ADDIS ABABA UNIVERSITY INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

ASSESSMENT OF WATER QUALITY (THE CASE STUDY OF ADAMA TOWN)

AThesis submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillmentof the Degree of Masterof Science in Civil & Environmental Engineering

BY ABREHAM GEBISSA SENBETO ID No: GSR/1667/04

Stream: Hydraulics Engineering

<abrehamgebissa@gmail.com>

Sponsor: ERA

Phone No-0912171170/0923608870

Advisor: Dr. Ing. Geremew Sahilu

Adama Town Water Supply river side box intake and row Water pumping station

May, 2016

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Approved By Board of Examiners

	Signature	Date
1. Dr.Ing. Geremew Sahilu (Advisor)	___________________	_______________
2. Dr.Ing. Agizew Nigussie (External Examiner)	____________________	_________________
3. Dr.Ing.Mebruk Mohammed (Internal Examiner)	___________________	________________
4. Chair man Of Department's	____________________	_________________

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I, Abreham Gebissa Senbeto, declare that this is my own original work and that it has not been presented and will not be presented to any other University for similar or any degree award.I have explained my study aimed at (Assessment of water quality "the case of Adama Town Water Supply"), in regional state of Oromia/Ethiopia. This thesis is a copy right material protected under the Berne Convention, the Copy right Act, 1999 and other international and national representations in the behalf, on the intellectual property. It may not be produced by any means in full or in part, except for short extracts in fair dealing, for research or private study, Critical scholarly review or disclosure with an acknowledgement, with out written permission of the School of Graduate Studies, on the behalf of the author and the Addis Ababa University / Instituteof Technology.

Signature ___________________________

Abreham Gebissa Senbeto, Thesis May, 2016

abrehamgebissa@gmail.com

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Acronyms and Abbreviations used forThesis

MoWIE	Ministry of Water, Irrigation and Electric
ATWS	Adama Town Water Supply
PF	Public Fountain
HC	House Connection
DCI	Ductile Cast Iron
U-PVC	Univinayl Polyethylene Pipe
GSP	Galvanized Steel Pipe
RMS	Root mean square
WHO	World Health Organization
UNICEF	United Nation International Children’s Emergency Fund
NTU	Nephotometric Turbidity Unit
TCU	True Colour Unit
ES 261:2001	Ethiopia Standard
ESISO	Ethiopia Standard International Standard Organizat.
GPS	Global Position System
GIS	Geographical Information System
DEM	Digital Elevation Model
MDG	Millennium Development Goal
MS EXCELL	Micro Soft Execell
EWWCA	Ethiopia Water Work Construction Authority
UNEP	United Nations Environment Programme
USEPA	United State EnvironmentalProgramme Agency
DO	Dissolved Oxygen
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand

Abstract

This study focuses on the assessment of existing drinking water quality in Adama Town, which is located in East Shoa zone; it is found in the administrative of National Regional state of Oromia. It is far from Addis Ababa 100km on the old asphalt high way road to Harar.The town gets its Water supply from a treatment plant.The two consequential methods were used to achieve these objectives.The first method in volved the collection of samples from different locations of the study area followed by laboratory analysis, and the Second method in volved the use of simulation models such as Epanet Software to identify the pressure effect on residual chlorine in the water supply gravity distribution network system.For bacteriological analysis, the whole 45 representative samples were randomly selected from sensitive areas for expected pollution such as raw water, treatment plant ,service reservoir, water points, ends of pipe network, Sensetive points and customer point of user, and 45 samples were used for physico-chemical analysis. The results obtained show that Iron concentration is equal to World Health Organization permissible limit.The residual chlorine was zero in 45 samples except Koka treatment plant on frist round sample taking and laboratory test results. But after Constant-Head drip chlorinator on Lugo reservoirs and taken sample second round and test in laboratory the results of residual chlorine give us 0.02-0.3mg/l at the consumer's water tap and at reservoirs get 0.8mg/l residual chlorine.The results of Color concentration during Wet and Dry seasons were found between the ranges of 9-17 TCU.This result is greater than WHO maximum permissible limit values and less than Ethiopian maximum permissible limit values.The majority of samples less than the maximum World Health Organization and Ethiopia permissible limit.the result of bacteriological analyses indicated that in most of the samples no risk was observed after construct temporary Constant-head drip chlorinator. For future parmenently chlorination is recommended at Lugo reservoirs. The simulation results showed that the pressure has inversely relationship with the residual chlorine in the distribution systems of the networks.

Key words: - Water quality Modeling, GIS, GPS, Global Mapper, Epanet, Physical, Chemical, Bacteriological, Adama Town Water Supply.

Chapter-1

1. Introduction

1.1. Background

Water is one of the main important abiotic components of the environment.With out water life on earth would not exist. Water mainly used for drinking, cooking and preparation of food, bathing, cleaning, washing and personal hygiene, watering in gardens, and water for live stock, sanitation. It should be clear and aesthetically attractive, low turbidity and color recommended (NTU 5 and TCU 15) respectively, by World Health Organization (WHO) guide lines and should not be saline, containany compounds that cause aggressive and taste, should not cause corrosion scale formation, discoloring or staining and should not have at emperature unsuitable for consumption. Water is essential for life, but it can and does transmit disease in countries in all continents from the poorest to the wealthiest.

The most major water borne disease, diarrhea, and has an estimated annual incidence of 4.6 billion incidents and causes 2.2millionde the very year (UNICEF/WHO, 2012). Access to safe drinking water and sanitation is a global concern.Today, close to a billion people, most living in the developing world, does not have access to safe and adequate water (UNICEF/WHO, 2012). The World Health Organization (WHO) estimated that around 94% of the global diarrheal burden and10% of the total disease burden is due to unsafe drinking water, in adequate sanitation, and poor hygienic practices (Pruss- Ustunand Covalan, 2006; Fewtrelletal. 2007; Doria, 2010).

One of the most important factors that affect drinking water quality through distribution and with sustainable use of town water supply systems is the quality of water, the distribution systems to users (Brikke, 2002; Schoutern and Moriarty, 2003). If domestic water supply of any town was fail to meet acceptable drinking water quality standards (that is, physical, chemical and Bacteriological) people may stop using the water and resort to unsafe sources and was further exposed to acute and chronic illnesses (Karnand Harada, 2002) there are several variants of the fecal–oral path way of water borned is ease transmission. These include contamination of drinking water catchments (e.g. by human or animal faces), water with in the distribution system (e.g...Through leaky pipes or outdated infrastructure) of stored house hold water as result of unhygienic handling. Millions of people are exposed to unsafe levels of chemical contaminants in their drinking water.This may be due to a lack of proper management of urban and industrial waste water or agricultural run-off water potentially giving rise to long-term exposure to pollutants, which can have arranged of serious health implications.

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

The existing drinking water system of the Adama town was designed from Awash River, which was located at down stream of the Koka Dam and neighbor towns like Addis Ababa, Mojo and Sebeta towns sewerage and Industries wastage with Agricultural application of chemical fertilizer discharge to Awash, by tributaries’ of Awash river. It is critical to identify whether the water obtained from the river, along its various stages until it reaches the consumers, is safe with regard to water quality parameters. Therefore, this study efforts to assess the drinking water quality from the main existing drinking water system of Adama town in terms of water quality parameters such as physico - chemical, bacteriological and pollution loads at the source. The final results of this study is useful to address the main cause of public health problems related to declined quality of drinking water, and to point out the way to produce safe water for the population of the town.

1.2. Statements of the problems

Potable Water quality safe and the risk of water borne diseases are serious problem of puplic health concerns of Ethiopia. Therefore, Adama town is one of the town, which mainly suffering from water borne diseases especially in diarrhea, coliforms, E.coli micro-organisms and Chemical contamination due to poor and inadequacy of drinking water quality. This is mainly due to lack proper study and consequent monitoring of water quality parameters for most of the towns in Ethiopia. The population of Adama town obtains their drinking water from a river source, which is located on the downstream of Addis Ababa and Mojo town. Earlier there is no research activity conducted on the Water quality and water supply system of Adama that may any one enable to know the quality of drinking water and the effectiveness of the water supply network systems. The health sector of the town regularly reports that water associated diseases are one of the top-ten diseases, and there are certain indicators that the population of the town is suffering from water-associated diseases, very probably due to poor drinking water quality. Contributions to improve the quality of drinking-water provide significant benefits to health. Adama town potential health consequences of microbial contamination were such that its control must always be of supreme importance and must never be compromised.

The large transmission and distribution lines may have problem on changes of pressure in the distribution system. Intended for the reason that the increase in water age is dependent on the difference large distance between the production and consumption rates, and high residence time in pipes and storage duration in water tanks are cause of icreasing waterage.This is the big problem of Water quality. All diseases from drinking water borne commonly occur in Adama Town affects normal lives or productivity situation of the people by way of absenteeism from normal working time, reduced labor productivity even when present at work (production, learning, teaching and other office works, etc.) besides imposing heavy medication expenses.According to Water bore diseases recorded for past six years (2010-2015) the data from Adama Town health Office the infected poeple were 176,727 in six years. So, the Water boren diseases and Water related diseases are big problems of Adama Water quality.

1.3. Research Questions

The principal research questionary that were tried to be addressed are:

1. Are the potable water quality parameters of Adama Town appropriate with the guide lines set by WHO standard and that of Ethiopian recommended guidelines?

2. Do the potable water quality of the AdamaTown, articulated in terms of potable water quality parameters, is in the WHO guidelines and the Ethiopian recommended maximum

and minimum permissible limits, what will be the health implication of the water on the health of the users?

3. What is the variation of pressure change on residual chlorine concentration in the water supply transimission mains and gravity distribution system of Water supply?

1.4. Objectives

1.4.1. General objectives

The general objective of this assessment of water quality is try to find ways to improve the drinking water quality and generating safe drinking water for the Adama Town through studying the quantitative and qualitative measures of water quality parameters referencing to the WHO guidelines and Ethiopian recommended guideline values. Although, the assessments of water quality is focus on the major components of water quality parameters such as phsico-chemical and Bacterological analysis.

1.4.2. Specific objectives

To fulfill the above general objective the following specific objectives are used:

- To assess the acceptable safety of drinking water quality using different characteristics unit process such as (physical, chemical and bacteriological) through laboratorial experiment.
- To analyze the results of the investigation comparing with World Health Organization and Ethiopian guide lines of drinking water quality standard.
- To assess the occurrence of water associated diseases in the Adama Town.
- To assess the relationship of effects of pressure variation on water quality (residual chlorine concentration) in transimission main lines and gravity distribution system at different pressure nodes of network pipes systems.

1.5. Scope of the Study

This study specifically focused on assessment of factor affects potable water Quality of water supply schemes. The study area was limited to Adama Town Water Supply scheme. May be the problem of enough budgets, logistics were some of the main challenges/ limitations for the study work. The assessmentofWater quality in water supply scheme was a multi-dimensional and dynamic concept which is the result of interactions of various factors (physical, chemical and bacteriological, etc). Rather, attention has been given to identifying major factors water quality deterioration and residual chlorine concentration of the water supply scheme. The result and findings of the modeling by using Epanet software were the reflections of the study area. However, it might reflect problems in other areas of Water Supply scheme with similar characteristics.The major significance of this study was to allow planners, decision makers and any concerned persons to know the current situations of the Water quality conditions of the Adama Town Water Supply system.

1.6. Thesis origanization

The thesis is organized into the following six chapters.

Chapter-1: Consists of the back ground of the importance drinking water quality parameters tests and health significance of water-associated diseases, statements of the problem, research questionaries, objective, general objective, specific objectives, and scope.

Chapter-2: Consists of literature review and conceptual frame of drinking water quality assessment, main importance of drinking water quality parameters regards to physico - chemicals, and bacteriological tests and analysis with in maximum permissible limits regards to World Health Organization and Ethiopia guidelines, and significance on the human health, as well as the review of the assessment effect on water quality.

Chapter-3: Consists of Methodology and Materials used description of the study area in detailed and samples location points of study area were explained.

Chapter-4: Consists of the result and discussion of the thesis in detailed.

Chapter-5: Consists of the conclusion and recommendation of the thesis.

Chapter-6: Consists of Reference materials and Appendix (The evidence ofdifference pressures withfree residual chlorines)

2. CHAPTER-2

2. Literature review

2.1. General

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

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

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

- Those spread through drinking water (water borne diseases, such as typhoid, cholera, gastroenteritis etc.)

- Those transferred through aquatic vectors (water based diseases, such as schistosomiasis)
- Those spread by insects that depend on water (water related diseases, such as malaria and yellow fever)
- Those diseases produced by the lack of adequate water for personal hygiene (water washed diseases, such as scabies and trachoma.

Based on the morbidity records, there is still a high incidence of communicable diseases which most of the time is related to water supply conditions in the country among which about 60% of the top ten diseases are relate to poor quality and scarcity of house hold water consumption (UNICEF, 2008).

2.2. Water quality modeling

2.2.1. Water quality modeling

Water quality models can be used to address a number of needs for utility that are primarily associated with disinfection levels, bacteria elimination, and by-product growth. Water quality modeling can assist with (Lansey and Boulos 2005); Formulating sampling plans to meetcompliance standards Locating measurement devices for on-line (real-time) and compliance water quality monitoring Understanding the impact of tank storage on system quality Providing an understanding of system response to operational changes selected to reduce energy consumption or improve water quality Locating booster disinfection stations and determining their operationsEstimating water age as a surrogate water quality when disinfectant decay parameters are not available.

Identifying and controlling of accidental/planned contaminations from backflow events and determining mixing levels in multi-source systems tracking of conservative substances such as fluorideformulating a flushing plan for a post-contaminant event. The maintenance of residual disinfectant in the water distribution systems is key criteria to assess the portability of water in the systems.Chlorine is the most popular water treatment disinfectant in municipal water distribution system. Chlorine is an oxidizing agent and it decays with time. Therefore, a minimum level of chlorine residual must be maintained in the distribution system to preserve both chemical and microbial quality of treated water (Vasconcelos et al. 1997, Munavalli and Mohan Kumar 2003). While chlorine travels through the distribution system, it reacts with different materials inside the pipe. Reactions are impacted by the surrounding conditions due to the availability of reacting substances. Reactants are present in the bulk water and may also occur at high concentrations on the surface of the pipe. Bulk reactions predominate in relatively less turbulent water. On the other hand, wall or surface reactions predominate in turbulent flows. Water quality transport mainly occurs by advective transport in which the constituent (chlorine) moves with water in the direction of flow with the magnitude of the main velocity component. In other words, advection transport is the carrying of constituent (chlorine) along with the flow of water (Lansey and Boulos 2005). Thus, in addition to direct reaction parameters i.e., bulk reaction coefficient and wall reaction coefficient hydraulic parameters i.e., pipe diameter and roughness, and flow play important roles in determining the chlorine concentrations at all junction nodes in the systems.

The purpose of this study is to predict the level of chlorine residual in a drinking water distribution system and to help operators to determine chlorine dose in drinking water treatment plant (WTP) using by softwares. Water quality modeling is conducted by chlorine bulk decay from bottle tests. A chlorine decay test for the finished Water of the Water Treatment Plant is to be performed on a monthly basis. As the result, a simple equation for the target chlorine concentration in the finished water is to be derived by a multiple regression analysis method in relation to initial chlorine concentrations (C_o), temperatures Temp (^{o}c), total organic carbon (TOC) and chlorine decay coefficients (K_b).

The chlorine concentration after it leaves a Water Treatment Plant, before entering its distribution networks, is critical in maintaining chlorine residual levels throughout the system. It is apparent that the chlorine concentration of the finished water be maintained to be flexible to keep it at over 0.2 mg/l throughout the system because chlorine consumption is different depending on the season, flow and pipe networks. These chlorine values of the finished water are the target chlorine concentrations for determining the chlorine dosage to the filtered water in aWater Treatment Plant.

2.2.2. Water Quality Modeling Capabilities

In addition to hydraulic modeling, Epanet provides the following water quality modeling capabilities: models the movement of a non-reactive tracer material through the network over time models the movement and fate of are active material as it grows (e.g.,a disinfection by-product) or decays (e.g., chlorine residual) with time models the age of water throughout a network tracks the percent of flow from a given node reaching all other nodes over time models reactions both in the bulk flow and at the pipe wall uses n-th order kinetics to model reactions in the bulk flow uses zero or first order kinetics to model reactions at the pipe wall accounts for mass transfer limitations when modeling pipe wall reactions allows growth or decay reactions to proceed up to a limiting concentration employs global reaction rate coefficients that can be modified on a pipe-by-pipe basis allows wall reaction rate coefficients to be correlated to pipe roughness allows for time-varying concentration or mass inputs at any location in the network models storage tanks as being either complete mix,plug flow,or two-compartment reactors. By employing these features, Epanet can study such water quality phenomena as: blending water from different sources age of water throughout a system loss of chlorine residuals growth of disinfection by-products tracking contaminant propagation events.

2.2.3. Application of the model out put

The work discussed so far has led to the construction of a computer model designed to serve as a tool for analysis and improvement of the drinking water supply system in Adama town. The following sentence gives a brief overview of the system and evaluates the success of this model in predicting different parameters associated with the water supply. It then provides an analysis of potential improvements of the system. EPANET computer program can show pressures, demand, and water quality at different nodes as well as flows, velocities and head loss in pipes throughout the distribution period. Out puts can be exported to tables and graphics or visualized on the graphical interface. The flow is coming in the opposite direction but a valve blocks it from entering the pipes supplied by the Adama Koka treatment plant. Many other analysis tools are available in Epanet, such as drawing contour plots of the region based on a parameter of choice, or time series plots of specific nodes. This study will deliver very fast and least cost technology of predicting a safely and quality water supply system development and for data collection, like coordination (x,y) and elevation GPS needed for most civil engineering works.

2.3. Bacteriological limits of drinking water quality

2.3.1. Bacteriological limits of drinking water quality

The completely coliforms and Ecoli micro-organismsgroup could be seat as the primary indicator bacteriafor the presence of disease causing organisms in drinking water. It is aprimary indicator of suitability of water for consumption. If large numbers of coliforms could be found in water, there is a high probability that other pathogenic bacteria or organisms exist. The World Health Organization and Ethiopian drinking water guide lines require the absence of total coliform and Ecoli micro-organisms group in public drinking water supplies. The frequency of testing for public water supplies depends on the size of the population served. The diseases caused by water related microorganisms were divided into four main classes: Water borne diseases: caused by water that to be contaminated by human, animal or chemical wastes. Examples include cholera, typhoid, meningitis, dysentery, hepatitis and diarrhea. Ahost of bacterial, viral, causes diarrhea and parasitic organisms most of which can be spread by contaminated water (WHO, 2006). Poor nutrition resulting from frequent attacks of diarrhea is the primary cause for little growth formillions of children in the developing world (Meseret Belachew Addisie, 2012). Water-related vectordiseases: diseases that transmitted by vectors, such as mosquitoes that breed or live near water.Examples include malaria, yellow fever, dengue fever and filaria. Malaria causes over 1 million deaths a year alone (WHO, 2006). Stagnant and poorly managed waters provide the breeding grounds for malaria- carrying mosquitoes.Water-based diseases: Parasitic aquaticorganisms referred to helminths cause that and to be transmitted viask inpenetration or contact. Examples include Guinea worm disease, filaria, paragonimia, clonorchiasis and schistosomiasis. Water-scarce diseases: These diseases flourish in conditions where freshwater is scarce and sanitation is poor. Examples include trachoma and tuberculosis.

2.4. Water quality analysis

Previously determining on the sources of surface or groundwater, it is important to comportment water quality tests through representative samples. These tests preferably should be performing on site and through samples taken to the laboratory for definitive analysis (WHO Edition 4^{th}, 2004).

2.4.1. Aspects parameters of drinking water quality

Water quality parameters are classified in to three parts such as physical, chemical, and biological characteristics of water in association to the set of standards. These parameters directly connected to the safety of the drinking water to human use. Water quality parameters deliver important information about the fitness of a water body. These limits are used to find out the quality of water for drinking purpose (D.Gupta& J. Saharan, 2009). Attractive limits are those obvious by the senses, namely turbidity, color, taste, and odor. They are important in monitoring public water supplies because they may cause the water supply to be disallowed and alternative (possibly poorer-quality) sources to be adopted, and they are simple and cheap to monitor qualitatively in the field.

2.4.2. Physical characteristics of drinking water quality

Physical characteristics of drinking water quality mainly classified as; residual chlorine, temperature, color, odor, taste, turbidity, PH, electrical conductivity, and total dissolved solids and regards to examination of quality test categorized in to physiochemical andaesthetical parameters (De Zuane J., 1996).

2.5. Physico-chemical examination

2.5.1. Residual chlorine

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

2.5.2. P^H and Alkalinity of pure water

The pH of pure water refers to states of acidity and alkalinity of solutions with respect to hydrogen and hydroxide ions can be expressed by a series of positive numbers between 0 to14. In general, water with a pH of 7 is considered neutral while lesser than this referred acidic and a pH larger than 7 known as basic. Normally, water pH ranges from 6 to 8.5. It is noticed that water with low pH tends to be toxic and with high degree of pH, it is turned into bitter taste. According to the WHO standards, pH of water should be 6.5 to 8.5 It is significant to measure pH at the similar time as chlorine residual since the effectiveness of disinfection with chlorine is extremely pH dependent: In water, a small number of water (H_2O) molecules dissociate and form hydrogen (H^+) and hydroxyl (OH^-) ions. If the relative proportion of the hydrogen ions is greater than the hydroxyl ions, then the water is defined as being acidic. If the hydroxyl ions dominate, then the water is defined as being alkaline. The relative proportion of hydrogen and hydroxyl ions is measured on a negative logarithmic scale from 1 (acidic) to 14 (alkaline)7 being neutral :where the pH exceeds 8.0, disinfection is less effective. To check that the pH is in the optimal range for disinfection with chlorine (less than 8.0), simple tests may be conducted in the field using comparators such as that used for chlorine residual. With some chlorine comparators, it is possible to measure pH and chlorine residual simultaneously (USEPA, 1997; Friedl et al., 2004).

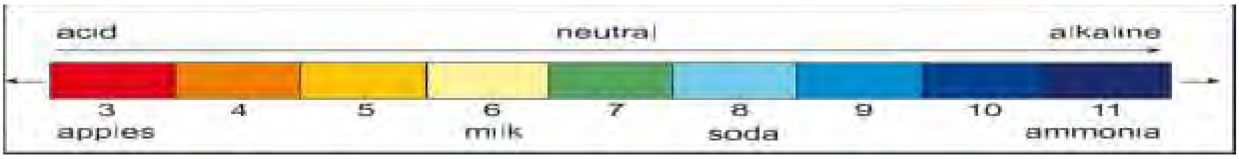


Figure2-1: pH scale bar

2.5.3. Electrical conductivity (EC)

Used to measure the ability of aqueous solution to carry an electric current such as; concentration of ions, mobility, valence and temperature clean water is not a good electrode of electric current rather a good heat proofing and increase in ions concentration improves the electrical conductivity of water. In general, the amount of dissolved solids in water concludes that the electrical conductivity. Electrical conductivity (EC) is really measures the ionic process of a solution that allows it to transmit current. Therefore, according to WHO standards EC value of drinking water quality should not exceeded 400 μS/cm and the conductivity of potable waters varies generally from 50 to1500 μ mhos/cm (Gaur, 2008).

