ADDIS ABABA UNIVERSITY

INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Water Supply Quality Problem and its Impact of Agaro Town

A Thesis Submitted to the School of Civil and Environmental Engineering of Addis Ababa University in Partial Fulfilment of the Degree of Masters of Science in Water Supply and Environmental Engineering

By:

Rezika Dafiro

Addis Ababa

Ethiopia

March, 2017

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DECLARATION

I declare that this thesis, which I submit to School of Civil and Environmental Engineering of Addis Ababa University in partial fulfillment of the requirement of degree of Master of Science in Water Supply and Environmental Engineering, is my own personal effort. The thesis has not been submitted previously, in whole or in part, to qualify for any other academic award. Furthermore, I took reasonable care to ensure that the work is original, and, to the best of my knowledge, does not breach copyright law, and has not been taken from other sources except where such work has been cited and acknowledged within the text.

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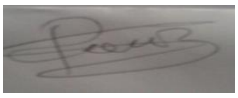

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Ethiopia

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LIST OF ABBREVIATION

AWWA------------------------------American Water Works Association

AWSSA------------------------------Agaro Water Supply and Sanitation Authority

AWSSB-------------------------------Agaro Water Supply and Sanitation Board

Cuf ------------------------------------Colony forming unit

DDR-----------------------------------High Dynamic Range

EC---------------------------------------Electrical conductivity

EDWQS----------------------------- Ethiopian Drinking Water Quality Standard

EPA-------------------------------------Environmental Protection Agency

FAO-----------------------------------Food and Agricultural organization

JICA ----------------------------------Japan International Cooperation Agency

HH-------------------------------------Household

M/DBP-------------------------------Methylene dioxy benzyl piperazine

µS/cm--------------------------------Microsecond per centimeter

MDG---------------------------------Millennium Development Goal

Mow----------------------------------Ministry of Water and Irrigation

NRC----------------------------------NationalResearch *Council*

NTU----------------------------------Nephelometric Turbid Unit

SMI ----------------------------------Small and micro intersperse

SP1-----------------------------------sample point one

UNICEF-----------------------------United Nations International Children's Emergency Fund

U.S. EPA --------------------------United States Environmental Protection Agency

UNESCO --------United Nations Educational, Scientific and Cultural Organization

TDS -------------------------------Total Dissolved Solid

WHO ----------------------------World Health Organization

GLOSSARY

Distribution system- a system of conveyances that distributes potable water(All pipes, storage tanks, pipe laterals, and appurtenances that comprise the delivery system).

Corrosive- a characteristic of water related to alkalinity, pH, dissolved oxygen, total dissolved solids and hardness. Any combination of these features under localized conditions can cause water to be corrosive, gradually weakening or destroying the distribution system pipes and other materials. This affects the quality of water at the tap.

Bacterial Analysis- a test to detect the presence or absence of coli form bacteria. It requires a sterile container, available from the testing laboratory.

Contaminant - any physical, chemical, biological or radiological substance or matter in the water.

Potable water - water safe for drinking.

Ppm - parts per million; a metric unit used to denote concentration of chemicals or other substances in water. Equivalent to mg/l. The unit implies a part of something in one million parts of water. The following comparisons help in putting this concentration in perspective: one inch in 16 miles; one cent in $10,000; or one drop in 60 quarts.

Mg/l - milligrams per liter; metric unit used to denote concentrations of chemicals or other Substances in water. Mg/l and ppm are equivalent expressions of concentrations.

Water supply System – The water supply source, treatment plant infrastructure and processes, and the water distribution system.

ABSTRACT

Agaro Town has been experiencing the problem of potable water supply in adequate quality even if the modern water supply system was installed since in 1961 and expanded its service by drilling a number of boreholes, it is common to see red water color in different interval of months .Still a number of people do not have access adequate amount of potable water and also they are not used for all home consumption. This research has focused on Water quality problems in town and its impact different bodies.

Laboratory analysis characterizing and evaluating its quality by comparing with WHO and Ethiopian Standards is used in this research for identifying water quality problems in the town. By preparing Questionnaires with the aim of recognizing impact of water quality problems , for different people that cannot used distributed water for all home consumptions like merchant of the town that can partake coffee and tea, and people that can follow Muslim religion they cannot used for preparation of soup in the month of Ramadan. Economical loss by requiring another source of water is described in this body of this study.

TWATER CAD software is used in water distribution system to analyze pressure and velocity and Pressure measurement was taken in different location of distribution system for the purpose of calibration. The parameters like Iron, Electrical conductivity, Total coli form, Turbidity, Dissolved oxygen and E. coli are not within the maximum permissible limit prescribed by WHO and Ethiopian drinking water quality standard.

The max and min pressure by WATER CAD is at 7 and 10 junction respectively and max and min velocity is at 5 and 21 links respectively, whereas by Gagged pressure at sample location point is 3 junction low pressure observed . The total simulation accuracy of pressure in the network systems as assessed by statistical methods, R^2=0.899

Generally it can be concluded that the source of water supply contain high level of iron, it affects color of coffee, tea and soup this results affect high cost loss in merchant of the town that participate on preparation of coffee and tea , the people that follow Muslim region because of soup is prepared during the month of Ramadan, high level of iron contain high corrosive problem it affect pipes and pumps in the borehole . The other is as they not used pre and post chlorination total coli form and ecoli is show above permissible limit because this water born and water related disease is the first top ten diseasesshown in the town.Aeration, chlorination and house hold water treatment like boiling is the most recommended for removal of these contaminants in the town water supply system. KEY WORD:-water quality parameters, physical, chemicaland biological, water cad pressure and velocity, Agaro East of Ethiopia.

CHAPTER ONE

1. INTRODUCTION

1.1 Background of the Study

Water, air, food and shelter are the essential items for any living beings. It is possible to survive without food and shelter for some days. Next to air, one cannot survive without water even for much time.(GURCHAN SINGH march 1974).

All peoples, whatever their stage of development and their social and economic Conditions, have the right to have access to drinking water in quantities and quality equal to their basic needs"(Mar del Plata Water Conference 1977).

Water is most vital liquid for maintaining the life on the earth. About 97% water is exists in oceans that is not suitable for drinking and only 3% is fresh water wherein 2.97% is comprised by glaciers and ice caps and remaining little portion of 0.3% is available as a surface and ground water for human use (M Mohsin ,Miller, *1997*).

The most fundamental human needs of water are for drinking, cooking and personal hygiene. To meet these needs, the quality of the water used must pose no risk to human health, in nature also not affects the condition of ecosystems that all living organisms depend on. Most users of water depend on adequate levels of water quality when these levels are not met, these users must either pay an additional cost for water treatment or incur at least increased risks of damage or loss.(DP Loucks - 2005).

The production of drinking water is a major problem of developing countries and particularly those in tropical area of Africa. Degradation of drinking water quality in distribution networks represents a problem for water supply in majority of urban area. There are serious problems regarding the water supplies in the towns with high density of population (highly cash crop area), because the quantity and quality of groundwater are not sufficient to ensure the total potable water demands(Paul R. Hunter mail, November 09, 2010) .

The impact of water quality problems in the world includes such as; 88% of diarrhea disease is attributed to unsafe water supply, inadequate sanitation and hygiene. 1.8 million People die every year from diarrhea diseases (including cholera); 90% are children under 5, mostly in developing countries. Every 8 seconds a child dies from drinking contaminated water (that is 10,000 a day). 500 million people are at risk from trachoma, 146 million are threatened by blindness and 6 million people are visually impaired from this disease. In Bangladesh, between 28 and 35 million people consume drinking water with elevated levels of arsenic. Over 26 million people in China suffer from dental fluorosis due to elevated fluoride in their drinking water (WHO,2004).

Every Ethiopian citizen shall have access to sufficient water of acceptable quality, to satisfy basic human needs.Water quality/safety management is not part of water supply Operation and management as the result of budget, human resource and Knowledge and capacity gaps at national, regional, woreda and scheme level(MoWE 2013)

About 50% of Ethiopia's population are without access to "safe" and "adequate" domestic water supply; Indication that majority people forced to meet drinking water needs from unprotected & contaminated water sources; the health of majority population is exposed to various types of water borne/related diseases that are cause for high mortality and morbidity in the country(JICA , 2013).

Water distribution systems that are vital in supplying communities with their water demand Include pipes, pumps, valves and reservoirs and are designed to deliver water at adequate discharge and pressures according to demands and with specific quality. (Leanne Tippet, Dec. 10, 2013)

The larger the quantity and the better the quality of water, the more rapid and extensive has been the advance of public health (Wagner *and Laniox*, 1959).

Poor water supply source (Groundwater) quality is due to the presence of contaminants. The term contamination' is considered here in broad sense, including salinity, physic-chemical characteristics, and inconvenient solutes at very different concentrations, biological components, radioactivity and temperature. Groundwater contaminants may be: natural origin induced by aquifer exploitation; introduced as a result of human activity; and a combination of the two (*Kazner* – 2009)

Agaro town is the capital city of Gomma woreda in Jimma Zone of Oromia Region of Ethiopia at 396 KM from AA in direction of the west and 45KM from Jimma zone in the same direction. Its population 41,000 (2014), its coverage area is 2160 hectare. The modern water supply system was introduced at 1968 for first time. Spring development the first water supply sources of the town its name is chanchospring and its uses gravity distribution system.

after 12yearse addition of one borehole was done. In 1997 E.C the Agro town Water Sapply and sanitation Authority was upgrading of the source up to four(4) number of borehole 80-110m depth, service the community of the town up to know .

Agaro Town are characterized by having old water distribution networks from 1968 upon which new extensions are linked in order to serve new areas, as more of the pipe materials is GSI pipe it affects the quality of the water ,as network where full rehabilitation may not be convenient due to economic constraints.

According to GTP Increase rural water supply access coverage from 65.8% (baselineat2010) to 98% at15 litters per person per day within the radius of 1.5km in 2015 Safe Water Chain Management from Source to mouth/household water treatment and safe storage 77% by 2015 and Water quality management measures are actions taken to ensure that the total the physical, chemical and biological parameters of water quality do not the levels of quality specified by quality standards set for those waters(MoWE,2013).

Since the distributed water supply in Agaro town are not good the community can not used for the preparation of coffee, tea and soup(shorba) during Ramadan month.The study aimed to assess and compare the quality water of the town with WHO and EDWQ standards, its impact and model the distribution system using WATERCAD software in order to checked Pressure, velocity.

1.2 Statements of the Problems.

As water is the basic need next to air at the second level its wholesome is the very important some people cannot use distributed water for drinking purpose and different home consumption. For example the people affected by kidneys, gastric and another stomach disease. They exposed to additional coast of water and if they use for drinking and other house hold purpose disease can increase and also vulnerable on healthy problem, extra cost of medicine and other social and economical aspects .

The problem quality of water supply affects merchants of Agaro Town . There are 250 small and micro enterprise that can participate on preparation of tea and coffee they are not used tap water for this purposes. They my forced to use the local unprotected well around their area and they are affected by high water prices as well as high labor force to carry and pull water from the well.

According to Agaro Town statically Agency 80% of the community is Muslim. Therefore as we know the Muslim people can use soup or shorba during the month of Ramadan. Theycannot usetap water for the above mentioned purpose.

In the Town it is common to see red color of water in different interval of months. The pipe conveying water from borehole is GSI (Galvanized steel iron pipe). It replaced two wise in a year when the color of supplied water start changed to red color if the replacement of pipe is immediately didn't done all submersible pumps and pipe material damaged this is huge problem on supply side and demand side .

Source selection is the first characteristics of raw water quality; if physical, chemical and biological characteristics are not good its quality can be under or excess WHO or EDWQS. These happens economical and healthy impacts on the town community. Knowing of these characteristics can help for selection of treatment technology (removal of the impurity). Therefore this research can determined out quality problems that pass or below EDWQS and rise their impacts and propose the appropriate removal of water contaminants for sustainable use.

1.3 Research Questions

Questioners prepared for assign the magnitude of water supply quality problem and its impacts on Agaro Town. The detail of these questioners shown on annex A.

1.4 Objective of the Study

1.4.1 General Objective

The general objective of this research is to assess water supply system quality problems and its impacts of Agaro town in order to recommend mitigation measurements.

1.4.2 Specific Objectives

- To characterize the drinking water quality from source to point of distribution.
- To assess pressure and velocity variation in the system.
- To measure night pressure for the purpose of calibration .
- To describe the possible impacts of the water quality problems on demand and supply side.
- To recommend necessary mitigation measures

1.5 Significance of the Study

The significance of this study is a clearly identifying the problem of water quality in the town and its impacts.

Additionally it may give awareness and use as reference for sustainable problem solving and future planning.

Non-governmental organizations (NGOs) which have interest in assessing Agaro town with financial and technical support in the area on impact of water supply problems can use the research outcomes as reference for their objective.

The research findings can initiate other researchers to further study the Delivery of similar town services And it

Itdesigning and modifying the town'swater supply based on evidence and contributes to proposed treatment technology.

1.6 Scope and Limitation of the Study.

The scopes of this research will extended to assessing water quality on the source(raw water), and distributed water on the system and its impact and give the genera recommendation and model the distribution system using software in order to checked pressure and velocity in the distribution line .WATER CAD) mode (water quality) not include age, trace and constraints of water.

1.7Organization of the Study

This study has been organized into five chapters. The first chapter deals the proposal part and its approach which contains background, statement, objectives and research design and procedures. The second chapter presents theoretically by reviewing different literatures. The third chapter treats presentation and analysis of data study area and different data collected from the organizations under the study areas. The fourth chapter presents the major findings and discussion and the last one is conclusion and recommendation.

1.8 Outline of the Thesis.

This report is divided into 5 Chapters. Chapter one contains the introduction and background, Chapter two contains Literature review information regarding water quality , parameters of water quality , water quality problems in Ethiopia , water quality impacts , water cad models , pressure and velocity in water distribution system .

Chapter three presents a general description of the study area, material and n methodology.

In Chapter four the obtained results from laboratory analysis and model analysis present, water quality, pressure and velocity on distribution system results. The results using laboratory analysis and WATER CAD.

Chapter five finally, presents the conclusion and recommendation about the obtained results.

CHAPTER TWO

2 LITERATURE REVIEW

Deterioration in drinking water quality either at source or in the distribution system has been caused by factors such as natural, human made (or demand driven) and institutional (like lack of monitoring system). Natural factors such as geological and geographical characteristics lead to inorganic contamination with excess iron, while human made factors like over extraction of groundwater, discharging pollutants to surface and ground water bodies, inadequate and improperly designed drainage and sewerage systems too add their share of pollution. In addition, the common practice of using open places for defecation, washing clothes and animals, bathing around water bodies, also pollute water sources. Industrial effluents discharged to open place and water bodies is another major cause for decline in water qualityGleick, Peter H (1998),

Throughout the world there is a strong correlation between access to safe drinking water and economic growth that correlation may be explained in different ways higher levels of access to safe drinking water are likely to increase the rate of economic growth, by improving the health and education of a population and minimizing the costs of unsafe drinking water. Economic growth and access to safe drinking water both depend on the same factors, such as socioeconomic stability. Economic growth results in higher levels of access to safe drinking water because governments may increase spending on water infrastructure (WHO and Unicef 2006

Biological or organic contamination of water gives rise to water-borne diseases The common diseases occurring due to unsafe drinking water are gastroenteritis, cholera, typhoid ,malaria,deharria The common diseases occurring due to unsafe drinking water are gastroenteritis, cholera, typhoid ,malaria and others(Puttas wamaiah S 20011)

Worldwide, infectious diseases such as waterborne diseases are the number one killer of children under five years old and more people die from unsafe water annually than from all forms of violence, including war. (WHO 2002)

Unsafe or inadequate water, sanitation, and hygiene cause approximately 3.1 percent of all deaths worldwide, and 3.7 percent of DALYs (disability adjusted life years) worldwide WHO 2002)

2.1 Water Quality Criteria

Potable water quality fulfill the basic requirements such as free from bacteria that causes disease, Free from compounds that cause an offensive taste & odor, It should be colorless/clear , It should not corrode pipes, It should be free from all objectionable matters, It should be not saline and low in concentrations of compounds are acutely or toxic (JICA2013)

2.2 Ethiopia's Water Quality Situation

According to JICA 2013 report About 50% of Ethiopia's population are without access to "safe" and "adequate" domestic water supply; Indication that majority people forced to meet drinking water needs from unprotected & contaminated water sources it Implies that the health of majority population is exposed to various types of water borne/related diseases that are cause for high mortality and morbidity in the country.

2.3Water Quality Problems in Ethiopia

The major prevalent/common water Quality problems In Ethiopia are those related to: Microbiological including Total and Fecal Coli forms, Physical problems are Turbidity, Color, Odour , temp and Taste and Chemical problems F, NO3 NO2 ,Fe, $So^3{}_4$, $Cl_{2.}$(MoWE2013)

2.4Water Quality Characteristics

Absolutely pure water is never found in nature and contains number of impurities in varying amount. The rain water which is originally pure also absorbs various gases, dust and other impurities while filling. This water when move on the ground farther carries salt, organic and in organic impurities. So this water before supplying to the public should be treated and purified for the safety, of public healthy ,economy and protection of varicose industrial process For the purpose of classification the impurities present in water may divided intoPhysical parameters /characteristics/,Chemical parameters/ characteristics/ and Biological parameters/ characteristics/(Puttas wamaiah S 20011).

2.5 Basic Water Quality Parameters

The physical chemical and biological basic parameters required for drinking water supply are pH ,Specific conductance (EC) , Salinity ,Total dissolved solids (TDS) Turbidity , Dissolved oxygen DO) , and .Temperature(J.R. Dojlido ,Zanieczyszczenia 1991)The detail description illustrated in table 1.

Table 1Basic physical chemical and biological parameters required for drinking water supply

Physical	Chemical	Biological
TDS	Dissolved oxygen	Total coliforms
Color	pH	E.coli
Turbidity	Total Alkalinity	
Conductivity	Chloride	
Taste	Residual chlorine	
Odor	Iron	
	Nitrate	

Source: - Water Treatment Processes & Design lecture note.

2.5.1 Physical Parameters/ Characteristics/.

Consumer perception and acceptability of their drinking water quality depends on user sense of taste, odor and appearance (Sheat 1992; Doria 2010). That is why consumers have differing opinion about the aesthetic values of water quality. Relying on their own senses may lead to avoidance of highly turbid or colored but otherwise safe waters in favor of more aesthetically acceptable but potentially unsafe water sources (WHO, 2009).

Taste and odor can originate from various natural chemical contaminants, biological sources, microbial activity, from corrosion or as a result of water treatment (e.g. chlorination) .Color, cloudiness, particulate matter and visible organisms can also contribute to unacceptability of water sources. These factors can vary for each community and are dependent on local conditions and characteristics(WHO, 2004).

True color (the color that remains after any suspended particles are removed); Turbidity (the cloudiness caused by particulate matter present in source water, re suspension of sediment in the distribution system, the presence of inorganic particulate matter in some groundwater or sloughing of bio-film within the distribution system (WHO, 2009).

Un usual taste, odor and „feel‟ problems (usually due to total dissolved solids) Turbidity is the most important problem for the aesthetic value of water quality. Alt hough it doesn‟t necessarily adversely affect human health, it can protect microorganisms from disinfection effects, can stimulate bacterial growth, and indicate problems with treatment processes (WHO, 2004).

Turbidity should be below 0.1 NTU although turbidity of less than 5 NTU is usually acceptable to consumers (WHO, 2010).

An important operational water quality parameter is pH, although within typical ranges it has no direct impact on consumers. Low pH levels can enhance corrosive characteristic resulting in contamination of drinking-water and adverse effects on its taste and appearance (WHO, 2010). Higher levels can lead to calcium carbonate deposition. Careful consideration of pH is necessary to ensure satisfactory water disinfection with chlorine, which requires pH to be less than 8 (WHO, 2010). The physical characteristics of drinking water supply include:-

Temperature

Temperature affects physical, chemical and biological processes in water bodies; Chemicals used in water treatment dissolve more easily in warm water than cold water; Particles settle out more quickly in warm water High water temperature enhances the growth of microorganisms and may increase taste, odor, color and corrosion problems and Cool water is generally more palatable than warm water(EPA2010). The temperature of ground water is more or less than atmospheric pressure .the most desirable temperature for public supply between 4.4^0c to 10^0c.the temperature above 35^0c are unfit for public supply, because it is not palatable(Bartram J et al., eds (2003).

