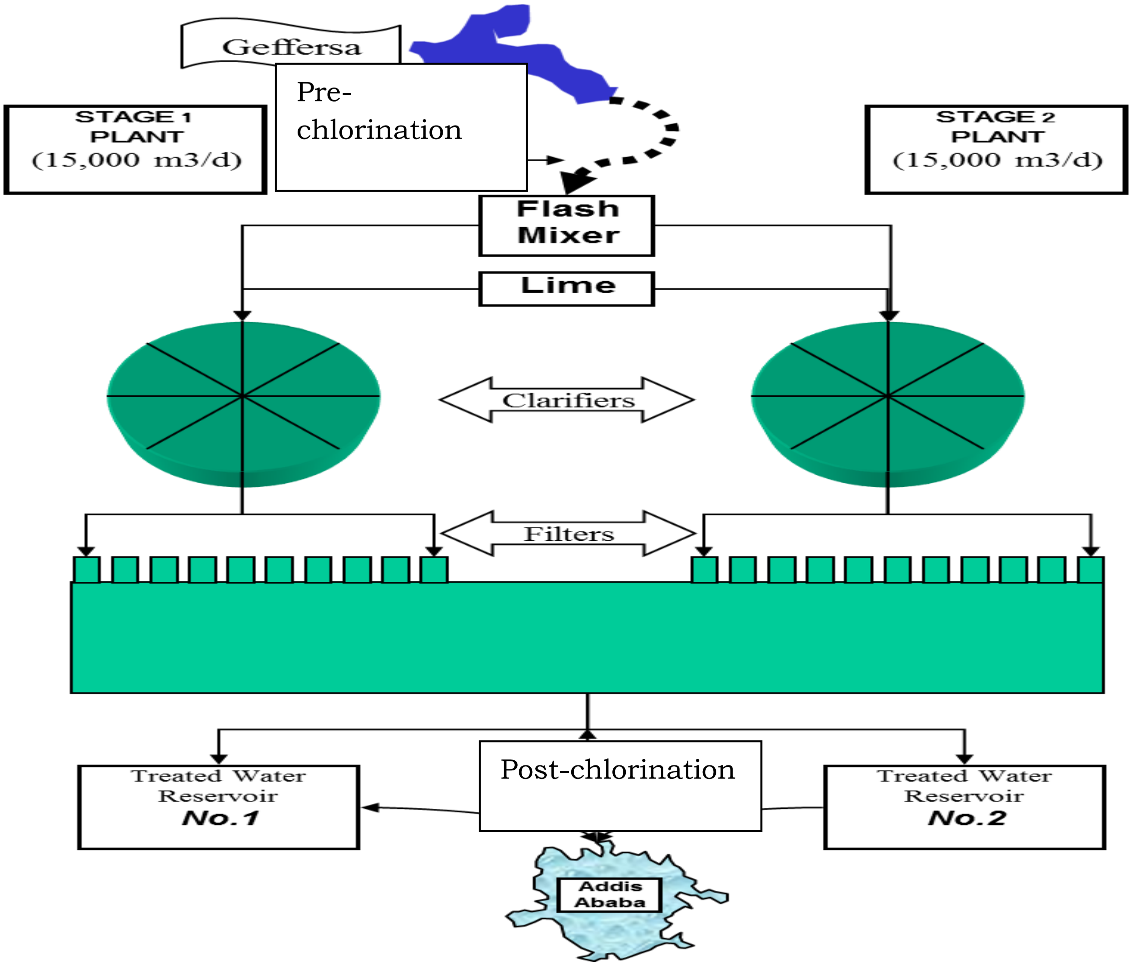


Fig. 4.1Geffersa water treatment plant scheme

Source: - AAWSA, 2002

4.1.2 STUDY AREA

4.1.2.1 BASIC SANITATION

From the sanitary survey on the status of Latrine of the community the following results were gained.

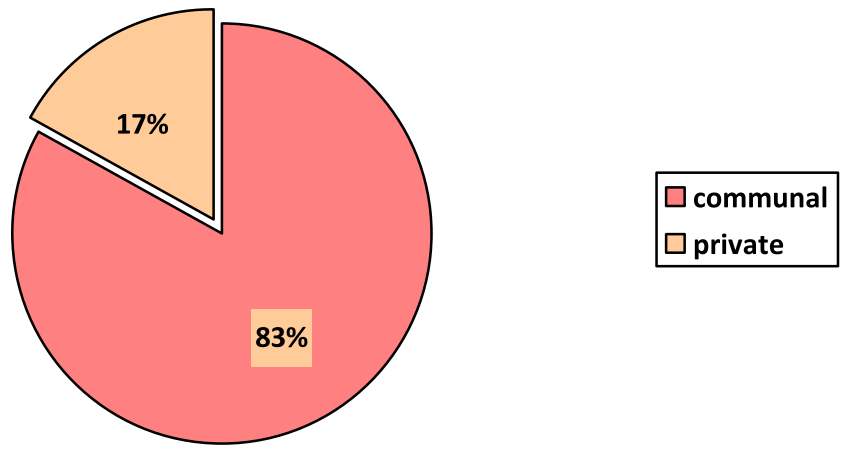


Fig 4.2 existing condition of latrine in the sub-city

The two most important requirements for infrastructure implementation are income and space. But as realize from the people in this area they fail to satisfy these requirements. Based on the informal discussion with the community most of the people in Mercato were economically not stable and had no sufficient income. And also due to lack of space the people were forced to do their day to day activity in small space this crowded living style leads them not only to use communal toilets but also leads them to be infected by upper respiratory tract infection as presented in Table 2.4 and 2.5. In the mean time due to lack of ownership the community does not clean up them frequently as a result of this they were not pure and comfortable for the community. Because of this, people are forced to defecate outside of the latrine which may cause possible cross contamination of drinking water pipes. Concerning the technologies as described by Kebede *et.al* 2002, Drop-and-store excreta management (pit latrine) can prevent pollution in some places, but it is not often feasible in urban crowded communities because of lack of space. In contrary to this, the entire communal latrine and almost all of the private latrines in the study area are pit latrines which deviate from the above mentioned statement.

4.1.2.2. ENVIRONMENTAL SANITATION

Subsets of environmental sanitary conditions considered in this project work were solid and liquid waste generation and management practice of the community, liquid waste disposal trend, drinking water pipes in relation with solid and liquid wastes and leaks from drinking water pipes was assessed.

✓ **SOLID WASTE DISPOSAL SYSTEM**

From observation in the study area food waste, paper, rubbish, ashes and residues, special wastes such as street sweeping and roadside litters were the main solid wastes in the study area. As gained from checklist result 32% of household units have big sack (which serves as dustbin) at a selected place for solid waste storage inside their garden. At last private waste collectors collect the wastes, by moving home to home with the aid of handcart, and then they transport it to the point where solid waste collection trucks are located. But most of the people about 68% residents were dumping out the waste materials along the streets and on open spaces. Until now theses people do not practice waste removal through paying for private waste collectors this was due to their economic constraint and insufficient health promotion. Furthermore, based on the data from Addis city sub-city solid waste collection and removal sector (Table 4.1) and field observation (Fig 4.3). Even if people were disposing the solid waste at appropriate place it was not timely pulled out by waste removal sectors.

Table 4.1 solid waste generation and removal of Addis ketema sub-city

Year	**Total amount of solid waste generated (Kg)**	**Amount of solid waste removed (Kg)**
2000	129980	87600
2001	132673	99645
2002	135421	117895
Total	**398074**	**295140**

Source: Addis city sub-city solid waste collection and removal sector (2000-2002)

As pointed out in Table 4.2, on an average about 74% of the waste were removed from the total amount of waste generated in addition the public garbage cans stay for a long time after filled with waste. In such working condition people were discouraged to dispose the waste to these collection equipments because it generates unpleasant odor and leachate which damage the aesthetic condition of the area. As a result people prefer to dump the waste into drainage systems, on the straight and to an open area which has risk for health and may result environmental pollution.

Fig 4.3 solid waste disposal in the community: (a) improper waste handling at common storage points (b) damping of solid waste on the street

- ✓ **LIQUID WASTE DISPOSAL SYSTEM**

It was obvious to see improper management of Liquid waste in the study area like the Solid waste management system. Report from the sub-city indicates that 15.78% of the households have access to closed ditch sewer system, which does not have a chance to be filled by solid waste. Whereas 78.94% of the people have access to an open drainage system therefore, this lines were exposed to fill by stones and other solid wastes as shown in Fig 4.4. And the rest 5.26% of the houses do not have any access to sewer system. From the checklist result about 48% has no liquid waste drainage system. In most household units drainage lines were not observed and the people were discharging liquid wastes on the nearby place around their gate. These result occurrences of bad smell to the community and can cause diseases that will affect birthing system. And also in some places the drainage lines were not supported by proper inlet and outlet.

Fig 4.4 drainage lines crammed by stones and other solid wastes

- ✓ **DRINKING WATER PIPE IN RELATION WITH SOLID AND LIQUID WASTES**

From the total household assessed about 63% of household's drinking water pipes (including the communal ones) and sewage lines were not positioned at an appropriate distance. In addition to this about 40% of household drinking water pipe lines are getting in touch with solid and liquid wastes nearer to the faucet as shown in Fig 4.5. Furthermore, 72% of the resident's drinking water pipe is not lined in a safe and sound manner or it was not away from any potential source of pollution like kitchen, toilet, solid and liquid waste storage and disposal facilities. 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 indicate that the extent to which the community lives in a non-conduciveness environment or lives with potential hazards that can damage the health status of residents. For this, economic constraint, lack of space, low community enrolment, lack of awareness, low level attention of stake holders can be taken as responsible factors.

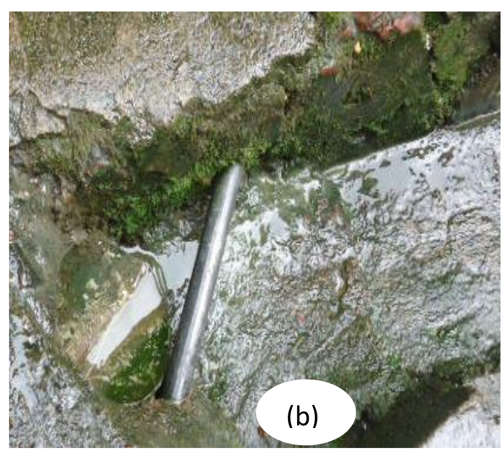


Fig4.5 a) contact of drinking water pipe with solid waste and b) contact of drinking water pipe with liquid wastes

- **DISCONTINUITY IN WATER SUPPLY AND LEAKS IN DISTRIBUTION SYSTEM**

In the study area about 85%of households were served by communal taps, this was due to their low income. As realized from the informal discussion with the communities which were served by these taps they were forced to fetch water at a specified time from morning 12-3 o'clock otherwise the tap will be closed. This results the per capital consumption of water by the community to become on average 15L and the people use the water they capture for special uses like drinking and preparing their meal. Due to this there was poor hygiene in the community that increases the spread of water washed diseases in the study area. In addition from checklist result at time of survey flow of water were continuous for about 32% of the household units only. So discontinuity of water supply was also the major problem. Since drinking water pipes are underground their fail does not get timely response. But about 87% of the pipes seen have frequent leakage problem as shown in Fig 4.6. This may be due to presence of old pipes, external load on the pipes and inappropriate instillation due to unqualified man power. As discussed above the taps were not sited at appropriate places from any potential source of pollutants and as well solid and liquid waste removal mechanisms were not as such motivating. Along with collection and disposal equipments were not located at an appropriate distance to the water supply system. So if there is a possibility of contact with these leaky pipes it may result water quality deterioration. That facilitates the creation of favorable environment for growth of pathogens.

Fig 4.6 leaky pipes on the study area

4.2 CONSUMERS KNOWLEDGE, ATTITUDE AND PRACTICE REGARDING TO WATER QUALITY

As shown in Fig 4.7 from the questionnaire distributed around 71.6% of the community does not expect that their tap water would be contaminated. This was due to their inadequate knowledge on water quality deterioration and absence of appropriate education from water and health sectors. Even though all of them have good understanding about waterborne diseases but they do not expect that it will occur in big cities like Addis Ababa rather it might be a problem in rural areas. Due to this the habit of using home treatment mechanisms was very low. In addition about 72% of the people transport the water fetch from tap with uncovered containers. This may increase the possibility for dusts and other contaminants to enter towards water container. And also 85% of the people have no separate water containers for storing drinking water in the house. These results in further quality deterioration of water as proved by the study done by Getnet in Bahir Dar that water stored inside the household had often a worse bacteriological quality than water from the source.