2.5.4. Turbidity

Turbidity is a measure of the degree of cloudiness or muddiness of water. It is an expression for an optical property that causes light to be scattered and absorbed. It is not possible to correlate turbidity with the weight concentration of suspended matter because light scattering properties of the suspended particulate matter depends upon size, shape and refractive index of the particulates. It is caused by suspended matter such as clay, silts, finely divided organic and inorganic matter, soluble colored organic compounds, plankton, and other microscopic organisms.Turbidity is important because it touches both the acceptability of water to consumers, and the selection and competence of treatment processes, particularly the efficiency of disinfection with chlorine since it uses a chlorine demand, defends microorganisms, and may stimulate the growth of bacteria.In all procedures in which disinfection is used, the turbidity must always be low preferably lower than 1 NTU. It is recommended that, for water to be disinfected, the turbidity should be reliably less than 5 NTU (John C.et al, 2012) and preferably have a median value of less than1 NTU (Nephelometric Turbidity Unity).

2.6.5. Color

Color is due to the presence of colored substances in solution, such as vegetable matter and iron salt. It does not necessarily have detrimental effects on health. Color intensity could bemeasured through visual comparison of the sample to distilled water. Colored water is not acceptable for drinking (Aesthetic as well as toxicity reasons). Therefore, Drinking water should be colorless.Intended for the purposes of investigation of public water supplies; it is useful simply to note the presence or lack of observable color at the time of sampling. Changes in the color of water and the appearance of new colors serve as indicators that additional investigation is needed (WHO Edition4th, 2004).

2.5.6. Odor and tastes

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

2.6. Chemical aspects of drinking water quality parameters

Chemical impurity of drinking water supply sources may be causes due to natural sources such as; certain industries and agricultural exercises. While toxic chemicals are present in drinking water, there is the risk that they may cause either acute or chronic health effects. Chronic health effects are more common than acute effects because the levels of chemicals in drinking water are rarely high enough to cause acute health effects (Benignos, 2012).The major chemical or inorganic parameters of drinking water quality mainly categorized as: hardness, calcium, magnesium, chloride, sulphate, fluoride, alkalinity, nitrate, nitrite, phosphate and some toxic metals such as; copper, chromium (cr^{+6}), Iron, Manganese, etc.

2.6.1. Hardness

Hardness of drinking water is due firstly to calcium and magnesium carbonates and bicarbonates (which can be removed by boiling) and calcium and magnesium sulfate and chloride (which can be removed by chemical precipitation using lime and sodium carbonate).Hard water is mainly described with high mineral contents that are usually not dangerous for humans. It is frequently measured as calcium carbonate (CaCO3) because it contains mainly calcium and carbonates which are the most dissolved ions in hard water. Public acceptability of the degree of hardness of water may be different considerably from one community to another. The taste threshold for the calcium ion is in the range of 100–300 mg/l and maximum permissible concentration for total hardness of 500mg/l as Caco3, According to World Health Organization (WHO, 2004) and according to National drinking water qualityrecommended for Ethiopia total hardness permissible limit is 300mg/l (Girmay et al, 2011).

2.6.2. Nitrate (NO3)

Nitrate is one of the extreme significant disease causing parameters of drinking water quality, particularly blue baby syndrome in babies and has been used as an indicator for the presence of organics. Nitrates can cause mathemoglobinemia at greater than 100 mg/l where a baby cannot take breaths enough oxygen (Roberts, 2006). The sources of nitrate are nitrogen cycle, industrial waste, nitrogenous fertilizers etc. The WHO guide lines maximum permissible values of nitrate in drinking water is 50 mg/l as NO3 for nitrate and 3mg/l as NO2 for nitrite (Alan et al., 2000).

2.6.3. Phosphate

Phosphates in surface waters mostly originated from sewage effluents, which contains phosphate, based synthetic detergents, from industrial effluents, or from land runoff where inorganic fertilizers have been used in farming. Ground water usually contains insignificant concentrations of phosphates, unless they have become polluted. Phosphorous one of the crucial nutrients for algal growth and can contribute significantly to eutrophication of lakes and reservoirs (Alan et al., 2000).

2.6.4. Sulphate (SO4-)

Sulphate comes from several sources such as the dissolution of gypsum and other mineral deposits containing sulphates from seawater intrusion, from the oxidation of sulphides, sulphites, and thiosulphates in well-aerated surface waters and from industrial effluents where sulphates or sulpheric acids have been used in process such as tanning and pulp paper manufacturing.High levels of sulphate in drinking water supply can impart taste and, when combined with magnesium or sodium, can have a laxative effect (e.g. Epsom salts). Sulfate concentration in natural water varieties from a few to a several hundred mg per liter but no major negative impact of sulfate on human health is reported so far. According to the WHO (2004) guide line maximum permissible limit values recognized 250 mg/l SO_4 based on taste and corrosionPotential.

2.6.5. Chloride (Cl)

Sometimes special significance is given to the chloride contents of water, particularly sodium chloride and is mainly obtained from the dissolution of salts of hydrochloric acid as table salt (NaCl), NaCO2 and sources of chlorides are mainly from road salts, wastewater, storm sewers and animal feed etc (Terence, 1979). Surface water bodies often have low concentration of Cl and are a home of main physiological processes. High chloride concentration demolition metallic pipes and structure as well as harms growing plants. Permitting to WHO guideline maximum permissible limitvalues of the concentration of chlorideshould not exceed 250 mg/l.

2.6.6. Iron and manganese

Groundwater usually contains more of these two minerals than surface water. Iron and manganese are irritants that should be avoided if in excess of 0.3 mg/l and 0.1 mg/l correspondingly. They stain clothing and plumbing fixtures, and the growth of iron bacteria causes strainers, screens to clog, and metallic conduits to corrosion. The appearance of a reddish brown or black precipitate in a water sample after shaking indicates, respectively, the presence of iron or manganese (Alan et al., 2000).

2.6.7. Calcium

Calcium is the greatest significant and abundant in the human body and sufficient consumption is essential for normal growth and health. Around 95 percent calcium in human body stockpiled in bones and teeth. The high deficiency of calcium in humans may cause of; rickets, poor blood clotting, bones fracture etc. The maximum daily requirement is of the order of 1 - 2 grams and come from mostly dairy products. There is certain evidence to indication that the incidence of heart disease is reduced in areas served by a public water supply with a high degree of hardness, the primary component of which is calcium, so that the presence of the element in a drinking water supply is advantageous to health (Environmental Protection Agency, 2001). According to WHO (1996), its mamixmum permissible limit rangein drinking water is up to 75 mg/l.

2.6.8. Magnesium (Mg)

Magnesium is plentiful and a major nutritional requirement for humans (0.3-0.5 g/day). It is the second major component of hardness and it generally comprises 15-20 per cent of the total hardness expressed as $CaCO_3$ (Environmental Protection Agency, 2001). Human body contains about 25g of magnesium (60% in bones and 40% in muscles and tissues). According to the WHO standards, the allowable range of magnesium in water should be 150 mg/l (Muhammad et al., 2013).

2.6.9. Total dissolved solids (TDS)

Water has the aptitude to dissolve an extensive variety of inorganic and some organic mineral deposits or salts such as potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulfates etc. These mineral deposits formed undesirable taste and diluted color in appearance of water. The palatability of water with a total dissolved solids (TDS) level of less than about 600 mg/l is generally considered to be good; drinkingwaterbecomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/l. The presence of high levels of TDS may also be objectionable to consumers, owing to excessive scaling in water pipes, heaters, boilers and household appliances; (WHO Edition 4^{th}, 2004).

2.6.10. Toxic substances

A quantity of toxic chemical substances, if present in appreciable concentration in drinking water, may create a danger to health. These toxic substances include copper, hexavalent Chromium, lead etc.

2.6.11. Dissolved Oxygen (DO)

Oxygen is considered poorly soluble in water. The aforementioned solubility is related to pressure and temperature. In water supply technology, dissolved oxygen in raw water is considered as the necessary element to support life of fish and other aquatic organisms. It is also an indicator of water treatment process and is an important factor in corrosively. The DO content is evaluated in comparison to its maximum level of solubility for a given pressure and temperature, defined as saturation. Because saturation is obtained from the atmosphere, oxygen is only a portion of the dissolved gases; but fortunately, its content in water is approximately 38% of the dissolved gases that is twice its percentage in air. Therefore, in fresh water, dissolved oxygen reaches 14.6mg/l at 0^0C and approximately 9.1, 8.3, and 7mg/l, respectively at 20^0C, 25^0C, and 35^0C at 1atm of pressure. It must be noted that the popularity and frequency of the DO testing in sanitary Engineering, and even more the BOD (Biochemical Oxygen Demand) and the COD (Chemical Oxygen Demand) are due to the necessity of evaluating particularly wastewater and industrial waste biological processes, stream aeration, and pollution load in water pollution control surveys and programs. However, less importance is given by the sanitary engineer to these tests when water supply is involved with the exception of stream analysis. There is no WHO guidance level for DO standards were ever issued by the Health Authority, mainly due to the lack of toxicity. Moreover, the low concentration and the continuous variation in concentration (change in pressure and temperature) make the dissolved oxygen a parameter of limited importance from a health viewpoint, but its effect on corrosion has practical piping life and psychological results for consumers due to discolored water and taste problems (De Zuane, 1996).

2.7. Standard of Drinking Water Quality guide fulfillment criteria

2.7.1. Physical requirements

The drinking water shall be fairly clear (i.e., of low turbidity and color) and contain no compounds that cause offensive taste and odor and free of substances and organisms that cause corrosion or encrustation of water supply system as presented in Table.2-1 below.

Table2-1: Physical characteristics of drinking water quality

Characteristics	Maximum permissible level	Test method
Odor*	Unobjectionable	ES605
Taste	Unobjectionable	
Turbidity,NTU	5	ESISO 7027
Color ,TCU	15	ESISO 7887

(Sources: National DrinkingWaterQualitymonitoringandsurveillance strategies, 2011)

2.7.2. Chemical requirements

Characteristics that affect the delicious properties of drinking water quality shall be conforming to the level specified in Table 2-2.

Table2-2: Chemical requirements

Substances or characteristics	Maximum permissible level	Test method
Total hardness (as caco3)mg/l,max	300	ES 607
Total dissolved solids mg/l,max	1000	ES 609
Total iron (as Fe) mg/l,max	0.3	ESISO 6332
Manganese(as Mn) mg/l,max	0.5	ESISO 6333
Ammonia (NH_3+NH_4^+) mg/l,max	1.5	ESISO 7150-2
Residual freechlorinemg/l, max	0.5	ESISO 7393
Anionic surfactants as mass concentration ofMBASmg/l,max	1	ESISO 7875-1
Magnesium(as Mg) mg/l,max	50	ESISO 7980
Calcium (as Ca) mg/l,max	75	ESISO 7980
Copper (as Cu)mg/l,max	2	ESISO 8288
Zinc(asZn)mg/l, max	5	ESISO 8288
Sulfate (as So4) mg/l,max	250	ESISO 9280
Chloride (as Cl) mg/l,max	250	ESISO 9297
Total alkalinity(as Caco3)	200	ESISO 9963-1
Sodium(as Caco3) mg/l,max	200	ESISO 9964-1
Potassium(as K),mg/l,max	1.5	ESISO 9964-2
P^H value ,units	6.5 to 8.5	ESISO 10523
Aluminum (as Al) mg/l,max	0.2	ESISO 12020

Sources: National DrinkingWaterQualitymonitoring and surveillance strategies, 2011

2.7.3. Bacteriological requirements

When tasted with the corresponding test methods, the bacteriological requirement so treated drinking water shall not exceed the levels shown in the following table.

Table2-3: Maximum permissible bacteriological level

Organism	Maximumpermissiblelevel	Test method
Total viableorganisms ,colonies per100ml	Must not detectable	ESISO 4833
Fecal streptococci per100ml	Must not detectable	ESISO7899-1 ESISO7899-2

Coliformorganisms,number per 100ml	Mustnot detectable	ESISO 9308-1
E. coli, number per 100ml	Must not detectable	ESISO 9308-1 ESISO 9308-2

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

2.7.4. Bacteriological analyses of drinking water quality

Potable water practitioners are concerned with water supply and water purification through a treatment process. In treating water, the primary concern, of studyis producing potable water that is safe to drink (free of pathogens) and has no accompanying unpleasant characteristics, such as a vulgar taste or odor. To achieve this, the drinking water practitioner must possess a wide range of knowledge. In short, to correctly examine raw water for pathogenic micro organisms and to determine the type of treatment necessary to ensure that, the quality of the product potable water meets regulatory standards. Absolutely the most serious public health risk associated with drinking water supplies is microbial contamination. Pathogens; bacteria, viruses and parasites, then can cause a wide range of health problems when consumed in drinking water, but the primary concern is infectious diarrhea disease transmitted by the faecal-oral route. It is unpractical to analyze water for every individual pathogen, some of which can cause disease at very low doses. As an alternative, since most diarrhea causing pathogens are faecal in origin, it is more practical to analyze water for indicator species that are also present in faecal matter. The most commonly used indicator species are coliform bacteria, which include a wide range of bacteria, all of which can ferment lactose and produce gasat 37°C. Many but no total coliforms are faecal in origin, so the presence of total coliforms in water is not a good indicator of poor water quality.

Coliforms that come from faecal matter can tolerate higher temperatures than most environmental coliforms, so those that ferment lactose and produce gasat 44°C are called thermo tolerant coliforms, or faecal coliforms. These are more closely associated with faecal pollution than total coliforms. The most specific indicator of faecal contamination is Escherichiacoli (E.coli), which unlike some faecal coliforms never multiplies in the aquatic environment (UNICF, 2008). When evaluating faecal contamination, it is suggested to measure turbidity along with E.coli (or faecal coliforms), since pathogenscanads or bontosuspended particles, and to some extent be shielded from disinfection. When water has been disinfected, it is also important to measure chlorine residual and pH.These four parameters (E.coli/faecal coliforms, turbidity, disinfectant residual chlorine and pH) are considered the minimum set of “essential parameters” required to assess micro-biological quality of drinking water (WHO, 2006). Therefore, bacteriological analysis mainly includes estimation of faecal coliform and total Coliforms.

2.7.5. Total coliforms

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

2.7.6. Faecal coliforms

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

Table2-4: Water quality counts per 100ml and the associated risk (Source: MichaelH. 2006)

No	Water quality counts per 100ml and the associated risk count per 100ml	Risk category
1	0	In conformity with WHO guide lines
2	1-10	Low risk
3	11-100	Intermediate risk
4	101-1000	High risk
5	>1000	Very high risk

2.8. Effects of pressure changes on water quality in distribution system

One of the parameter that could contribute to decrease water quality in distribution system is pressure change in water distrbution network. Numerous researchers have been carrying out about effects of pressure change in the water quality in distribution systems (published Online January 2013 (http://www.scirp.org/journal/eng)). Changes in pressure could cause leakage in distribution systems, and that changes in pressure could lead to a problem of drinking water quality. High residence time, high pressure and low pressure systems and distribution network will cause a decline in the water quality in the gravity distribution system. In drinking water distribution system high pressure could cause decay of water quality as it had been responsible for increase in the rate of bacteria growth. When high pressure changing the velocity could increase turbidity and corrosion in distribution systems; high pressure burst (breakage) pipe line and create high leakage on distribution system, then the bacteria and pollution are inter of the distribution system from outside. Also bacteria could growth with low pressure distribution system; because velocity is almost zero. Low pressure established water stagnate, less water distribution, and costumer complaint. The stagnate water highly growth bacteria and increase turbidity in the distribution network system. Therefore, high pressure and low pressure have bulk relationship.It is Declared that systems with high pressure will have problem of pipe break in the distribution system (Shamsaei .etal, 2013). Even so, in large distribution networks and systems, hydraulic changes are high, there is so much pressure along the gravity distribution lines and this might cause breaks or cracks in pipes even at the dead end areas of the system.

3. CHAPTER- 3

3. Methodology and Materials

3.1. Description of the Study area

It is the best way of expressing any location as it utilized both direction and latitude and longitude points. Accordingly Adama is located within grid references point that stretches between 8^0 35’00” to $8^0$36’00’’ North latitude and 39^0 11' 57" to 39^0 21' 15" East longitude. And 100km far away from Addis Ababa Capital City of Ethiopia. Adama is characterized by very flat and plain of low land rounded by a lot of mountainous. Thus, because of its topographic features Area of the town is deeply deselected by numerous valleys formed by the seasonal rivers crossing the town. These streams are irregular in nature. As regard to the proposed expansion, most of the areas are characterized by flat and undulated plains as well as mountain natural barriers.

The town is accessible by a good asphalt road from Addis Ababa, located on the main road leading to the eastern part of the country and the Republic of Djiboutiand currently the new Express Highway construction for more linkage with Addis Ababa is in progress. The Max.Ground elevations of the town vary from 1,595masl to 1,750masl with lowest level ranging from 1595masl to 1630masl with the highest point nearly outside the town. Areas with higher altitudes are found from the central to the northern and on the southern verges of the town. The area of the AdamaTown iscovering13, 300 hectares; based on the CSA census result (2007).Nowcurrently the total population of the town is about 351,000 in 2015 years.The demographic and population study of Adama master plan Revision project shows that the population of the Adama Town will continue to increase at a rate of 3.8% until the end of master plan period, 2020 yrs.

Figure 3-1: Geographical map and location of the Adama Town in Ethiopia

Figure2-2: Location Map of the Adama Town in Oromia regional state

3. 2. The history of Existing Adama Town Water Supply System

History of the Adama Water Supply began in 1942E.C with the water service given by the former Ethiopian Electric Light and Power Authority (EELPA) which started by drilling about 10 boreholes at the place called Melka Hidda in South-West of Adama Town, some 11 km on the road leading down to Wenji Sugar Factory. The yield of the Melka Hidda 10 boreholes (sources) was estimated to 2.0 – 7.7 l/s at the depth of min. 36 m and max.145 m. The Authority had therefore the responsibility of drilling water wells, installation and supply of electric power, and distribution of drinking water to customer until the month of January 25, 1983GC. After Water Supply and Sewerage Authority (WSSA) established in Ethiopia; then Adama water supply system was transferred to Water Supply and Sewerage Authority. Since establishment the town has constantly been involved in two problems: High Fluoride [F-] concentration 2.4 - 11.8 mg/l.There were high Water shortage in the Town.

In the causes of the above two problems; Melka Hidda's 10 boreholes were Fluoride concentration Analysed by the Central Regional Water Supply and Sewerage Authority Laboratory (WSSA) in 1990GC and on November 3/2002GC abandonedand the former water supply system that shifted from Melka Hidda Groundwater sources to the Awash River source. Being designed for 330 l/s the water treatment Plant system faced several shortcomings due to changes in the raw water characteristic as a result of ecologic and climatic changes on top of poor watershed management respective to the upstream side of the Awash River. As a result chemical applications have many times been researched and types of chemicals that fit with the changing characteristics have usually been selected and implemented in order to mitigate the usually appearing water shortage problems occurred due to high detention time required whereby reduction in quantity of production resulted.

3.3. Climate of the study Area

Climate is the average weather condition of atmosphere that was observed for a long period in a given area. "The climatic conditions of Adama are drying sub-humid with hot summers and cold winters. The Adama Town is belonging to hot and semi-desert climatic condition. There are two distinct seasons; wet season between July and September and the dry season starts from October to June. The healthful climate of Adama is dry and hot with sunny weather and blue sky stretches out over the city all year around. Seeing cloudless and clear sky all year round is common in Adama except in rainy season of the year.

3.4. Meteorological Data

Temperature is the degree of measurement of hotness and the coldness of an object. According to information gathered from metrological observation station of Adama, its annual average of temperature is 22.3^0c. Adama is one of the Towns that are located in the big Rift Valley of east Africa. Intense sunlight splashes and heats the surface of the earth for many months of the year. It characterized by high temperature of warm and sunny days and scorching sun all the year round that has debilitating effect. There are sunshine and cooling evenings through most of the year. The temperature can climb higher than30.8^{o}c in April and drop lower than 25.8 ^{o} c in July. The coolest months are July and August that overlapped with heavy rainfall. January is the hottest month in Adama. Adama gets high temperature throughout the year with minor seasonal variations and an ideal place for generating solar energy.

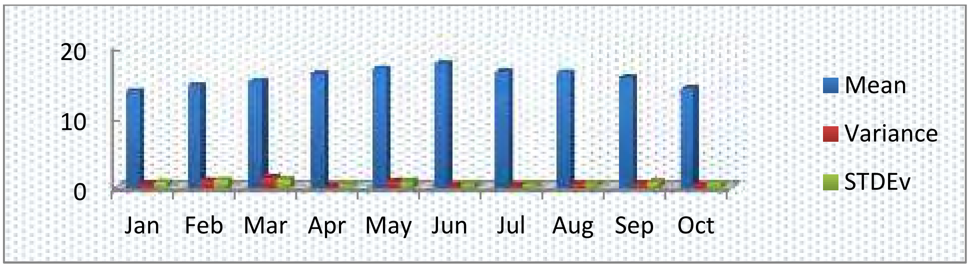


Figure3-3: Average Minimum temperature of Adama (2001-2011)

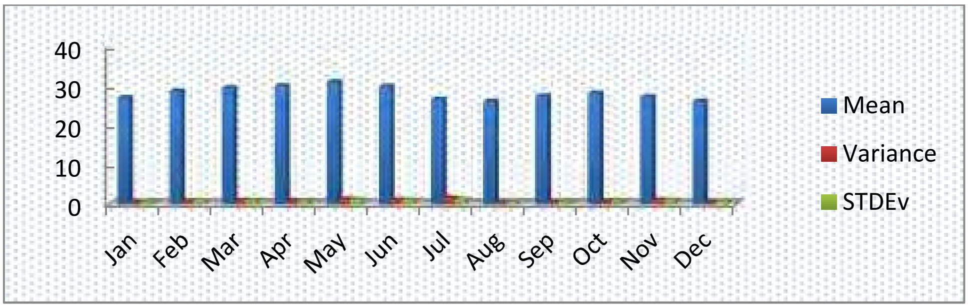


Figure3-4: Average Maximum temperature of Adama (2001-2011).