Warmer temperatures are associated with increased growth rates of bacteria.Coliform-positive and corrosive water conditions, samples occur more frequently when the distribution system water temperature is above 15º C (HDR Engineering, Inc 2006 Volk and Joret, 1994; Volk and LeChevallier, 2000; Besner et al., 2009).

Temperature is a very important parameter for many physical and chemical water treatment applications Changes in temperature are also important to predicting distribution system integrity breaches including mains breaks, corrosion, nitrification and changes in hydraulic conditions. Temperature difference between storage tanks and entry to the distribution system can suggest stratification in storage tanks and hence degradation of water quality that could lead to microbial re growth in the distributions system (HDR Engineering, Inc 2006).

Temperature of groundwater depends mainly on the depth of water occurrence. Temperature can exert great control over aquatic communities, especially influence on biological activity and growth. If the overall water body temperature of a system is altered,

Turbidity

Turbidity is a principal physical characteristic of water and is an expression of the optical property that causes light to be scattered and absorbed by particles and molecules rather than transmitted in straight lines through a water sample. It is caused by suspended matter or impurities that interfere with the clarity of the water. These impurities may include clay, silt, finely divided inorganic and organic matter, soluble colored organic compounds, and plankton and other microscopic organisms (Hall, T., J. Presdee, and E. Carrington. 2008).

Typical sources of turbidity in drinking water include :-Waste discharges, Runoff from watersheds, especially those that are disturbed or eroding, Algae or aquatic weeds and products of their breakdown in water reservoirs, rivers, or lakes, Humic acids and other organic compounds resulting from decay of plants, leaves, etc. in water sources and. High iron concentrations which give waters a rust-red coloration (mainly in ground water and ground water under the direct influence of surface water). Air bubbles and particles from the treatment process (e.g., hydroxides, lime softening) simply stated, turbidity is the measure of relative clarity of a liquid.(Kenneth M. Vigil, P.E.. 2013)

Turbidity can be used as an indicator for identifying contamination entry, hydraulic problems or finished water reservoir rehabilitation frequencies in the distribution system. Sudden increases in turbidity can indicate main breaks, backflow, fire fighting or hydrant opening, flushing, scheduled maintenance or repairs, valve failures, and treatment failures in the distribution system .Particles in treated drinking water may also be introduced during new construction. Clarity is important when producing drinking water for human consumption and in many manufacturing uses. Once considered as a mostly aesthetic characteristic of drinking water, significant evidence exists that controlling turbidity is a competent safeguard against pathogens in drinking water (Kirmeyer et al., 2002b).

Turbidity's Significance to Human Health Excessive turbidity, or cloudiness, in drinking water is aesthetically unappealing, 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, which have caused significant cases of gastroenteritis throughout the United States and the world. Although turbidity is not a direct indicator of health (riskFox, K.R. 2007).

Hydraulic changes (velocity) will be too much in the network and transmission lines. High velocity could cause increased turbidity and corrosion rate in the water distribution system and could lead to decline in water quality in the distribution systems. The high turbidity makes loss of chlorine, coli forms will be attached to the particles it would not be able to reach and kill the bacteria. EPA (1992) opined that high velocity has been responsible for increased bacterial growth in to material of the pipes(. Lalzad London, May 2013).

TDS and Conductivity.

TDS and EC is the chemical characteristics of water. Both of them are used to grossly estimate the extent of the ionic species and non-filterable solids. In other words, conductivity is a measure of the ability of water to conduct an electric current and is expressed in µS/cm. It indicates the physical presence of dissolved chemicals in the water.

Natural ground source of water contain mineral ions. These ions slowly dissolved from soil particles, rocks and sediments as the water travels along mineral surface in the pores or fractures of the unsaturated zones and the aquifer .these referred to as dissolved solids(Conner, S.L. and Freeman, L.A., 2007).

The total mass of dissolved constitute shows as total dissolved solid concentration (TDS) . In water the total dissolved solid can be either positive charge (cations) or negative charge(anions) the total cations is always equal to the total anions . Higher TDS means the more cation and anion in the water. . EC can also be related to the concentrations of total dissolved solids (TDS) and major ions (JPS Cabral Oct 15, 2010

The greater amount of ions in the water reffed to as the electrical conductivity (EC) is in the water is high. high TDS concentration shows the water become saline. It becomes problematic for irrigation /crop. And desalination for water supply is difficult and required high investment of cost.

Electrical conductivity is the ease to which a substance allows free flow of electricity through the ions in electrolytes example of water sample, (M wendera, 2006). The Ethiopian Standard for Drinking Water Quality has set a maximum permissible level of the conductivity to be 400µS/cm. Any level above this can pose health risk of defective endocrine functions and also total brain damage with prolonged exposure (Hunter et al., 2009b).

Total dissolved solids (TDS) and electrical conductivity (EC) are measures of the total ions in solution and ionic activity of a solution respectively. As TDS and EC increase, the corrosive nature of the water increases (WHO/UNICEF2013)

Higher value means water is a better electrical conductor Increases when more salt (e.g., sodium chloride) is dissolved in waterConductivity, or specific conductance, is a measure of the ability of water to carryan electric current .This ability depends on the concentration, mobility, and valence of ions in the water as well as on water temperature. In general, watercontaining substantial concentrationsof inorganic compounds has higher conductivity. Water containing organic molecules that do not dissociate well will have lowerConductivity(HDR Engineering, Inc 2006).

Conductivity will remain fairly constant throughout a distribution system as longas the water is in equilibrium with the pipe material. Conductivity may vary more if thereare corrosion problems thus changes in conductivity may indicatecorrosion problems (USEPA. 2004)

Taste, Odour and Color

Chemically clean water is odorless, while odour of natural waters depends on the type and quantity of dissolved substances. Taste and odour are usually inter-related. Compounds in water that are perceived as giving it a taste are generally inorganic substances present at concentrations much higher than those of organic pollutants. Inorganic chemicals that can affect taste but not cause any odour are salt (NaCl), minerals and metals. The salt concentration in water should be approximately the same as in saliva for the water to taste neutral. Of the ions that may be present in water, iron can be tasted in distilled water at concentration of about 0.05 mg/dm, copper at about 2.5 mg/dm, manganese at about3.5 mg/dm and zinc at about 5 mg/dm Iron, in particular, I suspected of affecting the tastes(Murray et al 22augast2013).

Color in water result of contaminant by natural or man-made organic or inorganic. It indicates the presence pollution of drinking water of decomposed organic material from natural like leaves, roots & man-made sources of domestic or industrial waste waters and inorganic, such as Iron & Manganese

2.5.2 Chemical Characteristic

Secondary concern of the impact of chemical constituents is the effect on distribution and treatment systems that may be implemented to improve the access to a safe water supply. Corrosive properties of constituents can induce structural failure, which can also result in deterioration of the quality of the water and cause additional concerns for health and safety. Due to these concerns, corrosion control is an important aspect of the management of a drinking water system. PH can control the solubility and reaction rates of most metal species involved in corrosion reactions (WHO, 2008).

Iron, lead, copper, brass and nickel can also be used in construction of piping systems (WHO, 2004). Concrete is a composite material consisting of sand, gravel and cement, a binder consisting primarily of calcium silicates, aluminates and some lime (WHO, 2004). Structural deterioration or failure of cement may result from prolonged

Exposureto aggressive or highly corrosive waters which can result in leaching of metals from the cement into the water (WHO, 2008).

When ferrous iron oxidizes to ferric iron, it can give a reddish-brown color to the water, which could be aesthetically displeasing (WHO, 2004). Manganese can cause an undesirable taste as well as staining laundry when levels exceed 0.1 mg/liter. The presence of manganese may also lead to the accumulation of deposits in the piping system (WHO, 2004). There is no health-based guideline value set for iron but for manganese it is four times higher than the acceptable threshold of 0.1 mg/liter (WHO, 2004).

PH

The PH of pure water is refers to the measure of hydrogen ions concentration in water. It ranges from 0 to 14. In general, water with a PH of 7 is considered neutral while lower of it referred acidic and a pH greater than 7 known as basic. Normally, water pH ranges from 6 to 8.5. It is noticed that water with low pH is tend to be toxic and with high degree of pH it is turned into bitter taste. According to WHO standards pH of water should be 6.5 to 8.5.It is used to determine the condition of water for proper coagulation, softening, and stabilization (*Kenneth M. Vigil*, P.E.2013).

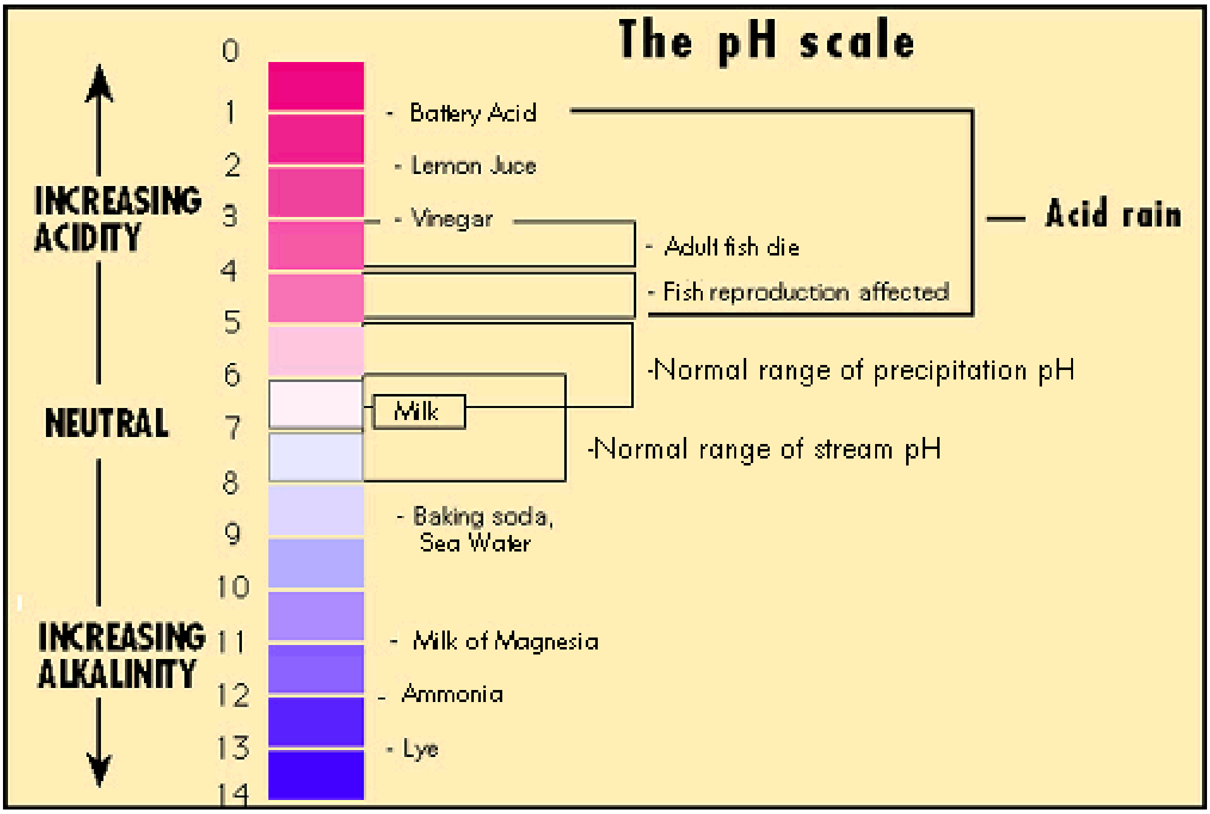

Figure 1PH Scale

An increase or decrease in the PH of the distributed water will affect corrosion and can therefore be an indicator of potential corrosion problems. Corrosion control efforts may be less effective due to decreases in PH. The pH of water in the distribution system is an important factor in nitrification activity (Harrington et al., 2003).

A reduction in pH can be an indication of problematic biofilmgrowth. For example, a decrease in pH can result from growth of sulfur-reducing bacteria such as *Thiobacillus*. These bacteria generate hydrogen ions which lowers the pH .A growth in nitrifying bacteria may also decrease the pH by oxidizing ammonium to nitrate and other nitrogen compounds. Monitoring for pH is one of the most common tests conducted for water. As part of the corrosion control treatment plan, pH must also be monitored and a minimum pH of 7.0 must be maintained within the distribution system (HDR Engineering, Inc 2006).

Dissolved Oxygen (DO)

The amount of oxygen that can be held by water depends on the water temperature, salinity, and pressure, Gas solubility increases with decreasing temperature (colder water holds more oxygen) Gas solubility increases with decreasing salinity (freshwater holds more oxygen than does salt water(Stanley E. Manahan USA 1993).

Excessive amounts of oxygen can become very corrosive .Excessive oxygen can cause additional problems in the treatment plant by, for example, causing air binding of filters (Utsev, J. T. , Aho, dec 18 (2011).

Depletion of dissolved oxygen in water supplies can encourage the microbial reduction of nitrate to nitrite and sulfate to sulfide. It can also cause an increase in the concentration of ferrous iron in solution with subsequent discoloration at the tap when the water is not aerated. No health-based guideline value is recommended and less than 9.5mg/l and greater than 110 mg/lis not recommended for domestic water supply. (WHO 2010)

Chloride (Cl).

Chloride is mainly obtained from the dissolution of salts of hydrochloric acid as table salt (NaCl), NaCO and added through industrial waste, sewage, sea water etc. Surface water bodies often have low concentration of chlorides as compare to ground water. It has key importance for metabolism activity in human body and other main physiological processes. High chloride concentration damage metallic pipes and structure as well as harms growing plants (Utsev, J. T. , Aho, dec 18 2011).

Total Alkalinity (mg/l) as $caco_3$

Alkalinity is the presence of one or more ions in water including hydroxides, carbonates and bicarbonates .It can be defined as the capacity to neutralize acid. Moderate concentration of alkalinity is desirable in most water supplies to stable the corrosive effects of acidity. However, excessive quantities may cause a number of problems.

First, a reduction of total alkalinity may accompany nitrification because a significant amount of bicarbonate is consumed in the conversion of ammonia to nitrite. While reduction in alkalinity does not impose a direct public health impact, reductions in alkalinity can cause reductions in buffering capacity, which can impact pH stability and corrosivity of the water toward lead and copper. Thus pH as an indicator can be used along with alkalinity as an indicator of nitrification(Harrington et al., 2003).

Alkalinity can be used to evaluate pipe replacement or storage tank coating Rehabilitation needs (Kirmeyer et al., 2002b).

Cement-lined pipes and storage tanks canleach calcium carbonate into thewater, which may significantly increase the alkalinity of the water. This is especially true when the cement-lined material is new, but also depends on the type of cement used, the contact time between the water and cement material, and the diameter of the pipe (Friedman et al., 2002).

Alkalinity can be used as an indicator to determine the corrosively of water in the distribution system. For example, leaching from metal pipes most commonly occurs in low alkalinity waters. In addition, a reduction in alkalinity results in a reduction of the buffering capacity of the water. Without buffering, the pH can more easily fluctuate, which may lead to corrosive conditions (Kirmeyer et al., 2002b).

Nitrate mg/l(no3).

Nitrate one of the most important diseases causing parameters of water quality particularly blue baby syndrome in infants. The sources of nitrate are nitrogen cycle, industrial waste, nitrogenous fertilizers etc(Michael H. (2006).

Iron.

The main source of iron in natural waters is erosion of minerals from rocks and soil. It is also introduced to water with acid mine, sewage from metallurgical, dyeing and galvanizing plants and due to corrosion of pipelines and steal constructions (W.F. McCoy, B.H. Olson 1986) .

Iron is present in water as Fe(II) and Fe(III) in dissolved, colloidal or suspended form. In presence of oxygen or oxidizing agents Fe(II) compounds easily oxidize to Fe(III) ones, which precipitate as hydroxides or oxides. Colloids can appear if organic substances are present in water, e.g. humic substances .Iron is an essential element in human nutrition (blood formation). Large quantities of iron in drinking water (acceptable 0.5 mg/dm3) cause turbidity, yellowish color and an un pleasant(M.W. LeChevallier, T.M. Evans, R.J. Seidler 1981).

Iron is an essential element in human nutrition. Estimates of the minimum daily requirement for iron depend on age, sex, physiological status, and iron bioavailability and range from about 10 to 50 mg/day(Putta swamaiah S.(2001).

The deposition of iron in water distribution networks is a complex electrochemical and physicochemical phenomenon between a metal surface and germ of crystallization. The deposition in the pipe depends on chemical factors, such as pH, alkalinity and physical properties, such as flow and velocity, as well as the pipe material..

Anaerobic groundwater may contain ferrous iron at concentrations up to several Mg/l without discoloration or turbidity in the water when directly pumped from a well. On exposure to the atmosphere, however, the ferrous iron oxidizes to ferric iron, giving an objectionable reddish-brown colour to the water. Iron also promotes the growth of "iron bacteria", which derive their energy from the oxidation of ferrous iron to ferric iron and in the process deposit a slimy coating on the piping. At levels above 0.3 mg/l, iron stains laundry and plumbing . There is usually no noticeable taste at iron concentrations below 0.3 mg/l, although turbidity and color may develop. No health-based guideline value is proposed for iron (WHO 2011)

2.5.3 Biological Characters.

Total Coliform.

There are three groups of coli form bacteria. Each is an indicator of drinking water quality and each has a different level of risk. Total coliform is a large collection of different kinds of bacteria. Fecal coliform are types of total coliform that exist in feces. *E. coli* is a subgroup of fecalcoliform. Labs test drinking water samples for total coliform. If total coliform is present, the labalso tests the sample for fecal coliform or *E. coli*, depending on the lab testing method(Stevens et al., 2003)..

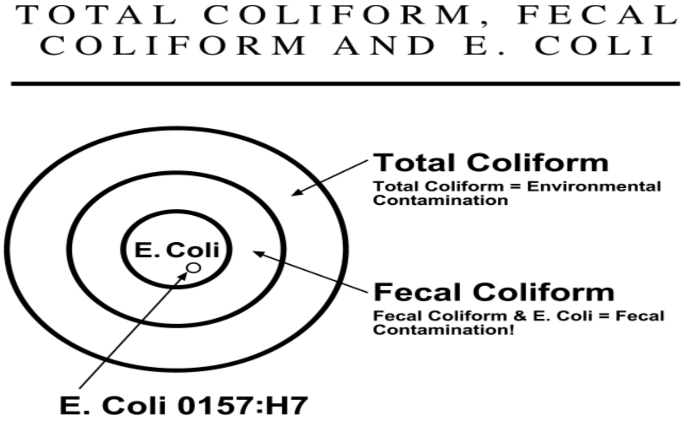

Figure 2Total coli form faecal coli form and E. coli.

Source from:-Coli form Bacteria and drinking g Water.

Bacteriological quality of water is important to determine the degree of disinfection and possible presence of waterborne pathogens. Bacteria, being small, are present almost everywhere, such as in air, water, and on lab equipment.

Total coli form bacteria have been used to indicate the presence of fecalcontamination; however, this parameter has been found to exist and grow in soil andwater environments and is therefore considered a poor parameter for measuring thepresence of pathogens (Stevens et al., 2003).

Itis the ability to grow in drinking water distribution systems and their unpredictable presence inwater supplies during outbreaks of waterborne disease, the sanitary significance or quality of water is difficult to interpret in the presence of total coli forms (Stevens etal., 2003).

To ensure the absence of waterborne pathogens, the water is tested for coli form bacteria. Coli form bacteria are present in human wastes and in soil contaminated with human wastes. These bacteria in human wastes are known as fecal coli form bacteria. Those in the soil are callednon fecal coli forms. Both fecal and non fecal coli forms are called the total coli form group. This group is used as an indicator of the presence of human wastes in water and the possible presence of waterborne pathogens(JPS Cabral Oct 15, 2010).