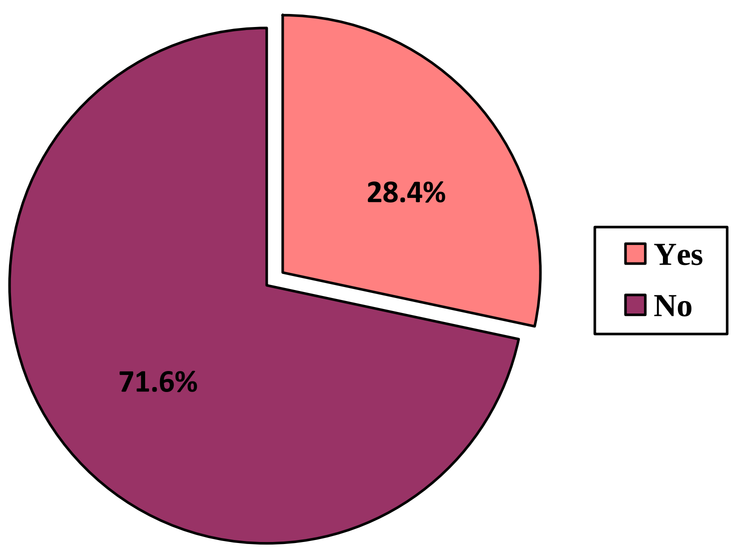


Fig4.7 people expectation on tap water contamination

The sub-city water sector does not try to do any activity to advance consumer's knowledge on water quality deterioration and practice that must be taken to minimize harms related to usage of poor water quality. Due to this more than half (54%) of the community in the study area does not use home treatment mechanisms this escort them to be infected with water borne diseases like ameba and cholera. In contrary those which have good understanding about water quality deterioration were using some household water treatment measures. Like boiling and freezing before use, use of water disinfection tablets, and those which are financially good use water purifier. Even if this options are good but in order to select home treatment mechanisms water quality must be done because the selected option to minimize the effect of one parameter may have a chance to increase the impact of other parameter. Additionally by following their tap water physical properties like color and taste this people go and announce that their tap water was not pure and attractive but the branch water sector was not giving timely response. And as well tap water quality reports were not announced to the community. These kinds of problems were not actively answered by the water sector and the people are forced to use this water after flashing for some minutes.

This people think that the following are the possible sources for water quality deterioration at their tap:-

- ✓ cross connection with sewers
- ✓ Interconnection with toilet
- ✓ Pipe corrosion
- ✓ Pipe breakage and entrance of contaminants in to the distribution system.

4.3 PHYSICO-CHEMICAL WATER QUALITY ANALYSIS OF WATER SOURCE, RESERVOIR AND TAP WATER

To reach at acceptable and finalized conclusion about water quality it is important to start from source and then pull out up to point of use. The results of this study on water quality at Water source, Reservoir and Consumers tap for all selected parameters are presented under:-

4.3.1WATER SOURCE

Surface water joins Geffersa water treatment plant to be treated and delivered to be used for drinking and many other purposes. On this base the raw water of Geffersa was characterized by high turbidity and color .And as well low alkalinity and hardness, normal rainwater has a pH of 5.6 (slightly acidic). This is because it is exposed to the carbon dioxide in the atmosphere. The carbon dioxide gets dissolved in the rainwater and forms carbonic acid H_2CO_3 (may, 2005) .The average values of each parameter at different time for the raw water and measured physico-chemical parameter values for treated water quality of Geffersa are presented in Table 4.2.

Table 4.2 Mean values of raw and treated water quality of Geffersa

status of water	T	pH	A (mg/l)	N (mg/l)	Cl (mg/l)
Geffersa Raw	42.55	7.56	0.33	0.2	-
Geffersa Treated	1.2	7.2	0.087	0.15	0.7

T: Turbidity, A: Ammonia, N: Nitrate, Cl: Chlorine

- pH:- The pH of water entering the distribution system must be controlled to minimize the corrosion of water mains and pipes in Household water systems (WHO, 2008). Because of this AAWSA has done an activity to adjust the raw water that has acidic character to neutral. Through pH adjustment by neutralizing with soda ash which increases the sodium content of the water as a result of this pH value of treated water at source was found to be 7.2. This was in the range of WHO guideline and Ethiopian standard. This solves the problem regarding with higher and lower pH values. Lower pH water is likely to be corrosive. Whereas Higher pH value requires longer contact time (CT) and high free chlorine residual (FCR) for effective chlorine disinfection (ADWG, 1996). From this the pH value of water source was under an acceptable range to be used for dinking purpose. According to a study done on River Beressa which had been used as drinking water source for the town of Debre-Brihan prior to the present system had a pH value range of 7 - 7.5. (Ermias, 2007). And the researcher concludes that the River Beresssa poses no problem to be used as drinking water source in terms of pH value. This has same series as this study.
- Turbidity: - Turbidity of water is one of the important physical parameters that affect not only the quality of water, but also other chemical and bacteriological parameters and efficiency of treatment (WHO, 2006). Due to this through process of raw water screening or Pre-sedimentation, Coagulation, Flocculation and Sedimentation the turbidity of raw water of Geffersa was improved and reclined. Accordingly turbidity of water at treatment plant becomes in tolerable limit (1.2 NTU). This improves the efficiency of treatment plant by reducing problems related to an increase in turbidity such as reduction in power of disinfection agent which then leads to an increase in probability of biofilm growth and others.

- Free residual chlorine: - To overcome any contamination that might enter to the distribution system, to inhibit biofilm formation and to stabilize water quality within the distribution system free chlorine residual must be maintained. For this reason WHO and ES allow a free chlorine residual of 0.5-1mg/L. On account of this water released from Geffersa water treatment plant were with free chlorine residual starting from 0.7 up to 1mg/L. That obey the standard and this amount of free chlorine were assumed to be sufficient for the whole disinfection process along the distribution system.
- Ammonia: - Water source of Geffersa were collected from different land uses this consequences the water to contain slightly higher ammonia concentration that possibly will not be recommended for drinking purpose from health point of view. So to lower this concentration ion exchange method was done by AAWSA. As a result concentration of Ammonia was nil at source which comply with the recommended value of WHO and ES.
- Nitrate: - The detection of nitrate is an important water quality indicator that shows organic matter pollution due to microbial activity and accumulation of Ammonia **(**Desta, 2009). Since Ammonia concentration was nil during the analysis nitrate concentration was also zero. From here water released from treatment plant satisfies all the necessary requirements for drinking purpose. And one can conclude the water released from treatment plant is aesthetically and biologically pure.

4.3.2RESERVOIR

The evaluation of water quality at reservoir water system after having taken water samples from two of reservoirs along the distribution networks was found to lounge in the range of the standards. As that of treatment plant the water in reservoirs were wholesome.

4.3.3TAP WATER

Apart from water sources and reservoirs, it is all most important to analyze water quality at tap that reaches to the household units which determines health status of the population. The following water quality parameters were analyzed:-

- pH:-None of all household water samples tested in wereda 1 had a ph value in a range of 6.5-8, where as in wereda 8, 11% of household or on average 5.3% from the total samples in the study area had pH value in a range of 6.5-8.This shows that only small portion of households use water that comply with the standard of drinking water with regard to pH. For drinking purpose pH value within this range is preferable and recommended because it does not have consequence on the effectiveness of other parameters. 30% of samples from wereda 1 and 33% of water samples in wereda 8 in summery 31.6% of water samples taken from the study area have a pH value of less than 6.5. This may be due to mix up of hydrogenous waste to water along the distribution system in the presence of leaky pipes. Water with a low pH can be acidic, naturally soft and corrosive. Acidic water can leach metals from pipes and fixtures, such as copper, lead and zinc. It can also damage metal pipes and cause aesthetic problems, such as a metallic or sour taste, laundry staining or blue-green stains in sinks and drains.

From the study area 63.1% of the total households had pH value of greater than 8. This may be due to reaction of water with Carbonous wastes in presence of leaky pipes. Drinking water with higher levels of pH does not pose a health risk; however will have bitter taste that may reduce the aesthetic acceptability of water. Conversely because of increasing in pH chlorine vapor pressure reduce due to this the dominant chlorine species in the Disinfection process may be the hypochlorite ion (Brain, 2006). And also it may tend to facilitate the solubilization of ammonia. This result in formation of chloramines those are not so effective against viruses, protozoan cysts, and bacterial spores. And as well an increase in pH value may result in formation of scale which reduces in carrying capacity of pipes and provides shelter for biofilm growth. As shown in Fig. 4.8 more than half of the total water samples have pH value above the standard.

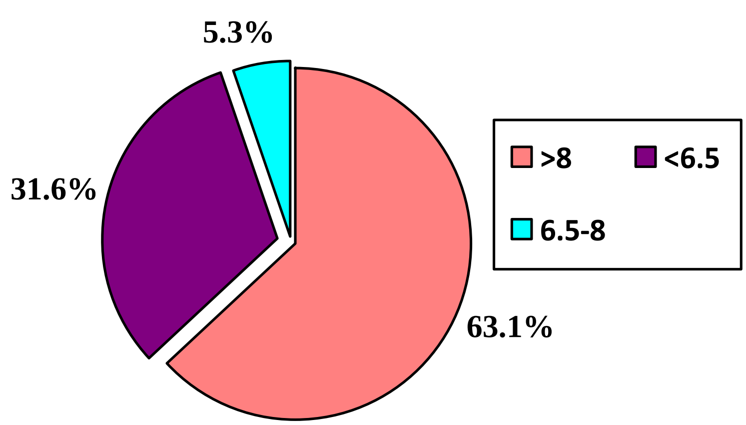


Fig 4.8 laboratory result of pH

To check the certainty of the discussion and the correctness of data the statistics was done by using JMP and is presented in Table 4.3.

Table 4.3 Means and Standard deviation of pH

Level	Number	Mean ± Std
R1	3	$6.43333 \pm 0.208167^{BC}$
R2	3	6.93333 ± 0.513160^{B}
p1	3	8.60000 ± 0.100000^{A}
p2	3	8.31667 ± 0.275379^{A}
p3	3	8.16667 ± 0.208167^{A}
p4	3	8.13333 ± 0.208167^{A}
p5	3	8.26333 ± 0.063509^{A}
p6	3	8.11667 ± 0.525198^{A}
p7	3	7.96333 ± 0.464794^{A}
p8	3	$6.26667 \pm 0.404145^{BCD}$
p9	3	$5.56667 \pm 0.568624^{DE}$
p10	3	5.30000 ± 0.100000^{E}
p11	3	8.40000 ± 0.100000^{A}
p12	3	8.33333 ± 0.057735^{A}
p13	3	8.00333 ± 0.513842^{A}
p14	3	7.88667 ± 0.375810^{A}
p15	3	8.26000 ± 0.341174^{A}
p16	3	8.21333 ± 0.970429^{A}
p17	3	$6.10000 \pm 0.529150^{CD}$
p18	3	$5.66667 \pm 0.208167^{DE}$
p19	3	5.00000 ± 0.866025^{E}

All values are means of duplicate ± standard deviation

A-E Means with the same superscript letters within a column are not significantly different ($p>0.05$).

From the above table some sampling points are not represented by same letter. Water sample taken from most vulnerable group have almost unchanged pH value the reason why they are represented by same letter. As proved from the above table there exist a significant difference in pH from one sampling point to the other.