(Source:-Adama branch office of Ethiopian meteorological agency)

3.5. Rainfall

Precipitation (rainfall) means the deposit of water in either liquid or solid form and reaches the earth's surface from the atmosphere. The rainfall pattern of Adama has a bimodal nature. Rainfall is rare in Adama semi-desert nature of the city. Most precipitation falls from June through September. The short rain season extends from March to April and the major rainy season from July to mid-September. The three-month long seasons of rain sometimes, disrupt outdoor affairs of city residents. The largest amount of annual rainfall occurs during the three-month periods July through September followed by a dry season that may interrupt in

March by a short rainy season. The annual average of precipitation is 760 mm. Rainy season is the most exciting time to visit or dwelling the city due to good climate condition of the city raincoat and an umbrella are not badly wanted as many parts of the country except in rainy season. The rainfall creates critical deluge and flood risk in the city that causes much damage in the city every year.

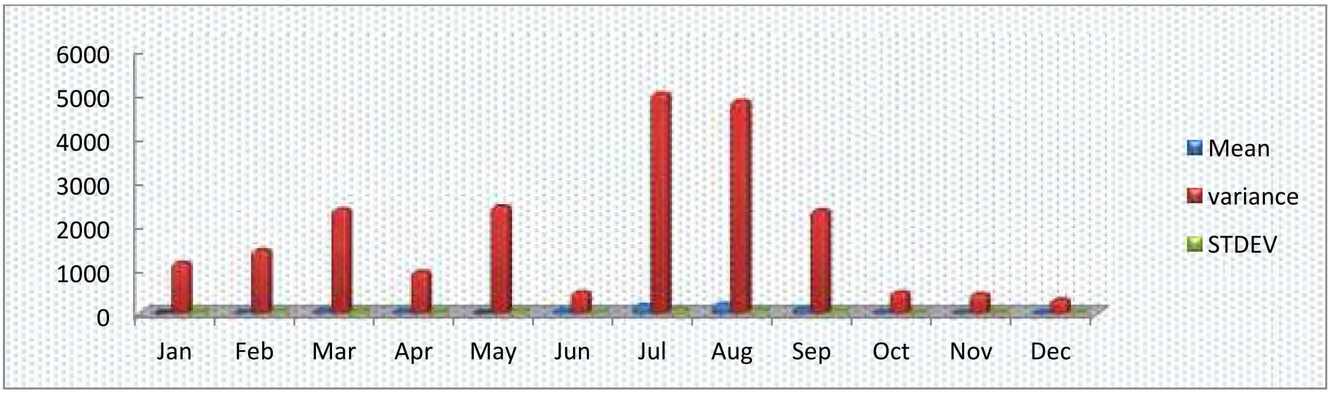


Figure3-5: The monthly total rain fall of Adama (in mm) (2001-2011)

(Source:-Adama branch office of Ethiopian meteorological agency)

3.6. Topographic and vegetation

AdamaTown is located in the East part of the north eastern plateau of the Ethiopia physic graphic subdivision. As can be seen the physio graphic map and observed during site visit, Adama and Its close surroundings are characterized by a rolling plateau land scape type which is the result of the geographical set up of the area and the action of erosion to the main source of drinking water quality of the town. Elevation varies between 1660 and 2140m at mountain peak South - West of Adama and the variation in elevation around the closer environs of the town is about 400m being about 1800m at the flat plateau and 2000-2140m at the peaks of the mountains around the town.

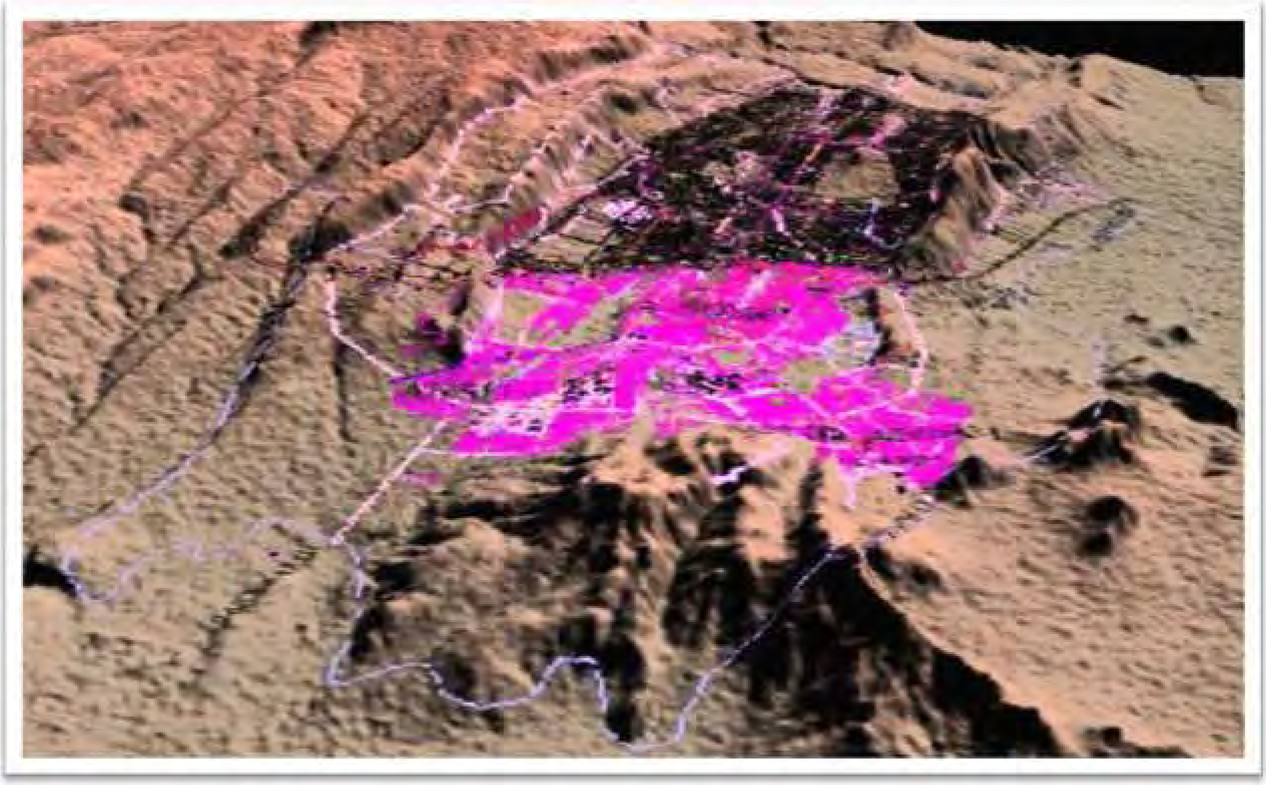


Figure3-6: Topographic and Vegetation Shape.

3.7. Topography

Topography of Adama varies from ground elevations of 1460masl to 1970 masl but currently areas within the elevation of above 1750m are used as storage and distribution reservoir site for the optimized clean water distribution systems. The southern central part of the town constitutes the lowest areas with ground elevation ranges from 1595masl to 1630masl. Areas with higher altitudes are found from the central to the northern and on the southern verges of the town. The altitude of these areas vary from 1630masl to 1750masl, and the western rocky mountain chains are elevated to as high as 1890 masl Adama is bounded by Rural villages namely, Kechema Ridge in the west, kurfagutu Peaks on the north, Dibbibisa and Migira Ridge in the east and Boku Ridge in the South.Generally elevation in the catchment ranges from 1972 masl around Kechema ridge to about 1588msl at the foot Migra Ridge. The slope also varies between less than 1% around Migra Plain to greater than 30% around Kechema ridge. The prevailing slopes of the town could be taken as 4%. The major land uses of the catchment include built up area, bare rock and cultivated land. Generally, it is characterized by very flat and plain of lowland surrounded by chain of Rocky Mountains.Thus, because of its topographic features; area of the town is deeply deselected by numerous valleys formed by the seasonal streams crossing the town. These streams are irregular in nature and can be sited as collectors and transporters of stormwater during the rainy seasons while dry at other times. As regard to the proposed expansion, most of the areas are characterized by flat and undulated plains as well as mountain natural barriers.

Figure3-7: Topography of the Adama town (Source: Adama Town administration Office)

3.8. Population size of the water supply of Adama Town

The population that is served by Adama water supply system with a projected total population of 220,212.Adama Town is one of the rapidly growing Towns in the region of Oromia as well as in the country since the period of 1964. Based on the 2007 Census conducted by the Central Statistical Agency of Ethiopia (CSA), this Town has a total population of 220,212, an increase of 72.25% over the population recorded in the 1994 census, of whom 108,872 are men and 111,340 women.

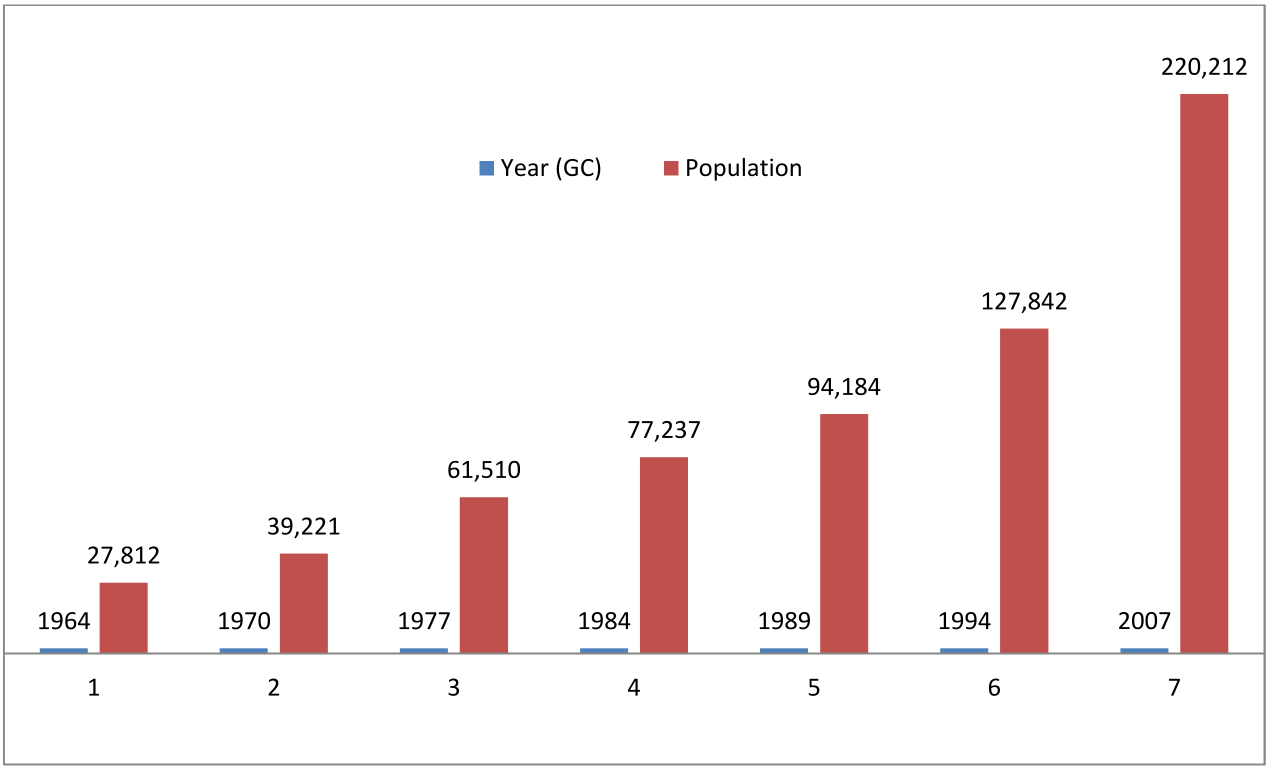


Figure3-8: Number of population in Adama town according to conducted sample surveys

(Source: CSA Adama Branch Office)

The crude population density (the ratio of total population to total area) is 62.27 people/ha. The Adama Town built-up areas cover 4640.66 ha. Assuming the standard house hold size 4.8 or approximately 5 the gross residential density will be 12.5 dwelling units/ha. Assuming residential areas account for 40% of this area the density would be 100 inhabitant/ha. The current total population in 2016 of the Town are 351,000.

3.9. Natural Hazards/constraints (Seismicity)

3.9.1. Seismicity

Since the town is located with in the Ethiopian Rift Valley Zone seismic hazard risk is high. According to the following seismic risk zoning map of Ethiopia, Adama falls within the zone that is characterized by earth quakes of intensity of 8 mm with probability of occurrence of 0.1 for 100 years return period. Earthquake can be predicted and controlled by long- term forecasting, paleo-seismology. (Study of prehistoric), and seismic gaps. Knowing this the design and construction of building should be given great attention in the town.

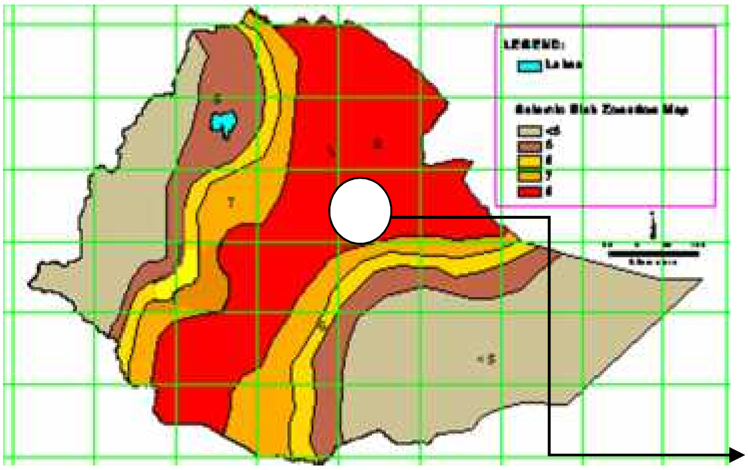


Figure3-9: Shows the seismic risk zone within the seismic risk zone of Ethiopia

(Source: Adama Town Administration Office)

3.10. Current Status of Adama Town Water Supply System

3.10.1. Water Supply System of Adama Town

The current water supply source of Adama town is Awash River with a Concrete River Side Box intakes tructure. The scheme was studied and designed from Awash River and in 2002years, the Town funding by Ethiopia Governmentand constructed by EthiopiaWater Work Construction Authority (EWWCA) 14years ago and the main components of systems are Concrete side box intake, Rapids and filter treatment plant, two Lugo Reservoirs capacity 2000m3 and 4000m3with153, 700m long Transimission main and Distribution pipe lines.

3.10.2. River Side Box intake and Raw Water Pumping Station

The raw water river side box intake is a type of Concrete River Side Box located at the left bank side of Awash River. The design capacity of the river side box intake is 330/s for phase I and 550 l/s for phase II.The intake consists of four openings through which water are conveyed to the raw water pumping station as shown in lower figure11. The water is then lifted from this row waterpumping station to the treatment plant located at 200m with eight submersible pumps. The maximum and minimum water levels are set at 1,538 masl and 1,536 masl respectively.

Figure3-10: Adama Water Supply Concrete River Side Box intake and row Water Pumping Station

3.10.3. Adama Water Supply treatment plant compound

Figure3-11: Adama Water Supply Koka Treatment plant

3.10.3.1. Inlet to Treatment Plant and rapid mixing the flow then enters the first mixing chamber where soda ash is dosed

Figure3-12: Raw Water Inlet to treatment plant and rapid mixing

Figure3-13: USB Rapid Sand clarifiers

The second chamber is a flash mixing chamber where Aluminum Sulphate is dosed. The flash mixer is fitted on this chamber by hot dip galvanized supports. The mixer is rated 7.5 KW and absorbs approximately 75% of motor power.The inlet to treatment Plant comprises of an Ultrasonic Flow Meter which is the latest measuring device, however it is not working at present.

3.10.3.2. Chlorination systems

The chlorination systems at Treatment plant have two methods:

- The pre-chlorination dosing in to inlet raw Water before clarifier.
- The post-chlorination dosing in to clear water after clarifier.

The raw water direct pumped from side box intake, drain into the rapid sand filter unit after chemicals dosing. The treated water from the rapid sand filter after post-chlorination dosing leads to Lugo Reservoirs. After post-chlorination for disinfection, water pumped to service reservoir supplying to consumers 11km length ways.

Figure3-14: Mixing and dosing systems of chlorination to Treatment plant (USB Rapid Sand clarifiers)

3.10.3.3. Major Problems of Treatment plant System

1. Damages of chemical dosing electro mechanical components are being started due to design life phase out, since these components are expected to serve a maximum of ten years. Replacement of these components is a must to the soonest possible.
2. The chemicals dosing system has been designed for dosing 3 types of chemicals such as:
   - Aluminum Sulfate for coagulation of impurities
   - Soda Ash for pH correction
   - Calcium Hypochlorite for disinfection

At present, the Water Supply is using additional coagulant aids such as **polyelectrolyte** due to the water quality changes in rainy season. In addition, the post chlorination system is not appropriate for safety chlorination. It is therefore required to review the chemical dosing system to solve the existing problems.

3. There are also many problems related with water quality management due to inappropriate and insufficient laboratory services at treatment plant as shown below.

- Lack of roof ceiling
- Lack of shelves
- Lack of furniture, like chairs, laboratory stools
- Lack of laboratory sink

Figure3-15: Inappropriate arrangements of laboratory service equepment

3.10.3.4. Current water supply demands and Supplys

Table3-1: Current water supply and demands

Label	Supply zone	demand (l/s)	Supply (l/s)	Coverage (%)
RLU-1765m	Lugo Reservoirs	410	285	69.52
Adama	Adama Town	337	234	69.44
RAU-1720m	Adama University	66	46	69.69
RGAG-1750m	Gelma Aba Gada	7	5	71.43

3.10.3.5. Future Expansion and Improvement Plan for Adama Town

As the development and population number of Adama is getting higher and higher, the Oromia Water, Mineral and Energy Bureau is also competing to keep step with supply of clean water to the existing and projected figures. At the moment rehabilitation of existing treatment plant is underway and expected output from the improved system (to complete in the end of 2016 year) is estimated to over 43,000 m^3/day. In addition the study and design for the 32 new boreholes system is also completed and budget is requested for further improvement. This new system will be in service until the year 2035 (Phase -II, see well field map below). It is predicted that this system will be in action in 2016/17 and may be able to deliver an estimated amount of 33,000m^3 of clean water per day. Thus the Town will be served by a total of 43,000 + 33,000= 76,000m^3/day of water supply which will be serving until the next phase takes over.

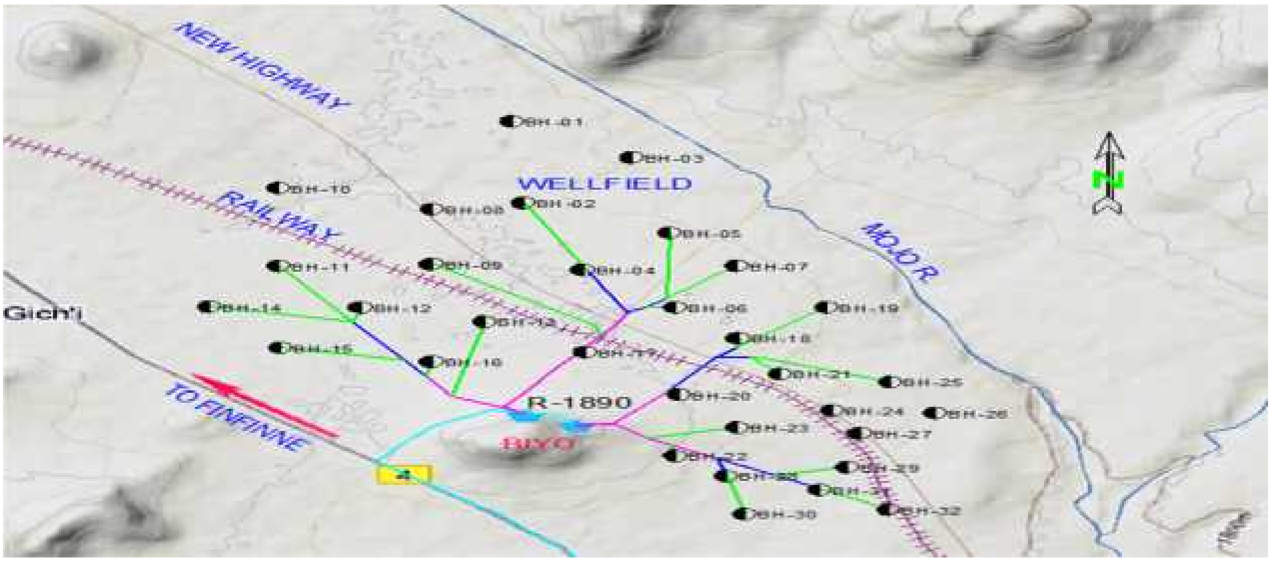


Figure 3-16: New Ground water Supply Systems designed for Adama (well field around Mojo area)

3.10.3.6. Health status of Adama Town

The Town administration has made tire some work in improving health infrastructure by expanding, equipping, furnishing, and managing health related facilities to improve the health care system in the Town. Health sector is another significant development to be mentioned being it has experienced a tremendous growth in the Town. At present, four hospitals, five health centers, 73 clinics, 70 pharmacies and 7 medicine and medical equipments distribution shops are found in the Adama Town to ensure sufficient service and equity in health. According to information gathered from Adama Town health office, the coverage health services of the Town is 70%. In respect to health professional distribution Adama has 50 medical doctors, 15 health officers, 170 nurses, 8 medical directors 96 health extension workers and other 196 supportive staffs those are giving medical services in different health institutes in the Town. Many drug shops and health facilities are plentifully found in the Town to balance the demand and supply for them. The distribution of drug centers not uniform and are concentrated mainly in the center of the Town. Out of 44 drug stores found in the Town 23 and 9 of them are found in Kebele14 and Kebele 06 respectively. According to officials of the health institutes in Adama Town, the major health problems are internal parasite, thiphod, and acute feverillness. These are the most common water borne, and water related diseases linked to poor water quality supply of the town.The high occurrence of these water-associated diseases of these is an indication of the status of drinking water supply and personal hygiene.