The risk of coli form presence can depend on the health or sensitivity of the consumer.The risks of E. coli presence, slight ly greater than WHO Guidelines zero count per100ml may be of only low or intermediate risk. According to IRC, 2002 as cited by Michael H., 2006 aboutrisk classification for thermo tolerant coli forms or E. coli ofRural water supplies shown below.

Table 2Water quality counts per 100mL and the associated risk.

Count per 100ml	Risk Category
0	Inconformity with WHO guide line
1-10	Low risk
11-100	Intermediate risk(polluted)
101-1000	High risk(dangerous)
>1000	very dangerous

Source: WHO, 1997; Harvey, 2007

2.6Impact of High Level of Physical, Chemical and Biological Parameters in Drinking Water Supply.

2.6.1 Deteriorations Quality of Drinking Water Supply Impacts.

Microbial pollution is the term given to water contaminated with biological pathogens such as bacteria, viruses and protozoa. This microbial contaminates enters in drinking water through fecal contamination or may grow in the water itself. Drinking water can also become contaminated by chemical pollutants, which can enter the water from agricultural, industrial and household sources. (Geoff rey Wood, Professor London.2013).

Chemical pollution is also a frequent cause of disease. Health effects caused by chemical pollutants often arise after many years and may even be intergenerational. Five million people, mostly children, die from diseases caused by poor-quality water supplies every year. Is explains the strong correlation between access to safe drinking water and child mortality and life expectancy rates. The others is the physical pollutant when the water is polluted it is not acceptable by the community (JPS Cabral Oct 15, 2010).

2.6.2 Impact on Health.

The diseases caused by water related microorganisms can be divided into four main Categories.Water-borne diseases: caused by water that has been contaminated by human, animal or chemical wastes. Examples include cholera, typhoid, meningitis, dysentery, hepatitis and diarrhea. Diarrhea is caused by a host of bacterial, viral and parasitic organisms most of which can be spread by contaminated water(WHO, 2006). Poor nutrition resulting from frequent attacks of diarrhea is the primary cause for stunted growth for millions of children in the developing world(Gadgil, 1998).

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

Water-based diseases: These are caused by parasitic aquatic organisms referred to ashelminthes and can be transmitted via skin penetration or contact. Examples include Guinea worm disease, filariasis, paragonimiasis,Clonorchias is and schistosomiasis (WHO2011).

Water-scarce diseases: These diseases flourish in conditions where freshwater is scarce and sanitation is poor. Examples include trachoma and tuberculosis. All biological parameters can affect the human healthy and aquatic environment .there are many water related ,water born, water washed and water based disease come from these category of water quality problem impacts . Therefore the many released to prevent or to manage the health of human being and aquatic life is the high impact on the income of the individuals as well as the economy of the country. High content chemical parameters like residual iron in drinking affect the human healthy or water may be responsible for

The neutralization of the disinfectants used to kill microorganisms. It affects disease caused by microorganisms.

Excessive iron in selective regions of the brain may be involved in the neurodegenerative disorders.

Excessive ingested iron can cause excessive levels of iron in the blood because high iron levels can damage the cells of the gastrointestinal tract, preventing them from regulating iron absorption. Humans experience iron toxicity above 20 milligrams of iron for every kilogram of mass, and 60 milligrams per kilogram is a lethal dose (inte.jor september 2010) .Chronic iron overload results primarily from a genetic disorder (haemochromatosis) characterized by increased iron absorption and from diseases that require frequent transfusions.

In general the diseases/ impact on healthy / come from biological and chemical characteristic shown in table below.

Table 3Healthy Impact of all high level of biological, chemical and biological parameters.

No.	Type of disease/impacts/	Remark
1	Acute fever disease	Water related disease
2	Common diarrhea diseases	Water born disease
3	Pneumonia	"
4	Typhoid	Water-borne diseases
5	gastroenteritis, ,	"
6	bacillary dysentery	"
7	Cholera	Water-borne diseases
8	Hepatitis	"
9	cholera, typhoid	Water-borne diseases
10	Trachoma	Water-washed diseases.
11	Schistosomiasis	Due to High level of iron
12	Hypertension	Due to High level of iron
13	Genetic disorder	Due to High level of iron
14	Neuron disorder	Due to High level of iron

Source:-WHO (2010)

2.6.3 Impact on Drinking Water Distribution System and ElectromechanicalParts

Corrosion can be the result of physical actions that erode the coating of a pipe, chemical dissolution that leaches a pipe's lining or wall material, or electrochemical reactions that remove metal from the wall of the pipe Biological growths within the distribution system can also cause corrosion by providing an environment in which physical and chemical interaction can occur. Some of the factors that influence corrosion are water velocity, pipe material, and water quality within the distribution system, such as pH, alkalinity, temperature, chlorine residual, and hardness of the water (HDR Engineering, Inc 2006).

The residual iron in drinking water affect the distribution pipe and water quails italso;

React with disinfectants (neutralizing them) and that causes proliferation of micro-organisms in distribution networks.

Can hydrolyze and settle throughout the pipeline system. Soft deposition can cause coloration of water and sometimes obstruction of the drinking water network.

It causes proliferation ferruginous bacteria sources of soft deposit. Growth of ferruginous bacteria can reduce the diameter of the pipe or cause corrosion.

Ochre deposition can cause a serious hydraulic clogging problem in drinking water network.

The coloration of water.

Metallic tastes of water.

Figure 3Impact of high level Iron on Pipe Material.

The problem arises when the iron, as soluble Fe(II), is oxidized to insoluble Fe(III) either biotical via bacteria, or abiotically.

The deposition of iron in water distribution networks is a complex electrochemical and physicochemical phenomenon between a metal surface and germ of crystallization. The deposition in the pipe depends on chemical factors, such as pH, alkalinity and physical properties, such as flow and velocity, as well as the pipe material.

Corrosion of iron pipes in a distribution system can cause three distinct but related problems.

Pipe mass is lost through oxidization to soluble iron species or iron-bearing scale.

The scale can accumulate as large tubercles that increase head loss and decrease water capacity.

The release of soluble or particulate iron corrosion-byproducts to the water decreases its aesthetic quality and often leads to consumer complaints of "red water" at the tap.

2.6.4 Impact on Economy.

There are many and diverse potential economical impacts associated with un improved water supply quality problems. The impacts include both increasing the costs associated with poor water supply quality (e.g. health care costs) as well as developmental Impact directly associated with un improving water supply quality, such as Decreasing productive (WHO, 4 Dec 2010).

Cost loss by lack of safe drinking water.

A lack of safe drinking water can create a heavy cost burden on nations' economies, potentially Hindering growth. Economic costs incurred by a lack of access to safe drinking water can be divided into the direct costs of contracting disease, the indirect costs related to disease and the cost of time lost due to the lack of (WHO, 4 Dec 2010)

Direct costs of Controlling Disease,

The cost of the treatment of water-related diseases is a heavy burden on families throughout the developing world. Many nations have a roughly static incidence rate of three episodes of diarrhea every year in these nations; a child could suff er from a water-related disease every four months. In a family of four young children, the parents would be likely to have a child with a potentially fatal disease once amonth. At these rates, even the cheapest drugs used for this treatment become (WHO, 4 Dec 2010).

Economical Health Effects of Unsafe Drinking Water Quality

According to the World Bank, 88% of disease in the developing world is caused by unsafe drinking water. Diseases from microbial pollution may be the result of the contamination of drinking water by human or animal feces containing pathogenic bacteria and viruses that may cause cholera, amoebic and bacillary dysentery and other diarrheal diseases. Parasites, such as ranunculus medicines, in organism living in the water.

Indirect costs related to disease

The cost burden of ill health on the economy is twofold: Lost economic contribution of the sick or prematurely deceased Lower productivity resulting from sick and less educated workers the indirect costs may accrue from lost work and lower productivity of those acted in addition to those who care for the affected(WHO, 4 Dec 2010)

Costs related to time spent on water collection.

In many parts of the world, collecting safe drinking water is extremely time-consuming. It is, for example, estimated that the average time each household in India spends on water collection every days 56 minutes. is time that could be spent on economic activity. A study conducted by the Self Employed Women's Association (SEWA) in India found that reducing water collection by one hour a day would enable a woman to earn up to $100 more a year, depending on her enterprise.

2.7 Modeling Water Quality in Drinking Water Distribution Systems

Drinking Water Distribution Systems carry potable water from water sources (reservoirs, water tanks) to industrial, commercial, residential and consumers through complex pipe networks.

Water distribution system models have become widely accepted within the water utility industry as a mechanism for simulating the hydraulic and water quality behavior in water distribution system networks.

Early network models simulated only steady-state hydraulic behavior. In the 1970s, modeling capability was expanded to include Extended Period Simulation (EPS) models that could accommodate time-varying demand and operations. Subsequently, in the early 1980s, investigators are introducing the concept of water quality modeling. Most water distribution system modeling software packages now routinely incorporate water quality simulation capability.

2.7.1 History of Water Quality Modeling

Water quality in a distribution system resulting from sources of differing quality was suggested by Wood (1980b) in a study of slurry flow in a pipe network. The steady-state hydraulic model was extended by solving a series of simultaneous equations at each node. In a generalization of this formulation, Males et al., (1985) used simultaneous equations to calcu- late the spatial distribution of variables that could b, (Larocket al., 2000)

The network hydraulic model provides the foundation for modeling water quality in distribution systems.

Hardy Cross first proposed the use of mathematical methods for calculating flows in complex networks (Cross, 1936). This manual, iterative procedure was used throughout the water industry for almost 40 years. With the advent of computers and computer based modeling, improved solution methods were Developed for utilizing the Hardy Cross methodology.(Walski et al., 2003).

The improved implementations of this method were in widespread use by the 1980s (Wood, 1980a). Also, in the early 1980s, the concept of modeling water quality in distribution system networks was developed based on steady-state formulations (Clark et al., 1986) (water distribution system analysis filled study modeling and management EPA united state environmental protection agency (Walski et al., 2003)

By the mid-1980s, water quality models were developed that incorporated the dynamic behavior of water networks (Grayman et al., 1988). The usability of these models was greatly improved in the 1990s with the introduction of the public domain EPANET model (Ross man, 2000) and other windowsbased commercial water distribution system models. Initially, hydraulic models simulated flow and pressures in a distribution system under steady-state conditions where all demands and operations re- mained constant.

Since system demands (and consequently the flows in the water distribution network) vary over the course of a day, EPS models were developed to simulate distribution system behavior under time-varying demand and operational conditions. These models have now become ubiqui- tous within the water industry and are an integral part of most water system design, master planning, and fire flow analyses.

The theory and application of hydraulic models is thoroughly explained in many widely available references (Walski et al., 2003 ;). Essentially, three basic relations (conservation of mass; energy and momentum) are used to calculate fluid flow in a pipe network.

2.7.2 Hydraulic and Water Quality Modeling Software

There is an abundance of network modeling software in the marketplace today. Some are free and others can be purchased at a nominal cost. Costs can vary significantly between models, depending on the range of features and capabilities provided; some of these programs are listed in Table below.

Table 4Names and vendors of hydraulic simulation software.

Software	Vendor	Country
AQUA	Computer Modeling, Inc	USA
BOSS EMS	BOSS International	USA
WATERCAD	Haestad Methods, Inc	USA
EPANET	US EPA	USA
FAAST	Faastsoftwere	USA
FLOW	Kelix Software Systems	USA
PICCOLO	SAFEGE Consulting Engineers.	FRENCH
RINCAD	CEDEGER	CANADA
SDPE	Charles Howard & Assoc.Ltd	CANADA

TDHNET	DTH engineering	USA
WATNET	WRc	USA
AVWATER	CERDA	USA

Source: - Advance water distribution system.

WATERCAD.

Water CAD is powerful, easy to use program that helps civil engineers design and analyze water distribution. Water utility managers also use it as a tool for theefficient operation systems. Water CAD provides intuitive access to the tools that isneeded to model complex hydraulic situations, analyzes water quality, determinesfire flow requirements, calibrate large distribution network. WaterCAD is a sophisticated tool that enables engineers and decision–makers to analyze and manage distribution network with unprecedented accuracy and efficiency(advance water distribution modeling book.)

Capabilities

Perform steady –state, extended – period, and water quality simulation.

Analyze multiple time – variable demands at any junction node.

Model flow control valves, pressure reducing valves, pressure sustaining valves, pressure breaking valves, and throttle control valves.

Model cylindrical and non- cylindrical tanks and constant hydraulic grade source nodes

Determine water source and age at any element in the system.

Estimate construction costs.

Simulate the operating of constant cycles of constant or variable speed pumps.

The most available software in Ethiopia is Epanet and WaterCAD, but WaterCAD was chosen because (advance water distribution modeling book.)

WaterCAD can do more than one scenario in one file and more than one alternative in the same scenario, while Epanet can do one scenario in one file. Water CAD has "undo" facility while Epanet don't have this facility.

2.7.3 Basic Hydraulic Input Data

Characteristics of the pipe network components (pipes, pumps, tanks and valves).Water use (demands) assigned to nodes (temporal variations required in EPS) (advance water distribution modeling book.)..

Topographic information (elevations assigned to nodes). Control information that describes how the system is operated (e.g., mode of pump operation). Solution parameters (e.g., time steps, tolerances as required by the solution techniques).

Pipe Network Input.

Pipes (length, diameter, and roughness factor).

Pumps (pump curve).

Valves (settings), and.

Tanks (cross section information, minimum and maximum water levels).

Water Demand Inputs.

Water consumption or water demand is the driving force behind the operation of a water distribution system.

It assigned to nodes, which represents an obvious simplification of real-world situations in which individual house taps are distributed along a pipe rather than at junction nodes.

A universal adjustment factor should be used to account for losses and other unaccounted water usage so that total usage in the temporal patterns can be applied to the individual network node. A typical hierarchy for assigning demands includes the following.Baseline Demands(advance water distribution modeling book). The purpose of common network modeling element

Table 5Common network modeling elements.

Element	Type	Primary Modeling Purpose
Reservoir	Node	Provided water to the system
Tank	Node	Stores excess water within the system and releases that water at times of high usage.
Junction	Node	Removes (demand) or adds (inflow) water from/to the system
Pipe	Link	Conveys water from one node to another
Pump	Node/link	Raises the hydraulic grade to overcome elevation differences and friction losses.
Control valve	Node /link	Controls flow or pressure in the system based on specified criteria

Source:-Advance water distribution modeling book.

2.7.4 Output of the Model Software

Pressure and Velocity.

The criteria used in the design of the distribution network, nodal pressure during the period of peak demand, and optimum velocities of the distribution lines are ;Minimum static head is 20 m, which can supply a 4-storey building from the distribution system(15 - 30 m in residential districts with structures of four stories or less, 40 – 50 m in commercial districts and for hydrants not to be less than 150 kPa (15 m of water)) , Maximum static head within the distribution network was limited to 130 m, Minimum dynamic head was established at 10 m and).In general for any node in the network the pressure should not be less than 6/10 m of water. Moreover, the maximum pressure should be limited to 70 m of water (Advance water distribution system book).

The velocity in the distribution line is not be lower than 0.6 m/s to prevent sedimentation, not be more than 3 m/s to prevent erosion and high head losses and commonly used values are 1 - 1.5 m/sec. the design criteria for velocity show in table below.

Table 6Design Criteria (Velocity)

Diameter (mm)	Velocity(m/s)
100	0.9
150	1.21
250	1.52
400	1.82

Indicator of Distribution System Contamination.

Pressure measurements a useful operational monitoring parameter that can be used as an indicator of possible contamination in piped distribution systems (WHO, 2004). Fecal contamination may occur in large buildings through cross-connections and backflow and from buried/immersed tanks and pipes, especially if not maintained with positive internal water pressure (WHO, 2004).

The other indicators is when the velocity is lower and above the limit itcan be affect the quality of water in distribution system , through stagnation of water in the pipe (water age) react with pipe material and washing the contaminant from high to low .

Effects Velocity Changes on the Water Quality in Distribution Systems.

One of the parameter that could reason to decrease water quality in distribution system is velocity change in networks. the changes in bacteria growth patterns in the distribution system depend on changes in hydraulics (velocity), pH, temperature, water age, piping materials and chlorine residuals(EPA December 2013).

Pathways by which contaminants can enter the distribution system during a Pressure reduction event include cross connections, leaks, water main break and repairsites, and short-term pressure transients . Pathogens or chemicals in close proximity to pipes Experiencing low or negative pressures are potential contamination sources even though they are external to the distribution system (HDR Engineering, Inc 2006,Kirmeyer et al., 2001; EPA, 2002; Karim et al.,2003; WHO, 2004).

Effects Pressure Changes on the Water Quality on Distribution Systems.

Low water pressure in distribution systems is a well-known risk factor for outbreaks of waterborne disease (Hunter, 2005), Low water pressure and frequent water outages had contributed to widespread increases in contamination within the distribution system (Hermin et al., 2006).

Pathways by which contaminants can enter the distribution system during a pressure reduction event include leaks, water main break and repairsites, and short-term pressure transients. Pressure monitoring in all parts of the distribution system can identify changes inPressure that may leave a system vulnerable to contaminant entry into the distribution system (J.R. Dojlido ,Zanieczyszczenia 2008). Pathogens or chemicals in close proximity to pipes experiencing low or negative pressures are potential contamination sources even though they are external to the distribution system.

The pressure change are caused by sudden changes in water velocity due to loss of power, sudden valve closure or opening, a transmission line break, fire flow, or an uncontrolled change in on/off pump status. Pressure surge is created by these conditions, causing very high pressure followed by low and negative pressure. (Utsev, J. T. , Aho, dec 18 2011)

2.7.4 Standard of Water Quality and Guidelines

A standard is a set of norms established by authorized legal body, which would be implemented under legal framework. Guideline is flexible and designed to be more supportive to specific quality control activities. World Health Organization (WHO) Drinking Water Quality Guideline can be used as a general framework of water quality activities for United Nation member countries.The EDWQGL has been formulated in order to make the implementation of the water quality control activities practical and feasible in the country. it developed based on the actual drinking water quality data of the country and within the context of local/national environmental, socio-economic, cultural conditions and the existing drinking water quality problems of the country. The following table shows the WHO guideline and EDWQS. And the all standards shown in the annex B

CHAPTER THREE

3.0 MATERIAL AND METHODOLOGY

3 .1 Description of the Study Area

Agaro Town is located at distance of 496 km East of Addis Ababa capital city of Ethiopia in asphalt road via wol-kitte , and 45km to the same direction of the Zone Administrative centre Jimma.

It is the capital city of Gomma woreda in Jimma Zone of Oromia Region of Ethiopia . Situated between latitude and longitude of 7°38′N 36°38′ . It shares border boundaries Seka Chekorsa, Gera, ,Gummay and Mana with South ,west ,North and East respectively .It has a total surface area of 2160 hectare and a current estimated (2014) Population of 41, 000, giving an approximate population density of 19 persons per hectare.

The modern water supply system was introduced at 1968 to the town for first time. At that time the first water supply sources is spring development its name is chancho spring , distribution with gravity and pump . At 1980 after 12yearse as the size of the city increase expansion of source was done with addition of one borehole. In 2004 a another expansion of water supply source borehole up to 500m depth four (4) in numbers.