- Turbidity:-30% of household samples tested in wereda 1 and 33% of household samples tested in wereda 8 had a turbidity value of less than 5. Turbidity measurements taken from tap water samples were found to be higher than source (1.2) and reservoir (1.18NTU). Even though this value is on the range of the standard water at tap may consist of any objectionable matter during the distribution process. In view of the fact that these values does not matter the performance of distribution system it will not be my point of discussion for this study. Because turbidity values within this range improves the performance of many water quality parameters. Like disinfection process that improves the capacity of the available disinfectant agent for elimination of pathogens within drinking water distribution system. But most of the water samples 70% from Weredea 1 and 67% of samples from wereda 8 have turbidity greater than 5. These were above WHO and Ethiopian standard (≥5NTU) (WHO & ES, 1993, 1998). Since turbidity is the measure of cloudiness of water, it mainly indicates growth of pathogen along the distribution system that pathogens may contaminate the water and entrance of any objectionable matter towards the distribution system (Olson, 2004). The turbidity records of the present study (1.16-8 NTU) was slightly higher than the lowest limit and the highest limit of 0.3-7.6 NTU from Debrezeit town tap water samples(Desta,2009). And lower than the lowest limit and higher than the highest limit of 1.6-4.4 NTU from Bahir Dar town (Getnet, 2008) tap water samples respectively. Typical sources of turbidity within the distribution system maybe Waste discharges and Algae or aquatic weeds and products of their breakdown along the distribution network. Excessive turbidity, or cloudiness, in drinking water is aesthetically unpleasant, and may also represent a health concern. Turbidity can provide food and shelter for pathogens. If not removed, turbidity can promote regrowth of pathogens in the distribution system, leading to waterborne disease outbreaks. As a result of this water used by the community was not aesthetically pure and the disinfection process was not successful that is why pathogen causing organisms were found at consumers tap. Proportion of turbidity value above and below the standard is presented in Fig 9.

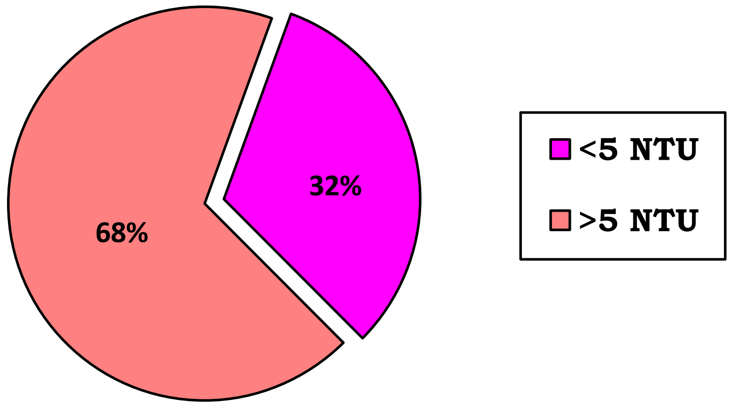


Fig 4.9 percentage of turbidity values above and below the standard in the study area

Mean and standard deviation of the results and variation on turbidity is presented in Table 4.4.

Table 4.4 mean and standard deviation of Turbidity

Level	Number	Mean±Std
R1	3	1.16667 ± 0.28868^{I}
R2	3	1.19000 ± 0.32909^{I}
p1	3	8.00000 ± 1.00000^{A}
p2	3	$6.60000 \pm 1.30000^{CDEF}$
p3	3	$6.36667 \pm 1.41539^{DEF}$
p4	3	$7.26667 \pm 1.10151^{ABCD}$
p5	3	$6.83333 \pm 0.92376^{BCDEF}$
p6	3	$7.03333 \pm 0.15275^{ABCDE}$
p7	3	6.20000 ± 0.43589^{EF}
p8	3	2.91333 ± 0.12055^{G}
p9	3	2.50000 ± 0.62450^{G}
p10	3	$2.10000 \pm 0.10000^{GHI}$
p11	3	7.83333 ± 0.20817^{AB}
p12	3	7.96667 ± 0.20817^{A}
p13	3	$7.43333 \pm 0.50332^{ABC}$
p14	3	5.90000 ± 0.10000^{F}

Level	Number	Mean±Std
p15	3	6.26667±0.25166^{DEF}
p16	3	7.20000±0.20000^{ABCDE}
p17	3	1.36667±0.15275^{HI}
p18	3	2.20000±0.20000^{GHI}
p19	3	2.36667±0.55076^{GH}

Levels not connected by same letter are significantly different All the above results point out existence of turbidity fluctuation. That is why most of the results are represented by different letters.

- Residual chlorine: - When water leaves the treatment plant residual free chlorine of about 0.5 up to 1 mg/l (WHO & ES, 1993, 1998) is needed for health reasons and it is recommended that 0.1-0.2mg/l is maintained at points of consumption. But in this study, the concentrations of residual free chlorine in most water samples 70% in Wereda 1 and 56% in Wereda 8 on average 63% from the study area were below the recommended limit of WHO and Ethiopia standard (0.1-0.2 mg/l). This water points consists of disinfection agent less than the standard which may indicate possibility inefficiency of disinfection in the distribution system and require an excessive disinfectant. Accordingly waterborne diseases in the study area were dominant. This study directly related to the study done at Debrebehan (Solomon, 2011) out of 15 tap water samples tested for Free chlorine residual 60% of it had a value of less than 0.1. This may be the result of any of the following conditions:
    - The age of the water in the system since it was treated;
    - Microbial re-growth within the distribution system;
    - Reaction with corrosion byproducts; and Cross-connection or other contamination that consumes the disinfectant.

Only 20% of the samples tested in Wereda 1 and 22% samples tested in Wereda 8 total of 21% from the study area had a free chlorine value of greater than 0.2 mg/l. Even if dangerous related to chemical may present after long exposure and large dosage this proportion cannot be taken as good, so appropriate mechanisms must be taken to lower the concentration. And about 10% of water sample in wereda 1 and 22% of water samples in wereda 8, on average 16% from the study area have a residual chlorine concentration in the range of 0.1 to 0.2.from this one can conclude that only small amount of households get the appropriate proportion of disinfectant at their tap. even if this household units gets appropriate proportion but the disinfectant power of chlorine may not be good due to all the above mentioned parameter results. The higher pH value, highly turbid water, contact time of disinfection agent with water and number and type of microorganisms will play vital role in reducing the efficiency of chlorine along the distribution system. The percentage proportion is presented in fig 4.10.and also one way analyses of residual chlorine using JMP is presented in Table 4.5.Which prove there were statistically significant differences in concentration of free residual chlorine between reservoirs and tap.

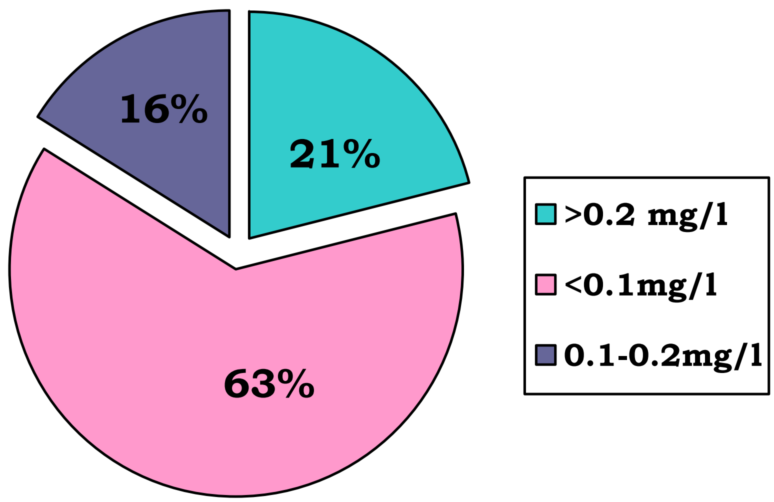


Fig 4.10 summery of residual chlorine at consumer taps

This distribution shows that most of the point's residual chlorine concentration is less than the standard.

Table 4.5 Means and standard deviations of free residual chlorine

Level	Number	Mean± Std Dev
R1	3	0.533333±0.057735^{A}
R2	3	0.400000±0.173205^{B}
p1	3	0.000000±0.000000^{F}
p2	3	0.033333±0.057735^{F}
p3	3	0.066667±0.057735^{EF}
p4	3	0.050000±0.086603^{F}
p5	3	0.016667±0.028868^{F}

Level	Number	Mean± Std Dev
p6	3	0.050000±0.050000**F**
p7	3	0.066667±0.057735**EF**
p8	3	0.166667±0.028868**DE**
p9	3	0.300000±0.100000**BC**
p10	3	0.233333±0.057735**CD**
p11	3	0.016667±0.028868**F**
p12	3	0.033333±0.028868**F**
p13	3	0.066667±0.028868**EF**
p14	3	0.100000±0.000000**EF**
p15	3	0.066667±0.028868**EF**
p16	3	0.066667±0.057735**EF**
p17	3	0.233333±0.057735**CD**
p18	3	0.216667±0.076376**CD**
p19	3	0.166667±0.057735**DE**

Levels not connected by same letter are significantly different, All values are means of duplicate ± standard deviation, A-F Means with the same superscript letters within a column are not significantly different (p>0.05).

- **Ammonia: -** From total of 19 household samples tested 30% from wereda 1 and 33% from wereda 8 had Ammonia concentration of less than 0.5Mg/L. Regarding to the guideline values concentration of Ammonia must be less than 0.5mg/L. small proportion of the community get Ammonia concentration that does not possess any impact on them. 70% households in wereda 8 and 67% household units in wereda1 have Ammonia concentration of greater than 0.5Mg/L. In nature ammonia is formed by the action of bacteria on protein and urea. On the study area as a result of cross connection of drinking water pipes with sewer pipes there will be great chance of increased concentration of ammonia. And also people day to day activities plays vital role in the increment of Ammonia concentration due to in appropriate management of wastes. If these solid and liquid wastes get a chance to meet leaky pipe there will be probability to increase Ammonia concentration. The presence of Ammonia at higher concentration than the standard levels is an important indicator of fecal pollution (ISO, 1984, 1986). And also Taste and odor problems as well as decreased disinfection efficiency are to be expected. The presence of Ammonium in drinking water may result in an increase in nitrite concentration as the result of catalytic action (Lochtmann, 1984). The proportional representation of ammonia concentration is presented in fig 4.11. The comparison as well the status of water quality was analyzed using JMP which is presented in Table 4.6.

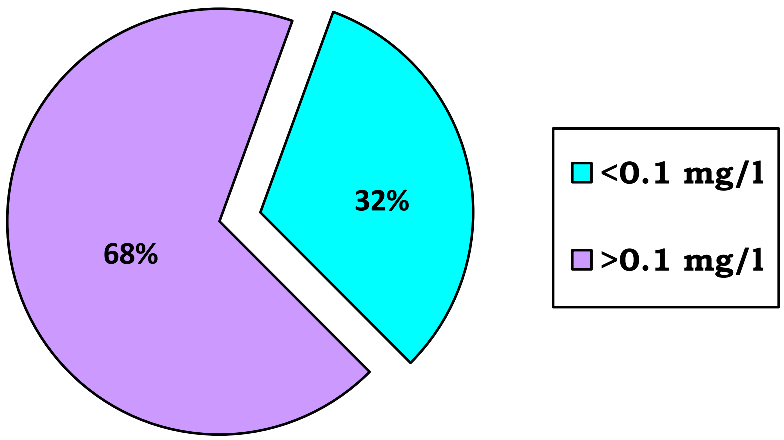


Fig 4.11 percentage concentration of ammonia at consumer taps

Table 4.6 analysis of Ammonia using JMP

Level	Number	Mean± Std Dev
R1	3	0.00000±0.000000 M
R2	3	0.00333±0.005774 M
p1	3	0.92667±0.064291 CD
p2	3	0.90333±0.068069 DE
p3	3	0.99667±0.005774 AB
p4	3	0.81000±0.026458 FG
p5	3	0.80333±0.045092 FG
p6	3	1.05333±0.128582 A
p7	3	0.73333±0.035119 H
p8	3	0.26000±0.036056 JK
p9	3	0.32667±0.030551 J
p10	3	0.22000±0.010000 K
p11	3	0.96000±0.020000 BCD

Level	Number	Mean± Std Dev
p12	3	0.97333±0.030551$^{\mathbf{BC}}$
p13	3	0.99667±0.005774$^{\mathbf{AB}}$
p14	3	0.62667±0.025166$^{\mathbf{I}}$
p15	3	0.77000±0.020000$^{\mathbf{GH}}$
p16	3	0.85000±0.010000$^{\mathbf{EF}}$
p17	3	0.21333±0.015275$^{\mathbf{K}}$
p18	3	0.13667±0.015275$^{\mathbf{L}}$
p19	3	0.04333±0.032146$^{\mathbf{M}}$

Levels not connected by same letter are significantly different. All values are means of duplicate ± standard deviation, A-M Means with the same superscript letters within a column are not significantly different (p>0.05).