- The Ten Top diseases of Adaama Town

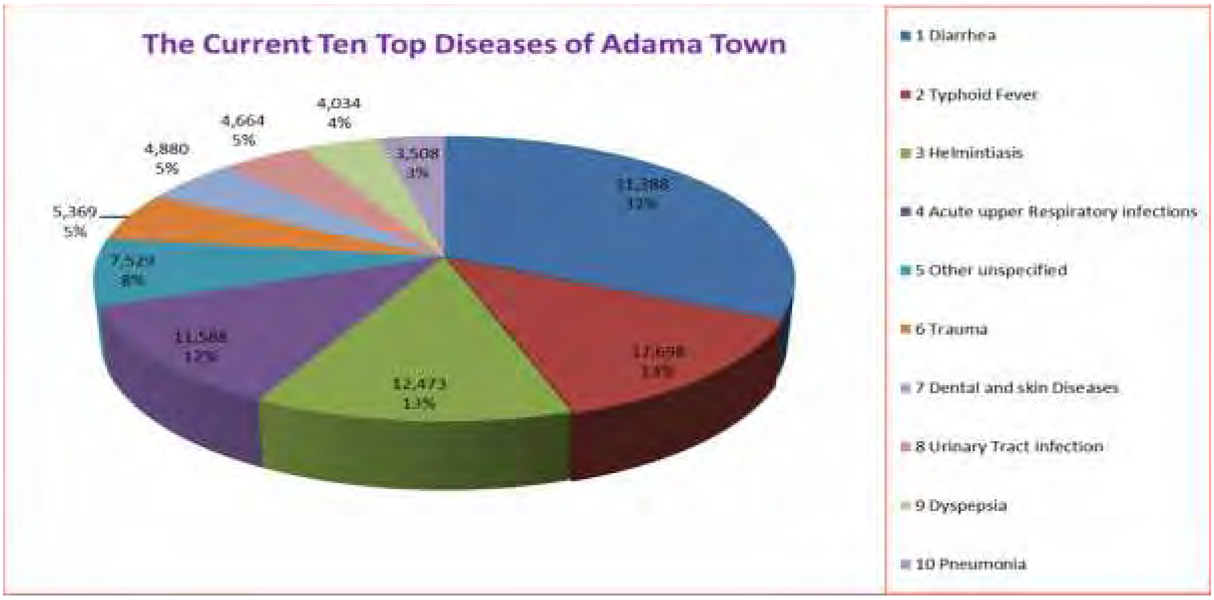


Figure 3-17: Current Ten Top diseases of Adaama Town.

(ources: Adama Town Health Centre)(Source: Map showing the location of the study region within the seismic risk zone of Ethiopia)

3.9.3.7. Methods for evaluating the causes of water pollution and occurrence of Water Borne diseases

Consultations was made with appropriate stake holders such as Adama Water Supply office, municipality, Health center and hospital regarding sanitation situation and occurrence of water associated diseases such as water borne and Water related diseases.Secondary data regarding water borne diseases recorded forth past six years (2010-2015) were collected from the Adama Town health center as shown inTable3-2. In addition, the actual sanitation situation of the area was observed during site visit.

Table 3-2: Population affected bywaterbornediseases (Sources: AdamaTown Health Centre)

year	Total population in the town	Dry season Infected population with water borne diseases in number	% of Dry season infected population with Water borne diseases	Wet season Infected population with water borne	%ofWetseasoninfected population with Water borne diseases
2010	284,750	11,933	4.19	14,292	5.02
2011	298,000	4,714	1.58	14,006	4.7
2012	304950	11,264	3.69	23,429	7.68
2013	311900	9,728	3.12	21,074	6.76
2014	337,100	9,143	2.71	19,281	5.72
2015	351,000	13,078	3.73	24,785	7.06

The population infected by Water borne diseases in the wet season was more than the population infected by Water borne diseases in dry season. Therefore detail discussion has been held with Adama Water Supply office regarding the way to operate carries out maintenance work and daily monitoring of water quality status before distributing to the customers.

3.10.3.8. General overviews of Sanitation service situation of the Adama town

The systems might be:

- On-site: retaining wastes in the vicinity of the toilet in a pit tank or vault.
- Off-site: removing wastes from the vicinity of the toilet for disposal away.
- Hybrid: retaining solids close to the latrine but removing liquids for off-site disposal elsewhere.

As to the above definitions in urban areas, even a good *on-site system* was normally required periodic removal of the fecal sludge and septage from pits, tanks, and vaults. Thus, no urban sanitation system is completely self-contained. To achieve total sanitation in a town, consideration must be given to the way in which household services are linked with higher level transport and disposal facilities. The overall sanitation of the town is poor. There is no modern system for collecting, transporting, and dumping waste in the Adama town.

3.10.3.9. Solid Waste Collection and disposal methods

The Adama TownSolid Wastedisposal methods are extremely in poor condition. This also has turned out to be the major obstacle in the development step of the Town. It is also recommended to be part of the sanitation program whereby taking into consideration the liquid waste management only is not bring the status of the Town and health, beauty, etc of its residents as well as security of the environment.

Figure 3-18: Pictures showing existing solid waste disposal condition of Adama

3.10.3.10. Liquid waste disposal

There is liquid waste disposal system in the town. The waste resulting from bathing and other domestic washing activities almost entirely thrown out into the resedance septic tank not all resedances. So, there is specific site for liquid waste disposal.

3.10.3.11. Sludge disposal method

Adama Town Water Supply has one (1) own vacuum truck andprivately there were nine (9) vacuum trucks workin the Town adminstration for sludge disposal. Accordingly, Adama Town is some how facilitated for sludge disposal.

3.11. Method and Materials used

Both **primary** and **secondary data** are collected and analyzed using the following methodologies.

1. Physical observation of scheme facilities and the condition of the sources of the water supply scheme.

2. Conduct discussion with Adama water supply office staff to get their over views on the water supply services condition.

3. Discussions with relevant stakeholders such as municipality and Health center

4. Organizing and conducting of sample household survey on water quality situation.

5. Observing Records of surveillance report from health center

6. Conduct bacteriological analysis on the Adama Water Supply source.

7. Determination of chlorine dosage and feeding rate.

8. Preparation of chlorine solution as disinfectant and applied to the system

9. Data Analysis and Interpretation of results.

9. Observing water tank level from **staff gauge** and **flow meter reading** for link flow data's

10. Model Calibration and Validation.

Water sample were collected in pre-sterilized plastic bags and were filtered on the spot using membrane filter with a pore size of 45micro-meter.The filters were incubated in a ELE pqualab 25 field incubator, in sterilized aluminum petridishes with a bacterial medium of Lauryl-sulfate on absorbed pad,at37^0Cand 44^0C for total coliforms and Fecal-coliforms respectively. The filters were examined 24 hrs later for bacterial growth. Water quality modeling was conducted by chlorine bulk decay bottle tests under controlled conditions like in dark room. A chlorine decay test for the finished water was performed on monthly basis. A sample for the chlorine bulk decay tests was taken from the storage Reservoirs. Just before entering its distribution system. The 250 mL amber bottles screw capped with PTFE-lined septa were used for the tests. Chlorine concentrations were measured by DPD tablet, a pocket colorimeter (Pocket Colorimeter TM II, Hatch, Loveland, CO), spectrophotometer & incubator. Samples including Temperatures, initial chlorine, K_b was measured in the laboratory and the residual chlorine at the selected location was measured accordingly.

3.11.1. Sampling Method

3.11.2. Sampling points

Samples were taken from locations that are representatives of the raw water source, treatment plant, storage facilities, distribution network, points at which water is supplied to the consumer, and Water points of use. In selecting sampling points, each locality was considered individually; however, the following general criteria are usually appropriate: Sampling points should be selected in such a way that the samples taken are representative of the different sources and points of distributions. These points should include the samples representative of the conditions at the most critical sources or places in the Water supply system, mainly points of possible contamination such as raw water sources, treatment plant before and after coagulation process, reservoirs, low-pressure zone and high pressure zone ends. The location of places represantatve by code -ATWS of sample points selected in this study are shown in figure below, the sampling points are located enclosed delineated map of the study area as shown in figure 3-19.

Figure 3-19: Location of the sampling points (Code ATWS-Adama Town Water Sample) in each Kebeles.

3.11.3. Sampling Method of the Chlorine measurement.

One objective of investigation is to assess the quality of the water supplied by the Adama Water supply office and of that at the point of use, so that samples of both should be taken. Any significant difference between the two has important implications for remedial strategies. Samples must be taken from locations that are representative of the water source, treatment plant, storage facilities, distribution network, points at which water is delivered to the consumer, and points of use. In selecting sampling points, each locality should be considered individually; however, the following general criteria are usually applicable: Sampling points should be selected such that the samples taken are representative of the different sources from which water is obtained by the public or enters the system.

•These points should include those that yield samples representative of the conditions at the most unfavorable sources or places in the supply system, particularly points of possible contamination such as unprotected sources, loops, reservoirs, low-pressure zones and high pressure zones, ends of the system, etc.

- Sampling points should be uniformly distributed through out a piped distribution system, taking population distribution and geographical administration system in to account; the number of sampling points should be proportional to the number of links or branches.
- The points chosen should generally yield samples that are representative of the system as a whole and of its main components.
- Sampling points should be located in such a way that water can be sampled from reserve tanks and reservoirs, etc.
- In systems with more than one water source, the locations of the sampling points should take account of the number of inhabitants served by each source.
- There should be at least one sampling point directly after the clean-water out let from each treatment plant.
- Sampling regimes using variable or random sites have the advantage of being more likely to detect local problems but are less useful for analyzing changes over time.A

typical network representation of a water network may include hundreds or thousands of links and nodes. However, only a small percentage of representative sample measurements can be made available for the use of model simulation due to the limited financial requirements for data collection.Therefore, it is of the most important to have a comprehensive methodology and efficient tool that can assist in achieving a highly accurate model under practical conditions. Selection of sampling sites is typically compromise between selecting sites that provide the greatest amount of information and sites that are most a men able to sampling. Sites should be spread through out the study area and should reflect a variety of situations of Interest, such as transmission mains and local lines, areas served directly from a source, and areas under the influence of tanks. Sampling taps should be placed close to (45) forty five representative sample nodes for residual chlorine measurement through out the study area have been selected by random sampling technique for modeling. Samples were collected daily from different sampling point from Town water supply and at the exit of water tank before distribution, these samples collected from the origin in order to represent water with moderate and high residence time with in the distribution system. The water samples were stimulated with sodium thiosulfate ($Na_2S_2O_3$) and stored in 40-ml vials closed with Teflon-lined screw caps at 4°C until the analysis.

Figure 3-20: Samples taken from treatment plant and Water point, 2016

Figure 3-21: Sample taken from concret River side box intake source.

3.11.4. Sampling frequency

The most important tests used in water-quality investigation or quality control in communities are those for microbiological quality (by the measurement of indicator bacteria) and turbidity and for free chlorine residual and p^H where chlorination is used. These tests should be carried out whenever a sample is taken, regardless of how many other physical or chemical variables are to be measured.Themeasurement of sampling frequency amount at the same location in the 5minutes interval take three (3) samples and test in the same time and the resultsare the same.The recommended minimum frequency of critical measurements in minimum sample numbers for piped drinking water in the distribution system is shown in table3-3. Below (WHO, 1997).

Table3-3: Minimum sample numbers for piped drinking water in the distribution systems

No	Population served	Numbers ofmonthlysamplesrecommended
1	Less than5,000	1
2	5,000-100,000	1 per 5,000 population
3	Greater than 100,000	1 per 10,000 population plus 10additionalsamples

Source: (WHO, 1997), Geneva, system.

3.11.5. Determination of chlorine dosage

Chlorine is the most popular water treatment disinfectant in municipal water distribution system. Chlorine is an oxidizing agent and it decays with time. Therefore, a minimum level of chlorine residual must be maintained in the distribution system to preserve both chemical and microbial quality of treated water. While chlorine travels through the distribution system, it reacts with different materials inside the pipe. Reactions are impacted by the surrounding conditions due to the availability of reacting substances. The principal factors influencing the disinfection efficiency of chlorine are free residual concentration, contact time, pH and water temperature. The term 'free residual' means the amount of free chlorine remaining after the disinfection process has taken place. Given adequate chlorine concentration and contact time, all bacterial organisms and most viruses can be inactivated. Thus a useful design criterion for the disinfection process is the product of contact time (t in minutes) and the chlorine-free residual concentration (C in mg/l) at the end of that contact time. This is known as the 'Ct value 'or 'exposure value'. On this basis the WHO guide level of 0.5 mg/l free residual concentration after 30 minutes contact time would have a contact time value of 15 mg. min/l.

3.12. Hydraulic Model: EPANET

3.12.1. The EPANET Model

EPANET is a computer program that performs extended period simulation of hydraulic and water quality behavior with in pressurized pipe networks. A network consists of pipes, nodes (pipe junctions), pumps, valves and storage tanks or reservoirs. Epanet tracks the flow of water in each pipe, the pressure at each node, the height of water in each tank, and the concentration of residual chlorine through out the distribution network (Rossman, 2000).

3.12.2. The EPANET Model Set Up Procedure

One typically carriesout the following steps when using EPANET to model a water distribution system:

- Draw a network representation of your distribution system or import a basic description of the network placed in a text file.

- Edit the properties of the objects that make up the system
- Describe how the system is operated
- Select a set of analysis options
- Run a hydraulic/water quality analysis
- View the results of the analysis

3.12.3. Water Quality Modelling

Water quality modeling is a direct extension of hydraulic network modeling and can beused to perform many use ful analyses. Designers of hydraulic network simulation models recognized the potential for water quality analysis and began adding water quality calculation features to their models in the mid-1980s (Thomas etal.,2003) .Transport,mixing,and decay are the fundamental physical and chemical processes typically represented in water quality models. Water quality simulations also use the network hydraulic solution as part of their computations. Flow rates in pipes and the flow paths that define how water travels through the network are used to determine mixing, residence times, and other hydraulic characteristics affecting disinfectant transport and decay. The results of an extended period hydraulic simulation can be used as a starting point in performing awater qualityanalysis.

In the large water supply network systems, water wants to travel a large distance with a long water residence time. The problem could affect water quality. Thus might be due to low pressure, big and multiple reservoirs to rages, in adequate disinfection in the system, leaking, fracture and work loose of joints, and soon.Eventhough, the problems of quantity are basic agents in the decay of water quality in distribution systems. One of the parameter that could reason to decrease water quality in distribution system is pressure change in network. Many researchers have been carried out about affects pressure change in the water quality in distribution systems (Shamsaei et al., 2013).

3.12.4. Bottle test

A bottle test allows the bulk reactions to be separated from other processes that affect water quality, and thus the bulk reaction can be evaluated fully as a function of time. The parameter of bulk reaction used to express the rate of the reaction occurring with in th ebulk fluid is called the bulk reaction coefficients can be determine doing a simple experimental procedure called a bottle test. In addition, a bottle test allows for the evaluation of the impact transport time on water quality and for an experimental determination of the parameters necessary to model this process accurately. Determining the length of the bottle test and the frequency of sampling is the first and most critical decision (Thomas, et al., 2003).

3.12.5. Method of Model Calibration and Validation

Once a water distribution model has been developed, it must be calibrated so that it accurately represents the actual work in greal-life water distribution network under a variety of conditions.This involves making minor adjustments to the input data so that the model accurately simulates both the pressure and flow rates in the system.Note that both the pressure and flow rates need to be matched together,since pressure and flow rates are dependent upon each other Pressures are carefully measured throughout the water distribution system using pressure gauge installed at selected sampling location; according to selected pressure zone boundaries such as, **high pressure zone,medium pressure zone, low pressure zone, public fountains, customer tap point, distribution water reservoir, pump house, and other sampling points at time intervals.** To monitor the level of service and to collect data for use in model calibration.Therefore, matching only pressures or flow rates is not sufficient. In addition, ideally the model should be calibrated over an extended period, such as a time range for the maximum of one day. The computed pressure and measured field pressure will not exactly match for every node contained with in the network system is 85% of field test measurements should be with in ±0.5m the computed or simulated pressure by Epanet soft ware at that node.

3.12.6. The effect of pressures on chlorine residuals

The analysis of the effects of pressure changes on the residual chlorine in water distribution systems are carried out by in stalling pressure gauge at selected sampling location such as, public fountains, customer tap point, distribution network, Lugo reservoirs, Koka treatment plant, and other sampling points.

Figure 3-22: Pressure measures in the field measurement

Inorder to assess the relationship betweent he pressure and residual chlorine concentration in the system, the measured pressures and chlorine residual collected from different locations were used for calibration and validation of Epanet software water quality model.

3.12.7. Additional tools

3.12.7.1. Method of data analyses

The result of the experimental data was used to analyzing by using application of software such as MS EXCEL, Epanet, and Global Mapper and GIS softwares. Finally the analysis results were compared with World Health Organization and Ethiopian standard values Guidelines.

3.12.7.2. Laboratory test Method

Some parameters such as Total Dissolved Solids (TDS), Electrical Conductivity (EC), pH, Turbidity and Temperature are tested on spot, when the sample was collected. The rest of the parameters are tested in the laboratory according to the procedures in the laboratory manual. Since different elements have differing storage time, it is important to follow the instructions on storage and protection in the manual. A total of 45 representative water samples were collected from sensitive areas for expected pollution like: Raw water, treatment plant, water reservoir, water points, end user of distribution pipe network. Water samples were collected in properly washed and cleaned appropriate sampling bottles. The pH meter, Cyber scan, PC300PH, Temp., TDS and EC meter having electrodes were used immediately on spot to measure pH, Temperature, Total Dissolved Solids (TDS), and Electrical Conductivity (EC), respectively. These electrodes were immersed in the samples and then the measured parameters were displayed on the LCD screen of the instruments and by onther method:

- ❖ Physico-chemicals analysis by:
    - EC,TDS, $Temo_C$ & pH-meter
    - Titration method (volumetric)
    - Spectrometric method
- ❖ Bacteriological analysis method by:
    - Membrane filtration method and incubator at $temp\ 37^0C$ & 44^0C for Total fecal & total coliform, respectively.
- ❖ BOD /COD test method by:
    - 5-day BOD test method

CHAPTER-4

4. RESULTS AND DISCUSSIONS

4.1. Bacteriological Analysis.

Based on the Adama Town Water Supply system Forty five (45) water samples have been collected from different sampling points for Bacteriological test. In addition to on spot analyzed parameters, 10 samples have been collected, well-preserved and transported to Addis Ababa, Oromia Water, Mineral and Energy Bureau central Water quality Control Laboratory for the remaining Bacteriological test. All the samples were found to be negative for fecal coliform or positive for total coliform, which should not occur in two consecutive samples. Depending on the risk level chlorination is recommended. The difference between the two is shown below

4.1.1. Total coliforms

The coliform organisms was better referred to as total coliforms to avoid confusion with others in the group, are not an index of fecal pollution or of health risk, but can provide basic information on source water quality. Total coliforms have been long utilized as a microbial measure of drinking water quality, largely because they are easy to detect and enumerate in water. Traditionally they have been defined by reference to the method used for the group's enumeration and hence there have been many variations dependent on the method of culture. In general, definitions have been based around the following characteristics; gram-negative, non-spore forming, round shaped bacteria capable of growth in the presence of bile salts or other surface active agents with similar growth inhibiting properties,oxidize-negative, fermenting lactose at 35-37^{o}C with the production of acid, gas, and aldehyde within 24-48 hours according to assessing Microbial Safety of Drinking Water (2002).See table 9 below for Total coliforms analysis and laboratory test results.

4.1.2. Faecal coliforms

The term "fecal coliforms‟, although frequently employed, is not correct.The correct terminology for these organisms is „thermo tolerant coliforms‟. Thermo tolerant coliforms were defined as the group of total coliforms that are able to ferment lactose at 44-45^{0}C. The genus Escherichia comprise to a lesser extent, species of Klebsiella, Entero-bacter, and Citrobacter. Of these organisms, only E.coli was considered to be specifically of fecal origin, being always present in the faeces of humans, other mammals, and birds in large numbers and rarely, if ever, found in water or soil in temperature climates that has not been subject to fecal pollution (Fujioka et al., 1999). The danger of coliform presence can rest on the health or sensitivity of the user. The risk of E.coli presence, rather than WHO Guideline is zero count per 100ml that may be of only low or intermediate risk. According to risk classification presence or absence of thermo tolerant coliforms or E.coli (Michael, 2006) of water supplies. See table 4-1and table 4-2 showns below for faecal coliforms analysis and laboratory test results.

Table 4-1: Bacteriological counts per 100ml and the associated risk

No	Bactiorological count per 100ml and the associated risk count per 100ml	Risk category
1	0	In conformity with WHO guide lines
2	1-10	Low risk
3	11-100	Intermediate risk
4	101-1000	High risk
5	>1000	Very high risk

(Source: Michael et al. 2006)

When the bacteriological test result compare with the above WHO standard the most of the samples have Intermediate and High Risk number of bacteria, therefore it is recommendable to apply chlorine to assure a quality drinking water. The following table shows Adama Town Frist round bacteriological laboratory tests and results.

Table 4-2: Adama Town Frist round Bacteriological test laboratory analysis and results

Samples Code	E-coli/100ml (faecal coliform)	Total coliform/100ml	Remark
ATWS 03	1250	TNTC	Very High Risk
ATWS 04	1000	TNTC	High Risk
ATWS 05	650	TNTC	High Risk
ATWS 06	98	15	Intermediate risk
ATWS 07	107	TNTC	High Risk
ATWS 08	35	63	Intermediate risk
ATWS 09	560	TNTC	High Risk

ATWS 10	38	98	Intermediate risk
ATWS 11	150	TNTC	High Risk
ATWS 12	210	TNTC	High Risk
ATWS 13	96	5	Intermediate risk
ATWS 14	78	23	Intermediate risk
ATWS 15	TNTC	350	Very high Risk
ATWS 16	100	32	Intermediate risk
ATWS 17	45	65	Intermediate risk
ATWS 18	TNTC	650	High Risk
ATWS 19	66	95	Intermediate risk
ATWS 20	TNTC	150	High Risk
ATWS 21	117	TNTC	High Risk
ATWS 22	165	TNTC	High Risk

The bacteriological test analysis of Adama Town before temporary constant chlorine solution drip system constructed by research team the samples laboratory tests and results were shown the above results. When compared with the values set by the WHO as presented Table 8. The result shows Intermediate risk, high risk and very high risk. This result indicates that no residual chlorine in the distribution net work system. So, additional chlorine dosing needed at Lugo balancing reservoirs Permanetly and in the distribution systems to be applied guarantee a better quality of drinking water see Table 1 in Appendex on page104 for detail laboratory tests and results.

4.1.3. Prevalence of water associated diseases in the study area

The proverb "water is life" is found in many cultures around the world. It underlines the fact that clean water is an absolute prerequisite for healthy living. The importance of water for human well-being cannot be over-emphasized. The normal functioning of the human body depends entirely upon an adequate quantity and quality of water. However, if the water is from contaminated sources, it causes numerous water-associated diseases.

In the developed world, water-associated disease are rare, due essentially to the presence of efficient water supply and wastewater disposal systems. However, in the developing country, the majority of people are without a safe water supply and adequate sanitation. According to WHO surveillance highlighted each day, 30,000 people die and 80% of all illnesses in developing countries from water-associated diseases Collabration with the Ethiopia Public training Initiative (Zeyede & Tesfaye, 2004).