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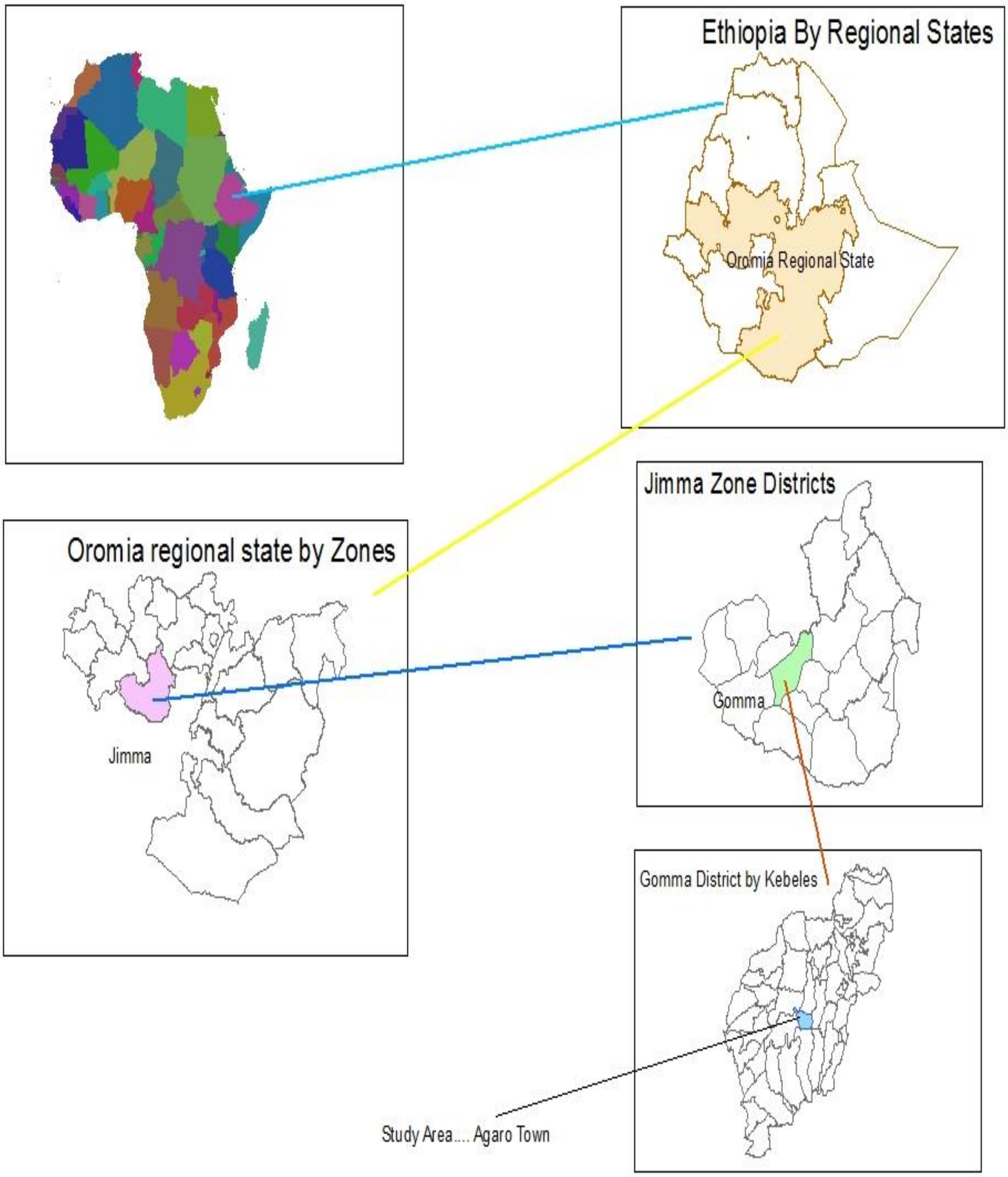


Figure 4Map of Study Area

3.1.1 Topography

Drainage

Agaro town is a lowland area and the Tamsaha rivers is cross the town in to two parts and the dogaja river is near to the boundary of Agaro Town one of the kebele namely Tige Koye cross in two parts .

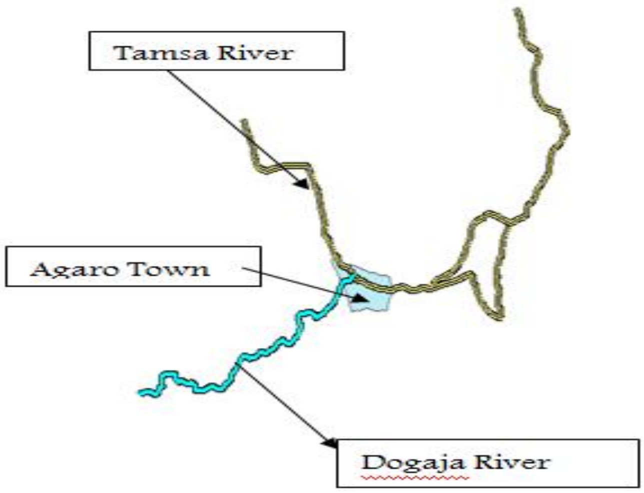


Figure 5Drainage of Study Area

Climate

The Town has four seasons-Kiremt ,Bega, Bulge and Tsedy . The climate is tropical, with medium warm and cold weather with annual rainfall ranging about 1100 mm. and its temperature is 20- 30 ^{o}c

Socioeconomic Characteristic

From Jimma zone Gomma wereda is the woreda known by coffee Arabica. Coffee is the major agricultural export crop, providing currently used foreign exchange.

Coffee cultivation plays a vital role both in the cultural and socio-economic life of this town About 99% of the Agaro Town population depend, directly or indirectly, on coffee production, processing and marketing.

Figur6. Coffee plantation in the Woreda

Infrastructure and Social Facilities

The town gets access of electric power from national grid line, all 39 rural kebeles have road connections, have Telecommunication Corporation and it incorporate a number of schools from kg to TVT colleges.

Health Institutions

According to the Town Health Office, one hospital and health center, five clinics, 8 pharmacies and two drugstores and also includes health professionals engaged in the institutions. With exception of the health center and hospital all of the remaining health institutions are privately owned.

Table 7 Health institutions in Agaro Town

Type of establishment	Number of establishment	Number of medical staff
Governmental hospital	1	15
Governmental health center	1	25
Private clinics	5	15
Private drug stores	1	1
Private pharmacy	8	1
Total	16	67

Source: Agaro Town Health Office

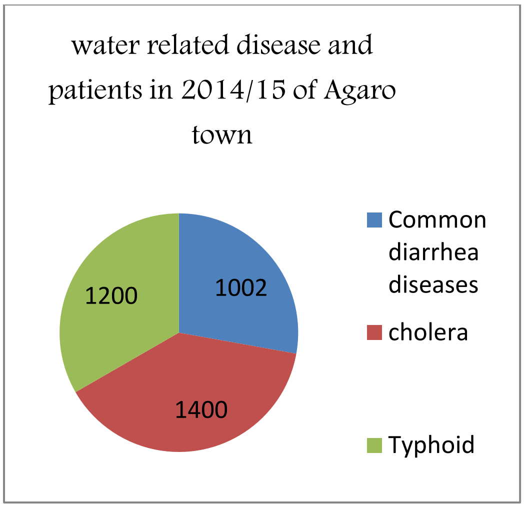
Table 8Top ten diseases and Number of patients of 2015 and 2016years of Agaro Town

No	Type of disease	Number of patients in different Year	
		2014/15	2015/16
1	Common diarrhea diseases	1002	1056
2	Acute fever disease	810	926
3	cholera	1400	1830
4	Typhoid	1200	1402
5	Acute upper respiratory tract infection	600	592
6	Hypertension	1080	1200
7	Genetic disorder	106	115
8	Epilepsy	300	241
9	Pneumonia	520	597
10	Trachoma	342	385
12	Gastritis	697	871

Source:-Agaro Town healthy office.

The top ten diseases Presented in above Table shown like typhoid, cholera, , hypertension acute fever ,Gastritis ,common diarrhea and disease is the leading in ascending order cause of illness in Agaro Town and its environs are related to Water and sanitations disease.

According to information gathered from the town health officein1014/15 and 2015/15 from top ten disease more of them are covered causes by water related and water born disease such as Common diarrhea diseases ,cholera and typhoid It was responsible almost greater than have of total diseases recorded in 2014/15 are water related and water born disease .detail graph is shows as bellow .



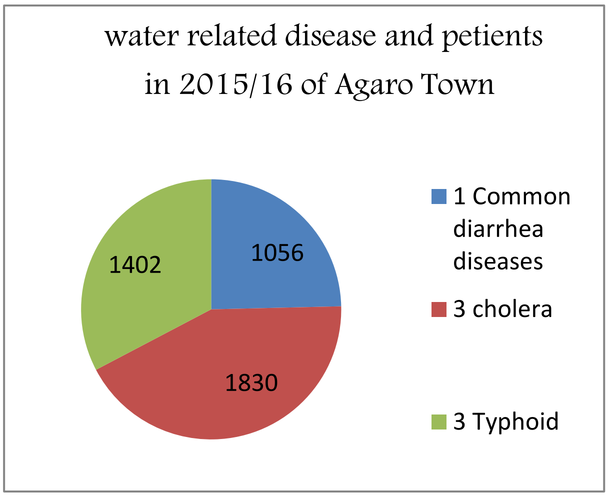


Figure7 Graph of top ten water related diseases and Number of patients of 2014/15 and 2015/16years of Agaro Town.

3.1.2. Existing Water Supply System

ExistingWater Source and*Rising Mains*

In the Town water supply Source are Ground water. The water is pumped from four boreholes distributed to in the vicinity of the town. Its depth from 80m to 110m below Ground level.

Table 9Existing Data on Boreholes of Agaro Town

Borehole Name	BH-1	BH-2	BH-3	BH-4
Drilling date	1992	1992	1992	1983
Drilled by	OWM and E B	OWM and E B	OWM and E B	OWM and E B
Yield (l/s)	5	6	5	8
UTMco-ordinates	X-0232892 Y-0868839	X-0232553 Y-0868487	X-0232275E Y-0868132	X-0232226E Y-0869943
Depth (m)	80m	110m	110m	110m
Pump position (m)	72m	87m	82m	82m

Source: - from report

The rising main line is collector pipes delivering water from four boreholes divided in two and by mixing the waters together and at the end all boreholes mix to gathered water can be delivering to the main reservoir. The figure and table below shows the detail history of rising main of the town

Table 10 Summary of rising main pipes from boreholes to the main reservoir.

<table>
<tr><th>Item No</th><th>From</th><th>Node</th><th>To</th><th>Pipe Material Description</th><th>Size (")</th></tr>
<tr><td>1</td><td>Borehole-1</td><td rowspan="2">Mix together at one node</td><td rowspan="4">Main reservoir</td><td rowspan="4">GS pipe</td><td>$2^1/_2$"</td></tr>
<tr><td>2</td><td>Borehole-4</td><td rowspan="3">4"</td></tr>
<tr><td>3</td><td>Borehole-3</td><td rowspan="2">Mix together at one node</td></tr>
<tr><td>4</td><td>Borehole-2</td></tr>
</table>

Source:- from Agaro Town water sewerage Authority.

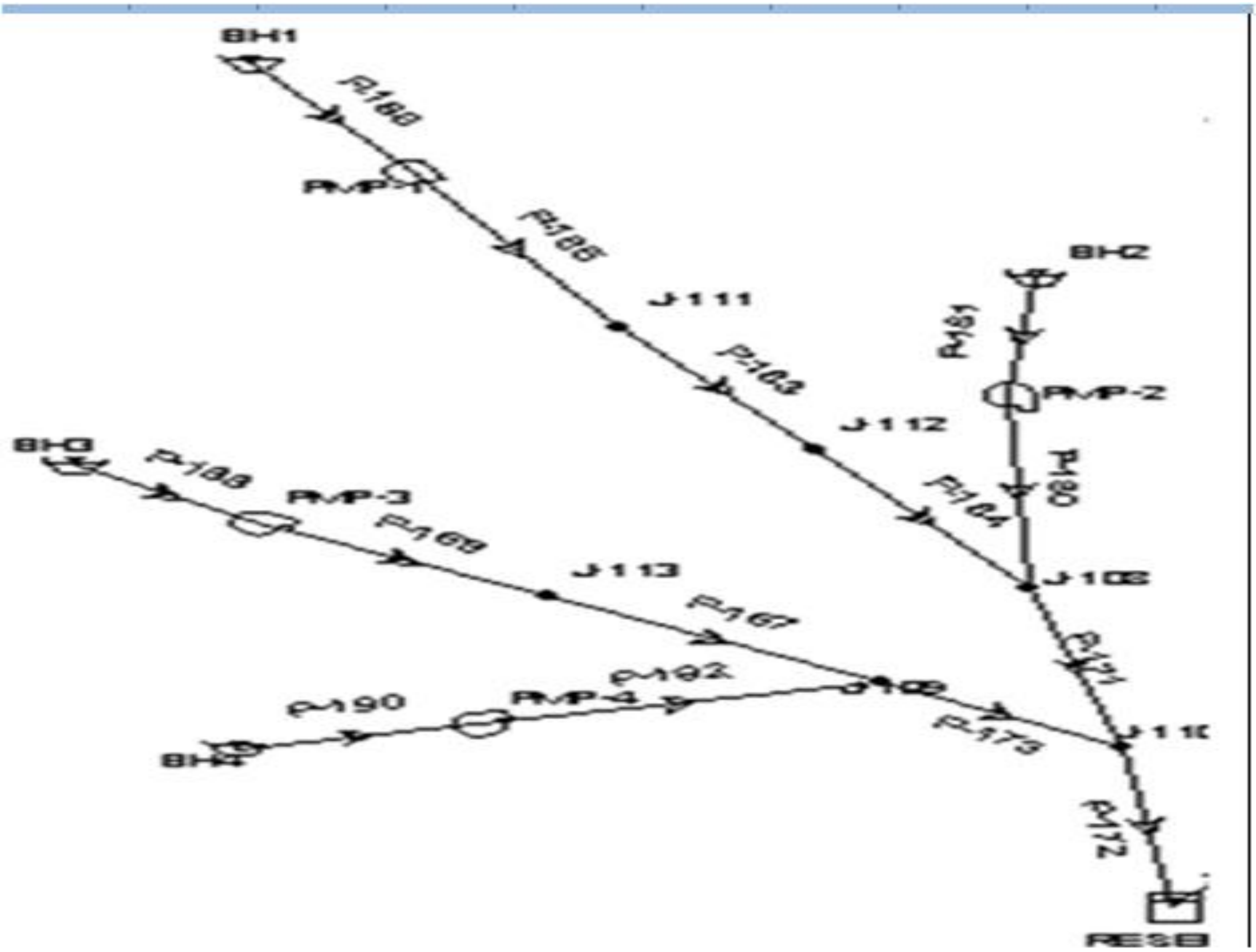


Figure8Schematic layout of water supply source, pressure line and service reservoir

Water Treatment and Distribution

According information gathered from the town water and sewerage authority as the source is Ground water, the town water supply system has not used any pre and post treatment. Chlorine disinfection is used during washing of this service reservoir and break pressure tanks in between three or four month's intervals. Used gravity distribution system and Its pipe material is Galvanized Steel (GS) pipes, PVC and DCI. Detail schematics layout of distribution system is shown bellow.

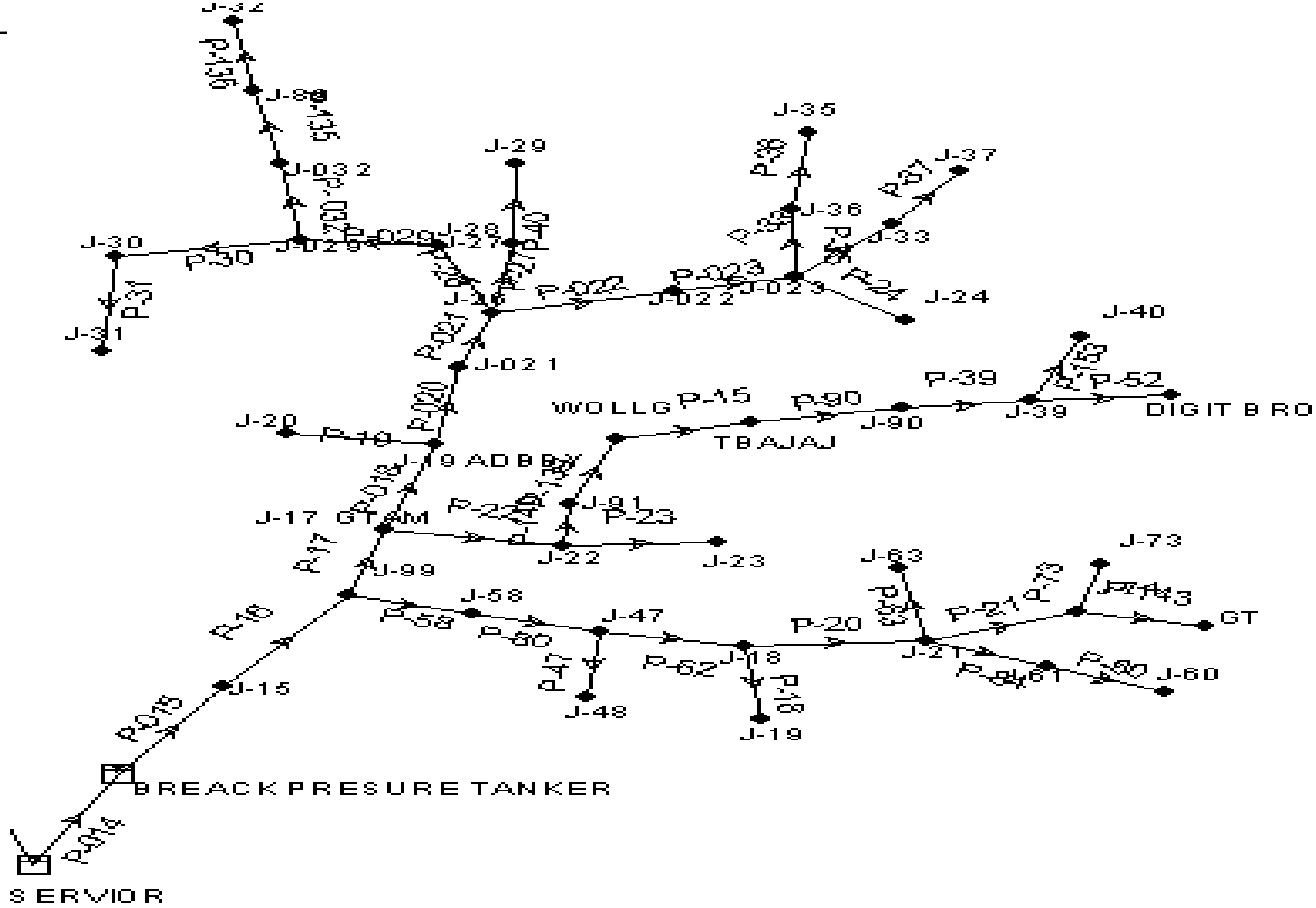


Figure 9 The schematic layout of the distribution system of Agaro Town.

3.2 Methodology

3 .2.1 Type of Data and Data sources

To be able to complete the mentioned objectives of this study, a number of relevant research methods, which included primary and secondary data collection, were employed.

Primary data

The main primary data collected have:

- Sample taking in different places in the town for laboratory analysis.
- Surveying and demand data's for model analysis.
- Questioners for clarification Impacts of suppled water for the town .
- Measured pressure throughout the water distribution system using pressure gauge installed at different locations. such as public fountains, customer tap and water reservoir for the purpose of calibration ,

Secondary data.

- Collection data from small and micro enterprise office number of people that can partake on preparation of coffee and tea in the town.
- Collection data from zonal statics agency entirety number of people of the town with in religion
- Collection data regarding the prevalence of water associated diseases from the town.
- Project reports of water supply in Agaro town.
- Literature reviews (books, journals, web) etc.

3.2.2 Sampling Methods and Techniques.

Sampling Methods

One of the central objectives of this thesis is investigating the water quality problem and its magnitude in Agaro town to conduct this and such kind of research.

Open distribution system is used for the completion of the research points. The water supply source under this study area was four borehole, pressure and distribution line .From these water supply system a sample of water taken at the points of described below;

- At the source four samples one for each of them.
- At the place of all source mix together or at reservoir , tank
- At a point such those samples are representative of the water in the branches of the chief main (at the center of the town, upstream are and at downstream of the city and the last(tap) .