- **Nitrate: -** 30% of samples tested from wereda 1 and 33% household on average 32% from total water samples tested from wereda 8 had Nitrate concentration of less than 0.5Mg/L. Whereas 70% of samples in wereda 1 and 67% of samples in wereda 8 or 68% from the total sample have Nitrate concentration of greater than 0.5Mg/l. As discussed above an increase in Nitrate concentration may be due to the presence of Ammonia caused by interconnection of drinking water pipes with sewer line. Because it is the final stage of oxidation of Ammonia. Since Nitrate does not evaporate the way chlorine does boiling, freezing, or letting water stand does not reduce the nitrate level. So there is no simple way to remove nitrate from water in home because home water treatment options are generally limited. High levels of nitrate in drinking water are a health concern primarily because of the potential for the nitrate to be converted to nitrite. That interferes with the ability of blood to carry oxygen. It does this by converting blood hemoglobin into methemoglobin. Unlike hemoglobin, methemoglobin does not function as an oxygen carrier to the tissue. The resulting condition is known as methemoglobinemia and causes severe oxygen deficiency and can lead to death. It is characterized by shortness of breath and blueness of skin. As a result, it is often called the blue baby syndrome. As shown from fig 4.12 more than half of the water samples in each Wereda have Nitrate concentration greater than the standard the analysis done using JMP is presented in Table 4.7.

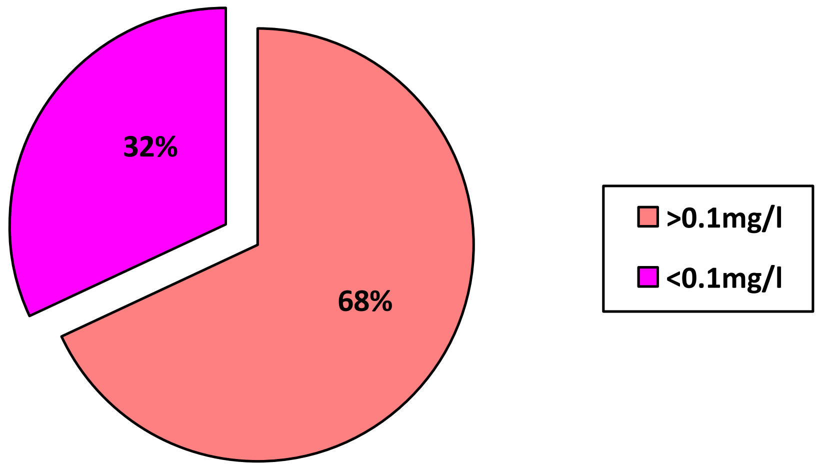


Fig 4.12 proportion of nitrate concentration at consumer taps

Table 4.7 Means ±Standard deviation of Nitrate concentration using JMP

Level	Number of analysis	Mean± Std Dev
R1	3	0.000000±0.000000^{J}
R2	3	0.000000±0.000000^{J}
p1	3	0.863333±0.055076^{C}
p2	3	0.846667±0.041633^{CD}
p3	3	0.913333±0.032146^{B}
p4	3	0.783333±0.020817^{E}
p5	3	0.780000±0.040000^{E}
p6	3	0.976667±0.032146^{A}
p7	3	0.706667±0.030551^{F}
p8	3	0.233333±0.030551^{H}
p9	3	0.126667±0.025166^{I}
p10	3	0.193333±0.005774^{H}
p11	3	0.936667±0.015275^{AB}
p12	3	0.953333±0.037859^{AB}
p13	3	0.940000±0.020000^{AB}

Level	Number of analysis	Mean± Std Dev
p14	3	0.600000±0.020000^{G}
p15	3	0.693333±0.011547^{F}
p16	3	0.806667±0.011547^{DE}
p17	3	0.103333±0.015275^{I}
p18	3	0.000000±0.000000^{J}
p19	3	0.000000±0.000000^{J}

All values are means of duplicate ± standard deviation, A-J Means with the same superscript letters within a column are not significantly different (p>0.05).

4.4BACTERIOLOGICAL WATER QUALITY OF SOURCE, RESERVOIR AND TAP WATER

The usefulness of water for human use is determined by its quality. Quality is a major determinant for the health of ecosystems. Proper monitoring and assessment of the quality of surface, ground and tap water is essential for efficient water quality management, which in turn can ensure human welfare and environmental sustainability. The direct merit of microbiological examination is to take immediate action such as disinfecting at source water, replacing leaking pipes if the sample examination proves pathogenic contamination. In order to evaluate the bacteriological quality of water arrive at Mercato area, the presence of two indicator bacteria, Total coliforms (TC) and Fecal coliforms (FC) was tested from water source, distribution points (reservoirs), and distribution networks (tap water).

4.4.1WATER SOURCE

Due to the well efficient disinfection process and proper management of treatment plant treated water from Geffersa water treatment plant were wholesome. Bacteriological water quality analyses results prove that water at source were free from both TC and FC. Thus quality of drinking water at source was within WHO, 1993 and ES, 1998 which was 0 CFU/100 mL of sample.

4.4.2 RESERVOIR

As that of water treatment plant water from reservoir were wholesome. The value of TC and FC in both reservoirs R_1 and R_2 were found within WHO (1993) guideline and ES (1998). This shows that in two of the reservoirs there was no coliform and the water were safe and palatable.

4.4.3 TAP WATER

Apart from water source and reservoirs, it is all most important to analyze water quality of tap water distribution system that reaches to households. This determines the health status of the population. Accordingly for this study to assess bacteriological quality of drinking water at consumers tap the following water quality parameters were done.

- **Total coliform: -** total coliforms were used as indicator bacteria to assay the level of bacteriological contamination of the water supplies. A total of 19 water samples were analyzed for thermotolerant coliforms and the result indicates that majority taps water were contaminated to a significant extent. With the help of laboratory analysis 70% household water samples in Wereda 1 and 67% water samples in Wereda 8 indicate presence of total coliform. Even if presence of total coliform is not index of fecal pollution or of health risk but provides basic information on treatment efficiency and water quality.
- **Fecal coliform: -** 60% of household samples tested in Wereda 1 and 23% household samples tested in Wereda 8 on average of 42% from total study area shows existence of thermo-tolerant (fecal) coliform. The presence of Fecal or thermo tolerant coliform that grows at 44-44.5^{0}c and ferment lactose to produce acid and gas. In drinking water presence of fecal coliform should not be ignored as the basic assumption that pathogens would not be presented in drinking water. But this result shows the presence of fecal coliform. Since they are indicator of possible presence of waterborne pathogens one can expect waterborne diseases on the study area. This was proved by the results of the questioner and the report from the sub-city heath center which shows the people are rapidly exposed to waterborne diseases. As shown in Table 2.4 and 2.5 among the ten top diseases in the study area as an example Diarrhea is caused by ingestion of contaminated water or food or poor sanitation. High counts of total coliforms and thermotolerant coliforms at the house hold drinking water indicates that the water has been fecally contaminated. The presence of coliform in drinking water on the study area could be attributed to cross-contamination between the municipal water supply and sewer, and reduction in efficiency of chlorine. The summarized result of the two Weredas' is presented in Fig 4.13. In this study the average count of total coliforms and thermotolerant coliforms were above the recommended value of WHO and Ethiopian Standards. Especially the total coliform and thermotolerant coliform counts were higher in household water samples compared to that of water from reservoir. This is in agreement to an intervention study done in Sri Lanka that Shows water from tap had often a worse bacteriological quality than water

from source or reservoir (Dissanayake, Dias, Perera, Iddamalgoda, 2004). And also results of this study are in agreement with studies conducted in South Africa and Zimbabwe which reported that compliance is significantly higher for water reservoir than from tap water (Gundry, Wright, Conroy, Dupreez, Genthe, 2006).

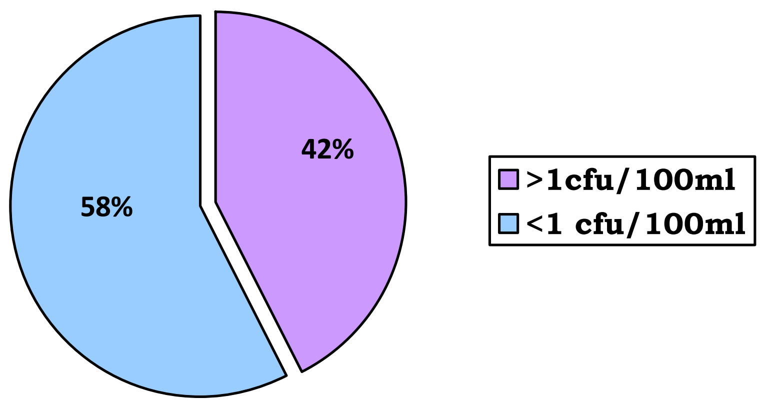
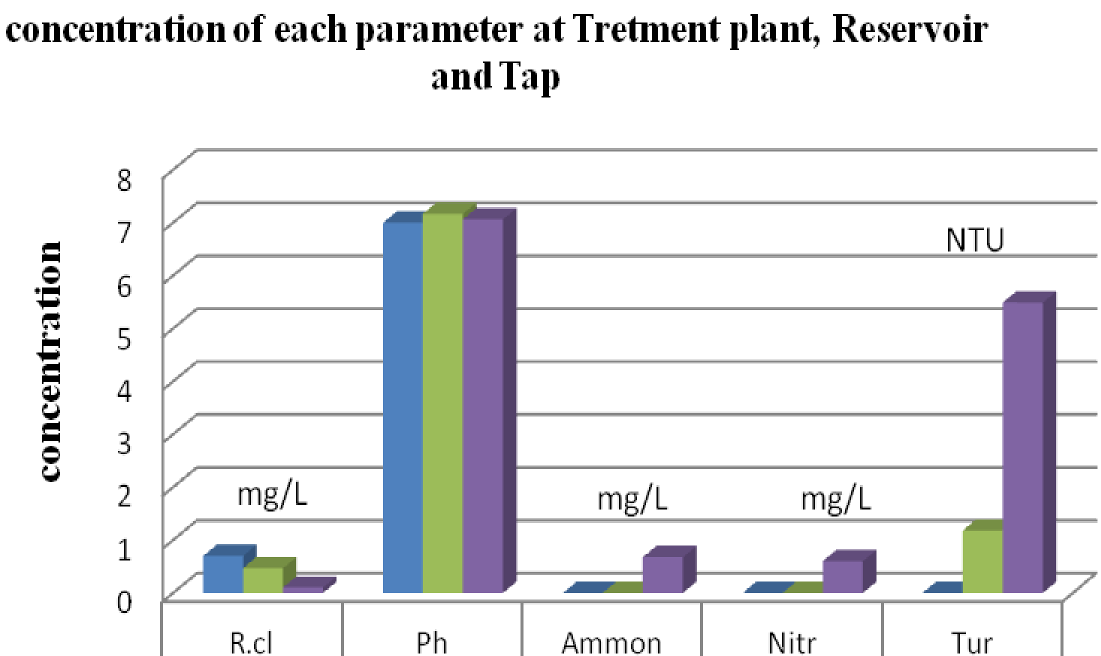


Fig4.13. summarized microbiological result (Fecal coliform)

Generally, from bacteriological water quality tests more than half tap water samples do not meet the TC standard set by WHO and Ethiopia. Due to this the samples failed to meet safe water quality with regard to TC and FC criteria of 0 CFU/100ml, respectively (WHO, 1996).

The summarized status of water quality from treatment plant up to place of consumption is presented in fig4.14.



	R.cl	Ph	Ammon	Nitr	Tur
Treatment plant	0.7	7	0	0	0
Reservoir	0.466666667	7.167	0	0	1.178
TAP	0.102631579	7.06386	0.677	0.602	5.49

Fig 4.14Graphical representation of parameters at Treatment plant, Reservoir and Consumer tap

The composition of different parameters at water treatment plant, reservoir and consumers' tap was done by taking the average values gained from laboratory results for each parameter. This helps to see where the quality of water starts to deteriorate from this one can talk about the water quality of Addis city sub-city water quality based on the above data's.