The Adama Town drinking water supply was very poor aesthetically and acceptability regards to lack of properly sewerage system and Indusrial waste management and location of the source as previously discussed in the description of study area. So that start from these situations of the Town to try surveillance water associated diseases such as water borne diseases recorded from 2010-2015 in different kebeles from Adama Town Health Centre by developed graph as shown in figure 4-1.

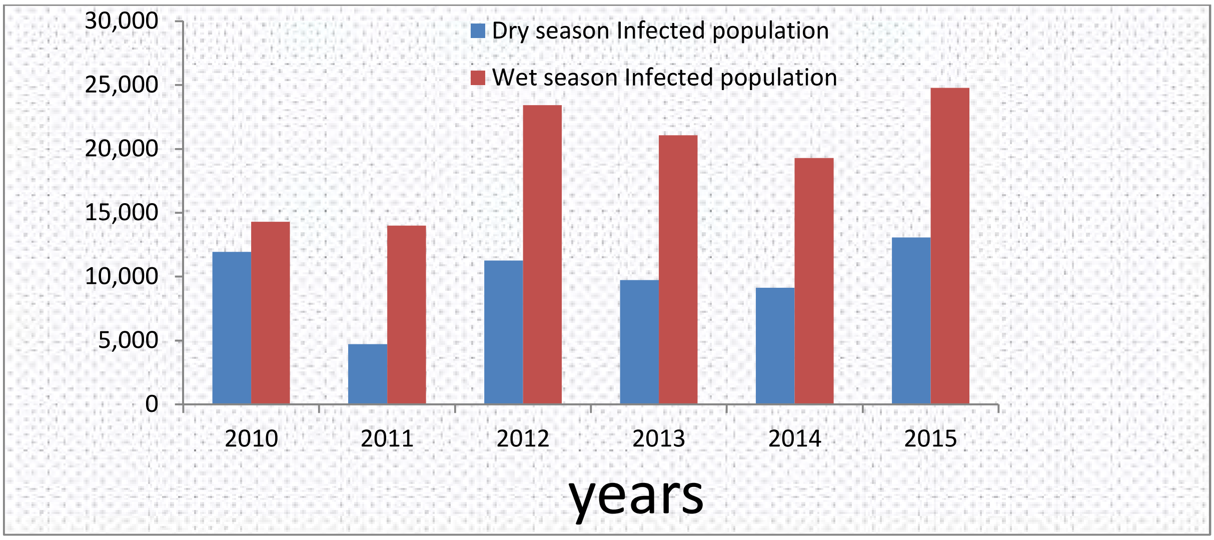


Figure 4-1: Population affected by water borne diseases (Source: AdamaTown Health Centre)

4.1.4. Free Residual chlorine tests

Chlorine is a chemical that is used to disinfect water prior to it being discharged in to the distribution system. It is used to ensure that water quality is maintained from water source to the point of consumption. When chlorine is fed in to water, it reacts with any iron, manganese, or hydrogen Sulphide that may be present. If there is any residualchlorine left, it will then react with organic materials, including bacteria. In order to ensure that water is sufficiently treated through the whole distribution system, excess chlorine is usually added.This amount is usually adjusted to make sure there is enough chlorine available to completely react with all organics present. Chlorine will decreases in concentration with distance from the source until it reaches the point where the chlorine level can be come in effective as a disinfectant. Bacterial growth will occur in distribution systems when very low levels of chlorine are encountered. Therefore, it is important to make sure there is enough chlorine to efficiently disinfect even at the far ends of the distribution system.

Chlorination can kill many pathogenic disease-causing microorganisms such as E-coli and total coliform, but others, like Cryptosporidium and Giardia, are very resistant to chlorine and require other measures to properly remove them. The World Health Organization guidance level for drinking water supply recommends a minimum free chlorine residual of 0.2mg/l and maximum residual chlorine 0.5mg/l (www.Safewater.Org) in the distribution systems of any water supply.

Studies have shown that when residual chlorine levels decline from recommended satandard, several water quality problems can occur.With regard to public health, bacteria and selected viruses called bacteriophage are able to multiply in water that was not properly disinfected. More over, depending on the species, could potentially cause water borne diseases.While recommendations only state minimum residual chlorine levels, it is important that a careful balance be maintained in drinking water. However, as shown the laboratory and model simulation results of the study area were high lost of chlorine in the system and no Residual chlorine in forty five (45) Samples tested in AdamaWater Supply except treatment plant (0.6mg/l Residual chlorine existed). Table 4-3 shows the **frist round Residual Chlorine 45 samples** laboratory tests and results.

Table 4-3: Frist round Residual Chlorine laboratory tests and results

Samples Code	Sample location			Date	Time (Hour)	Residual Chlorine , mg/l	Kebeles
	Easting	Northing	Altitude				
ATWS 01	519730	937132	1556	8/3/2016	11:45AM	0.0	Intake
ATWS 02	519810	937324	1570	8/3/2016	2:45PM	0.6	TP
ATWS 03	526891	943400	1653	8/3/2016	3:30PM	0.0	1
ATWS 04	528773	943551	1573	8/3/2016	4:250PM	0.0	2
ATWS 05	529931	945125	1632	8/3/2016	5:30PM	0.0	18
ATWS 06	529943	945427	1640	8/3/2016	6:18PM	0.0	12
ATWS 07	530194	945914	1656	8/3/2016	7:23PM	0.0	12
ATWS 08	529638	944478	1633	8/3/2016	8:25PM	0.0	4
ATWS 09	529852	944429	1631	8/3/2016	9:30PM	0.0	4
ATWS 10	529801	944442	1632	8/3/2016	10:15PM	0.0	14

The result of resdual chlorine sample test and analysis were shown above.When the sample test result compared with the values set by the World Health Organization standard and Ethiopian recommended valuces maximum permissible limit,the samples forty five (45) laboratory test results were zero residual chlorine except treatment plant.When the treatment plant sample test in laboratory the result is 0.6mg/l residual chlorine existed in the sample points.The distance between treatment plant and Lugo Reservoirs is 11km.So there is no residual chlorine in the sample of Lugo reservoir, this is shows Water travelling long distance has increasing waterage. Permanently chlorine solution dosing is recommended on Lugo Reservoir.

4.1.4.1. WaterAge Analysis

Many water distribution systems experience long retention times or increased waterage, in part due to the need to satisfy fire fighting requirements. Although not a specific degradative process, water age is a characteristic that affects water quality; because, many deleterious effects are time dependent. Characteristically, the loss of disinfectant residuals and the formation of Disinfection bi-products (DBPs) are due to increased waterage.

The chemical processes that can affect distribution system water quality are a function of water chemistry and the physical characteristics of the distribution system it self (for example, pipe material and age). More generally, however, these processes occur over time, making Water travelled long time in transmission line and residence time in the distribution system is a critical factor influencing water quality. The cumulative residence time of water in the system, or waterage has come to be regarded as a reliable replacement for water quality. Waterage is of particular concern when measuring the effect of storage tank turns over on water quality. It is also beneficial for evaluating the loss of disinfectant residual and the formation of disinfection by-products in distribution systems.

4.1.4.2. Water quality degradations

Water quality simulation requires a series of runs to understand the movement of water and water quality transformation in the system. Specific simulations included in this study are: water age and residual chlorine modeling. There is a variation of water quality in distribution system from hour to hour of a particular day. This hourly variation of water quality is mainly related to demand patterns. To obtain the dominant factors currently contributing to water quality deterioration specifically loss of residual chlorine in Adama water supply distribution system of the following one possible scenario was assessed.

4.1.4.3. Demand pattern

Hourly water use in a given day is subjected to changes due to many factors. Frequently there is high water consumption at 10:00 AM and low water consumption at mid-night (18:00). These variations lead to use of large storage tanks. However, large storage tanks have negative impacts on water quality is about assessing water quality conditions in the distribution system of Adama water supply system under the influence of water demand variations. Water quality situation at peak hour flow and low hour flow was assessed taking water age or residence time and residual chlorine as water quality parameters.

A. Water age (Residence time) at peak and low hour flow.

B. Residual chlorine at peak and low hour flow.

A) Water age (Residence time) at peak and low hour flow

Analysis for water age was based on assumption that the distribution system was loaded with continuous flow. Thus, any findings for this parameter are limited to this assumption. Table 4-4 and table 4-5 show water age distribution at peak and low hour flow.

Table 4-4: Water age distribution at low hour flow

Age(hr)	Node(number)	Percentage
<4	2	4.44
4---6	0	0
6----8	0	0
8----10	0	0
10---12	6	13.33
12---14	5	11.11
14---16	8	17.78
>16	24	53.34

Table 4-5: Water age distribution at peak hour flow

Age(hr)	Node(number)	Percentage
<4	2	4.44
4—6	1	2.22

6---8	6	13.34
8----10	4	8.89
10----12	3	6.67
12---14	28	62.22
14---16	1	2.22
>16	0	0

As it is illustrated in table 4-4 at low hour flow majority of nodes 53.34% receive water with age exceeding 16 hours. Only 46.66% receive water with age less than 16 hours. While at peak hour flow nodes receiving water with age exceeding 16 hours is reduced to nill. There is significant difference between water age reaching nodes at high water consumption time and low water consumption time.

B. Residual chlorine at peak and low hour flow.

It had been long time since it was proved that microbiologically safe water would be supplied only while continuous disinfection prior to water distribution is possible along with letting distributed water with optimum residual chlorine to control recontamination in distribution system. Recontamination of water in a distribution system occurs due to various factors and their outcomes also differ. No matter what the reason is microbiologically unsafe water shall not be tolerated since its consequence is very appalling. The widespread strategy to tackle the probable recontamination is ensuring residual chlorine in water distribution system. Recommended residual chlorine at the taps of the users usually lies between 0.2 mg/l to 0.5 mg/l Table 4-6 and Table 4-7 shows residual chlorine concentration distribution at low and peak hour flow.

Table 4-6: Residual chlorine distribution at low hour flow

Residual chlorine(mg/l)	Nodes(numbers)	percentages
0	4	8.88
0.01--0.1	21	46.66
0.1---0.2	6	13.33
0.2---0.5	8	17.8
>0.5	6	13.33

Table 4-7 Residual chlorine distribution at peak hour flow

Residual chlorine(mg/l)	Nodes(numbers)	Percentages
0	6	13.33
0.01--0.1	6	13.33
0.1---0.2	1	2.23
0.2---0.5	30	66.67
>0.5	2	4.44

As shown in table 4-6 at low hour flow only 17.8% of nodes ceive water with residual chlorine between (0.2 mg/l - 0.5 mg/l). Around 8.88 % of nodes obtain water of nil residual chlorine. While as it was shown in Table 4-7 at peak hour flow 66.67% of nodes obtain water with residual chlorine between (0.2 mg/l–0.5 mg/l). This indicates the quality of water in distribution system of Adama water supply is much better at peak hour flow than low hour flow. At peak hours, when consumption is high, the water transits more rapidly in the network pipes and the chlorine has not enough time to react; thus chlorine residual concentration values remain quite high. At off-peak hours, when consumption is low (e.g. during the night 18:00), water velocity decreases and the chlorine concentration decaying process is more pronounced; thus chlorine residual concentration decreases down.

This chlorine residual model results occur after constant head drip chlorine solution system is constructed on the top of reservoirs, but in first round Adama Town sample test residual chlorine is zero in all samples except treatment plant. See table 4-3, page 56 detail about first round sample laboratory test and result.

4.1.4.4. Drinking Water transport in Pipes

Most water quality models make use of one-dimensional advective reactive transport to predict the changes in constituent (chlorine) concentrations due to transport through a pipe, and to account for formation and decay reactions. Chlorine is the most popular water treatment disinfectant in municipal water distribution system. Chlorine is an oxidizing agent and it decays with time. While chlorine travels through the distribution system, it reacts with different materials inside the pipe. Reactions are impacted by the

surrounding conditions due to the availability of reacting substances.
Reactants are present in the bulk water and may also occur at high concentrations on the surface of the pipe. Bulk reactions predominate in relatively less turbulent water. On the other hand, wall or surface reactions predominate in turbulent flows. Water quality transport mainly occurs by advective transport in which the constituent (chlorine) moves with water in the direction of flow with the magnitude of the main velocity component.The lost of chlorine residual concentration along the water transimission main and distribution system are processed in three separated mechanisms:

- Chlorine reactions in bulk fluid;
- Chlorine reactions with pipe and other system element’s walls.
- Natural evaporation.

If, ideally, the chlorinated water was pure and the material of the pipes was inert, the only mechanism leading to the decay would be that of natural evaporation, especially in particular areas of the distribution system, namely reservoirs and other free surface flows. Therefore, a minimum level of chlorine residual must be maintained in the distribution system to preserve both chemical and microbial quality of treated water.

In Adama case treated water is travelled 11km long distance by high pressurized pumps. Pressure increases chlorine reactions in bulk fluid and with pipe wall due to long distance travelled. In those cuases residual chlorine concentration is lost in the transmission main system and zero chlorine residual at storage reservoir. See table 4-3, page 56 Adama Town first round sample laboratory test and result.

4.1.4.5. Temporary Constant Head Drip chlorination system on the Lugo resrvoirs

The chlorine compounds are found in a gaseous, liquid and powder forms. I used for this propse the powder form can have 65% available chlorine. It is advisable always to read the labels on the containers. To disinfect a water supply system, a chlorine concentration solution should be prepared. Typicaly chlorine concentration head drip by gravity from top of reservoir is frequently in the range 0.2–2.0mg/l of free chlorine to give residual chlorine

0.0 2–0.3mg/l at the end user's tap. As the concentration of ammonia in the Adama treated water is about 0.121 mg/l that is much less than WHO standards. So, chlorine concentration was adopted as 0.8pp construct a constant-head drip chlorinator of 2000 litres capacity plastic mixing tank is used. Feed rate = R, Q= flow rate, d=dosage of chlorine, 0.8mg/l as simulated by Epanet 2.0 software. Continuous chlorination can be done because we known the discharge. We use the following formula to prepare a chlorine stock solution.

V = Qd/C

Where: Q= Vol. of water to be treated per hour (m^3/hr)

C= concentration of chlorine in stock solution (g/l)

d = Chlorine dose rate (mg/l)

V= Chlorine solution flow rate (l/hr).

The Concentration of chlorine is in mg/l, chlorine concentration for Adama case is 65% powder calcium hypochlorite {$Ca(OCl)_2$} is used:

Let C=10g/L, C = M/V, V = 2000L

M=CVx100/65

= 10g/l*2000l*100/65 =30,769 grm=30.8kg of chlorine 65% powder calcium hypochlorite {Ca (OCl)2} is required to prepare 2000litres capacity plastic mixing tank chlorine solutions.Since in this time Six (6) pumps (each Pumps 42. 86 l/s on function) are on operational the flow is about 926m3/hr.

R=Q*d/C

Q = 926m^3/hr.

d = Chlorine dose rate is 0.8mg/las simulated by Epanet 2.0software

C = dissolve 30.8kg of calcium hypochlorite in a 2000L of water, this is the stock solution. This gives us a concentration of <u>30800g X 0.65</u> = 10g/l = 10,000mg/L.

2000litres

Therefore: V = Qd/C =<u>926,000l/hr X 0.8mg/l</u> = **74.08l/hr**

10,000mg/l

74.08l/hr is determined.Therefore; using 2000litres of mixing tank solutions of the chlorine application for 1.3days time is used.

Figure 4-2: Constant Head Drip chloration on top of 2000m^3 and 4000m^3 resrvoirs

Table 4-8: After constant Head drip Residual Chlorine laboratory test and results

Sample Code	Sample locations			Date	Time(Hour)	ResidualChlorine, mg/l	Kebeles
	Easting	Northing	Altitude				
ATWS 03	526891	943400	1690	10/4/2016	2:50PM	0.80	1
ATWS 04	528773	943551	1573	10/4/2016	3:00PM	0.30	2
ATWS 05	529931	945125	1632	10/4/2016	3:10PM	0.30	18
ATWS 06	531685	944664	1635	10/4/2016	1:55PM	0.30	11
ATWS 07	530194	945914	1656	10/4/2016	3:23PM	0.27	12
ATWS 08	524261	945553	1750	11/4/2016	9:00AM	0.20	9

ATWS 09	529852	944429	1631	10/4/2016	4:00PM	0.23	4
ATWS 10	529801	944442	1632	10/4/2016	4:50PM	0.17	14

After temporary constant head drip chlornation system constructed by research team on top of Lugoresrvoirsthe Residual chlorine sample test and analysis of the study area were corrected. When the sample test result compared with the values set by the World Health Organization and Ethiopian standard guidance's maximum permissible limit, the samples forty five (45) laboratory test and results were freechlorinetogive aresidualofabout 0.02–0.3mg/l at the consumer's tap.The above temporary arrangement of The Residual chlorine is needed continoution chlorine dosing system.Therefore the permanent chlorine solution concentration dosing system is recommended on Lugo Reservoirs. The following Table 4-9 shows bacteriological laboratory test analysis after constant head drip chlorination solution concentration on top of Lugo Reservoirs and results.

Table 4-9: Bacteriological test laboratory analysis after constant head drip chlornation on top of Lugo Reservoirs and results

Sample code	E-coli/100ml(faecal coliform)	Totalcoliform/100 ml	Results
ATWS 03	Nil	Nil	No Risk
ATWS 04	Nil	Nil	No Risk
ATWS 05	Nil	Nil	No Risk
ATWS 06	Nil	Nil	No Risk
ATWS 07	Nil	Nil	No Risk
ATWS 08	Nil	Nil	No Risk
ATWS 09	Nil	Nil	No Risk
ATWS 10	Nil	Nil	No Risk
ATWS 11	Nil	Nil	No Risk
ATWS 12	Nil	Nil	No Risk
ATWS 13	Nil	Nil	No Risk
ATWS 14	Nil	Nil	No Risk
ATWS 15	Nil	Nil	No Risk

4.1.4.6. Steps in shock chlorination

- Determine the amount of chlorine and dilution water to use.
- Pour the mixture of chlorine and water down the well
- Run water through the service lines in the house until you detect the odor of chlorine at each tap.

- Let the chlorinated water stand in the system depending on the concentration.
- Flush out the system beginning with the well.

Table 4-10: Chlorine concentration and recommended contact time

ppm	Contact time
25	12 hr
50	8 hr
100	6 hr
200	4 hr

Note: During continuous chlorination and after shock-chlorination residual chlorine must be checked at several points using a chlorine comparator. The residual chlorine should be between 0.2mg/l and 0.5mg/l for the water to be consumed.

4.2. Physical Quality Parameters Analysis

4.2.1 Physical Quality analysis

The physico-chemical parameters directly related to the safety of the potable water to human consumption.The physico-chemical water quality parameters deliver important information about the health of a water body. These parameters are used to find out the quality of water for drinking purpose. During field survey the following physico-chemical parameters were also investigated using laboratorial experiment. The forty five (45) samples collected at different components of existing water supply system from source to point of distribution network were analyzed. The physical parameters are analyzed on spot and in the laboratory respectively, were pH, Turbidity, Color, Temperature (^{0}C), Electrical Conductivity (EC), Total Dissolved solids (WHO, 2004).

4.2.2. p^{H} of Potable Water

P^{H} is an index of the amount of hydrogen ions (H^{+}) that are in a substance. The p^{H} scale measured with respect to neutral substances as reference. Substances with a p^{H} higher than 7.0 (7.1-14.0) are considered alkaline or basic. Substances with a p^{H} less than 7.0(0-6.9) are considered acidic. According to the WHO, the minimum and maximum allowable p^{H} ranges from 6.5 to 8.5 for potable water. The pH of water is controlled by the equilibrium achieved by dissolved compounds in the system. In natural waters, the pH is primarily a function of the carbonates ystem, which consists of bicarbonate and carbonate. Acid in puts to a water system may substantially change the pH. The main sources of acid include acid mine drainage and atmospheric acid deposition. There is no health risks related to consumings lightly acidic or basic water.

a. Neutralizing filters increase the p^H by passing water through a filter bed of Calcium Carbonate ($CaCO_3$). This neutralizes the acid and increases the p^H.

b. Soda Ash (Sodium Carbonate) solution is fed through a tube in to the pumping in take and is automatically injected when ever the water pump is running.

The p^H Wet season values range from 6.66- 7.66 and the p^H Dry season values range from7.09- 7.58 for most of the sample as shown in figure 4-3. In general, the result shows that the existing water supply of Adama town clear Water is in the range of World Health Origanization potable water. Therefore, Adama Town Water Supply should not need adjustment for P^H.

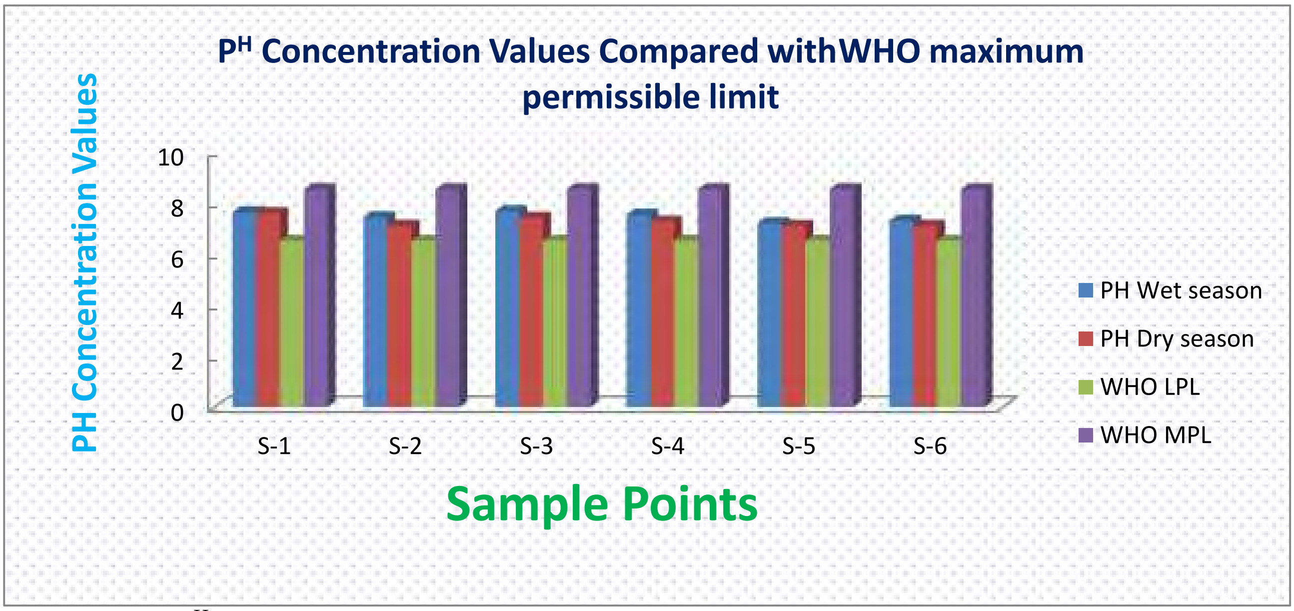


Figure 4-3: P^H values compared with the WHO maximum permissible limit

4.2.3. Turbidity

Turbidity is the unit of measurement for quantifying the point to which light traveling through a water column is scattered by the suspended organic (including algae) and in organic particles. The scattering of light increases as the presence of suspended load increases and turbidity is commonly measured in Nephelometric Turbidity Units (NTU). Turbidity may be classified as physical and microbiological parameters. Because it can raise aesthetic and psychological objections by the consumer, and as a microbiological parameter, it may harbor pathogens and obstruct the effectiveness of disinfection. Direct health effects depend on the precise composition of the turbidity-causing materials, but there is other implication. As turbidity can becaused by sewage matter in water the reis a risk that pathogenic organisms could be shielded by the turbidity particles and hence escape the action of the disinfectant. According to the WHO (2012) standard for turbidity, the maximum allowable permissible limit value must always below, preferably lower than1NTU. It is recommended that for water to be disinfected, the turbidity should be reliably less than 5 NTU and preferably have a median value of less than1 NTU, Figure 4-4 shows that the results of Adama Twon Water supply during dry and wet season .The results show that it is less than the maximum permissible limit values recommended by World Health Origanization in the both seasons.