At dead-end of the system (water point) as shown on fig below

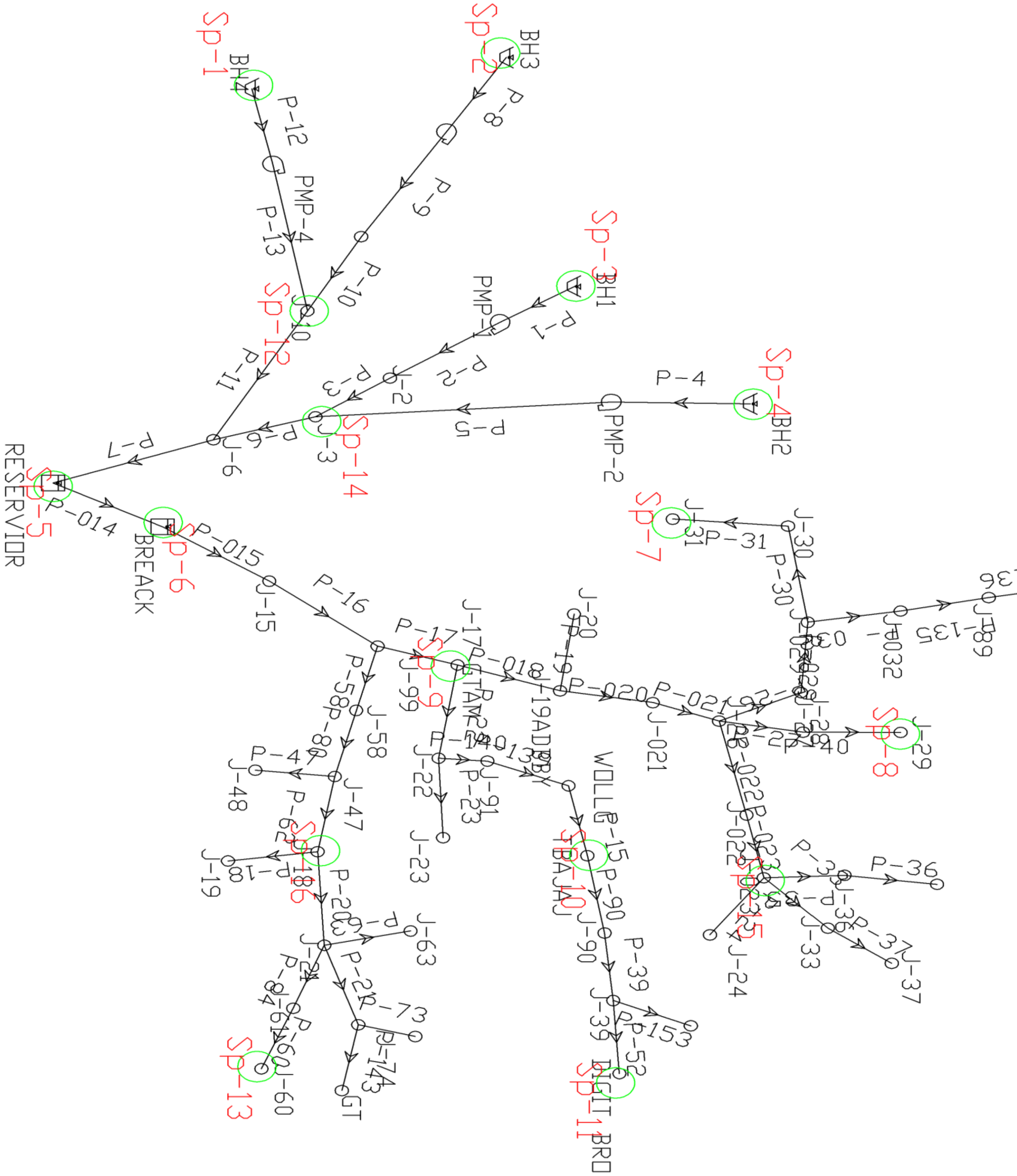


Figure 10sample taken location

The quality of water can be test sample numbers taken or to have a reasonable representative sample, four for boreholes, one from reservoir and break pressure tanker , there 7(seven) from distribution system in different place(tap) and 3(three) collect at dead end totally sixteen(water point) (16) sample in number is taken additionally for quality of works all sample taken was three times at each points at different months (July2014 and December 2015) physical, chemicals and biological characteristics of laboratory of test was done.

For assessing the impact of water quality problem impacts take certain number of respondent that cannot used tap water for preparation of soup during the month of Ramadan and the small and micro enterprise that chip in preparation of tea and coffee .

Sampling Technique

The sampling technique employed in this research was of two types. Simple Random sampling and purposive sampling methods.

The purposive sampling technique was applied to laboratory test of characteristics of water quality because the quality problem can be either on row water , or distribution line because of the reaction of water with cater carrier structures (pipes) in different places as the sample is a decisions maker of the study , while for identifying the impact of quality problems used random sampling technique . In applying the random sampling technique, lists of the merchants that can participates on preparation of coffee and tea

Material and Procedure

The sample is carefully collected in very clean disinfected containers and analyzed for color, pH, Temperature, Turbidity, Alkalinity, , Iron, Chloride, Electrical conductivity , Total Dissolved Solid ,DO , E-coli, Total coli form count and residual chlorine Determination of these parameters was done in the laboratory and on site using the procedures described in standard methods, kit method , multi meter model and membrane filtration method .

Water samples for biological test, were collected in non-reactive borosilicate glass bottles of 500 ml capacity each that had been cleansed and rinsed carefully, given a final rinse with distilled water and sterilized. Physicochemical parameters such as, dissolved oxygen, pH, temperature, Turbidity , Electrical conductivity and temperature was done on site and by using multymeter model methods. The iron levels of the groundwater source and in distribution system were analyzed using Atomic Absorption Spectrophotometer. Total coli form and E.Coli counts were performed using the standard membrane filtration technique. . And the other parameters have done using kit method.

3.3.7 Quality Assurance and Quality Control Methods

The purpose of QA is to identify which data best represent environmental conditions and which may have been affected by contamination or bias during sample collection, processing, storage, transportation, and (or) laboratory analysis.

1) Field blank samples were collected to assess contamination during sample handling or analysis.

The primary purpose of collecting blanks is to evaluate the magnitude of potential contamination of samples with compounds of interest during sample collection, processing, transport, and (or) analysis. Replicate samples were collected to assess the precision of the water-quality data. Estimates of data precision are needed to assess whether differences between concentrations in samples are because of differences in groundwater quality or because of variability that may result from collecting, processing, and analyzing the samples.

3.3.8 Model water distribution system using Water cadModel

Model set up procedure

The description of water cad Model set up procedure includes, Draw network representative and described network place, edit the properties of the object that make up the system, described how the system is operated, select a set of analysis options and run a hydraulic analysis.

Model calibration and validation

Model calibration and validation is done by measured and modeled pressure and its performance is evaluated using Statistical method.

3.4. Data Analysis and Synthesis.

The surveying and demand will be analyzed model using WTERCAD software. The sample taken will be analyzed in laboratory test and used Comprising of WHO guide line and Ethiopia recommended value. The whole data collected and analyzed will be synthesized in different forms like (literature, tables, charts figures

4 CHAPTER FOUR.

4.1 FINDINGS AND DISCUSSIONS.

This chapter is aiming at describing the laboratory analysis and identify the problem of water quality by testing the chemical, physical and biological parameters, model water distribution system using water cad and analyses the pressure and velocity at the junction and nodes, identify the impact of this water quality problem impacts in different way and furthermore, the propose remediation taken to reduce this quality problem impacts.

4. 1.1 Laboratory Analysis

All the Physical, chemical and biological Analysis of parameters done on laboratory to fulfill this thesis is including Dissolved oxygen, turbidity ,temperature , iron, total coli form ,E.coli , residual chlorine , Electrical conductivity , PH, alkalinity , nitrate ,Total dissolved solid and chloride. The detail result of this test shown in table below.

4.1.1.2 Residual Chilorine

There is no pre and post chilorination treatment used For the town water supply system.therefor the result test in two scensrios is Nill no residual chilorine .

Table 11 laboratory result of residual chloride in two scenarios

Sample point	location	Residual chlorine at dry season in mg/l	Residual chlorine at rain season in mg/l
SP1	BH4	Nill	Nill
SP2	BH3	Nill	Nill
SP3	BH1	Nill	Nill
SP4	BH2	Nill	Nill
SP5	Reservoir	Nill	Nill
SP6	Break pressure .T	Nill	Nill
SP7	Dead end	Nill	Nill
SP8	Dead end	Nill	Nill
SP9	B/N distribution .sy GT)	Nill	Nill
SP10	B/N distribution .sy (BJT)	Nill	Nill
SP11	Dead end	Nill	Nill

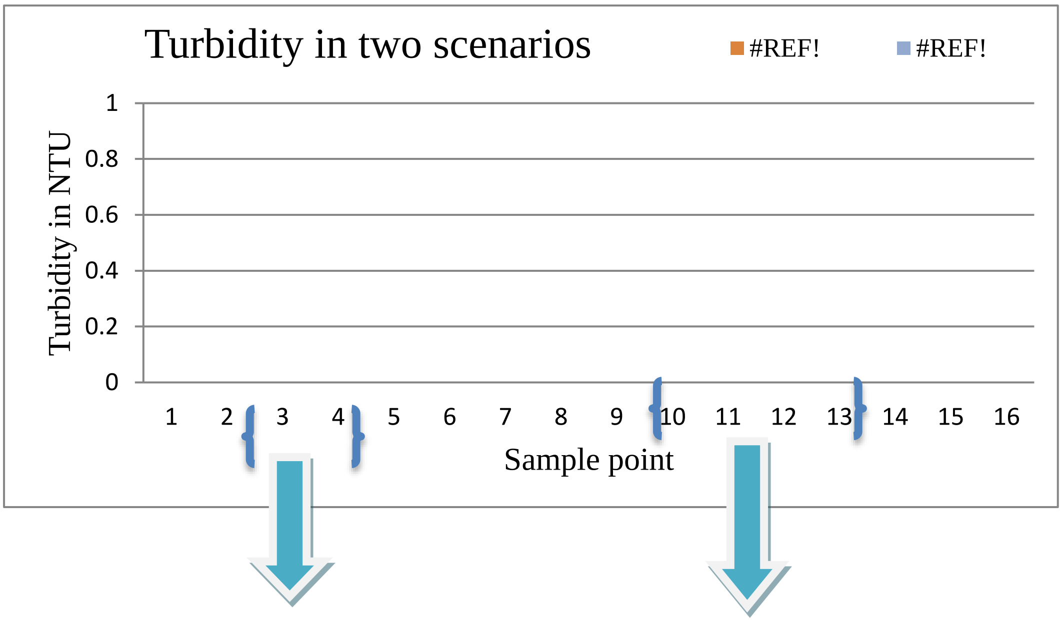
SP12	Dead end	Nill	Nill
SP13	Dead end	Nill	Nill
SP14	B/N distribution .sy (GT)	Nill	Nill
SP15	B/N distribution .sy (GT)	Nill	Nill
SP16	B/N distribution .sy (GT)	Nill	Nill

This is affect the town in many darrection the top ten desease is causedby water relateted and water born . if chilorination is use fof water treatment is figer is much and much less .

The increasing of e.coli and Total coliform one factor is the re is no chilorination used.non using of post and pre clorination fasilitate water born and rellated deseas . according to data gathered from helthy center of thetown the uper three runks from top ten desease is water related and water born desease .

4.1.1.2 Turbidity

Turbidity is very high greater than the maximum permissible limiting two scenarios at sample point number 11, 12, 13   at (dead end) shown at chart) of the distribution system and alsoat sample point number 3 and 4 (borehole number 1 and 2)



Sample point at3 and 4(borehole 1and 2)   Sample point as dead end (water point)

Figure11   Laboratory result of Turbidity in two scenarios

Because of high concentration of iron at borehole initiate high corrosion and during pumping of water the wall pipe material is washed and The another is deposition of water in the pipe, low flow of water, reaction between flow of water and pipe gives turbid water result. . Cause discoloration of drinking water in the town . There is an also economic loss to family income due to the desire for safe bottled water which is more expensive.

4.1.1.3 Total Coli form and E.coli

In study areas the laboratory results clear that amount of Total coliform and E.coli is both in two scenarios greater than maximum permissible limit in the system.the concentration is very high at dead ends as shown on chart below

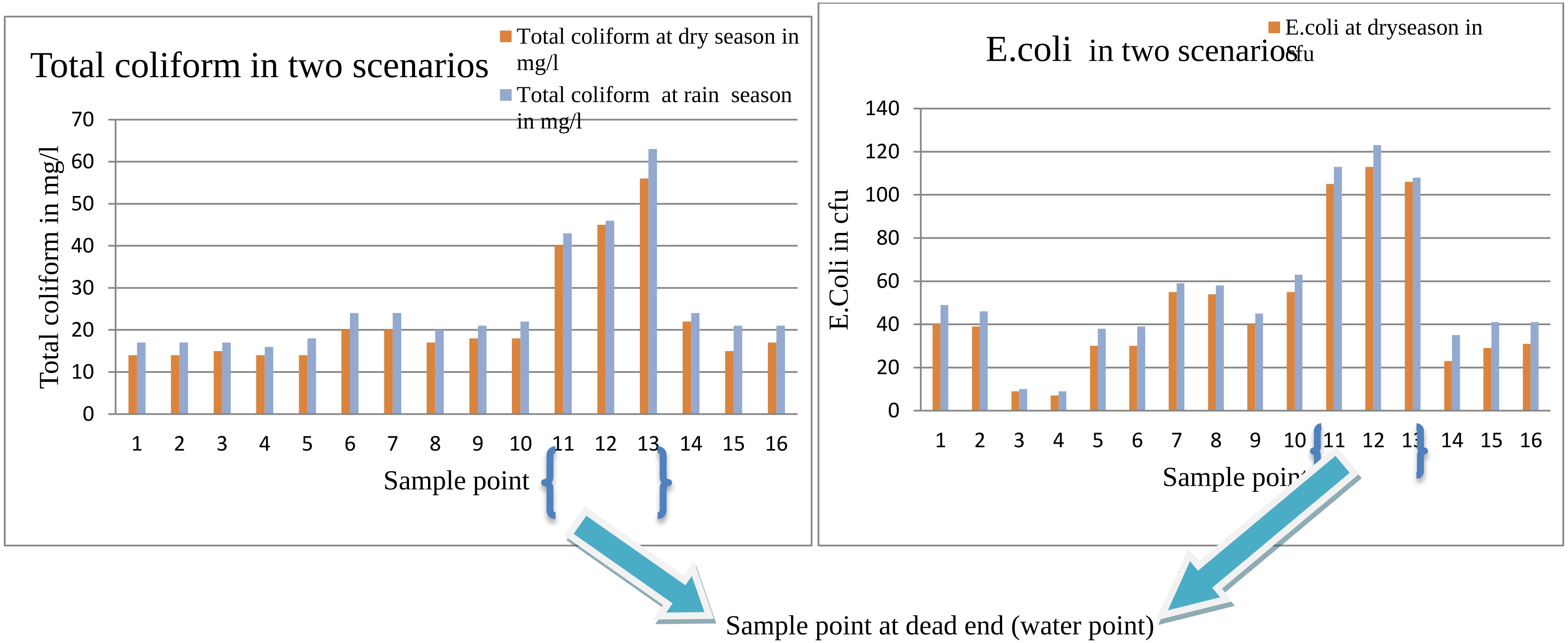


Figure12 Laboratory result of Total coliform and E.Coli in two scenarios

In the distribution system of Agaro town increased Total coliform and E.coli in the distribution system as show from laboratory analysis results in two scenarios . Both Total coliform and E.coli is more high in rain season its risk is medium and high in sample point as shown in table below.

The area around borehole is used for grassing that means support domestic animals, such as cattle, horses and sheep. it can alsobe a source of bacteria, as rainswash manurefromthe land into receiving water shade ; there is no post and pre chlorination in the town .therefore this is one source for increasing of Total coliform and E.Coli .

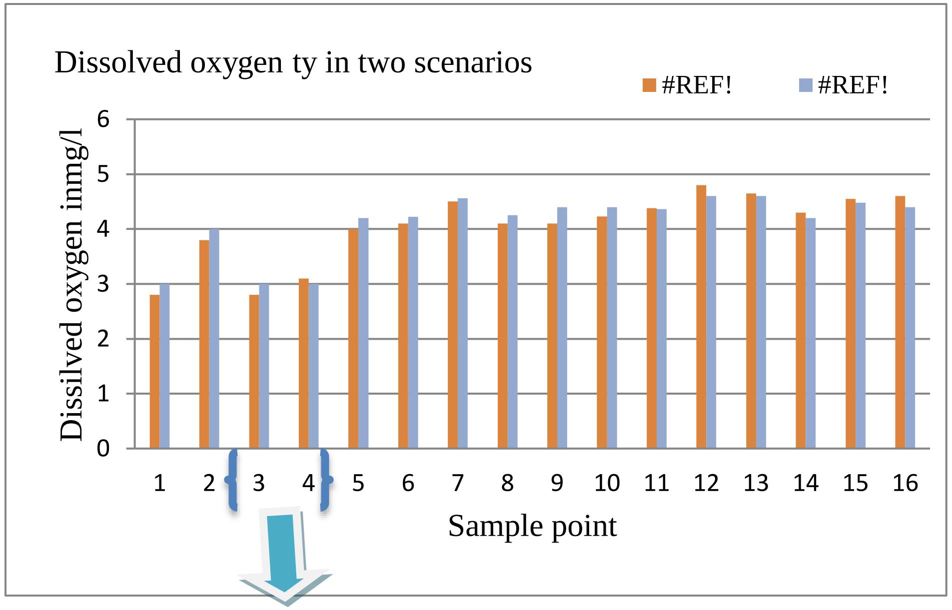
High levels of Total coliform and E.coli leads to economic losses. in terms of reduced health , and productivity from top ten disease more of the caused by water related and water born

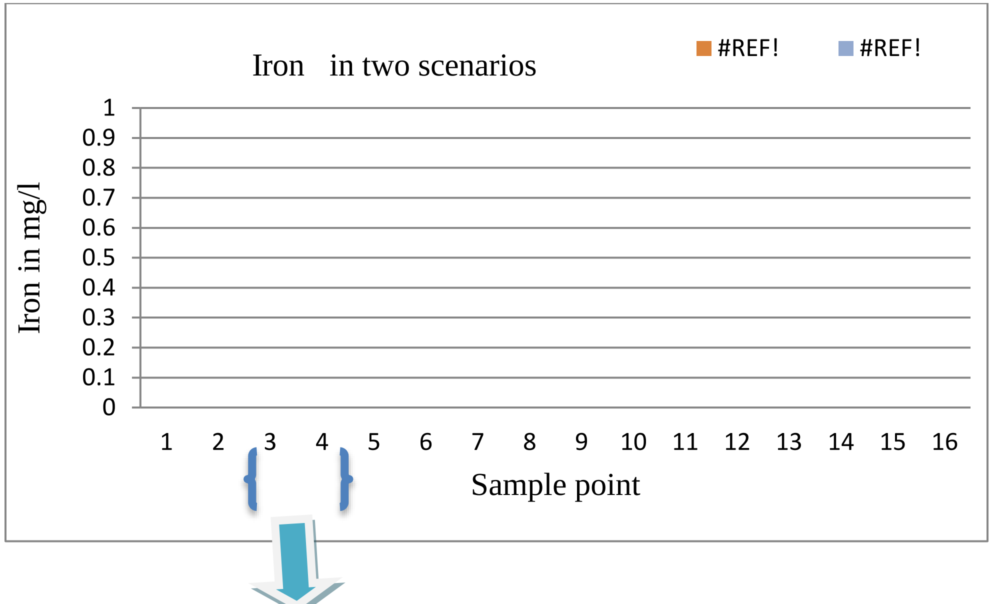
Table 12Biological analysis and its risk category of water supply of Agaro Town

Sampling location		E-coli/100ml or faecal coli form	Total coli form/100ml	Remark
SP1	BH4	49	17	Medium risk(Polluted)
SP2	BH3	46	17	Medium risk(Polluted)
SP3	BH1	10	17	Medium risk(Polluted)
SP4	BH2	9	16	Medium risk(Polluted)
SP5	Reservoir	38	18	Medium risk(Polluted)
SP6	Break pressure .T	39	24	Medium risk(Polluted)
SP7	Dead end	59	24	Medium risk(Polluted)
SP8	Dead end	58	20	High risk(dangerous)
SP9	B/N distribution .sy GT)	45	21	Medium risk(Polluted)
SP10	B/N distribution .sy (BJT)	63	22	Medium risk(Polluted)
SP11	Dead end	113	43	High risk(dangerous)
SP12	Dead end	123	46	High risk(dangerous)
SP13	Dead end	108	63	High risk(dangerous)
SP14	B/N distribution .sy (GT)	35	24	Medium risk(Polluted)
SP15	B/N distribution .sy (GT)	41	21	Medium risk(Polluted)
SP16	B/N distribution .sy (GT)	41	21	Medium risk(Polluted)

4.1.1.4 Dissolved Oxygen and Iron

In study areas (in Agaro town, laboratory results clear that amount of Iron is greater than maximum permissible limit in all source and distribution system. The town water supply source is Anaerobic groundwater contains iron at the maximum concentrations in two scenarios is 11.99 Mg/l and10 Mg/l and dissolved oxygen is in all source and distribution system is less than 4mg/las shown chart below





Sample point at3 and 4(borehole 1and 2

Shows more deficit of dissolved oxygen

Sample point at3 and 4(borehole 1and 2

concentration iron is more than the other

Figure13Laboratory results of dissolved oxygen and iron in two scenarios

In the town water supply system high concentration of iron and deficit of dissolved oxygen is show from laboratory analysis results in two scenarios. Both iron and dissolved oxygen is higher in rain season. The decreasing of dissolved oxygen more incites the increasing of iron in the system .at the sample more iron concentration is shows more decreasing of dissolved oxygen is observed from laboratory analysis.