It is very difficult to pinpoint the exact cause for water quality deterioration with in the distribution system because interrelationship between parameters is so complex and they result in antagonistic or synergistic effects with each other. From the above figure we can see that from treatment plant up to reservoir the quality of water reduces but it is within the standard, so this water will not lead to harm for those who consume it. As seen from the graph in 4.14 quality of water starts to deteriorate on the path from the reservoir to consumer tap. And it fails to achieve the standard values of water used for consumption or drinking purpose. This may be due to interface of solid and liquid waste with leaky drinking water pipes because of poor waste management trend of the people, interconnection of sewage pipes with drinking water pipe line, pipe corrosion, and discontinuity of water for long period of time. Consumption of this water cause waterborne disease for the people in the study area.

4.4HEALTH IMPACT ASSESSMENT

Under this title the researcher wanted to present the spatial and temporal changes in quality of drinking water. That result from the interaction of a particular human action compared with what would have occurred without the situation. Accordingly health impact assessment was done quantitatively as presented under in Table 4.8 and Table 4.9.

Before all significance of impact were done as presented in Table 4.8

Table 4.8 impact significance calculation

Characteristics of impact significance	Parameter			
	Ammonia	Nitrate	Turbidity	Coliform
Extension	3(Extensive)	3(Extensive)	3(Extensive)	3(Extensive)
Time of occurrence	2(Medium-term)	1(Long-term)	3(Immediate)	3(Immediate)
Persistence	3(permanent)	3(permanent)	3(permanent)	3(permanent)
Reversibility of the effect	4(impossible)	4(impossible)	4(impossible)	4(impossible)
Total	12	11	13	13

The significant of impact for all tested parameters was greater than 9 so all the parameters are highly significant for the entire environment. In addition taking this as input the overall health impact was done as shown in Table 4.9

Table 4.9 health impact of drinking water on the study area

Characteristics of impact	Parameter			
	Ammonia	Nitrate	Turbidity	Coliform
Character	- (Negative)	- (Negative)	- (Negative)	- (Negative)
Significance	3 (High)	3 (High)	3 (High)	3 (High)
Disturbance	3 (significant)	3 (significant)	3(significant)	3 (significant)
Occurrence	3 (Very probable)	3 (Very probable)	3 (Very-probable)	3 (Very probable)
Extension	3 (Regional)	3 (Regional)	3 (Regional)	3 (Regional)
Duration	3 (Permanent)	3 (Permanent)	3 (Permanent)	3 (Permanent)
Reversibility	2(partial)	2(partial)	3(irreversible)	2(partial)
Total	-17	-17	-18	-17

As mentioned in the methodology section this values represent that the impact is sever. Severity represents an event whose occurrence will impact the project's cost (and/or schedule) so severely that the project will be terminated. So in this case usage of this water for drinking or for any other purpose may lead to additional cost expenditure for the community and as well may reduce effective working days by the community which reduces the growing probability of the country.

CHAPTER FIVE

5. RISK MANAGEMENT OPTIONS

To reduce the health impact in usage of this water BMPs must be implemented. These BMPs can be overtaken either by the community or by the water sector as described below:

5.1 ADMINISTRATIVE BMPS

The following sections describe the different types of administrative BMPs that may be implemented as additional measures in the overall effort to reduce the potential water quality impacts of pollutants during drinking water system releases. Administrative BMPs are nonstructural BMPs, such as managerial practices, operations and maintenance procedures, or other measures designed to reduce or prevent potential pollutants from being discharged during drinking water system releases. Administrative BMPs may also be characterized as source controls. Such administrative BMPs can be applied before, during, and/or after water release activities.

5.1.1TRAINING

Training and education are essential tools to effectively implement BMPs for planned and unplanned releases. Water utilities should ensure that employees are thoroughly knowledgeable of all the requirements of drinking water system releases and know how to properly implement appropriate BMPs. Overall competence in BMP selection, application, techniques, and procedures are essential to ensuring compliance with regulatory requirements. Additional training on field sample collection and analyses should be provided to appropriate field personnel. Employees also need to be trained on the health and safety issues related to drinking water system releases and appropriate BMP implementation.

5.1.2 DOCUMENTATION AND MASTER PLAN PREPARATION

Developing documentation procedures is another administrative BMP that can help water utilities. Documentation of field activities is valuable and can be used as a tool to assist personnel with the appropriate implementation of BMPs. Procedures for documenting may include: inspections and visual observations; sampling and monitoring information; BMP implementation; and follow up activities. Photographs can also be a useful method to document activities in the field. In addition, master plan for water supply network and sewer line must be done .In our country the water supply pipes is installed in absence of plan from the water sector. This now a day's becomes a major cause for interconnection with sewer.

5.2 STRUCTURAL BEST MANAGEMENT PRACTICES

Structural BMPs are man-made systems or devices designed to prevent contamination. They can be imposed by regulations or ordinances or adopted voluntarily. Examples include making of reservoirs and drinking water pipe joints watertight.

5.3 EDUCATION

Providing education is a commonly recognized tool for encouraging source water protection. Employing educational strategies to address source water protection assumes that individuals or organizations that contribute to the degradation of water quality do so because they do not realize the existence or importance of the issue, or do not understand what can be done to manage it (May 2005). Educational approaches can address this challenge by raising awareness or providing technical assistance. And also drinking water suppliers are required to provide annual reports, called consumer confidence reports, which provide information about source water and tap water including a summary of the results of the assessment and information on how to obtain a copy. These reports can also be used as a vehicle to inform consumers about protection efforts planned or under way and enlist their support.

CHAPTER SIX

6. CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

All the result from this study put together on the following conclusion. In the study area most of the people does not expect deterioration in quality status of drinking water at their tap. This indicates that the level of knowledge on water quality deterioration has been significantly low. Due to this and low level of income the people has no habit in using home water treatment methods. Even though small portion of the community uses home water treatment mechanisms like boiling and water tabs. Due to lack of information on selection of treatment alternatives based on status of drinking water quality on basic parameters an antagonist and synergist effect were noticed. Moreover Poor sanitation and poor hygiene in household were the main factors for the contamination of water during transportation and after storage at home.

Those drinking water pipes having leakage problem caused potential hazard to contaminate the water by solid and liquid waste due to poor management of waste by the community. Due to this the physicochemical test results of samples from most (76.6%) of tap were not within the permissible standard limits of WHO and Ethiopia (1993, 1998). Thus from this study Water at taps was grossly contaminated with Nitrate and Ammonia than water tested from Treatment plant and Reservoir. This result an increase in Turbidity which reduces performance of disinfection process then leads to continued existence of water associated diseases causing organisms. And also there was an increase in bacterial indicator as the water moves from water treatment plant to tap water systems. The level of contamination was higher in water distribution systems (Tap) than in treatment plant and reservoir. Consequently the result from health impact assessment of drinking water on the study area shows that usage of this water for consumption purpose has a severe impact on the community's health. Poor domestic waste disposal, interconnection of drinking water pipes with sewer and presence of leaky pipe which result cross contamination with the surrounding seem to contribute largely to the higher level of bacterial contamination of water in the distribution systems. In addition comments from the users were not timely answered and as well were not reported to the main water supply sector AAWSA. These prove AAWSA and the sub-city water supply sector was not actively participating in management of distribution system and in water quality supervision and monitoring.

6.2 RECOMMENDATIONS

- The peoples must use home water treatment mechanisms mainly water tabs. But since the peoples have low income water sectors must take the responsibility to facilitate provision of water tabs to the community.

- Regular inspection of sanitary and hygienic aspects and strict control and appropriate management of the distribution system 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 waste removal must be increased and private involvement must be appreciated.

- Appropriate operator training must be given: - It is also important to hire appropriately skilled individuals and ensure they receive training to keep up-to-date. For their part, staff need to be aware of the requirements related to their work and exercise due diligence when carrying out their duties.

- Public Awareness and Involvement must be practiced; - To ensure public health clean water supply at sufficient quantity to the people of the town may not be enough. Water handling practice and sanitary condition of the people must be improved. So all concerned body should be working cooperatively and in integrated manner for upgrading peoples understanding on the causes of contaminants and how to use home water treatment mechanisms.

- The present work is limited to few physico-chemical parameters and sampling frequency. Therefore, year round sampling and analysis of additional parameters of water quality must be undertaken.

REFERENCES

- Addis Ababa water and sewerage authority (2002), Geffersa water treatment plant detail, Addis Ababa.
- Addis city sub-city (2003), sub-city administration land rehabilitation project sector, design and construction, Addis Ababa.
- Addis city Sub-city Health Office, (2003), Annual health status report of Addis city sub-city, Addis Ababa
- Addis city sub-city solid waste collection and removal sector, (2000-2002), Annual consecutive report on solid waste, Addis Ababa.
- ADWG (1996). Australian Drinking Water Guidelines, National Water Quality Strategy. National Health and Medical Research Council and the Agriculture and Resource Management Council of Australia and New Zealand.
- Alanc Twort, DonD.Ratnayaka and Malcomj.Brandt, (2000), water supply 5th edition, IWA publishing, Great Britain.
- APHA (1998). Standard Methods for the Examination of Water and Wastewater, 20th ed. American Public Health Association. Washington DC.
- Asamnew Abayneh, (2004), Hawassa University in collaboration with the Ethiopia public health training initiatives, the carter center, the Ethiopia minister of health and the Ethiopian minister of education.
- Atnaf M. (2006).Assessment of Bacteriological Quality of Drinking Water Supply at the Sources and Point-of–Use at Home in Worebabo District, South Wollo, M.Sc Thesis, Addis Ababa University, Addis Ababa
- Brian O. (2002).Water Testing Bacteria, Coliforms Nuisance Bacteria, Viruses, and Engineering and Earth Sciences. Wilkes University. Web Design pros.net
- Brain C. (2006), Chlorine Disinfection in the Use of Individual Water Purification Devices. Technical Information Paper 31-002-0306
- Cochran WG (1997), sampling techniques, John wiley and sons, Newyork

- CSA (2010),central Statics Agency number of total household for each sub-city
- D.D Silva zambrerlan ,(2007), comparison of bacteriological quality of tap water and bottled mineral water J.hyg.Environ.Health(Article in pares)
- Desta kassa, (2009), physico- chemical and bacteriological Quality assessment of drinking water From source to households distribution Point in Debrezeit town, Ethiopia thesis submitted to the school of graduate Studies of Addis Ababa university in partial fulfillment of the requirements for the Degree of masters of science in environmental Science, Addis Ababa
- Dissanayake SAMS, Dias SV, Perera MDC, Iddamalgoda IAVP, (2004), Microbial Quality Assurance of Drinking Water Supplies through Surveillance. Environment Division, National Building Research Organization, Colombo, Sri Lanka. Water Professionals' Symposium
- EPA (1999), guidance manual turbidity provisions, *[*April 2012], *URL:http://www.epa.gov*
- Ethiopian standard and WHO guideline values, (1993,1998), Drinking water guideline values, [Nov 2012], http://www.lenntech.com/drinking-water-standards.htm
- Ermias seyoum, (2007). Assessment of the physicochemical parameters of river beressa in Debre Berhan Town (North Shoa) for suitability of drinking water, M.Sc. Thesis, Addis Ababa University, Addis Ababa, Ethiopia.
- Feachem Richard , (1983),sanitation and disease , world bank studies in water supply and sanitation 3
- Getnet K, (2008), Physico-chemical and bacteriological drinking water quality assessment of Bahir Dar town water supply from source to yard connection.M.sc thesis Addis Ababa University.
- Guillermo Espinoza (2002), management and fundamentals of environmental impact assessment, ch7
- Gundry SW, Wright JA, Conroy R, Dupreez M, Genthe B, (2006),contamination of drinking water between source and point of use in rural households of south Africa and Zimbabwe; implication for monitoring the Millennium Development Goals for water, J water Prac Tech
- GTZ (1995). Environmental Hand Book Volume I: Cross Sectoral Planning, Infrastructure (GTZ, 592)
- Haworth (1996). A Survey of Pollution Indicator Bacteria in Water Wells of Rutherford Country, Tennessee. Journal of the Tennessee Academy of Science. 56(3), 73-75.