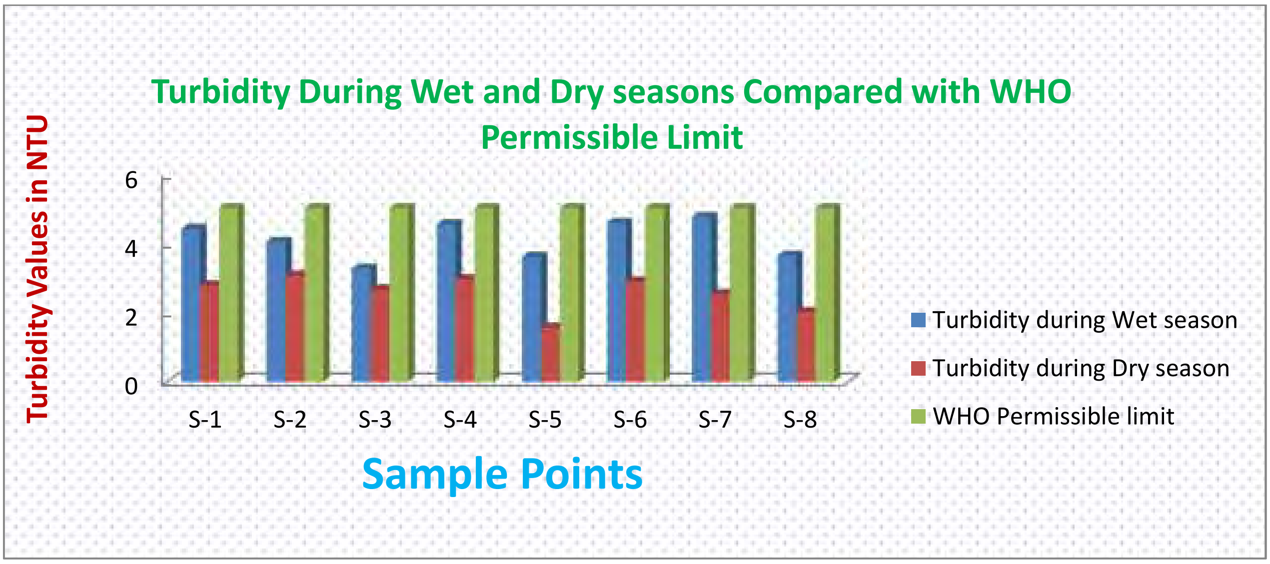


Figure 4-4: Turbidityof Water during dry and wet season as compared with the WHO Maximum Permissible Limit.

4.2.4. Color

Color can be classified in to two types: true and apparent color. The most common cause of true color is decaying organic material such as dead leaves and grass. This type of color usually found in surface water. Apparent color is caused by in organic materials, usually iron, copper or manganese. When water has a visible color to it, and it is usually due to the presence of decaying organic material or in organic contaminants such as iron, copper, or manganese. Limits for color in drinking water are usually set based on appealing considerations. According to the WHO (2012) standard guide line, it should not be more than15TCU, which is the maximum permissible limit. Figure 4-5. Shows that the comparism values of Adama Town potable Water color during wet season and dry season. The sample test result indicates that the values during dry season is less than the WHO Maximum Permissible limit values and during wet season greater than the WHO Maximum Permissible limit values. In addition, the color values are higher for wet season than the dry season. This is because of the liquid wastes from industries, Towns and Agricultural area drain to the sources of water supply.The color in water does not pose any health risks. If the color is due to a metal contaminant, such as copper, mild gastrointestinal symptomsmay result. We can see that the main causes of color in the study are a may be due to decaying of organic material such as dead leaves, grasses and might be due to high iron concentration.

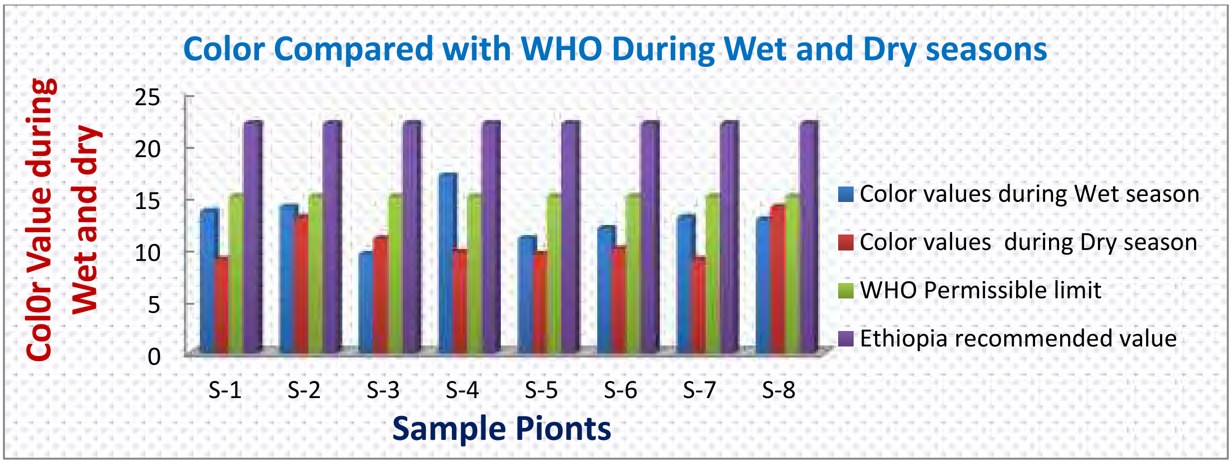


Figure 4-5: The Color Values during Wet and Dry Season as Compared to Maximum Permissible Limit

4.2.5. Electrical conductivity (EC)

Electrical Conductivity (EC) was an indicator of total dissolved salts (TDS). It establishes if the water is drinkable and capable of satisfying dehydration. The conductivity of potable waters varies generally from 50 to 1500µmhos/cm. The conductivity of municipal waste water may be near to that of the potable water. However, the industrial waste waters may have conductivities above10000µmhos/cm. According to WHO standards the EC value of drinking water supply should not be exceeded 400µS/cm. The result shows that the EC values of Adama town water supply during wet season varies from 370 -394 µS/cm and during dry season varies from 231 -278 µS/cm, which both are below the WHO maximum permissible limits as shown in figure 4-6. These results clearly indicate that the water in the systems are characterized by low ionized and has the low level of ionic concentration activity due to low concentrations of dissolved solids.

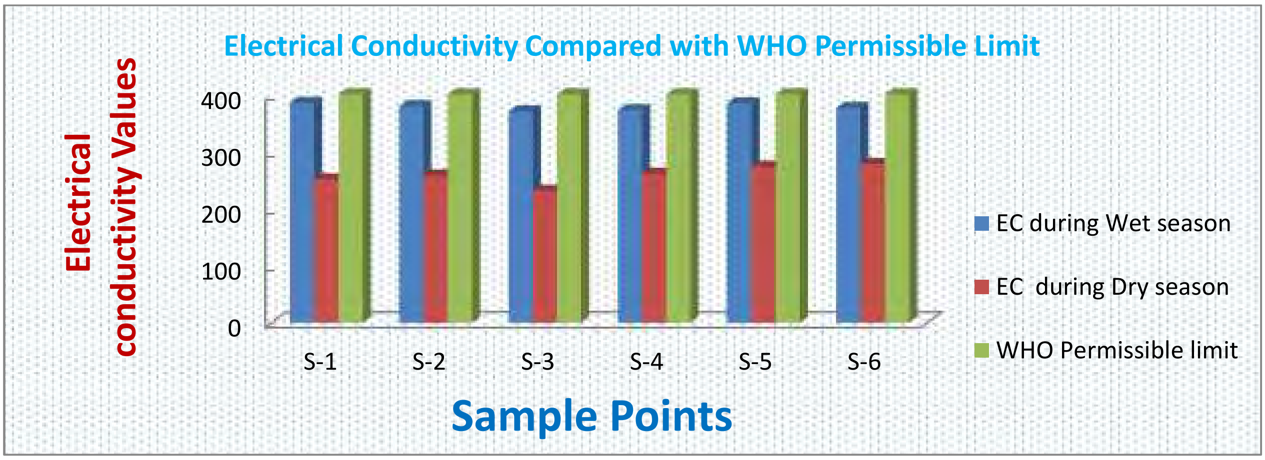


Figure 4-6: Electrical conductivity laboratory results

4.2.6 .Total Dissolved Solids (TDS)

In drinking water, total dissolved solids are primarily made up of in organic salts with small concentrations of organic matter. Contributory ions are mainly carbonate, bicarbonate, chloride, Sulphate, nitrate, potassium, calcium, and magnesium. Major contribution to total dissolved solids in water is due to the natural contact with rock sand soil. Minor contribution toTDS is from pollution including industries wastage and urban run off. The TDS sample tests are considered to determine the general quality of water. The TDS values of Adama Town sample test result in water supply systems during wet season ranges from217 - 237 PPM and during dry season ranges from115- 121ppm, in Adama Town drinking Water. The health risks are not significant as the values of TDS are much less than1000ppm, which is the WHO standard Maximum permissible limit.

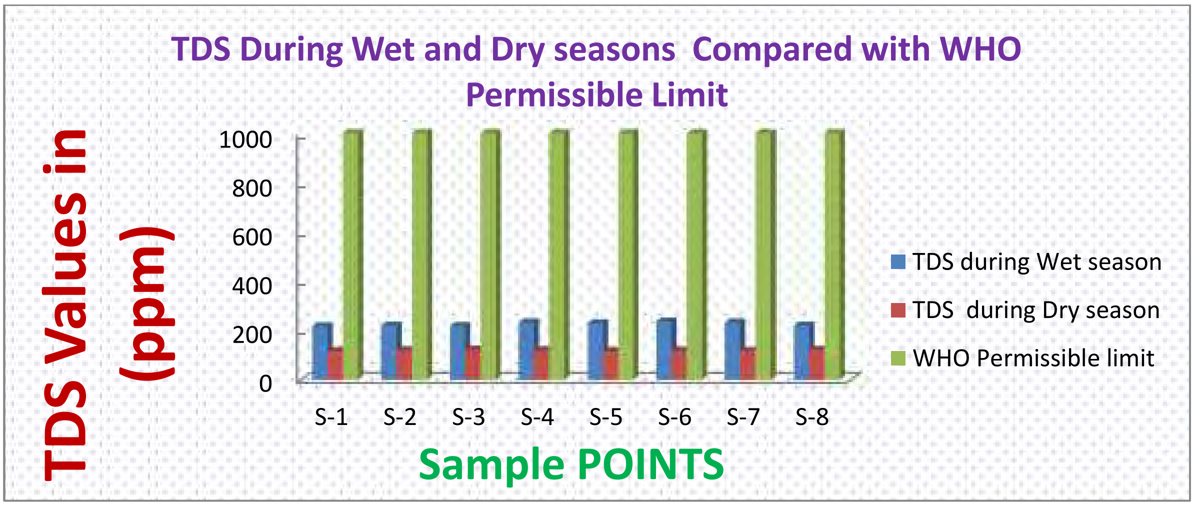


Figure 4-7: Total Dissolved Solids (TDS) Laboratory results

4.3. Heavy Metals Parameters Analysis and results

4.3.1. Copper (Cu)

Copper is a metal that is naturally present in the environment, but the levels of contamination can be increased around agricultural land (compost spreading), near smelting facilities, and phosphate fertilizer plants. There are also significant amounts of copper released from waste water treatment plants, which could lead to problems down stream for a community that uses this water as their source of drinking water. The World Health Organization has established a 2.0mg/l of Copper as maximum permissible limit guidance level in drinking water supply.

The most common health effects of the extreme consumption of copper bearing water would be nausea, vomiting, diarrhea, up set stomach, and dizziness. If extreme in take of copper occurs, kidney and liver damage is possible. Accordingly the laboratory result of the study area were shown in Table 14 page115 on (Appendix), the maximum permissible limit guidance level i.e. less than 2mg/l at all points of sample location. Therefore, there is no health effect regards to this parameters on the customers.

4.3.2. Chromium (Cr^{+6})

Natural occurrence of chromium is in ore, but chromium arises in surface waters from discharges of electroplating, tanning, textile, paint and dyeing plants. Regards to health significance, chromium is toxic, to a degree which varies with the form in which it occurs, whether as the trivalent, Cr^{+3}, or the hexavalent, Cr^{+6}, form. The element is an essential nutritional requirement in limited amounts and its deficiency can lead to disturbance of glucose metabolism. Certainly, it has been reported that chromium deficiency is of greater nutritional concern than over exposure. However, it is considered that the element is cancer-causing at high concentrations, though much more evidence of this is needed, and it can act as askinirritant. Hence, its hould have alimitation in domestic water supplies. The result of watering in chromium-contaminated water might be deaths of livestock. According to the WHO guidance level, the maximum permissible limit in drinking water supply is 0.05mg/l Cr. Consequently, as the samples laboratory results of Adama water supply were shown in Table 15 page116 on (Appendix), at all sample points the maximum result was 0.03mg/l Cr. This value is below the maximum permissible limit.This result indicates that there is no health significance on the community.

4.3.3. Lead

High concentrations of lead in drinking-water can cause severe health effects. The presence of lead in drinking-water is primarily a consequence of lead plumbing and lead-containing metal fittings in buildings. Although lead may be present in source waters, this is unusual except in some mining areas. Generally, lead is not a high priority for routine monitoring programmes because of the variability from place to place, but possible risks posed by lead in drinking-water should be assessed in localities where lead has been extensively used in plumbing materials, particularly if the water supplied is corrosive or is likely to dissolve lead. If lead concentrations significantly exceed guideline values, it may be appropriate to apply mitigating measures, such as corrosion control or replacement of pipes and plumbing materials. When found in drinking-water, lead usually arises from lead pipes and lead solder, mostly from plumbing in buildings. Monitoring is quite difficult and requires samples to be taken at the tap. Assessment of the presence of lead pipes, or the ability of the water to dissolve lead, is the most appropriate management approaches. Monitoring is only considered if significant resources are available. According to the WHO guidance level, the maximum permissible limit in drinking water supply is 0.01mg/l (Pb). Therefore, as the samples laboratory test results of Adama water supply were shown in Table 16 page 116 on (Appendix), at all sample points the maximum result was 0.01mg/l (Pb). This value does not exceed the WHO maximum permissible limit. This result in dicates that there is no health significance on the community.

4.4. Chemical Analysis

4.4.1. Calcium (Ca^{2+})

Calcium is one of the alkaline earth elements, fifth in abundance in the earth‟scrust (3%), reacts with water essential basic of bones and teeth. The most common compounds of calcium are limestone ($Caco_3$), gypsum ($CaSo_4.2H_2O$), fluorite (CaF_2), hypochlorite ($Ca(ClO)_2$) and nitrate ($Ca(NO_3)_2$). Since there are no, or very limited, standards propagated for calcium in drinking water because of no toxicity concern. According to WHO guidance, the maximum permissible limit of calcium, in drinking water quality is limited to 75mg/l for internationally acceptable value and 200mg/l as an excessive limit.

Calcium in drinking water supply has not been associated with any specific disease, and then an upper limit as a guide may be used, such as 75mg/l in relation to hardness.The sample laboratory test result of Adama Town Water supply with all sample points of the location. The maximum permissible limit set by WHO guide level, i.e. the result range was between 21-38mg/l of calcium. This indicates that the source of water is almost soft water and there is no any health effect on the comminuty.

4.4.2. Alkalinity

Alkalinity is a measure of the ability of water to absorb hydrogen ions with out significant pH change. Simply stated, alkalinity is a measure of the buffering capacity of water and is thus a measure of the ability or capacity of water to neutralize acids. The major chemical elements of alkalinity in natural water supplies are bicarbonate, carbonate, and hydroxyl ions. These compounds are mostly the carbonates and bicarbonates of magnesium, and calcium. These constituents originate from carbondioxide (from the atmosphere) and occurring as a by-product of microbial decomposition of organic material or minerals primarily from chemical compounds dissolved from rocks and soil.

The concentration of alkalinity varying from5 to125mg/l is expected, and extremes of these values are tolerated in water supplies. Titration with Sulpheric acid or other strong acids determine total alkalinity. According to the potability of drinking Water set by WHO standard guide line the maximum permissible allowable limit should not be exceeded 200mg/l of $CaCo_3$. The Total alkalinity assessment of the Adama TownWater Supply samples laboratory test results shows that it varies from 121 to 145mg/l of $CaCo_3$ as shown in Table 17 page116 on (Appendix). These results show that in all points of sample results less than the maximum permissible allowable limit values of World Health Origanization. Thus, there is no significance harm effect on human health.

4.4.3. Total hardness

Hardness may be considered as a physical or chemical parameter of water. It represents total concentration of Calcium and Magnesium ions. Originally, hardness was examined and evaluated in raw water sampling as an indicator of water quality in terms of precipitating soap. In this measurement, Calcium and Magnesium are the major precipitating ions. In other words, “hard”water requires more soap to produce foam or lather. The other negative aspect of hard water versus softwater is the natural capacity of hard water to produce scale in hot water pipes, boilers and heaters. Therefore, surface raw water is softer than ground water because of more rains, less contact with soil minerals. From a practical point of view, the degree of hardness can be interpreted as follow: Hardness is a natural feature of waters, reflecting calcium and magnesium, as carbonates, bicarbonates and sulfates. It is normally very stable and would only require analysis if there was concern about scale formation in distribution network and in plumbing. Low hardness may be a consideration if assessing the level of plumbing-related metals in water at the tap.

Table 4-11: Summary of hardness and softness categorize range (Source: Dezuane, 1996)

No	Range of Concentration (mg/l)	Categorized of hardness
1	0 - 50	Soft Water
2	50 -150	Moderately hardness
3	150-300	HardWater
4	More than 300	Very hard Water

According to WHO guideline, the maximum permissible limit of total hardness should not be exceeded 300mg/l as $CaCo_3$. The Adama Town Water Supply samples laboratory test results shown inTable 18 page117 see (appendix) so that the values range between 116mg/l and145mg/l of CaCo3. Consequently, the degree of hardness of the Adama Town water supply can be categorized as soft and moderately softwater, which is not harm ful for consumers according to the World Health Origanization standards.

4.4.4. Iron

Iron is the fourth most a bundant element in the earth‟scrust. Iron is a very common problem in drinking water and has a strong relationship with water hardness typically with both hardness and iron increasing at the same time. Iron can cause discoloration (laundry and plumbing), unpleasant taste, color and promotion of growth by iron bacteria. Iron can also precipitate in distribution systems and house hold plumbing there by causing additional problems.When there is no oxygen in the water then the iron is present in a reduced, dissolved form (Fe^{2+}), which is frequently present in well water. This form of iron is dissolved and has no color. When this iron is exposed to oxygen it will oxidize and this iron (Fe^{3+}) is not very soluble and instead forms small particles or colloids. These rus tparticles are red in color and are quite small making it a challenge to remove them.Both sedimentation and filtration is commonly used methods to remove oxidized iron.Based on aesthetic reasons the WHO Guide lines Drinking Water Quality recommended that their on levels should be kept below 0.3mg/l. However, the Adama Town Water Supply Samples laboratory test results were shown in figure 4-8 and the values were not exceeded the WHO maximum permissible limit value. But the concentration of iron result was equal to the WHO maximum permissible limit value so need some adjustment and also Iron result was increasing during Wet season than that of dry season. This implies that naturally their on concentration of the source high concentration of iron and in very old galvanized pipes of water distribution system. Even though Adama Town Water Supply was aware of this problem and to minimize the concentration of the iron in the Water distribution system with in permissible limit by replacing galvanized pipes with HDPE pipes and PVC pipes before distributed water to the cosumer.

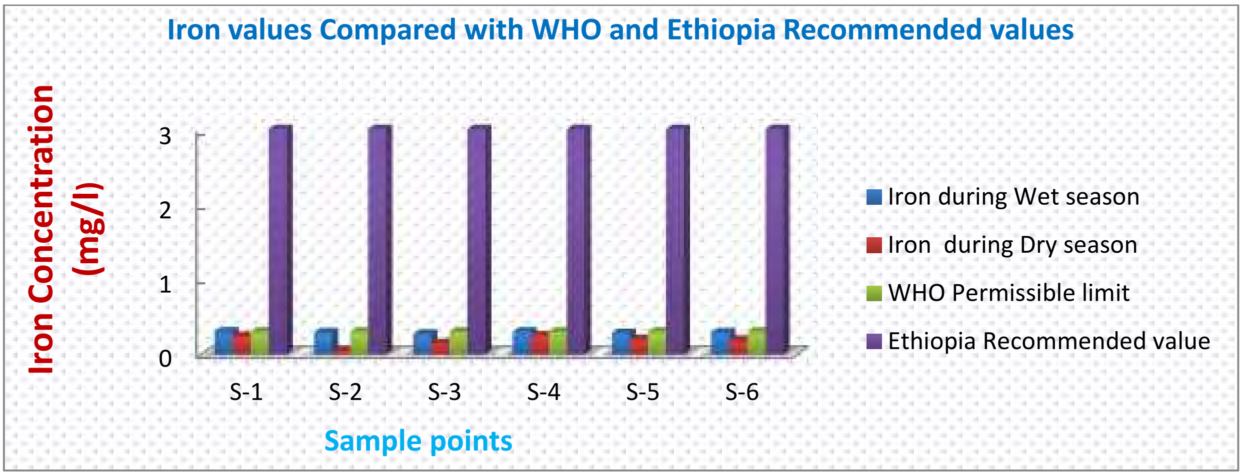


Figure 4-8: The Iron Concentration during Wet and Dry Seasonsas Compared with WHO Maximum Permissible Limit.