Corrosion can be the result of physical actions that erode the coating of a pipe, chemical dissolution that leaches a pipe's lining or wall material, or electrochemical reactions that remove metal from the wall of the pipe. Finally, the release of soluble or particulate high concentration of iron corrosion to the water decreases its aesthetic quality and often leads to consumer complaints of red water at the tap and the town water supply and sanitation authority forced to change pipe material in the borehole between six months intervals. It affects obstruction of drinking water network, damage pumps and electromechanical part. This makes the town to high cost of replacement of this material.

Result of this high concentration of iron affects corrosive of pipe, discoloration of tea, soup and coffee; it also develops turbid of water.; it Adverse effects of water quality problem impacts lead to economic losses in terms of reduced productivity or extra cost.

4.1.1.5 Electrical Conductivity

Therefore, conductivity can indicate groundwater Seepage or a sewage leak.

Clears that in this study area the result of laboratory analysis indicates the minimum concentration of Electrical Conductivity is 650µs/cm at Sp15 (at the dead end) while the maximum is 809 µs/cm at Sp (at the source one or BH1). In Hence, these indicate as the source of water supply is hard water and considerably ionized and has the higher level of ionic concentration activity.

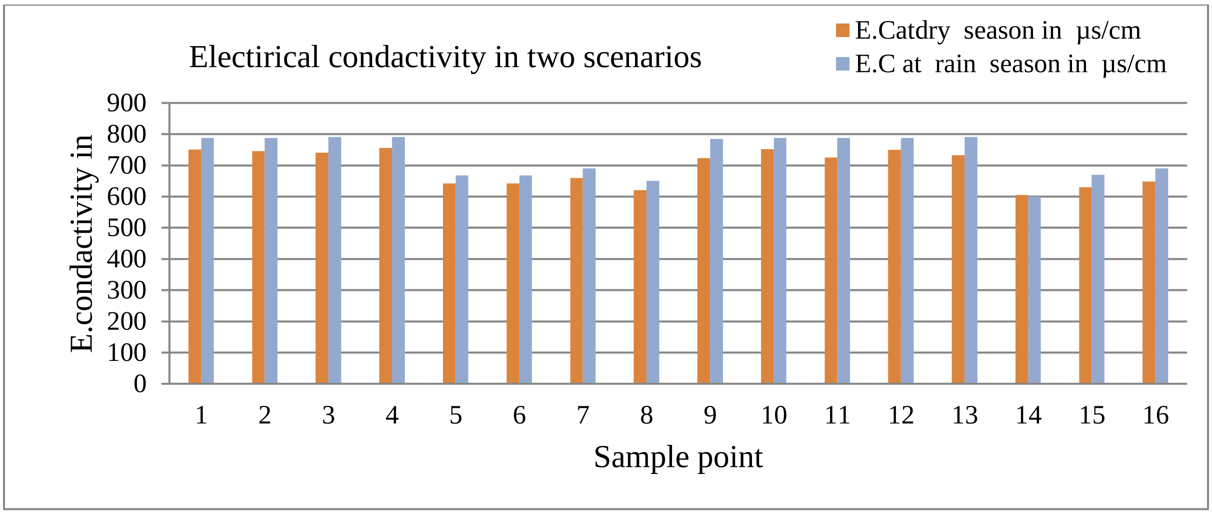


Figure14 Laboratory result of Electrical Conductivity in two scenarios

4.1.1.6 Chloride

In study areas the chloride value ranges from 3.99-17.999 mg/l. Thus, all the samples have lower concentration of chloride in two scenarios.

In study area the laboratory analysis shows the minimum concentration 3.99mg/l while the maximum concentration is 17.995 mg/l .In Hence, these ranges were acceptable

and concentration of CL is not harmful. The detail results can be shown in the table below..

4.1.1.7Nitrate (No_3)

The concentration of Nitrate at all point of test is less than the max limit .These results indicate that the quantity of nitrate in study sites is acceptable with in Ethiopian drinking water quality standard there is no health risk.

4..1.1.8 PH of water.

From lab result the minimum and maximum concentration in two scenarios 6.2 and 8.15 standard unit at different point between distribution system and at the Source (BH3) it is within the maximum limit .

4.1.1.9 Total alkalinity as CaCo3.

In study areas, results show that alkalinity ranges from 14mg/l in different point of distribution line and the maximum concentration is 241.5 mg/l in both scenarios. Thus, these values not caused health related problems

SOURCE OF WATER QUALITY PROBLEMS IN THE TOWN

The most common sources of iron in groundwater are naturally occurring, for example from weathering of iron and manganese bearing minerals and rocks. Industrial effluent, acid-mine drainage, sewage and landfill leachate may also contribute iron and manganese to local groundwater.

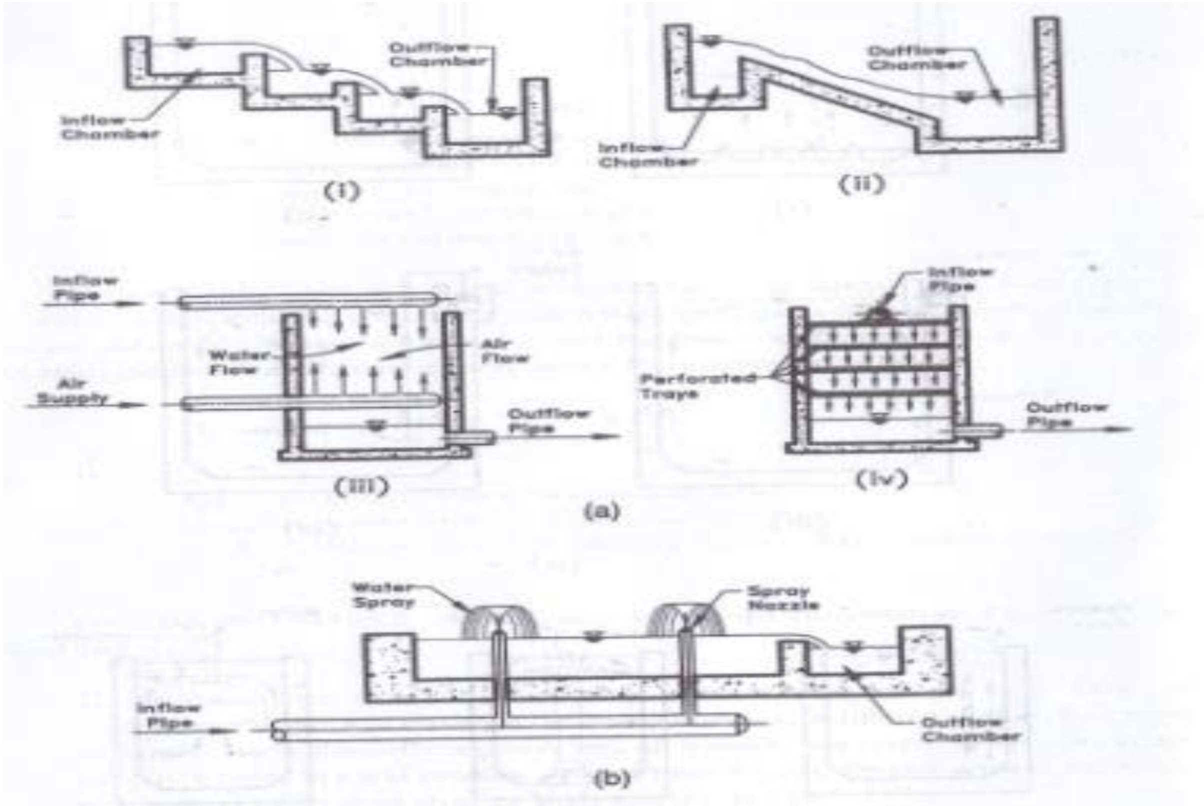
MITTIGATION MEASURMENTR

As the result of iron in study area is greater than 1mg/l so the recommended removal mechanism of this parameter is such as Pre-chlorination, Aeration, coagulation, and filtration.

AERATION

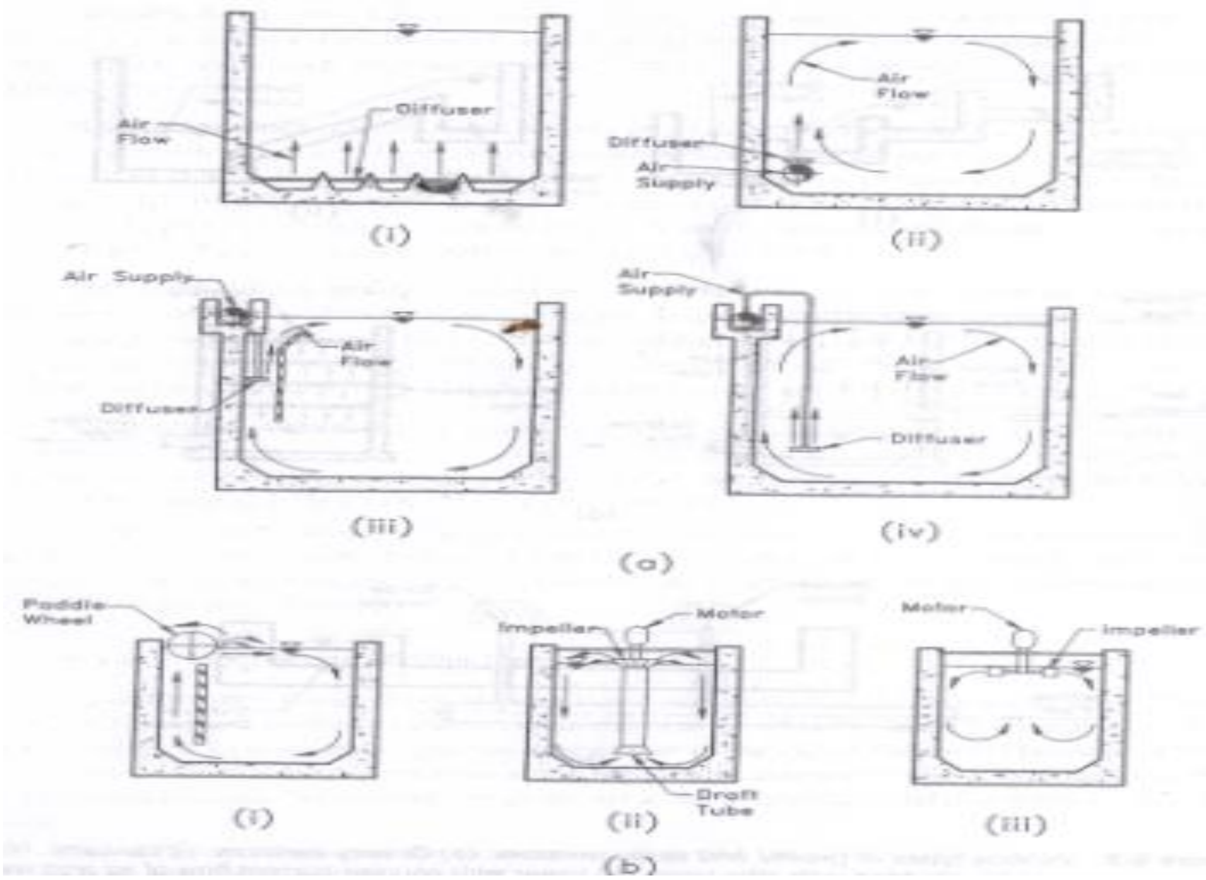
Types of aerators

- Gravity aerators: e.g. waterfalls, cascades, perforated tray towers
- Spray aerators: spray droplets of water into the air from orifice or nozzles



- Diffused-air aerator: compressed air is injected into the tank through porous diffuser plates, or tubes

- Mechanical aerators: employ either motor-driven impellers or a combination of impeller with air-injection devices

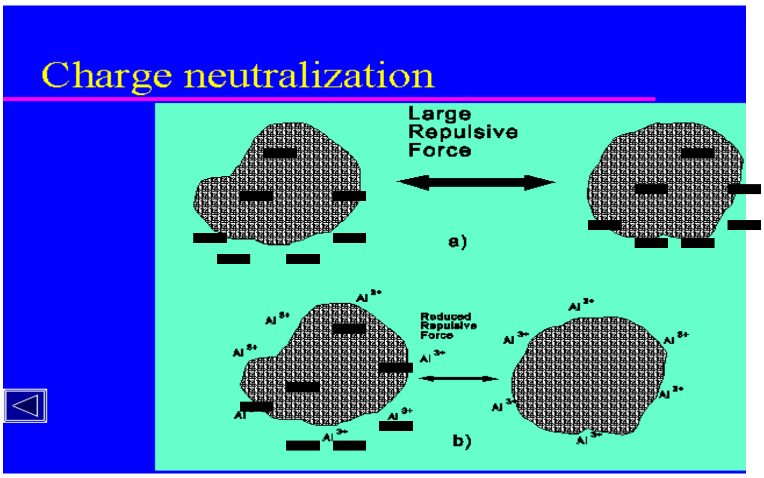


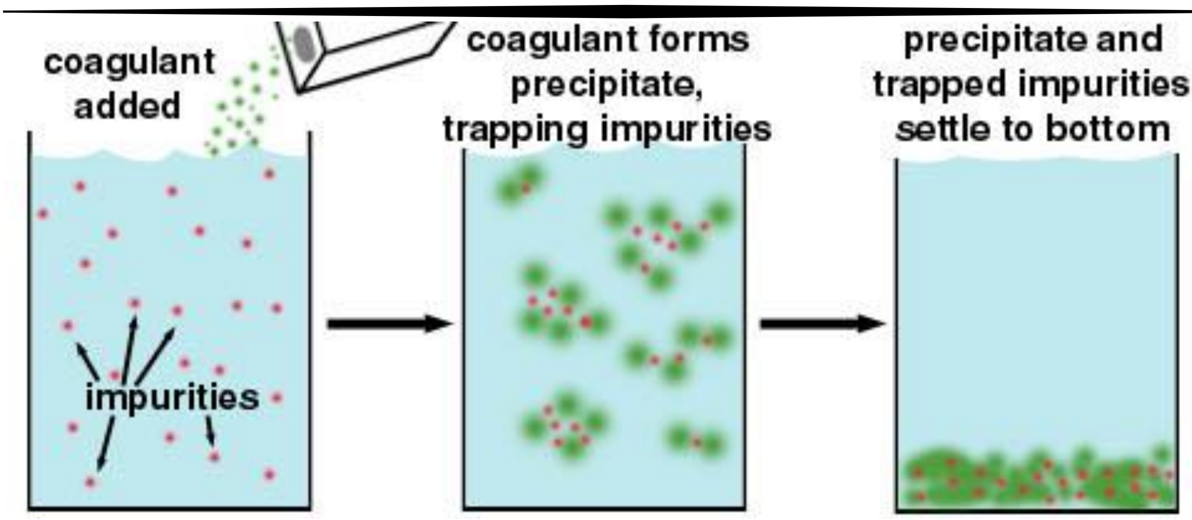
Coagulation

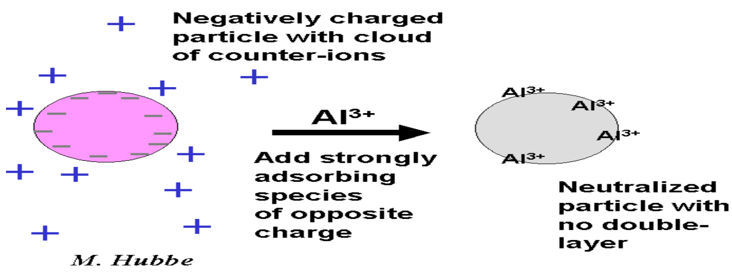
Coagulation is the destabilization of colloids by addition of chemicals that neutralize the negative charges.

The chemicals are known as coagulants, usually higher valence cationic salts (Al^{3+}, Fe^{3+} etc.)

Coagulation is essentially a chemical process



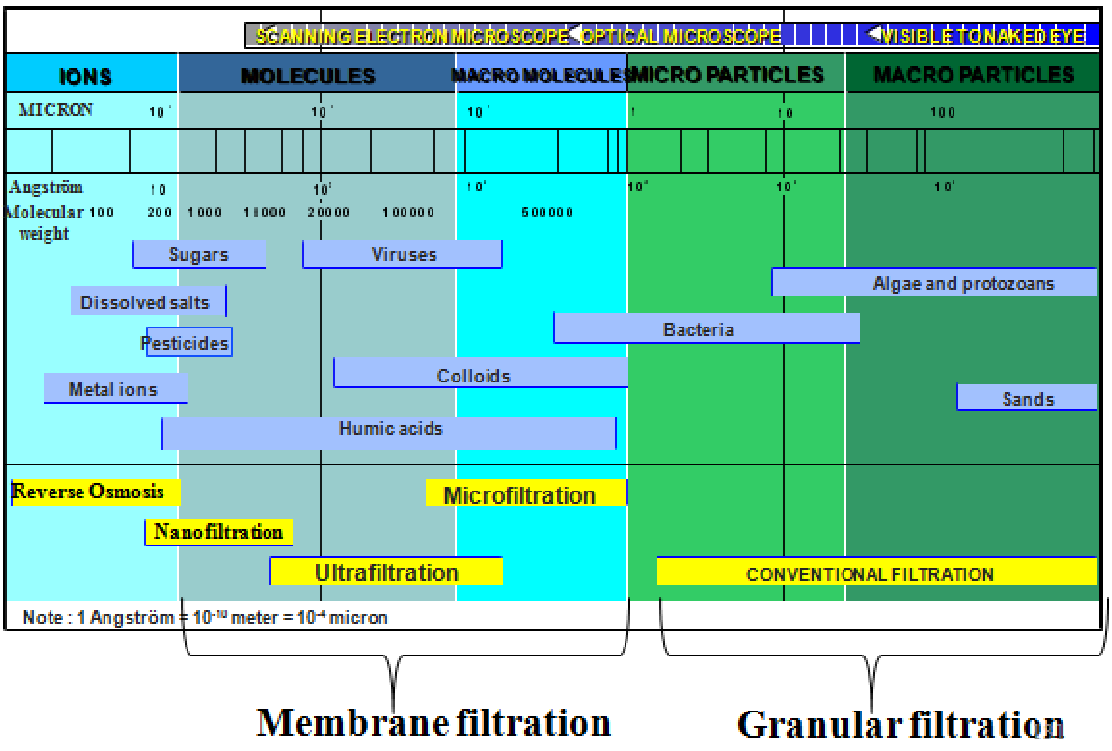




Filtration

Filtration: Removal of colloidal (usually destabilized) and suspended material from water by passage through layers of porous media.