- Hurst, C. J., Kundsen., Mclnerney,M. J., Stezenbach,L.D., and Walter,M.V. (2002). Manual of Environmental Micribilogy.2nd ed. PP: 265-284. American Society for Microbiology. American Society of Microbiology Press, Washington, DC.
- International Organization for Standardization, 1984, 1986, Water quality—determination of ammonium, Geneva, (ISO5664:1984; ISO6778:1984; ISO7150-1:1984; ISO7150-2:1986).
- James K.Edzwald, (2011), Water quality and treatment, a hand book on drinking water, American water works association, unitedstates,6th edition, chap 3
- Joseph A. Salvato, P.E., DEE, (2003) Environmental Engineering, 5th edition, John Wiley and sons, Inc., Hoboken, New Jersey ,chap1,9
- J. Bartram, (2000), Monitoring quality of drinking water during storage and distribution, department of natural resource, New Brunswick, ,chap.6
- Kadewa Phiro, (2005), Assessment of the impact of industrial Effluents the water quality receiving rivers in urban areas of Malawi, Environ.sci.Tech2 (3)237-241.
- Kassahun B. (2008). Assessment of physico-chemical and Bacteriological Quality of Drinking Water in the Central Rift valley System, Ziway Town Oromia Region, Ethiopia. M.Sc Thesis, Addis Ababa University, Addis Ababa
- Kebede Faris, (2002), Hawassa university In collaboration with the Ethiopia Public Health Training Initiative, The Carter Center, the Ethiopia Ministry of Health, and the Ethiopia Ministry of Education
- LeChevallier Mark, (2004), author. In: Water Treatment and Pathogen Control: Process Efficiency in Achieving Safe Drinking Water. Au Kwok-Keung., editor. London, UK: IWA
- Levi Yves. (2004), editor. WHO, author. Minimizing potential for changes in microbial quality of treated water. London, UK: IWA Publishing
- May, P.J. (2005). Regulation and Compliance Motivations: Examining Different Approaches. Public Administration Review 65(1): 31-44.
- Mengstayehu, B., (2007), Assessment of Physico-chemical Microbiological Quality of Rural Drinking Water Supply at the Sources and Selected Communities of Akaki-Kalit Sub-City, Addis Ababa City Administration. M.Sc Thesis, Addis Ababa University, Addis Ababa

- Milkiyas Tabor, Mulugeta Kibret and Bayeh Abera (2009). Bactriological and physicochemical quality of drinking water and Hygiene-sanitation practice of the consumer in Bahir Dar city, Ethiopia, *Ethiopian Journal of Health Science* 22(1): 21-25.

- Mombal M. Tyafa, Z., Malaka, Brouckaert, B.M., and Obi C.L. (2006). Safe Drinking Water Still a Dream in Rural Areas of South Africa: The Eastern Cape Province. J. of Water Science Res. and Technol.32 (5), 208-213.
- Muyima N. and Ngcakani F. (1998). Indicator Bacteria and Regrowth Potential in the Drinking Water of Alice. J. Biochem and Microbial.24 (1), 29.

- National research council (2012), Canada contraction innovation newsletter: volume17, number 2, [Jan 2012]. *URL:www.nrc-cnrc.gc.ca*

- Nath KJ, Bloomfield SF, Jones M. (2006), Household water storage, handling and point of-use treatment. A review commissioned by International Scientific Forum on Home Hygiene, (IFH). [Jan. 2012].http://www.ifh-homehygiene.org/.

- OECD, (2005), Water and Violent Conflict Development Assistance Committee Mainstreaming Conflict Prevention

- Olson (2004).What is on the Tap? Grading Drinking Water in the U.S Cities Natural Resources Defense Council.
- Ontario Ministry of Agriculture, Food and Rural Affairs. (2009). Canada-Ontario Environmental Farm Plan. http://www.omafra.gov.on.ca/english/environment/efp/efp.htm [Nov.2012]
- Pelletier LL Jr. (1996). Microbiology of the Circulatory System. in: Baron's Medical Microbiology (Baron S et al., eds.) (4th ed.). Univ of Texas Medical Branch.
- public health guide for emergencies, (2000) ,the international federation of red cross and red crescent society pa.376
- R.c.Gaur, (2008), Environmental engineers laboratory manual, new age international (P) Ltd., publishers, New Delhi, ,page 1
- ReichertJ, Lochtmann S. (1984), Occurrence of nitrite in water distribution systems, *Gas- und Wasserfach, Wasser-Abwasser*
- Sadig Rasheed, (1999), Water, Environment and Sanitation Technical Guidelines Series - No. 2, united nations children fund, New York, , pag. 56

- Solomon Jida, (2011) , Thesis submitted to the School of Graduate Studies of Addis Ababa University for Partial Fulfillment of the Requirements for the Degree of Masters of Environmental Science in Environmental Science program. Addis Ababa
- Temesgen E., (2009), Assessment of physico-chemical and Bacteriological Quality of Drinking Water Supply at Sources and Household in Adama town, Oromia Regional State, Ethiopia. M.Sc Thesis, Addis Ababa University, Addis Ababa.
- The national environmental service center, rural development service, water supply and health, (2011), [Aug.2012], *URL:http//www.nesc.wvu.edu/drinking water.cfm*
- Thomas & Andre vander, (2006), Quality assurance for water quality, Nether lands
- Tizita teshome and Wondessesn Birket, (2009), Introduction to environmental health, Addis Ababa Ethiopia.
- UN-WATER/WWAP, (2004), author. National Water Development Report for Ethiopia. Addis Ababa: United Nations Educational, Scientific, and Cultural Organization World Water Assessment Program.
- United Nations Children's Fund (2011), Assessing microbial safety of drinking water, United States of America , [Feb.*2012] URL:http:/www.unicef.org*
- United States Environmental Protection Agency (2012), *water quality parameters*, United States of America, *[Mar.2012], URL:http:/www.epa.gov*
- WHO/EU drinking water standards comparative table, (2011), http://wwwlenntech-com/drinking water standard.htm
- WHO, (1996), author. International Program on Chemical Safety. Geneva:. Guidelines for Drinking-Water Quality - Second Edition-Health Criteria and Other Supporting Information.
- WHO, (2001), Guidelines for drinking water quality, Vol.2. World Health Organizations, Switzerland, Geneva

➢ World Health Organization and United Nations Children's Fund, author (2002), World Bank Document. Federal Democratic Republic Ethiopian Urban water supply and sanitation project. United States of America [Dec. 2012]. http://www.worldbankorg

➢ WHO (2004), Guidelines for drinking water quality, 3rd edition Vol.1. World Health Organizations, Switzerland, Geneva

➢ WHO (2006), International programme on chemical safety Geneva.

➢ WHO (2008), Guidelines for Drinking-Water Quality, incorporating the first and second addenda, World Health Organization, Geneva Switzerland, volume 1.

➢ WHO, (2011) guideline for drinking water quality, 4^{th} edition, printed in Malta.

➢ Zeyede kebede, Tesfaye Gobena (2004), Alemaya university in collaboration with the Ethiopia public health training initiatives, The carter center , the Ethiopia minister of health and the Ethiopian minister of education.

➢ Z.Michael Lahlou, (2002), Water quality in distribution system, Tech Brief water treatment and supply fact sheet, West Virginia university, Morgan town, , page1-4

Annexes

Annex 1 check list format

<u>Check list for assessing the sanitary condition of Mercato area</u>

Name of data collector……………………………..phone……………………..

Date of data collection……………………………

Wereda…………………………house number……………………………..

1. Is there any Solid waste collection bins?

   Yes   No

2. Is there any drainage lines used for Liquid waste disposal?

   Yes   No

3. Is there a sewer or latrine within 30 m of any tap?

   Yes   No

4. Contact between drinking water pipes with solid or liquid wastes?

   Yes   No

5. Are any tap sheared with other house holders?

   Yes   No

6. Are there any leaks in the household pipe?

   Yes   No

7. Discontinuity in water supply at time of survey?

   Yes   No

8. Toilet facility

   Private   Common

Annex 2. Questionnaire format

Questionnaire to assess the knowledge, attitude and practice of mercato society on drinking water

Name ________________ sex _____ education status ___________ date___________ house no__________

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

☐ Yes ☐ No

2. In your house, is the water for drinking is stored in a separate container from water intended for other purposes?

☐ Yes ☐ No

3. Do you know there are water born agents that cause health problem?

☐ Yes ☐ No

4. If yes can you gust the source of these agents?

____

5. Do you think that the water you fetch from your tap is health?

☐ Yes ☐ No

6. If no what limitations do you think it has?

____

7. Do you think that water can be polluted in the distribution system?

☐ Yes ☐ No

8. If yes what are the factors that cause water quality deterioration with in the distribution system?

____

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

☐ Yes ☐ No

10. If yes what type of appropriate measures you think to resolve it?

____

11. Did you face water born diseases in recent years in your home?

☐ Yes ☐ No

12. If yes in what frequency and what measures do you take to solve the problem____

Annex 3 procedures in laboratory

1. Procedures for laboratory tastes

1 Electrometric Determination of pH

Apparatus

pH meter

Procedure

(i) Wash the electrodes carefully with distilled water.

(ii) Immerse the electrodes into the sample of water (whose pH is to be determined) and wait up to one minute for steady reading.

(iii) The reading is observed after the indicated value becomes constant.

2. **Turbidity**

Apparatus

(i) Spectrophotometer

Procedure

(i) Take 25ml of filtered sample in a flask.

(iii) Adjust the spectrometer by selecting from the spectrometer list for turbidity

(vi) put the samples to the spectroscope, and then press start

(vii) Take the reading from the screen.

3. **Measurement of Residual Chlorine in Water**

Apparatus Chloroscope

Reagent DPD (Diethyl Phenyl Damien)

Procedure

(i) Take water sample in one tube of the Chloroscope

(ii) Add 1pack of DPD to one of the tube

(iii) Colour shall develop only in the water having chlorine

(vi) Match the color with the color slides present in the Chloroscope

(v) Higher is the amount of chlorine present darker shall be the intensity of pink color.

(vi) If there is very less amount of chlorine (<0.1 Mg/l) the pink color produced shall be very faint and at that time compare it with the water in other tube and record the result.

4. Nitrates

Apparatus

(i) Spectrophotometer

Reagents

(i) Nitrate and Nitrite

Procedure

(i) Take30ml of filtered sample in a flask.

(ii) Add 1 pack nitrate power and shake it for 3min

(iii) Wait 2min and take 10ml from aliquots

(v) Add nitrite reagent and wait it 15 min

(vi) Adjust the spectrometer by feeding code for nitrate measure (2515) or select from the list

(vii) Insert the samples to the spectroscope, and then press start

(viii) Take the reading from the screen.

5. Ammonia

Apparatus

(i) Spectrophotometer

Reagents

(i) Nessler

Procedure

(i) Take 25ml of filtered sample in a flask.

(ii) Add 1ml of Nessler reagent

(iii)Adjust the spectrometer by feeding code for Ammonia measure (2400) or select from the list

(vi) Insert the samples to the spectroscope, and then press start

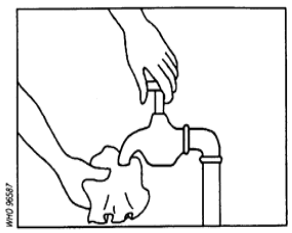
(vii) Take the reading from the screen.

Biological parameter (total coliform and facial coliform)

1. Sampling from a tap

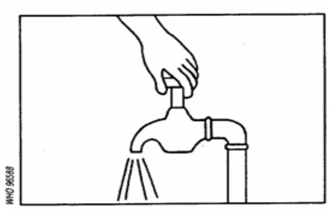
A) Clean the tap

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



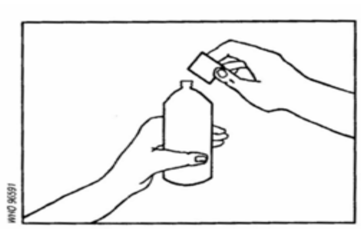
B) Open the tap

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 consumed.



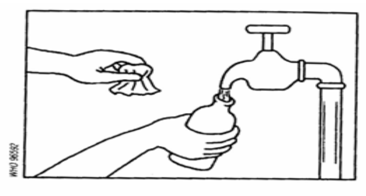
c) Open the sterilized bottle

Take out a bottle and carefully unscrew the cap or pull out the stopper.



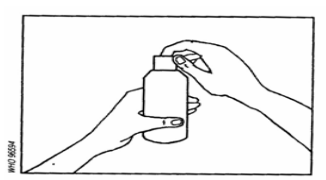
F) Fill the bottle

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.



G) Stopper or cap the bottle

Place the stopper in the bottle or screw on the cap and fix the brown paper protective cover in place with the string.