4.4.5. Manganese

Manganese is a gray is hard white metal similar to iron. Drinking water guide lines for manganese are set for aesthetic reasons as manganese can stain plumbing and laundry as well a stelling taste and odor to the water. Manganese containing water can react with coffee, tea and even alcoholic drinks producing a black sludge affecting both taste and appearance. According to WHO guideline the maximum permissible limit of manganese concentration in drinking water quality should not exceed 0.5mg/l. The laboratory results were shown inTable 19(page 117) (Appendix) and the values were below the maximum permissible limit values in distribution system for the Adama Town Water Supply sample test results; which was found between th eranges of 0.23-0.45 mg/l of Mn.

4.4.6. Nitrate (NO^{3-})

Nitrate (NO_3) is a compound of nitrogen and oxygen that is found in many every day food items such as spinach, lettuce, beets, and carrots. There are usually low levels of nitrates that occur naturally in water but the majority run-off from, animal feed lots, waste water and sludge, septics ystems, and nitrogen fixation from the atmosphere by legumes, bacteria, and lightning. Nitrate in water is color less, taste less, and odorless. Therefore, it can only be detected using chemical analysis as previously explained in methodology section. Generally, the ground water has high nitrate concentration than surface water because of the percolating sewage, industrial waste, chemical fertilizers, leaches from solid waste land fills, septic tank effluents to the ground water.What ever may be the reason the high concentration of nitrate is harmful to human beings, particularly for in fants.The low acidity in the infants in test in epermits the growth of nitrate reducing bacteria that converts the nitrate to nitrite that is the absorbed in the blood stream. The nitrite has a great attraction for hemoglobin than the oxygen and itreplaces oxygen in the blood. The deficiency of oxygen causes suffocation.

The coloroftheskinofthebabiesbecomesbluesoitistermedasbluebabydisease.Themedical name is mathemoglobinemia‷. This disease is a fatal disease and it takes splace when the Concentration of nitrates is more than50 mg/l according to WHO guideline. Figure 4-9 show that the Nitrate concentration during wet and dry seasons. The results show in both seasons the values of nitrate concentration is below the recommended WHO and Ethiopia guidelines recommended values. The result also in dicates that nitrate concentration duringWet season is greater than the nitrate concentration during dry season. This can be due to the draining of domestic sewerage and agricultural run off to the Awash River which is the Adama Town Water supply source.

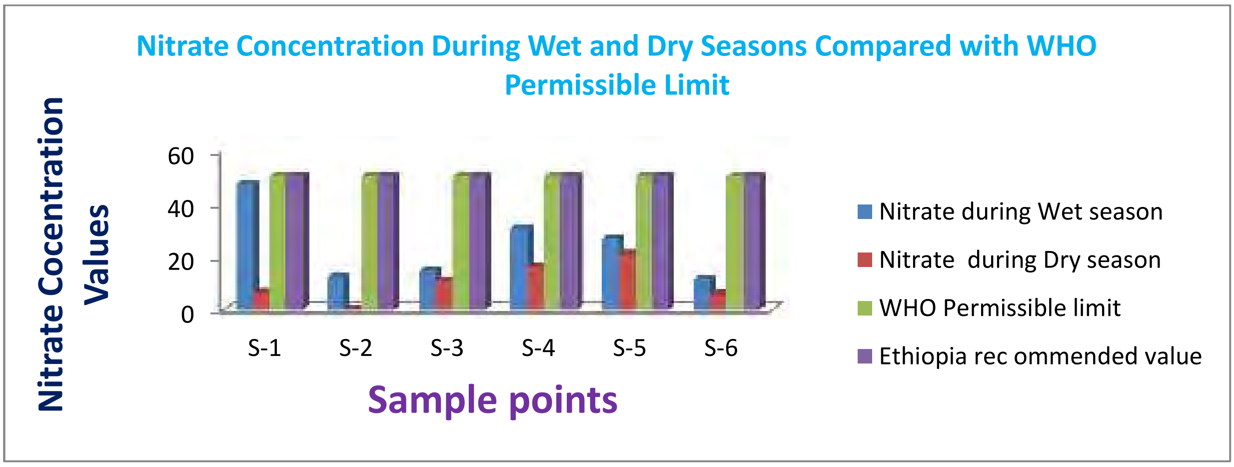


Figure 4-9: The nitrate concentration during Wet and Dry Seasons

4.4.7. Sulphate ($SO4^{2-}$)

Sulphur is a non-metallic element that is widely used for commercial and industrial purposes. Sulphur combines with oxygen to form the sulphate ion, SO4. Sulphate products are used in the manufacture of many chemicals, dyes, soaps, glass, paper; fungicides, insecticides, and several other things.They are also used in the mining, pulp, sewage treatment and leather processing industries. Aluminum sulphate (alum) is used in water treatment as a sedimentation agent, and copper sulphate has been used to control blue-green algae in raw and public water supplies. Drinking water with excess sulphate concentrations of ten has a bitter taste and a strong “Rotten-egg” odor. Sulphate can also interfere with disinfection efficiency by searching residual chlorine in distribution systems.Sulphate salts are capable of increasing corrosionon metal pipes in the delivery system and sulphate-reducing bacteria may produce hydrogen sulphate, which can give the water an unpleasant odor and taste and may increase corrosion of metal and concrete pipes.

There are no symptoms associated with sulphate deficiency. However, most people get the majority of their dietary sulphate through food and not from the water. High sulphate levels (1000 mg/L) have been shown to have a laxative effect on humans and can cause mild gastrointestinal irritation http://dx.doi.org/10.4236/eng.2013.51015 published on line January 2013 (http://www.scirp. org/journal/ eng) .

According to WHO (2012) guidance level the maximum permissible limit of sulphate in drinking water supply is limited to 250mg/l. Accordingly, the Adama Town Water Supply samples laboratory test results of all points location were shown in Table 20 (page117) (Appendix), and the values were less than the maximum permissible limit set by WHO.Then, the results clearly indicate that there is no significance effect on the health of the users.

4.4.8. Chloride

Chloride can originate from natural and human-made sources, such as sewage and industrial effluents. Where salt is used for de-icing, chloride can contaminate groundwater through road drainage.Upland and mountain water supplies are usually low in chlorides; whereas, concentrations are generally higher in rivers and groundwater. The main operational issue forchloride is its ability to increase the corrosiveness of water, particularly in low alkalinity water. High concentrations of chloride may result in a detectable taste in water, but consumer acceptability varies widely depending on the form of chloride (e.g. NaCl, KCl and CaCl2). Should monitoring be necessary, this would usually be at the treatment works. The frequency would depend on the variability in the source water, but would normally be low. Chlorides are compounds of chlorine.

They remain soluble in water, unaffected biological process, therefore, reducible by dilution. High chloride concentration damage metallic pipes and structure as well as harms growing plants. According to WHO standards, the concentration of chloride should not exceed 250 mg/l. In Adama Town Water Supply samples the chloride concentrations of the laboratory test results were ranging from 5.4- 49mg/l. Therefore, all the samples have lower concentration of chloride maximum permissible limit value set by World Health Origanization guidance level.

4.4.9. Fluoride

Fluoride is essential for human beings to fight against dental caries. The desirable concentration is 1mg/l, if it is more than this it proves to be harmful. Fluoride concentration of more than 3mg/l is not allowed in potable water in any case. As per WHO, the fluoride concentration should not be more than1.5mg/l. actually the higher concentration of fluoride leads to the discoloration of teeth known as dental fluorosis. The more dangerous is the deformation of the Skelton. In the study area, the fluoride concentration was ranging between 0.02-0.74mg/l, which is below the maximum permissible limit value set by World Health Origanization guidance level in surface water. As a result, clearly observed values from the study area there is no health effect of fluoride on the community that use the water.

4.4.10. Magnesium (Mg^{2+})

Magnesium is a light, silver-white, malleable, ductile, metallic chemical element; it is the eight most abundant elements in the earth'scrust, never found as a free element. Magnesium has been considered as non-toxic to humans at the concentration expected in water or not rejected by taste. Magnesium has been used in flash light photography, alloys, pyrotechnics, and incendiary bombs. In medicine, magnesium is known as "milk of magnesia" as a hydroxide or as "EpsomSalts" as a sulfate. In addition, it is a nutritional element in animal and plant life. According to WHO International Standard of Drinking Water (1963), the list of the maximum acceptable level is 50mg/l and a maximum allowable level is 150 mg/l. Eventhough, magnesium concentration was expected in raw and finished water supply system between range 1.8-62mg/l, and 0.8-49mg/l respectively (DeZuane, 1996). The AdamaTownWater supply samples laboratory test were found between the range of 14 -48mg/l of (Mg^{+2}) and these values is less than the maximum acceptable level set by World Health Origanization.

4.4.11. Potassium (K^{+})

A soft, light, sliver-white, wax like, metallic, common chemical element of the alkaline groups, similar to sodium that oxidizes rapidly when exposed to air. Potassium is the seven the most abundant element and establishes 2.4% by weight of the earth' scrust. It is never exist free in nature and most potassium minerals are in soluble. In drinking water supply, tap surveys indicated values of potassium ranging from a minimum of 0.5mg/l to a maximum of 8mg/l with an expected mean concentration of 2mg/l. According to the WHO, the maximum permissible limit value for potassium is limited to 1.5mg/l. The Adama Town Water Supply sample laboratory test results of potassium concentration at all sample points of the location were found between the ranges of o.5 - 1.4 mg/l this is below the maximum permissible limit values set by World Health Origanization.

4.4.12. Phosphate ($PO4^{3-}$)

Drinking water supplies may contain phosphate derived from natural contact with minerals or through pollution from application of fertilizers, sewage and industrial wastes. The significance of phosphorus is principally regard to the phenomenon of eutrophication (over-enrichment) of lakes and, to a lesser extent, rivers. Phosphorus gain in gaccess to such water bodies, along with nitrogen as nitrate, promotes the growth of algae and other plants leading to Blooms. Phosphorous concentration in raw water has been reported to be 50% of the samples tested, with mean concentration of 0.12mg/l and maximum of 5mg/l. But the WHO also did not issue regulations or guide lines for phosphorus, but European community (1980) is sued a guide number of 0.4mg/l and a maximum of 5mg/l measured as P2O5 (DeZua D.P.Gupta&J.P.Saharan, 2009) ne, 1996).

The laboratory results of phosphate of the study area were shows according to (DeZuane, 1996) below the maximum a acceptable limit, especially from raw water to treatment plant. This concentration of phosphate result might be due to location. Of the source own stream of the Town and lack of properly sewerage control system in the Town as previously explained in the description of the study area in this paper.Figure 4-10 shows that the phosphate concentration during wet and dry seasons. During the Wet season near to the maximum permissible, limit. This can be due to the draining of domestic sewerage and agricultural run-off to the water supply source located at up stream of the Awash River.

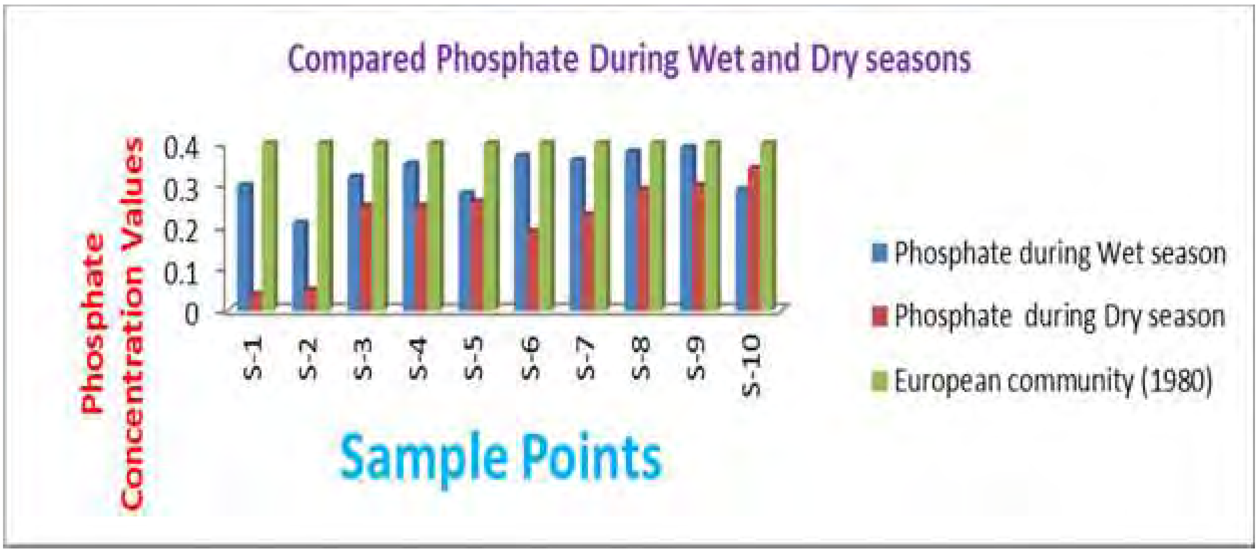


Figure 4-10: The Phosphate concentration during Wet and Dry Seasons.

4.4.13. Sodium (Na+)

Sodium can be found in drinking-water at concentrations in excess of 20 mg/l as a consequence of the use of more saline waters. There is no indication of health effects in the general population associated with high sodium levels in drinking-water, although such water may not be suitable for bottle-fed infants. Concentrations in excess of 200 mg/l may give rise to taste problems. Routine monitoring for sodium is unlikely to be a high priority.Sodium salts (e.g. sodium chloride) are found in practically all food (the main source of daily exposure) and drinking water. According to the WHO, the maximum permissible limit value for Sodium is limited to 200mg/l and the Ethiopian maximum permissible limit value for Sodium is limited to 358mg/. The Adama Town Water Supply sample laboratory test results of Sodium concentration at all sample points of the location were found between the ranges of 42 - 80mg/l this is less than the maximum permissible limit values set by World Health Origanization.

4.5. Dissolved Oxygen (DO)

Dissolved oxygen is included as an indicator parameter. It can be measured in the field using a dissolved-oxygen electrode. The dissolved-oxygen content of water depends on its source, temperature, and chemical and biological processes taking place in the water distribution system. Therefore, measurements can only be used in a relative, not an absolute, sense. However, large declines in dissolved oxygen in a water source could indicate high levels of microbiological activity, and should generate further sampling for microorganisms. Dissolved oxygen is not usually a candidate for routine monitoring unless a specific problem is recognizedRaw water evaluated for potential use as a drinking water supply normally sampled, analyzed, and tested for biochemical oxygen demand when water turbid, polluted water is the only source available. Therefore, the Adama Town Raw water sources Dissolved Oxygen as obtained from the laboratory result is found between the ranges of 2.43mg/l-5.47mg/l at all sample points of location See Table10, on Appendix page114.

4.5.1. Biochemical Oxygen Demand (BOD)

BOD was defined as the amount of dissolved oxygen demanded by bacterial during the stabilizationaction of the decomposable organic matter under aerobic conditions. This test, therefore, is abioassay procedure to measure the oxygen consumed by living organisms utilizing the organic matter contained in the sample more likely of waste water and the dissolved oxygen of the liquid. The BOD test is based up on determination of dissolved oxygen.

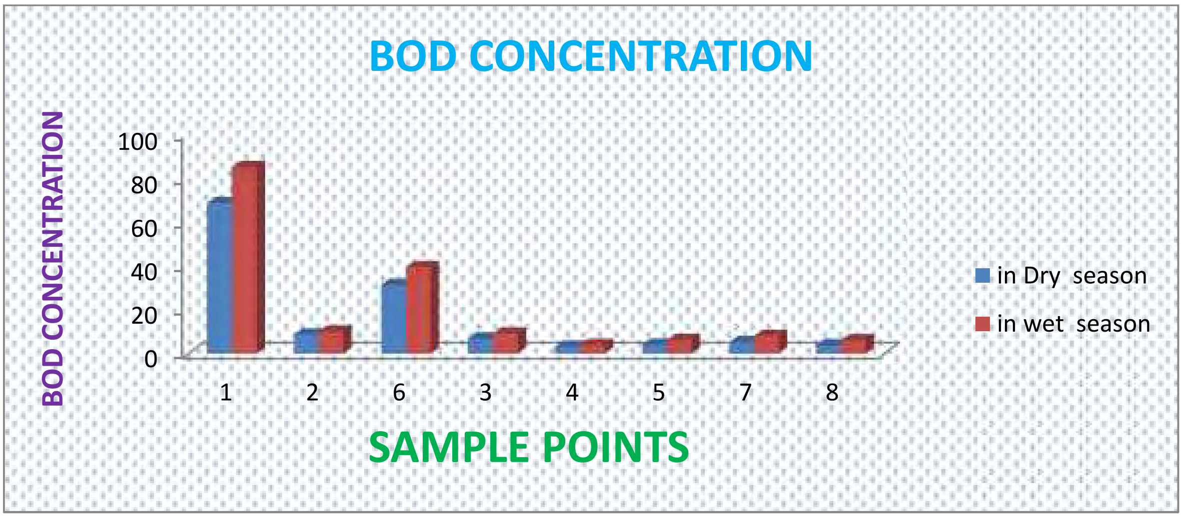


Figure 4-11: BOD concentration during Dry and Wet Season Seasons.

Most river water used as water supplies has a BOD of less than 7mg/l; therefore, dilution is necessary. According to DeZuane (1996), a BOD test isnot required for monitoring water supplies. However, in this study the determination of BOD was required because of the Sewerages and Industries wastes discharge in to Awash River. The BOD concentration laboratory results decreases from the source to the distribution system as shown in Table11on page 114 (Appendix). In addition, the concentration of BOD is higher during Wet season than during dry season at the source.

4.5.2. Chemical Oxygen Demand (COD)

This is another parameter not requested form on it oring water supplies but some times used for evaluation of industrial polluted raw water. Extremely use ful in the determination of industrial wastes, and very practical in the determination of domestic waste and polluted waters. COD determination"provides a measure of the oxygen equivalent of that portion of the organic matter in a sample that is susceptible to oxidation by strong chemical oxidant such as potassium dichromate standard method "(DeZuane,1996).The COD values are greater than the BOD values, but its handicap is the in ability to show difference between logical oxidizable and biologically inert organic matter .Since COD can be in 2hours versus the five day of BOD, sometimes COD for substitute the BOD test practically. As the result of the study area of COD test concentration were shown in Table12 on page115 (Appendix), the concentration from source to the distribution system was decreased and greater than concentration of BOD test.

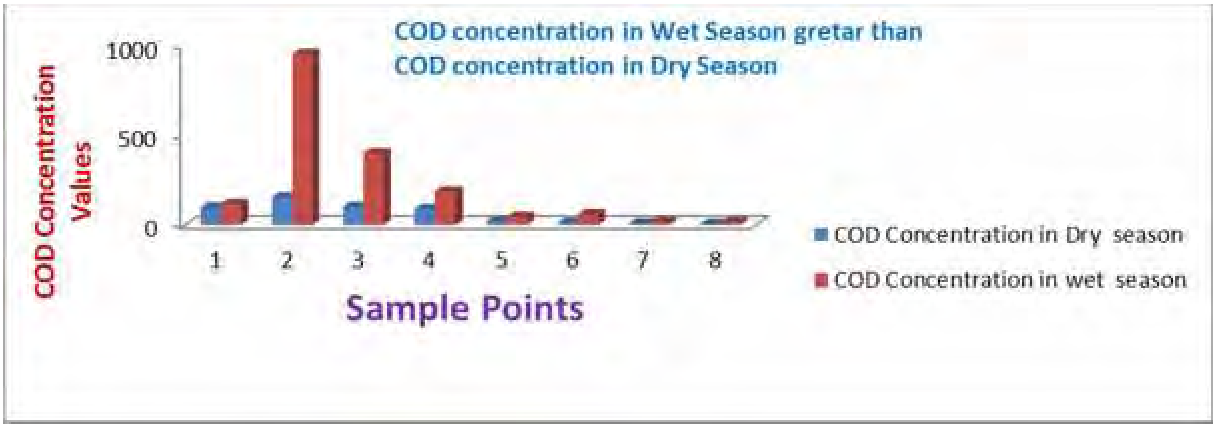


Figure 4-12: COD concentration during Dry and Wet Seasons

4.6. BottleTest

The bulk coefficient has to be determined by performing bottle test in laboratory. Since the test was entirely focused on changes observed in residual chlorine at time due to reaction with in the bulk water, collecting sample from all part of the distribution system was not required. Only one main entrance locations were selected. Accordingly, samples were collected random sampling method from the Water distribution system. Tests for bulk coefficient determinations were conducted in three (3) test periods. Basically three test periods were preferred in order to avoid possible error and make sure that the result of each test is almost the same. Three test samples were collected for each test period and measurements were taken starting from collection time. Then samples were brought to laboratory and stored in complete darkness with temperature held constant that is by keeping the sample in the dark room being protected from direct sun light. The samples were pulled at designated times and measured which provides the experimental result for all tested samples.

The first table contains three test results for samples collected from Adama Town water tank. Similarly these conductable contain results for samples collected in the second period. The third table contains the results for samples collected from same locations.For hydraulic analysis, simulation time step was 1 minute intervals over a 24 hour period. Along with hydraulic analysis, waterage and there by retention time was determined by setting initial estimates of waterage in reservoirs and tanks. The calculated waterage was used to fix maximum hour to run bottle Determine bulk reaction coefficient; Water samples were stored in severalamber bottles and kept at constant temperature. At several periods of time, a bottle was selected and analyzed for free Chlorine .At the end of the test, the natural logarithms of the ratio of measured chlorine to initial chlorine (Ct/Co) values were plotted against time. The rate constant was the slope of the straight line as shown in the following Figures36. Based on the test result presented in the figures 4-13, were plotted using the ratio of concentration at any time (Ct) to initial concentration (Co) as ordinate and time as abscissa. At the end of the test the natural logarithms of the ratio of measured chlorine to initial chlorine (C_t/C_o) values were plotted against time.The rate constant was the slope of the straight line. Therefore, the first bottletest, second bottle test and third bottle test of the slope of line is -0.376, -1.832, and -0.296, respectively.