Filtration Spectrum



4.2.2 Output of model analysis

4.2.2.1 Description of the network model

Model area is covered all the town distribution system. The color coding is used for the purpose of separation of low and high velocity. Red color links indicates low velocity that means less than 0.3m/s and green color links indicates normal velocity that means up to 1.8m/s. for pressure color coding is the same as velocity and red color junction indicates low pressure that means less than 10m and green color junction indicates normal pressure that means up to 70m. Pressure above 70m is shown pink color.

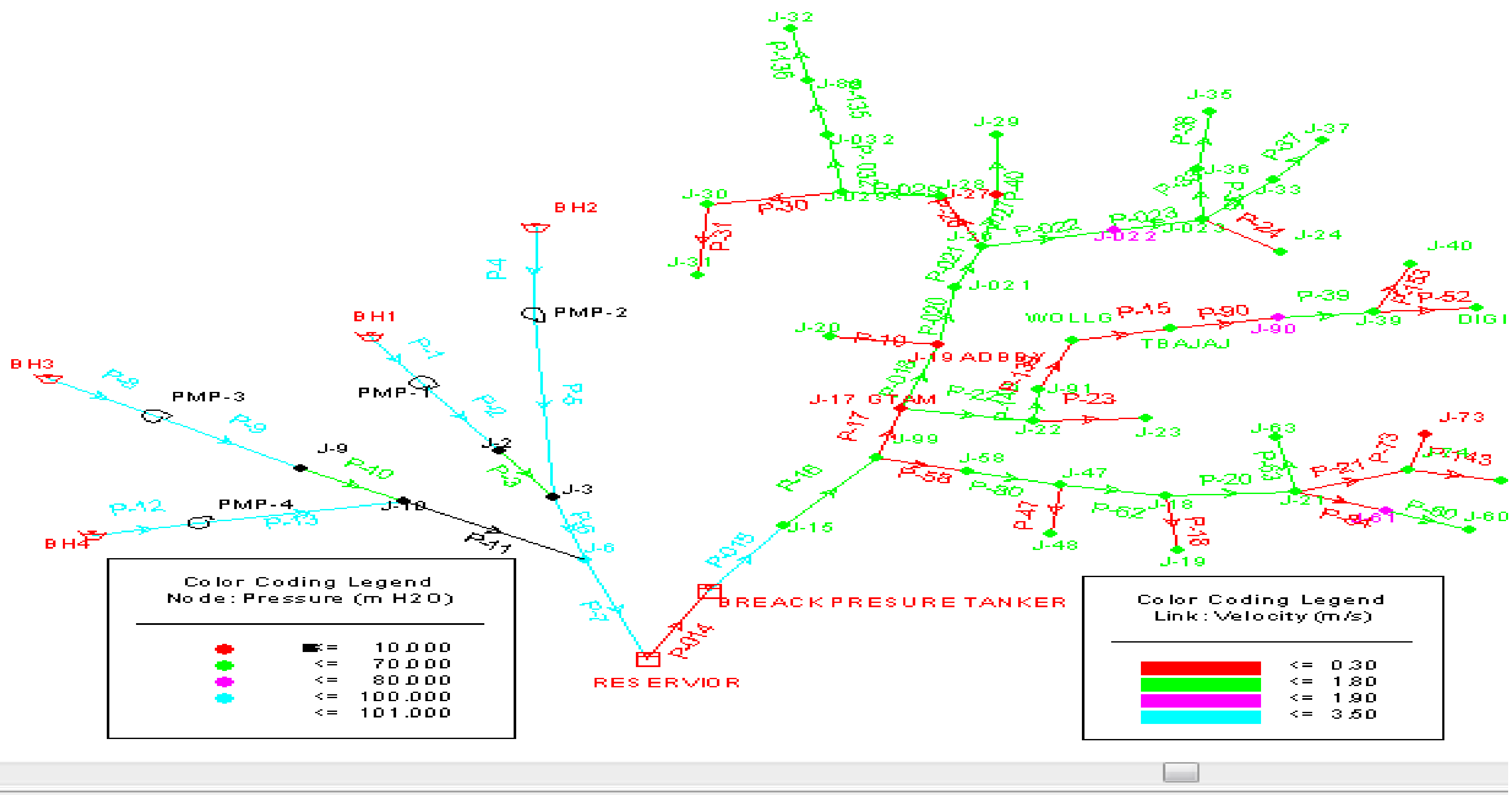


Figure 15Description of network model

4.2.2.2 Pressure

From output of model analysis there are both negative, low, high and normal pressure observed. At Low pressure the parameters like turbidity, total coli form and iron are greater than the maximum permissible limits increased.

Hydraulic changes velocity and pressure in the town is too much. It could cause increased turbidity and corrosion rate in the water distribution system and could lead to decline in water quality in the distribution systems. This happens because when turbidity is high, coli forms will be attached to the particles and as the town water supply any pre or post chlorination didn't used it leads high growth of bacteria and this increase the risk factor for outbreaks of waterborne disease.In the town from top ten disease cholera, typhoid and common diarrhea is covered the first three ranks . The detail output of pressure show on ANNEX C

Table 13 Result of low and high pressure

Location	Pressure (m H2O)
J-27	1.193
J-73	2.578
J-17 GTAM	3.802
J-19ADBBY	5.038
J-32	8.036
J-36	8.153
J-30	8.207
J-29	8.538
J-39	9.09
TBAJAJ	9.958

J-022	73.684
J-61	77.347
J-6	93.409
J-2	117.808
J-3	126.804
J-10	142.95
J-9	147.213

4.2.2.3 Velocity out put

The result of low velocity in the water distribution system is deposition occur and which eventually cause as the water source contain concentration of iron is high and the pipe material is Galvanized steel iron , corrosive of the pipe spead up in the system

Low velocity shows at 21 links from distribution line and at 5 linkes from sample taken.

As shown in table below.

Table 14low velocity in distribution system and sample taken .

Pipe	Sample location	Velocity (m/s)
P-52		0.05
P-31		0.06
P-18		0.18
P-15		0.22
P-17		0.27

Pipe	Material	Velocity (m/s)
P-24	Ductile Iron	0.001
P-73	PVC	0.001
P-19	Ductile Iron	0.001
P-014	Ductile Iron	0.01
P-127	PVC	0.02
P-52	Ductile Iron	0.05
P-31	Ductile Iron	0.06
P-153	Ductile Iron	0.06
P-23	Ductile Iron	0.07
P-14	Ductile Iron	0.07
P-143	Ductile Iron	0.08
P-26	Ductile Iron	0.09
P-21	Ductile Iron	0.15
P-30	Ductile Iron	0.16
P-58	Ductile Iron	0.16
P-18	Ductile Iron	0.18
P-90	Ductile Iron	0.18
P-15	Ductile Iron	0.22
P-84	Ductile Iron	0.24
P-47	Ductile Iron	0.25
P-17	Ductile Iron	0.27

at low velocity the parameters like turbidity , total coli form and iron, E.coli observed greater than permissible limit because of stagnation of water in the pipe and pipe materials .the high velocity also observed at 3 (three)linkes from all distribution system and 5 (five) links at sample location and at high velocity observed high turbidty ,total coliform , E.coli because of causes washing of pipe wall and the results is shown in table below and detail out put shows on the Annex .

Table 15 High velocity at distribution system and on sample location .

Pipe	Material	Velocity in m/s
P-4	Galvanized iron	2.86
P-7	Galvanized iron	3.01
P-015	Ductile Iron	3.37
P-12	Ductile Iron	3.5
P-11	Galvanized iron	3.9

Pipe	Material	Velocity in m/s
P-5	Ductile Iron	2.86
P-6	Galvanized iron	3.18
P-13	Galvanized iron	3.5

The output of model analysis is pressure at the junction and velocity at the link . generally links is shows minimum and maximum velocity at fifty and five links. And low that means below 10 m is shown at 4 junction and high pressure above 70m shown at 20 junctions. Generally the result of model analysis(pressure and velocity) at the sample taken from laboratory is shown at table below .

Table 16Output of model analysis(pressure and velocity) at sample location

Sample point	Location	velocity	pressure
SP1	BH4	3.5	98
SP2	BH3	1.09	64
SP3	BH1	2.23	74
SP4	BH2	2.84	86
SP5	Reservoir	1.01	62
SP6	Break pressure .T	3.25	40

SP7	Dead end	0.06	12.2
SP8	Dead end	0.41	1.2
SP9	B/N distribution .sy GT)	0.26	3.8
SP10	B/N distribution .sy (BJT)	0.22	10
SP11	Dead end	0.05	28
SP12	B/N Tranismition line (J-10)	3.64	143
SP13	Dead end	0.71	67.5
SP14	B/N Tranismition line (J-3)	3.1	126.8
SP15	B/N distribution .sy (J-023)	0.42	12.2
SP16	B/N distribution .sy (J-18)	0.47	17.8

4.2.2.4 Model Performance Evolution.

For the purpose of model calibration gagde pressure is important to measure at night time . Result of gagged pressure

Night pressure was taken at the simple point for the purpose of calibration. The results is shown on the table below.

Sample point	Sample	Junction	Gagged pressure
SP 8	Dead end	J-29	0.8
SP 9	B/N distribution	J-17 GTAM	3.7
SP 10	B/N distribution	TBAJAJ	9.8
SP 15	B/N distribution	J-023	11.8
SP 7	Dead end	J-31	11.8
SP 16	B/N distribution	J-18	16
SP 11	Dead end	DIGIT BRO	26.5
SP 6	Break pressure tanker	J-15	39.5
SP 12	Dead end	J-60	62
SP 14	B/n transmission line	J-3	126.5
SP 12	b/n transmission line	J-10	142.5

Coefficient of Determination (R^2)

$$R^2 = \left(\frac{\sum_{t=1}^{n} \left(q_t^{obs} - \overline{q_t^{obs}}\right)\left(q_t^{sim} - \overline{q_t^{sim}}\right)}{\sqrt{\sum_{t=1}^{n} \left(q_t^{obs} - \overline{q_t^{obs}}\right)^2} \sqrt{\sum_{t=1}^{n} \left(q_t^{sim} - \overline{q_t^{sim}}\right)^2}} \right)^2$$

4.2.2.5 Acceptable level of calibration

R^2 Approach to one and its shown on the graph.

Table 17 Gagde and mode presure

Sample point	Sample	Junction	Model pressure (H2O)	Gagged pressure
SP 8	Dead end	J-29	1.2	0.8
SP 9	B/N distribution	J-17 GTAM	3.8	3.7
SP 10	B/N distribution	TBAJAJ	10	9.8
SP 15	B/N distribution	J-023	12.2	11.8
SP 7	Dead end	J-31	12.2	11.8
SP 16	B/N distribution	J-18	17.8	14
SP 11	Dead end	DIGIT BRO	28	26.5
SP6	Break pressure tanker	J-15	40	38.5
SP 14	B/n transmission line	J-3	126.8	126.5
SP 12	b/n transmission line	J-10	143	142.5

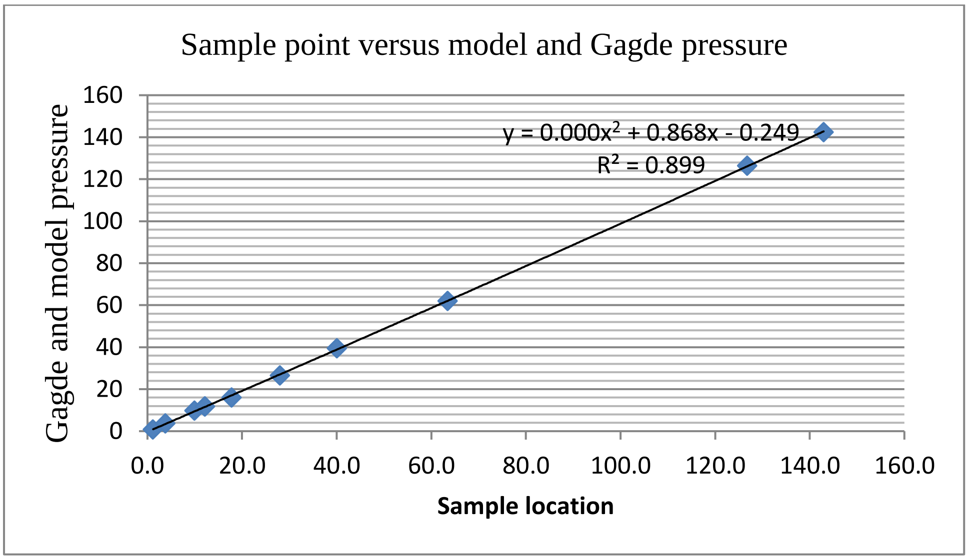


Figure 16 Calibration result of model out put and gagged pressure

The calibration and validation of the pressure gave excellent results. The model provided good simulation of both the peak and minimum demand. The R^2 values is 0.899 were deemed acceptable value. The calibration and verification results indicated that the model and gagged pressure matched in the distribution system of the network. and the calibrated model was suitable for simulating laboratory analysis in the study area.

4.1.3 Water Quality Problem Impacts in Agaro Town.

4.1.3.1 Impact on the Community.

In the public health point of view direct costs of controlling disease, the result of laboratory analysis indicates that the concentration of total coli form , E.coli, iron, residual chlorine and turbidity is the very high ; This situation opposed to health impacts highly affects on children by water associate diseases such as typhoid, cholera and diarrhea. In other case it contributes high cost of medicine, Lower productivity and the time consuming is a heavy burden on the town.

4.1.3.2. Impact on the Distribution System.

According to laboratory result the concentration of iron and from model analaysis in few pipes on distribution line velocity and pressure shows below the limits, it indicates that the stagnation of water on the pipe . Therefore this high level of iron and low pressure and velocity can be affects the pipe material of distribution system, color of the water , other electromechanical part and pumps.

Figure17 The corroded pipe and the new pipe prepared for installing.

Source : - photo taken during field study.

According to information gathered from Agaro Town water supply and sewerage Authority around six month intervals they change the rising pipe in the boreholes unless otherwise the color of water become red in color and the rising pipe and pump will be totally damaged. There for the cost lost due to poor water quality on the borehole is shown as table below.

Table 18The economical impact on the distribution system of study area.

	History of Borehole				
No	Total depth	Pump position in meter	Pipe materials	Diameter in inch	Total cost with EB
BH1	80m	72m	GSI	2 ½"	400,000
BH2	110m	87m	GSI	4	500,000
BH3	110m	82m	GSI	4	500,000
BH4	110m	82m	GSI	4	500,000
Total cost					1,900,000

Source: - from Agaro town water supply and sanitation authority.

4.1.3.2. Impact on the Merchants of Agaro Town that can Participate on Coffee and Tea preparation.

According to the data gather from Agaro town small and micro intersperse(SMI) the people can participate on tea and coffee preparation are 250 enterprise each enterprise contain 5-10 five up to ten members.

All of this small and micro interposes cannot used the distributed water for preparation of the coffee and tea. They said if we use the tap water for this purpose it can affect the coffee and tea color and test. And the other is the coffee after pick from fire it can be settled for a few second for settling purpose, but the coffee prepared by distributed water cannot settled and it affects the quality of the coffee so the reduction of the customer happened.This is occurred due to high level of iron it affects the quality of coffee and tea.

Figure18coffee prepared using polis tibia spring coffee prepared using tap water
It is a Good quality coffee for its colour and test It cannot settled always turbid
And its test is not good.

The Town is divided into 3 (three) sub katanas (small branchy) the first katana contain ninthly (90)small and micro enterprises and the second katana contain 97(ninety seven)SMI and the last one is have 63 (sixty three)SMI members

Table 19 Name of branchs and umber of small aand mico interpirse that can participate on preparation of coffee and teain agaro town .

Name of ketanas (branchs)	Name of small and micro interpirise
ketana (branchs 1	90
ketana (branchs 2	97
ketana (branchs 3	63
	250

According to the questioner gathered during field study they used another water consumption for preparation of coffee and tea between 4 jarkan (20litre container) up to seven (7 Jarka) therefore the average water per day is five (5) janrka of 20 litre of container and the average cost of water including transportation is 5(five) birr. In fig below shows the member of Small and micro enterprise buy water from another source .

Figure 19 The merchants that get a water from polis tibia sparing

Source photo taken during field study.

Therefore the summary of economical impact on merchant of Agaro Town show in table below

Table 20The economical impact on merchant of many loss due to lack of water quality in per day, per/month and per year with small branches of Agaro Twon.

Name of ketanas (branches)	Name of small and micro enterprise	Avg water consumption per cap/day in 20litre container	Unit cost of water per one container of 20litres	Total cost ofwater in E.Birr per day	Total cost of water in E.Birr per month	Total cost of water in E.Birr per year
ketana (branchs1)	90	5	5	2,250.00	67,500.00	810,000.00
ketana (branchs2)	97	5	4	1,940.00	58,200.00	698,400.00
ketana (branchs3)	63	5	4.5	1,417.50	42,525.00	510,300.00
Total	250			5,607.50	168,225.00	2,018,700.00

Therefore the cost lost per day for requiring pure water is 6250birr. And when we calculate per month and annually 168,225 and2,018,700 Ethiopian birr respectively Therefore the total cost lost per annual is very high.

Figure 20 Member of small and micro enterprise participate on coffee and tea preparation meeting on cost of water and used from another source.

Source : - photo taken during data collection

4.1.3.3. Cost Lost at Ramadan Month for Requiring Another Source..

The town is divided into 5 (five)kebeles, According Gamma wereda information gathered from staticallyAgency 80% Muslim and 15 % orthodox and 5 % is another's religions.

Table 21 The total population and house hold of Agaro town is shown in table below .

Name of kebales	Total population in 20014	Total House hold
Tamsaha Jidda(01)	8225	1507
Birbirsa Wirtu(02)	9775	2021
Tige koye(03)	8500	1901
Bake Agalo (04)	7842	877
Tullu Kidila (05)	6658	790
Total	41000	7096

Table 22There for total house hold of Agaro town that follow Muslim religion is shown as table below

Table the total HH that follow Muslim religion in kebeles .

Name of kebales	House hold
Tamsaha Jidda(01)	1205
Birbirsa Wirtu(02)	1616
Tige koye(03)	1521
Bake Agalo (04)	701
Tullu Kidila (05)	632
Total	5675

According to Muslim realign all Muslim its age is greater than 15 years can fasten (sthom) one month from everyone years. Therefore during this month the soup is a common food for all Muslims. According to questioners gathered during field study all Muslims do not use a tap water for preparation of soup during the month of Ramadan.

From door to door informationgathered during field study aboutwater consumption during this month, it depends on economy of the individual. That means rich family uses more water and the poor family consume thereverse. There for all family is consume water between the interval of five (5) and two (2) jar cans (container of 20litre) per day. For this paper use by taking the average three (3) container of 20litre per day total consumption of water during the month of Ramadan is shown in table below

Table 23 The total HH and water consumption in 20litree of container per day during ramadan month in kebeles .

Name of kebels	House hold	Total water Consumption in 20litre of container
Tamsaha Jidda(01)	1205	3615
Birbirsa Wirtu(02)	1616	4848
Tige koye(03)	1521	4563
Bake Agalo (04)	701	2103
Tullu Kidila (05)	632	1896
Total	5675	17025

According to questioner gathered during data collection 80% the people says the one 20litre Container buys from five(5) up to eight (8)Ethiopian birr.The value of many to buy water used for preparation of soup is highly bumming during the Ramadan month. By taking the average value for this purpose six (6)Ethiopian birr.Loss due to additional water sourceduring the month of Ramadanper day is shown in table below.