Annex4 preparation of reagents or media

Preparation of reagents (media)

Lactose broth

Steep1: put the pan to the kilo and adjust it at 0g

Step2: add 13g power form of lactose broth by using knife (spoon)

Steep3: add this powder to the bottle used to prepare lactose broth solution

Steep4: add 1litter of water and satire it

Steep5: use a conical shape bottle for this solution and adjust it at 10ml

Steep6: add 10ml Lactose broth to each tubes

Steep7: put the taste tubes in the sterilization machine for about 30min at a temperature of 121^0c

Steep8: pick out these sampling tubes and put in refrigerator

BGB (Brilliant Green Bile)

Steep1: put the pan to the kilo and adjust it at 0g

Step2: add 40g power form of BGB by using knife (spoon)

Steep3: add this powder to the bottle used to prepare BGB solution

Steep4: add 1litter of water and satire it

Steep5: use a conical shape bottle for this solution and adjust it at 10ml

Steep6: add 10ml Lactose broth to each tubes

Steep7: put the taste tubes in the sterilization machine for about 30min at a temperature of 121^0c

Steep8: pick out these sampling tubes and put in refrigerator

EC broth (Eschericacoli media)

Steep1: put the pan to the kilo and adjust it at 0g

Step2: add 37g power form of EC broth by using knife (spoon)

Steep3: add this powder to the bottle used to prepare EC broth solution

Steep4: add 1litter of water and satire it

Steep5: use a conical shape bottle for this solution and adjust it at 10ml

Steep6: add 10ml Lactose broth to each tubes

Steep7: put the taste tubes in the sterilization machine for about 30min at a temperature of 121^0c

Steep8: pick out these sampling tubes and put in refrigerator

Annex5. Laboratory results of Wereda 1 and 8

Sampling code	parameters						
	R.CI	PH	Nitrate	Ammonia	Turbidity	T.C	F.C
P1	0	8.6	0.86	0.92	8	5	3
P2	0.03	8.2	0.85	0.9	6.6	3	2
P3	0.07	8.17	0.91	0.99	6.4	4	1
P4	0.05	8.03	0.78	0.81	7.3	3	3
P5	0.02	8.03	0.78	0.8	6.8	2	1
P6	0.05	8.18	0.98	1.05	7.03	3	1
P7	0.07	8.24	0.7	0.73	6.2	2	0
P8	0.17	5.83	0.23	0.26	2.9	0	0

P9	0.3	4	0.13	0.33	2.5	0	0
P10	0.23	3.83	0.19	0.22	2.1	0	0
P11	0.02	8.4	0.94	0.96	7.8	3	1
P12	0.03	8.3	0.95	0.97	8	3	2
P13	0.07	8	0.94	0.99	7.4	2	1
P14	0.1	7.89	0.6	0.62	5.9	2	0
P15	0.07	8.26	0.69	0.77	6.3	1	0
P16	0.07	8.21	0.8	0.85	7.2	1	0
P17	0.23	5	0.1	0.21	1.4	0	0
P18	0.21	4	0	0.14	2.2	0	0
P19	0.17	5	0	0.3	2.4	0	0
R1	0.53	7	0	0	1.2	0	0
R2	0.4	7.3	0	0.003	1.2	0	0

Annex6 Questionnaire results of the study area

No	Question	Number of peoples	
		Yes (%)	No (%)
1	Is the water fetched from tap transported to your house with covered container	28	72
2	In your home is the water for drinking is stored in separate container from water intended for other purpose	15	85
3	Do u know the water you fetch from your tap will be polluted or contaminated through the path from treatment to your home	21.6	78.4
4	If yes what are the causes	✓ Waste water pipe connection ✓ Inter-connection with toilet ✓ Pipe corrosion ✓ Pipe breakage	
5	Do you know that drinking of contaminated water will causes water born disease?	100	
6	Did u expect that your tap water will be contaminated?	28.4	71.6

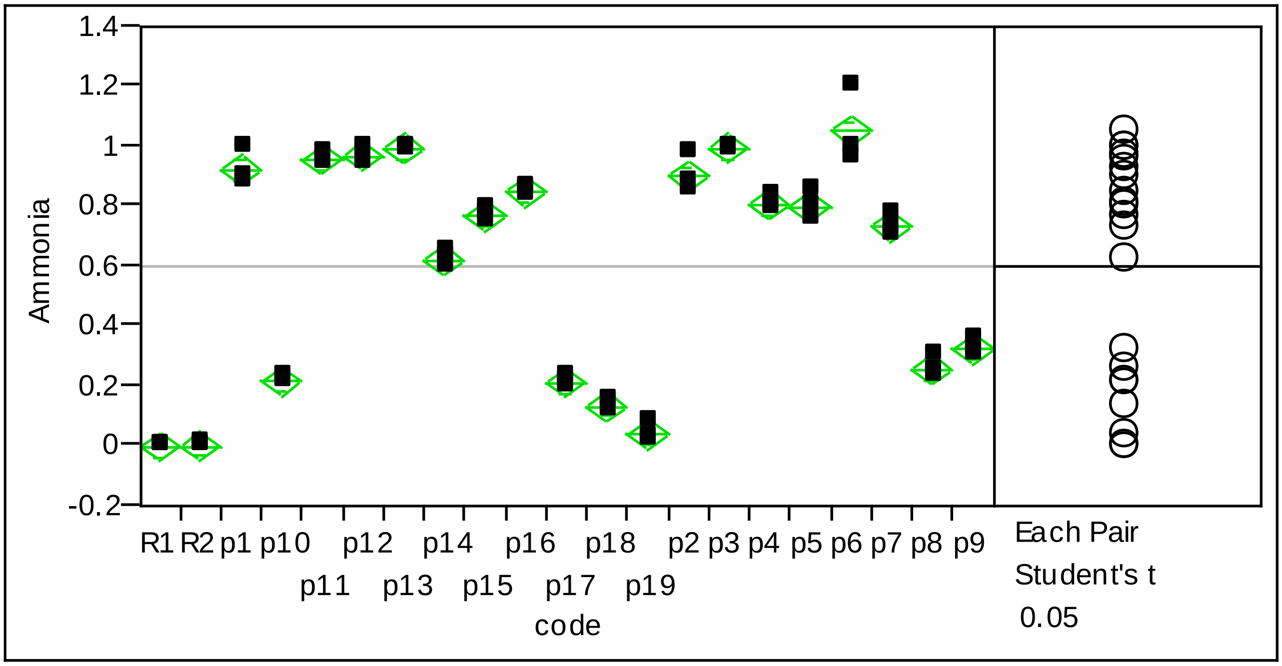
7	If yes what are the indications?	✓ Bad taste ✓ Smile ✓ color	
8	Is your tap away from any potential source of pollutant or contaminant?	21.6	78.4
9	If no what are the causes?	✓ lack of place ✓ economic deficiency	
10	Did u face any water born disease in your home?	71.6	28.4
11	If yes when?	35	Within the past month
		64	Within this month
		1	In this week
12	What practices did you take to overcome this problem?	13	Using water tab
		36	Boiling
		54	No treatment

Annex 7. Checklist results

Questions	Good (%)	Bad (%)
1. Drinking water and sewerage pipe line placement	37	63
	Yes (%)	No (%)
2. Solid waste management system or mechanism?	32	68
3. Liquid waste management system or mechanism?	52	48
4. Contact between drinking water pipes with solid or liquid wastes near to the faucet?	60	40
5. Placement of tap away from any potential source of pollutant or contaminant?	28	72
6. Are any tap sheared with other house holders?	85	15
7. Are there any frequent leaks in the household pipe	87	13
8. Discontinuity in water supply at time of survey?	68	32
	Private (%)	Communal (%)
9. Toilet facility	17	83

Annex 8 Analysis results of parameters using JMP

Oneway Analysis of Ammonia By code



Oneway Anova

Summary of Fit

Rsquare	0.99189
Adj Rsquare	0.988028
Root Mean Square Error	0.041212
Mean of Response	0.600317
Observations (or Sum Wgts)	63

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
code	20	8.7240603	0.436203	256.82 98	<.0001
Error	42	0.0713333	0.001698		
C. Total	62	8.7953937			

Means for Oneway Anova

Std Error uses a pooled estimate of error variance

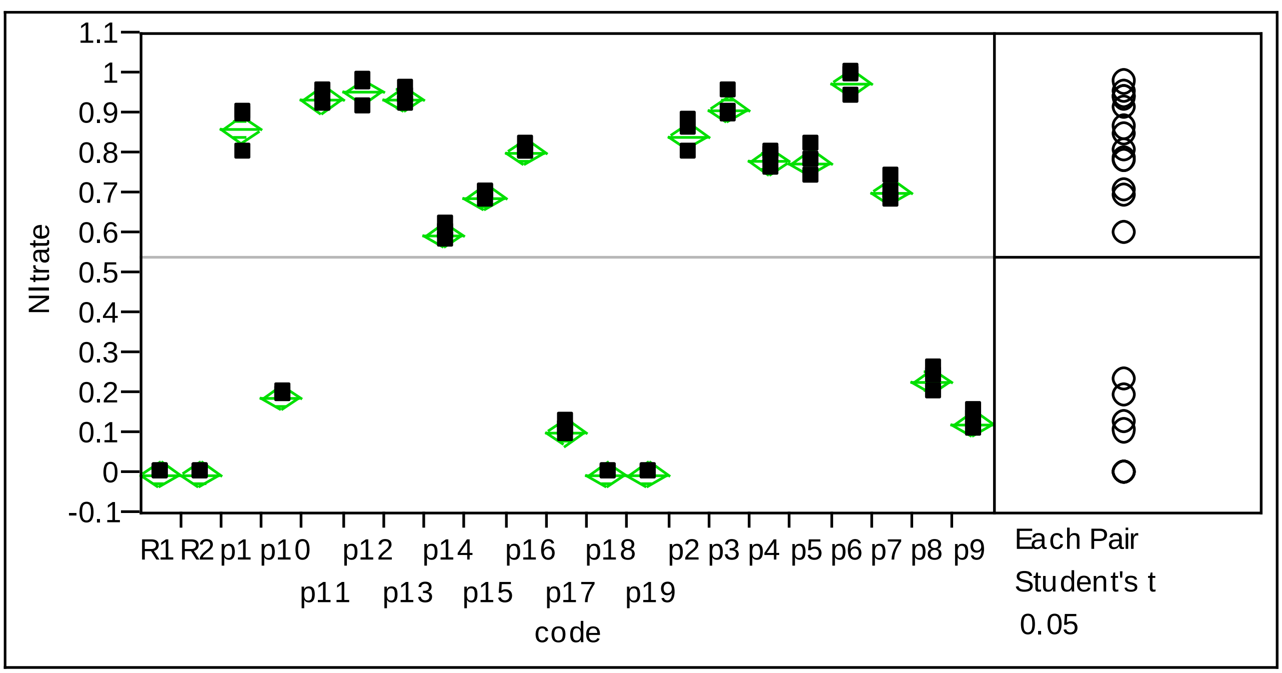
Means Comparisons

Level												Mean
p6	A											1.0533333
p13	A	B										0.9966667
p3	A	B										0.9966667
p12		B	C									0.9733333
p11		B	C	D								0.9600000
p1			C	D								0.9266667
p2				D	E							0.9033333
p16					E	F						0.8500000
p4						F	G					0.8100000
p5						F	G					0.8033333
p15							G	H				0.7700000
p7								H				0.7333333
p14									I			0.6266667
p9										J		0.3266667
p8										J	K	0.2600000

Level		Mean
p10	K	0.2200000
p17	K	0.2133333
p18	L	0.1366667
p19	M	0.0433333
R2	M	0.0033333
R1	M	0.0000000

Levels not connected by same letter are significantly different

Oneway Analysis of NItrate By code



Oneway Anova

Summary of Fit

Rsquare	0.996819
Adj Rsquare	0.995304
Root Mean Square Error	0.026156
Mean of Response	0.545556
Observations (or Sum Wgts)	63

Analysis of Variance

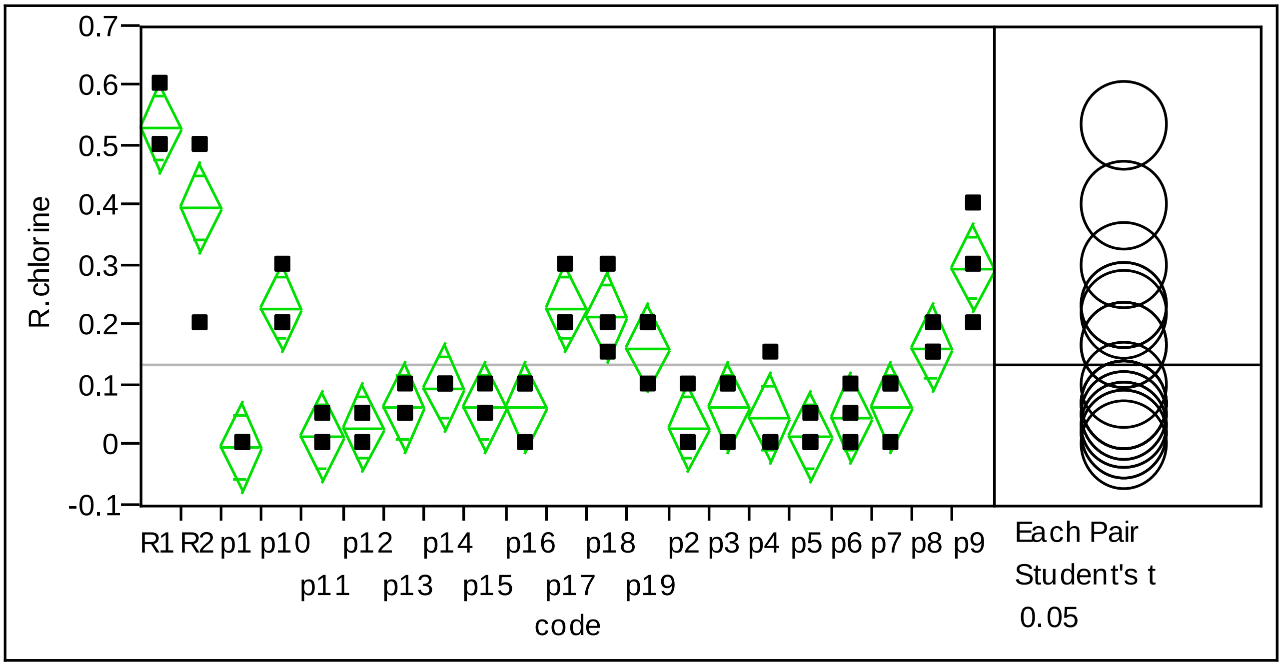
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
code	20	9.0034222	0.450171	658.022 7	<.0001
Error	42	0.0287333	0.000684		
C. Total	62	9.0321556			

Level								Mean
p6	A							0.97666667
p12	A	B						0.95333333
p13	A	B						0.94000000
p11	A	B						0.93666667
p3		B						0.91333333
p1			C					0.86333333
p2			C	D				0.84666667
p16				D	E			0.80666667
p4					E			0.78333333
p5					E			0.78000000
p7						F		0.70666667
p15						F		0.69333333
p14							G	0.60000000

Level				Mean
p8	H			0.23333333
p10	H			0.19333333
p9		I		0.12666667
p17		I		0.10333333
R2			J	0.00000000
p18			J	0.00000000
p19			J	0.00000000
R1			J	0.00000000

Levels not connected by same letter are significantly different

Oneway Analysis of R.chlorine By code



Oneway Anova

Summary of Fit

Rsquare	0.869873
Adj Rsquare	0.807908
Root Mean Square Error	0.06455
Mean of Response	0.137302
Observations (or Sum Wgts)	63

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
code	20	1.1698413	0.058492	14.038 1	<.0001
Error	42	0.1750000	0.004167		
C. Total	62	1.3448413			

Means for Oneway Anova

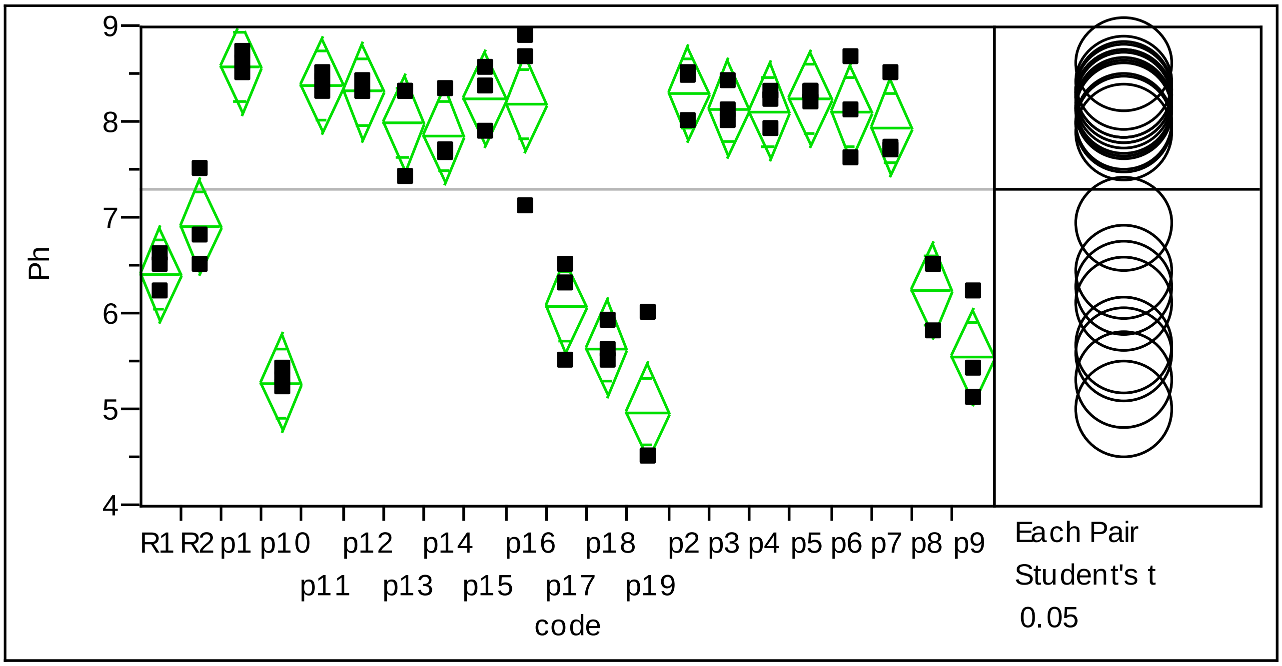
Std Error uses a pooled estimate of error variance

Level							Mean
R1	A						0.53333333
R2		B					0.40000000
p9		B	C				0.30000000
p17			C	D			0.23333333
p10			C	D			0.23333333
p18			C	D			0.21666667
p19				D	E		0.16666667
p8				D	E		0.16666667
p14					E	F	0.10000000
p3					E	F	0.06666667
p15					E	F	0.06666667
p13					E	F	0.06666667
p16					E	F	0.06666667
p7					E	F	0.06666667
p6						F	0.05000000
p4						F	0.05000000
p2						F	0.03333333
p12						F	0.03333333
p11						F	0.01666667
p5						F	0.01666667

Level		Mean
p1	F	0.00000000

Levels not connected by same letter are significantly different

Oneway Analysis of Ph By code



Oneway Anova

Summary of Fit

Rsquare	0.91646
Adj Rsquare	0.876679
Root Mean Square Error	0.437623
Mean of Response	7.329683
Observations (or Sum Wgts)	63

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
code	20	88.240794	4.41204	23.037 7	<.0001
Error	42	8.043600	0.19151		

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
C. Total	62	96.284394			

Means for Oneway Anova

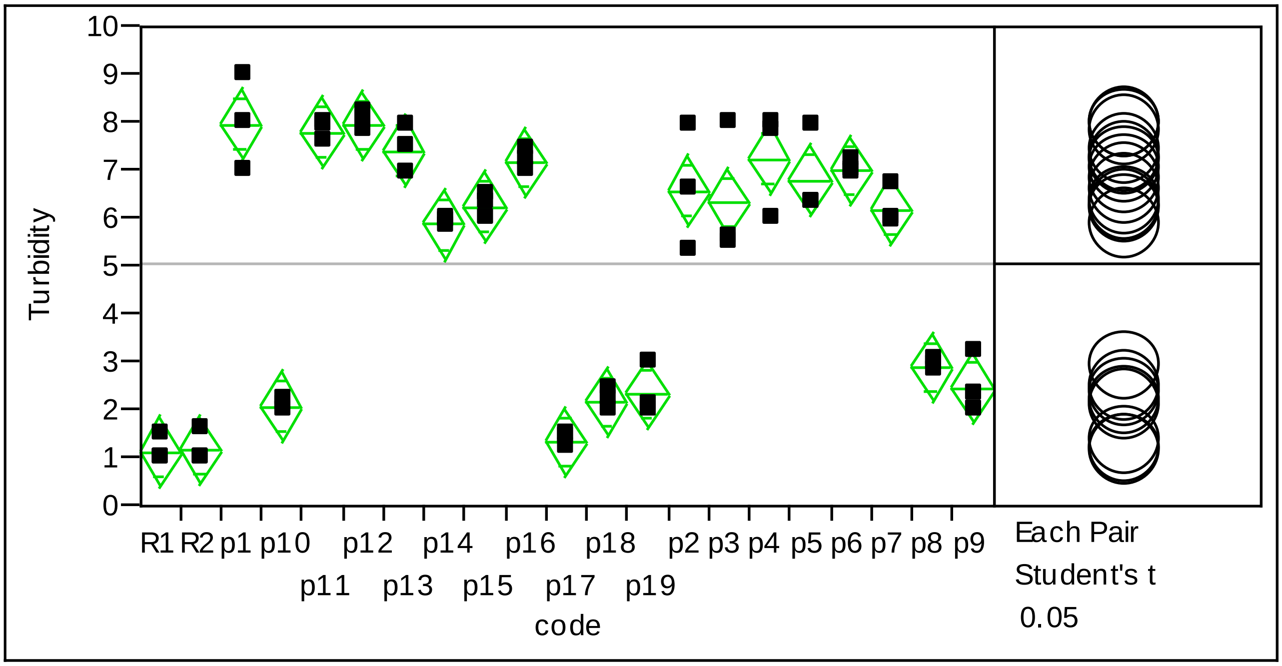
Std Error uses a pooled estimate of error variance

Level					Mean
p1	A				8.6000000
p11	A				8.4000000
p12	A				8.3333333
p2	A				8.3166667
p5	A				8.2633333
p15	A				8.2600000
p16	A				8.2133333
p3	A				8.1666667
p4	A				8.1333333
p6	A				8.1166667
p13	A				8.0033333
p7	A				7.9633333
p14	A				7.8866667
R2	B				6.9333333
R1	B	C			6.4333333
p8	B	C	D		6.2666667
p17		C	D		6.1000000
p18			D	E	5.6666667
p9			D	E	5.5666667
p10				E	5.3000000

Level		Mean
p19	E	5.0000000

Levels not connected by same letter are significantly different

Oneway Analysis of Turbidity By code



Oneway Anova

Summary of Fit

Rsquare	0.959763
Adj Rsquare	0.940603
Root Mean Square Error	0.632437
Mean of Response	5.081111
Observations (or Sum Wgts)	63

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	Ratio	Prob > F
code	20	400.70302	20.0352	50.09	<.0001

Source	DF	Sum of Squares	Mean Square	Ratio	Prob > F
				09	
Error	42	16.79900	0.4000		
C. Total	62	417.50202			

Means for Oneway Anova

Std Error uses a pooled estimate of error variance

Level								Mean
p1	A							8.0000000
p12	A							7.9666667
p11	A	B						7.8333333
p13	A	B	C					7.4333333
p4	A	B	C	D				7.2666667
p16	A	B	C	D	E			7.2000000
p6	A	B	C	D	E			7.0333333
p5		B	C	D	E	F		6.8333333
p2			C	D	E	F		6.6000000
p3				D	E	F		6.3666667
p15				D	E	F		6.2666667
p7					E	F		6.2000000
p14						F		5.9000000
p8							G	2.9133333
p9							G	2.5000000

Level				Mean
p19	G	H		2.3666667
p18	G	H	I	2.2000000
p10	G	H	I	2.1000000
p17		H	I	1.3666667
R2			I	1.1900000
R1			I	1.1666667

Levels not connected by same letter are significantly different