Table 24loss in Ethiopian Birr with HH and water consumption in 20litree of container per day during Ramadan month in kebeles

Name of kebales	House hold	Total water consumption in 20litre of container	Total amount in E. birr per day
Tamsaha Jidda(01)	1205	3615	21,690.00
Birbirsa Wirtu(02)	1616	4848	29,088.00
Tige koye(03)	1521	4563	27,378.00
Bake Agalo (04)	701	2103	12,618.00
Tullu Kidila (05)	632	1896	11,376.00
Total	5675	17025	102,150.00

As Ramadan is one month the total water conception or much loss due to lack of potable and safe water quality distribution is shown in table below.

Table 25loss of many in one month of Ramadan dueto lack of safe and potable quality of distribution of water quality(another source)

Name of kebales	House hold	Totalwater consumption in 20litre of container	Total amount in E. birr per day	Total amount in E. birr per month
Tamsaha Jidda(01)	1205	3615	21,690.00	650,700.00
Birbirsa Wirtu(02)	1616	4848	29,088.00	872,640.00
Tige koye(03)	1521	4563	27,378.00	821,340.00
Bake Agalo (04)	701	2103	12,618.00	378,540.00
Tullu Kidila (05)	632	1896	11,376.00	341,280.00
Total	5675	17025	102,150.00	3,064,500.00

In general greater than three million (3) of E. Birr is loss due to lack of water quality in one month or in a year.

Total many lost in month during Ramadan month by ketanas

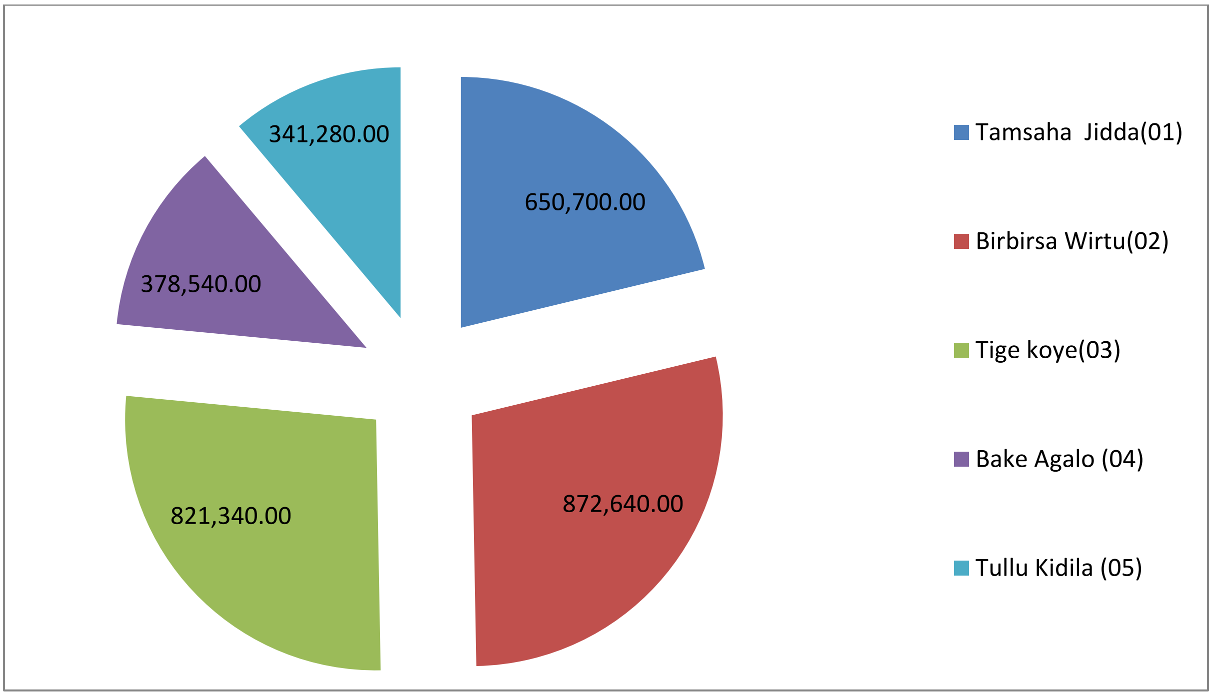


Figure21Graph of Total many lost in month during Ramadan month by ketanas

5. CHAPTERFIVE.

5.1 CONCLUSION AND RECOMMENDATION.

5.1.1 Conclusion.

Source potential of water at the study area boreholes. The parameters assessed were Color, pH, Temperature, Turbidity, Alkalinity, Iron, Chloride concentration, E-Coli, Electrical conductivity, dissolved oxygen, nitrate, residual chlorine and Total Coli form. Based on the study, it is discovered that, there is high prevalence of water quality problem; and associate different impacts like on health, water supply equipments like pipe material pump and economy of the individual and town as well as country.

The parameters like iron, electrical conductivity, total coli form ,Turbidity dissolved oxygen and E. coli are not within the maximum permissible limit prescribed by WHO and EDWQ in two scenarios

The parameters like nitrate and total alkalinity, Chloride are low permissible limit in both scenarios..

The parameters like TDS and PH are within permissible limit in both scenarios

The result of the analysis indicated that water supply in Agaro Town is not safe for drinking as a result of high value of Iron, E-coli, coli form count, turbidity Electrical conductivity thus its impact is different health problems like pathogenic diseases, direct and indirect economical impacts.

In the study area at low velocity parameters like TC, E.Coli, Turbidity, DO and E.C are above the permissible limit.

According to this study the Agaro Town water supply has a very high level of iron really its impact is very harmful on all the community of the town , on the pipe material of distribution systems, and other electromechanical parts of water supply

The concentration of total coli form categories is high risk and it cause different water born water related disease like cholera, Typhoid Diaries

The control of water quality is important to avoid contamination of food produced when water is used as a raw material. A certain amount of parameters like turbidity, iron, and total coli form electrical conductivity in samples is present in raw and distributed waters. However, this parameters cause corrosion of pipe, different economy of the individual and the country level And different part of water supply system equipments like pipe and pumps.

In general the economic impact for lost to find another source annually for preparing soup , coffee and tea and replacing the rising main in borehole respectively 3,065,580 ,68,437,500 and 1,900,000.

The discoloration of water is due to low pressure velocity and high velocity

5.1.2. Recommendation.

In order to address the problems discussed above, the following recommendations are made:

- Before distributing water supply to the community it should be treated to prevent incidences of diseases.
- In drinking water supply its quality may be acceptable when the water passes the variety of physical, chemical, and biological characteristics of analyses.
- The main solution of this problem in Agaro Town water supply system the first one is treating the source. As the level of iron is increase at the source the main mitigation is to aerate the water before distribute.
- Water disinfection is one of the most important processes which protect public health. Chlorination is the best disinfectant which owns the properties to remain until after the disinfecting process as it provides certain and continuous protection of drinking water from water sources leading to the final consumer. Besides being cheap, chlorination is the most widely used disinfectant in centralized water distribution systems.
- Improved water supply requires community participation and commitment by the locals to ensure that long-term needs are met. The Government with collaboration with Civil Society group and non-Governmental organizations should come to the aid of these people There is a need to create awareness of the water quality problem and its impacts.
- Before drilling and damming it's better to check the quality of water supply.
- Use household water treatment practice it can help improve water quality at the point of consumption, especially when drinking water sources are distant, unreliable or unsafe
- When microbiological parameters are taken into account, such as total coli form and E.coli , Turbidity , Iron then the analyzed in the study area (the concentration is high at the source and in different distribution system) would not be suitable for human consumption without prior treatment.
- Therefore, based on this study, it is highly recommended that the local authorities and responsible body should take suitable control measures for drinking water source. As an outcome of this research, it would be wise that all water should be treated with Aeration before distributed , chlorination or boiling before being used. For long term planning purposes, an installation of small-scale water treatment plant should be taken into consideration

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ANNEX

Annex A*Research questions*

This questioner is prepared to asses' water supply qualityproblem and its impacts on Agaro Town

Are you willing to respond for question below?

Yes No

Nationality ______________nation______________reliogn ____

Marital status of the household head

single married widow divorced

head of house hold work____________________________

Water supply condition

Can you use tap water for drinking purpose ?yes No

There is any problem on water supply? yes No

If the answer is yes describe the problems

Quantity

Quality

Cost

Onother____

Can you use the tap water for all purpose? Yes N o

Can you prepare coffee and tea by tap water yes No

If the answer is NO why do not use?

It affect the coffee and tea color

It affect the coffee and tea oduor

It affect the coffee and tea test

Another

10. Where do you get water?

11 .if you buy water how much 20l of container (jarkan) with ETB

A) 3 birr

B) 4 birr

C) 5 birr

D) Another

13. How much water used per day

A) For tea preparation.

B) For coffee preparation.

C) For soup preparation during Ramadan month.

d) For other purposes.

Annex B WHO and Ethiopian Standard of water quality

Parameter	WHO guideline	Recommended for Ethiopia
PH(range)	6.5-8.5	5.0-9.5
Total alkalinity(mg/l)	1000	1000
Total hardness(mg/l)	500	600
Chloride(mg/l)	250	800
Sulphate(mg/l)	400	600
Fluoride(mg/l)	1.5	4
Iron(ppm)	0.3	3/0.4
E. Coli(cfu)	10	30
Nitrate(mg/l)	10	40
Electrical conductivity	400µs/cm	400µs/cm
Total dissolved solid (mg/l)	1000	1767
Total coli form (cfu)	0	0
Temperature (0c)	25	

Source: WHO (2010)

Sample point	location	Turbidity at dry season in NTU	Turbidity at rain season in NTU	E.coli at dryseason in cfu	E.coliI at rain seasonin cfu	Ironat Dry season in mg/l	Iron at rain season in mg/l	Total coliformdry season in mg/l	Total coliform rain season in mg/l	dissolved oxygen at dry season in mg/l	dissolved oxygen at rain season in mg/l
SP1	BH4	9	10	40	49	10.2	10.98	14	17	2.8	3
SP2	BH3	9.5	10.3	39	46	9.98	10.998	14	17	3.8	4
SP3	BH1	10	11	9	55	9.6	8.77	15	17	2.8	3
SP4	BH2	12	13.1	7	69	9.42	7.22	14	16	3.1	3
SP5	Reservoir	7.4	7.7	30	38	7	7.23	14	18	4	4.2
SP6	Break pressure .T	7.3	7.5	30	39	6.3	6.99	20	24	4.1	4.22
SP7	Dead end	7.5	7.6	55	41	9	9.998	20	24	4.5	4.56
SP8	Dead end	7.2	7.3	54	36	6.3	6.99	17	20	4.1	4.25
SP9	B/N distribution .sy GT)	10	12	40	45	9.99	10.77	18	21	4.1	4.4
SP10	B/N distribution .sy (BJT)	12.5	13.6	55	63	9.98	10.778	18	22	4.23	4.4
SP11	Dead end	12.9	13.2	105	63	10.5	10.778	40	43	4.38	4.36
SP12	Dead end	14	13.2	113	73	9.32	10.98	45	46	4.8	4.6
SP13	Dead end	12	14	106	52	10	11.99	56	63	4.65	4.6
SP14	B/N distribution .sy (GT)	9	10	23	35	6.2	6.99	22	24	4.3	4.2
SP15	B/N distribution .sy (GT)	8	8.5	29	41	8.1	8.99	15	21	4.55	4.48
SP16	B/N distribution .sy (GT)	8.9	8.9	31	41	9.99	10.65	17	21	4.6	4.4

Annex C Result of Laboratory analysis in two scenarios that maximum permissible limit

Sample point	location	PH dry seasonin standard Unit	PH rain season in standard Unit	Temp erete 0c	E.C at dry season in μs/cm	E.Cat rain season in μs/cm	Alkalinity dry season mg/l as caco3	Alkalinity at rain season mg/l as caco3	Nitrate in mg/l	Chloride in mg/l	Residual chilorinmg/l at dry season	Residual chilorinmg/l at dry season
SP1	BH4	7.65	7.59	25	788	751	15.8	15	0.5	16	NILL	NILL
SP2	BH3	7.31	7.3	25	788	746	15.4	15	0.5	16	NILL	NILL
SP3	BH1	8.01	8	25.1	791	741	20	25	0.5	16	NILL	NILL
SP4	BH2	8.03	8	25.1	791	756	23	23	0.5	16	NILL	NILL
SP5	Reservoir	6.4	6.3	23.5	668	642	14	14	0.5	16	NILL	NILL
SP6	Break pressure .T	6.4	6.3	23	668	642	14	14	0.5	16	NILL	NILL
SP7	Dead end	7.11	7.1	24	690	659	14.2	14	0.5	16	NILL	NILL
SP8	Dead end	6.3	6.3	23	650	620	14	14	0.5	16	NILL	NILL
SP9	B/N distribution .sy GT)	7.11	7.1	25	785	723	15.1	15	0.5	16	NILL	NILL
SP10	B/N distribution .sy (BJT)	7.9	7.8	25	788	752	16	16	0.5	16	NILL	NILL
SP11	Dead end	7.966	7.9	25	788	725	16.1	16	0.5	16	NILL	NILL
SP12	Dead end	8.01	8	25.1	788	750	20	22	0.5	16	NILL	NILL
SP13	Dead end	8.15	8.15	30	791	732	22	22	0.5	16	NILL	NILL
SP14	B/N distribution .sy (GT)	6.2	6.2	23	600	80	14	14	0.5	16	NILL	NILL
SP15	B/N distribution .sy (GT)	6.5	6.4	24	670	630	14	14	0.5	16	NILL	NILL
SP16	B/N distribution .sy (GT)	7.11	7.1	24.9	690	648	15	15	0.5	16	NILL	NILL

Annex D Output of pressure from model analysis

Location	Elevation (m)	Base Flow (l/s)	Demand (Calculated) (l/s)	Pressure (m H2O)
J-27	1,686.00	0.2	0.2	1.193
J-73	1,677.00	0	0	2.578
J-17 GTAM	1,686.00	0.3	0.3	3.802
J-19ADBBY	1,684.00	0.3	0.3	5.038
J-32	1,668.00	0.2	0.2	8.036
J-36	1,672.00	0.15	0.15	8.153
J-30	1,678.00	0.2	0.2	8.207
J-29	1,677.00	0.2	0.2	8.538
J-39	1,679.00	0.15	0.15	9.09
TBAJAJ	1,679.00	0.3	0.3	9.958
J-47	1,679.00	0.5	0.5	10.243
J-37	1,670.00	0.15	0.15	10.755
J-89	1,666.00	0.3	0.3	11.434
J-35	1,667.00	0.2	0.2	11.581
J-023	1,672.00	0.2	0.2	12.161
J-31	1,674.00	0.12	0.12	12.173
J-28	1,675.00	0.3	0.3	12.936
J-26	1,675.00	0.3	0.3	12.946
J-63	1,655.00	0.6	0.6	13.309
J-20	1,674.00	0	0	15.018
J-22	1,674.00	0.3	0.3	15.329
J-23	1,672.00	0.3	0.3	17.308
J-029	1,669.00	0.15	0.15	17.357
J-18	1,671.00	0.5	0.5	17.811
WOLLG	1,670.00	0.3	0.3	19.033
J-21	1,657.00	0.5	0.5	22.613
J-91	1,664.00	0.5	0.5	25.18
J-58	1,664.00	0.5	0.5	25.792
J-33	1,655.00	0.12	0.12	26.49
J-19	1,662.00	0.35	0.35	26.646
DIGIT BRO	1,660.00	0.25	0.25	28.043

location	Elevation (m)	Base Flow (l/s)	Demand (Calculated) (l/s)	Pressure (m H2O)
GT	1,650.00	0.35	0.35	29.505
J-032	1,656.00	0.3	0.3	29.63
J-99	1,660.00	0.6	0.6	29.807
J-74	1,649.00	0.3	0.3	30.522
J-48	1,658.00	0.5	0.5	30.952
J-021	1,657.00	0.5	0.5	31.318
J-24	1,650.00	0	0	34.116
J-15	1,650.00	0.6	0.6	40.035
J-40	1,630.00	0.5	0.5	57.982
J-84	1,619.00	0.5	0.5	61.041
J-60	1,612.00	0.35	0.35	63.463
J-90	1,621.00	0.5	0.5	67.77
J-022	1,611.00	0.73	0.73	73.684
J-61	1,602.00	0.73	0.73	77.347
J-6	1,655.00	32	32	93.409
J-2	1,650.00	0	0	117.808
J-3	1,640.00	16	16	126.804
J-10	1,653.00	16	16	142.95
J-9	1,650.00	0.3	0.3	147.213

Annex E Output of Velocity from model analysis

Location	Length (m)	Diameter (mm)	Material	Velocity (m/s)
P-24	129.84	50	Ductile Iron	0.001
P-73	85.04	25	PVC	0.001
P-19	141.12	75	Ductile Iron	0.001
P-014	162.46	100	Ductile Iron	0.01
P-127	153.92	25	PVC	0.02
P-52	133.5	80	Ductile Iron	0.05
P-31	167.03	50	Ductile Iron	0.06
P-153	121.31	100	Ductile Iron	0.06
P-23	144.78	75	Ductile Iron	0.07
P-14	173.43	75	Ductile Iron	0.07
P-143	122.22	75	Ductile Iron	0.08
P-26	129.24	152.4	Ductile Iron	0.09
P-21	152.7	75	Ductile Iron	0.15
P-30	177.39	50	Ductile Iron	0.16
P-58	121.01	200	Ductile Iron	0.16
P-18	130.76	50	Ductile Iron	0.18
P-90	143.26	100	Ductile Iron	0.18
P-15	130.15	100	Ductile Iron	0.22
P-84	123.44	75	Ductile Iron	0.24
P-47	114.91	50	Ductile Iron	0.25
P-17	120.09	200	Ductile Iron	0.27
P-139	125.27	100	Ductile Iron	0.3
P-37	112.17	25	Ductile Iron	0.31
P-140	70.71	100	Ductile Iron	0.36
P-40	140.82	25	Ductile Iron	0.41
P-136	120.7	25	Ductile Iron	0.41
P-36	134.42	25	Ductile Iron	0.41
P- 032	135.33	50	Ductile Iron	0.41
P-023	116.74	50	Ductile Iron	0.42
P-22	172.21	100	Ductile Iron	0.44
P-27	122.83	50	Ductile Iron	0.45

Location	Length (m)	Diameter (mm)	Material	Velocity (m/s)
P-16	196.29	200	Ductile Iron	0.46
P-39	123.75	50	Ductile Iron	0.46
P-62	139.29	100	Ductile Iron	0.47
P-33	130.15	25	Ductile Iron	0.55
P-021	101.5	100	Ductile Iron	0.55
P-80	124.36	100	Ductile Iron	0.6
P-018	155.45	100	Ductile Iron	0.61
P-020	135.33	100	Ductile Iron	0.61
P-029	128.63	50	Ductile Iron	0.65
P-60	119.18	25	Ductile Iron	0.71
P-35	116.43	25	Ductile Iron	0.73
P-022	175.87	50	Ductile Iron	0.79
P-29	114.6	25	Ductile Iron	1
P-3	128.32	152.4	Ductile Iron	1.02
P-135	129.54	25	Ductile Iron	1.02
P-10	155.75	152.4	Ductile Iron	1.05
P-63	127.1	25	Ductile Iron	1.22
P-20	170.69	50	Ductile Iron	1.44
P-2	188.67	100	Galvanized iron	2.36
P-1	124.97	100	Ductile Iron	2.36
P-8	160.63	100	Ductile Iron	2.48
P-9	227.38	100	Ductile Iron	2.48
P-4	200.86	100	Galvanized iron	2.86
P-5	427.33	100	Ductile Iron	2.86
P-7	244.45	100	Galvanized iron	3.01
P-6	153.01	100	Galvanized iron	3.18
P-015	196.9	75	Ductile Iron	3.37
P-12	139.9	100	Ductile Iron	3.5
P-13	272.49	100	Galvanized iron	3.5
P-11	270.97	100	Galvanized iron	3.9