- K_b = the bulk reaction coefficient shows that the decay of chlorine in system

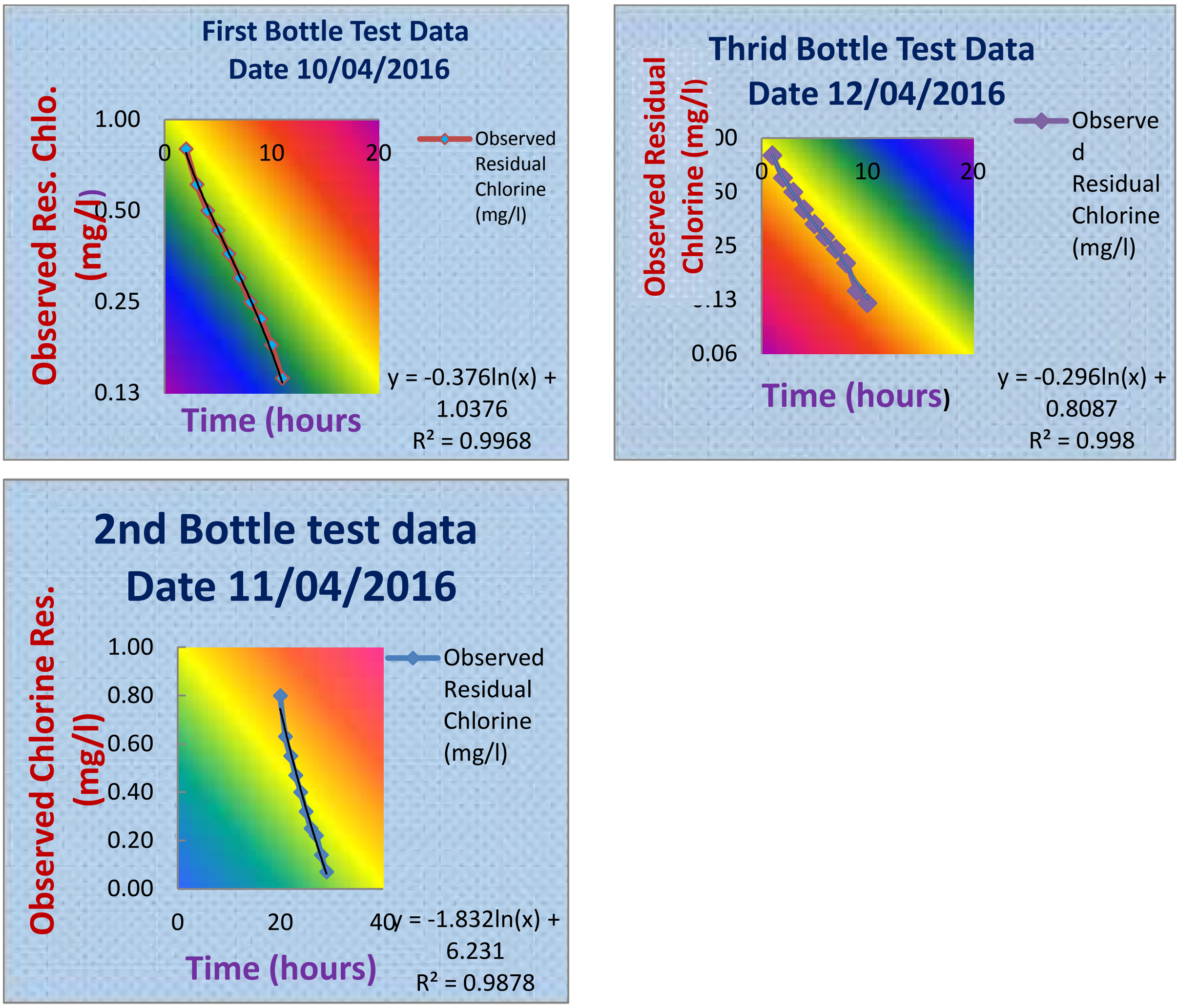
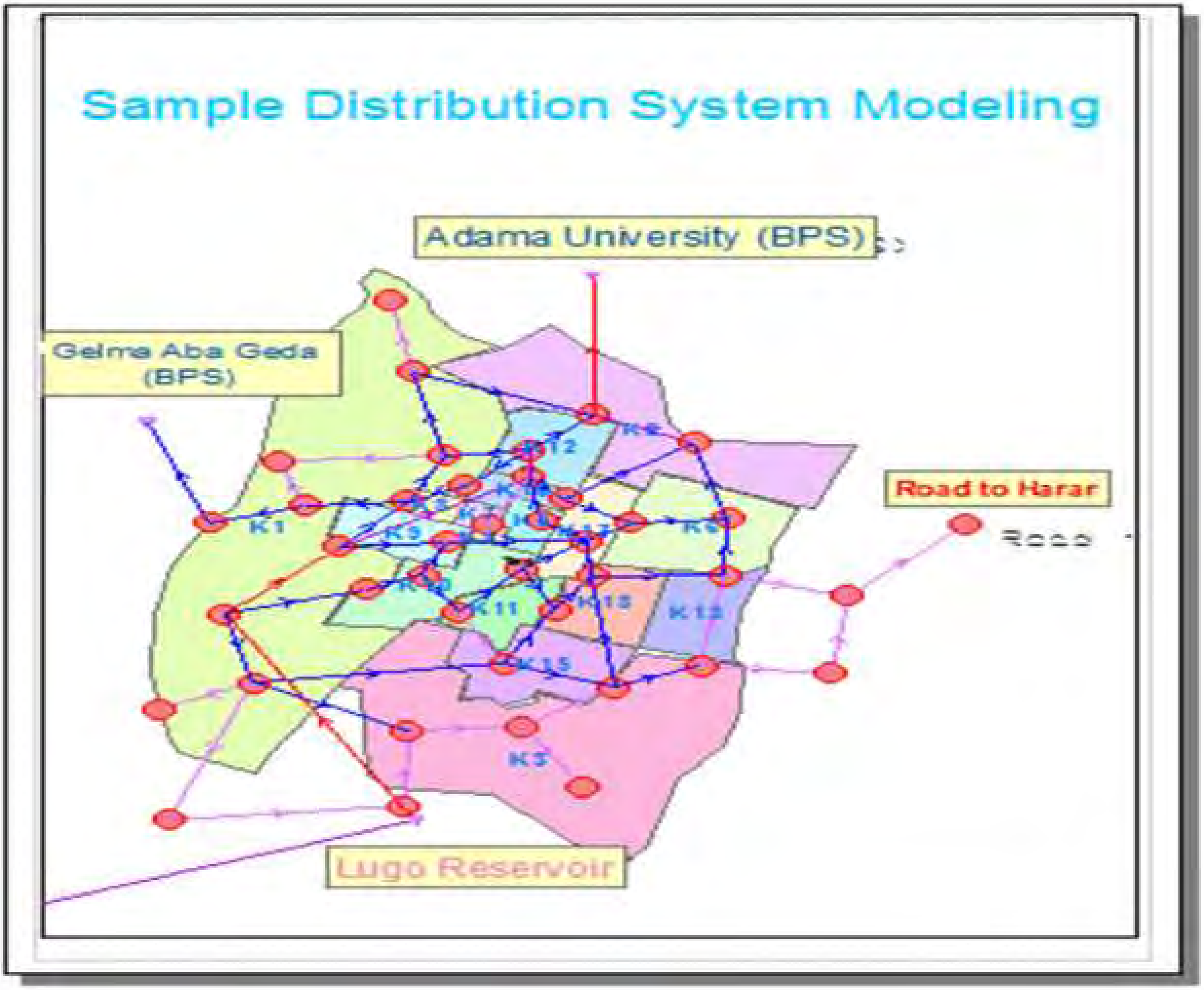
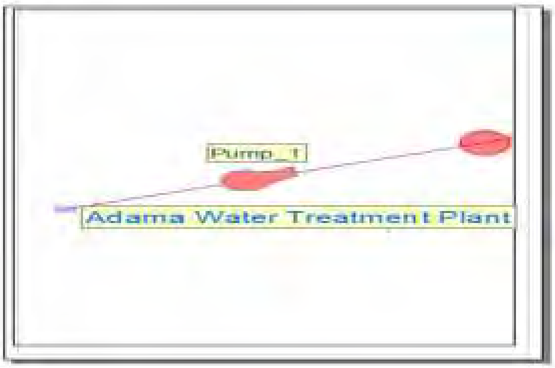


Figure 4-13: Plot of residual chlorine 3Bottles tests.

4.7. Adama Water Transmission main and Distribution system Modeling

Adama Water Supply system maps are drawn as combination of various system components enclosed in water distribution system. It is common to include: Reservoirs, Tanks, Pipes, Pumps and Valves as much as possible and the resulting sketch fairly represent the actual water network. With little difference the real water distribution system represented as combination of nodes and links. Junctions, Reservoirs and Tanks are usually referred as nodes. Pipes, Pumps and Valves are categorized as links. For the majority of water distribution models, calibration is an iterative procedure of parameter evaluation and refinement, as a result of comparing simulated and observed values of interest. Model validation is in reality an extension of the calibration process. Its purpose is to assure that the calibrated model properly assesses all the variables and conditions which can affect model results, and demonstrate the ability to predict field observations for periods separate from the calibration. Hydraulic behavior refers to flow conditions in pipes, valves and pumps, and pressure/head levels at junctions and tanks.





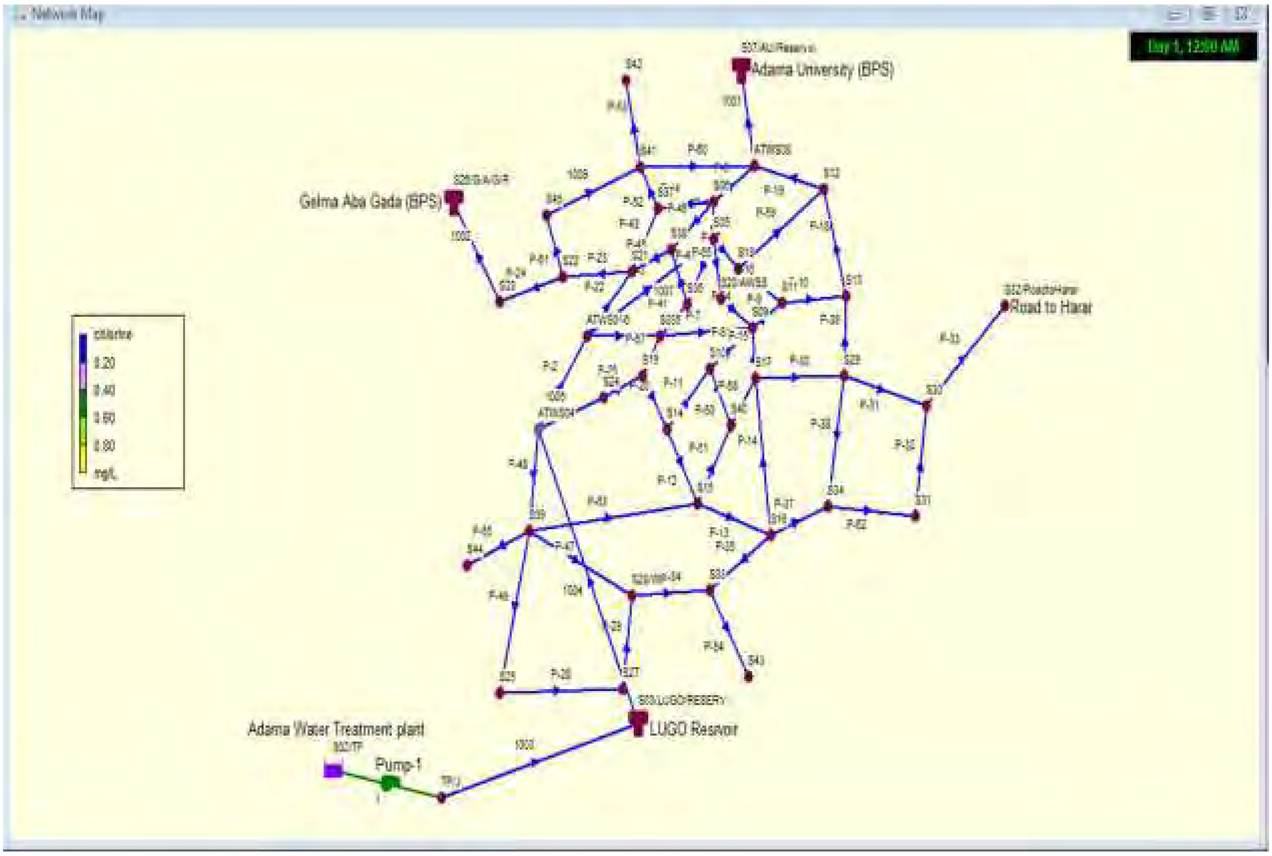


Figure 4-14: Adama Epanet Model Set up Transimission main and distribution network.

4.8. Water Quality, Hydraulics (Pressures) Model calibration and validation

4.8.1. Model calibration and validation

The majority of water distribution models, calibration are a procedure of parameter evaluation and modification, as a result of comparing simulated and observed values of interest. Model validation is in reality an extension of the calibration process. Its purpose is to assure that the calibrated model properly evaluates all the variables and conditions which can affect model results, and demonstrate the ability to forecast field observations for periods separate from the calibration.

The Epanet Model was calibrated by adjusting sensitive parameter such as Hazen Williams's coefficient. Forty five (45) observed pressure data were collected at public fountains, distribution reservoir, customer tap point, institution tap point, and commercial tap points. These pressures, tank level and flow data were taken at both peak hourly demand and minimum hourly demand (mid night). Model validation is in reality an extension of the calibration process. It is used to assure that the calibrated model properly assesses all the variables and conditions, which can affect the model results, anddemonstrate the abilityto forecast field observations different dataset.

The hydraulic model calibration parameters that are typically set and adjusted include pipe roughness factors and Control valve setting. The change in these parameters affect shead losses, demand set node, pressure and residual chlorine. The result shows that when the Hazen-Williams roughness coefficient increases the value of pressure increases and head losses decreases.The importance of a model is simply evidentifamodelresultprecisely reflectsobserved field values. Thus, to have a confidence on model result it needs to calibrate andvalidate a model.

4.8.2. Water QualityModel Calibration

The water quality model calibration has to be executed independently. To this effort data sets were collected from different part of water distribution system. An effort to water quality model calibration as guide line recommends: average error of roughly 0.1 to 0.2 mg/l. The software can make each pipe's K_W be a function of the coefficient used to describe its roughness where *C*= Hazen-Williams C-factor, *e* = Darcy-Weisbach roughness = diameter, *n*= Manning roughness coefficient, and *F*= wall reaction-pipe roughness coefficient. The coefficient F must be developed from site-specific field measurements and will have a different meaning depending on which head loss equation is used. The advantage of using this approach is that it requires only a single parameter, F, to allow wall reaction coefficients to vary through out the network in a physically meaning ful way.

Table4-12: Pipes roughness group

Group	Range	C - value taken
Group 1(G.S.P)	(100-130)	120
Group 2(D.C.I)	(110-140)	130
Group 3(u-PVC)	(140-150)	140

Source: C-factors for various pipe materials, based on Hazen-Williams C-factor.

Wall reactions depend on the bulk conditions, pipe dimensions (i.e., pipes with smaller diameters encourage greater solution/wall interaction and therefore greater reaction rates), and pipe wall conditionThe dependency of K_w and the reaction order on pipe material and condition (i.e., age, encrustation and corrosion) makes determining the coefficients difficult. Although conceptually K_w may be measured under ideal conditions (i.e.,long isolated pipes, no connections, controlled flow, in line chlorine measurements), In real- world conditions such measurements are in feasible and therefore, models generally incorporate a calibrated K_w with initial estimates based on pipe roughness coefficients, flow velocity, and pipe diameter, This approach is practiced widely in the industry because wall decay coefficients vary greatly due to pipe condition (material, roughness, corrosion, and biofilms) and can not be measured directly with in the distribution systems, but estimated by the following relation.

$R(C) = A/V * K_w * C^n$ 2.18

Where K_w= wall reaction coefficient

A/V =surface area per unit volume with in a pipe.

The values for wall reaction coefficients are in the range of 0 to 5ft/day (0 to 1.5m/day). Because these values are difficult to measure, estimates can be based up on field concentration measurements and water quality simulation results as part of a calibration analysis. Postulated that the wall reaction coefficient is related to pipe roughness according to the following equation:

$K_w = \alpha/Cc$..2.19

WhereK_w = wall reaction coefficients

α=correlation coefficientswhich is constant value

Cc=adjusted roughness value

The models hould reproduce the pattern of observed disinfectant concentrations over the time samples were taken to an average error of roughly 0.1 to 0.2mg/l. Subsequent to the proper calibration of a hydraulic model, additional calibration of parameters in a water quality model may be required.The following parameters are used by water quality models that may require some degree of calibration:

- Initial Conditions Defines the water quality parameter (concentration) at all locations in the distribution system at the start of the simulation.
- Reaction Coefficients: Describes how water quality may vary over time due to chemical,
- Source Quality: Defines the water quality characteristics of the water source over the time period being simulated

4.8.3. Residual Chlorine Calibration and Validation

Chlorine disinfectant models, the model should reproduce the pattern of observed disinfectant concentrations over the time when the samples were taken to an average error of roughly 0.1 to 0.2mg/l.The water quality model calibration has to be performed independently.To this effort data sets were collected from different part of water supply distribution networks. Table 4-13 and Table 4-14 show an effort to water quality model calibration as guideline recommends having an average error of roughly 0.1 to 0.2 mg/l (Thomas et al. 2003).

The residual chlorine was calibrated by adjusting Hazen Williams's roughness coefficient. Initially the value of Hazen Williams's roughness coefficient in the system was 140 for PVC, 100 for galvanized iron pipe, and110 for DCI pipe. The corresponding value of residual chlorine decreases in the pipe networks from distribution reservoir to point of use. This implies that the wall reactions materials of pipe increases.

Table4-13: Water quality model calibration for first data sets.

S.No	Time (Hours)	Location of SamplePoints			Nodes	Observed Residual chlorine (mg/l)	Computed Residual chlorine (mg/l)	Differences
		X(m)	Y(m)	Z(m)				
1	20:00	530640	945072	1646	ATWS 03	0.43	0.35	-0.08
2	21:00	527759	944712	1625	AWTS05	0.30	0.18	-0.12
3	22:00	528800	944749	1626	ATWS 06	0.16	0.05	-0.11
4	2300	528665	941719	1626	ATWS 07	0.25	0.18	-0.07

5	24:00	528832	944230	1622	ATWS 08	0.17	0.24	0.07
6	25:00	530588	943943	1620	ATWS 09	0.21	0.33	0.12
7	26:00	530094	942655	1620	ATWS 10	0.28	0.23	-0.05
8	27:00	526832	940536	1620	ATWS 11	0.34	0.21	-0.13
9	28:00	528832	944230	1622	ATWS 12	0.13	0.33	0.20
10	29:00	531687	943970	1603	ATWS 13	0.18	0.30	0.12
							RMS	**0.154**

Table 4-14: Water quality model Validation for Second data sets

S.No	Location of Sample Points			Calibration statistics for Residual chlorine				
	X(m)	Y(m)	Z(m)	Time (Hours)	Nodes	ObservedResidual chlorine(mg/l)	Computed Residual chlorine (mg/l)	Differences
1	526891	943400	1690	1:00	ATWS 03	0.8	0.67	-0.13
2	529931	945125	1632	2:00	ATWS 05	0.3	0.15	-0.15
3	529943	945427	1640	3:00	ATWS 06	0.3	0.13	-0.17
4	530600	948142	1670	4:00	ATWS 07	0.25	0.11	-0.14
5	529638	944478	1633	5:00	ATWS 08	0.27	0.11	-0.16
6	529852	944429	1631	6:00	ATWS 09	0.13	0.19	0.06
7	529801	944442	1632	7:00	ATWS 10	0.23	0.12	-0.11
8	530640	945072	1646	8:00	ATWS 11	0.21	0.15	-0.06
9	530634	945083	1644	9:00	ATWS 12	0.23	0.2	-0.03
10	531685	944664	1635	10:00	ATWS 13	0.3	0.19	-0.11
							RMS	**0.169**

As shown in Table 4-13 and Table 4-14 after adjustment of C-value of higher values of the truck mains the computed values are with in an average RMS error of 0.154 mg/l and 0.169 mg/l to observed values. Hence, the model is well calibrated.

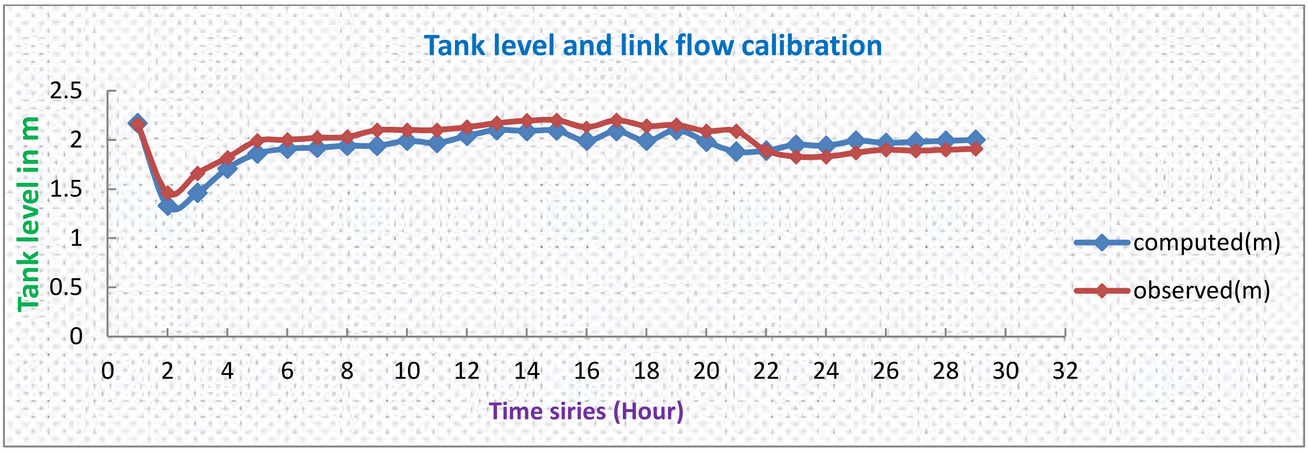
4.8.4. Calibration and Validation using Time-Series Datas

According to a vital step in calibrating and validating an extended-period simulation is to compare time-series field data to model results. If the field data and model results are acceptably close, the model is calibrated. If significant variations exist, Adjustments can be made to various model parameters in order to improve the match. Ideally, one set of data should be available for calibration, and another set of data should be available to validate that the model is properly calibrated. Hydraulic measurements, water quality data, and tracer data are frequently used in combination in the extended period simulation (EPS) calibration and validation process.

4.8.5. Hydraulic Calibration and Validation

Two sets of data were collected for hydraulic model calibration and validation effort. The **first** sets of data were used for model **calibration** purpose and detailed inTable 5 on Appendix111. While the **second** sets of data were used for model **validation** purpose and detailed in Table7on Appendix112.Figure 4-15 and Figure 4-16 illustrate plots of observed and computed values along with minimum and maximum difference.

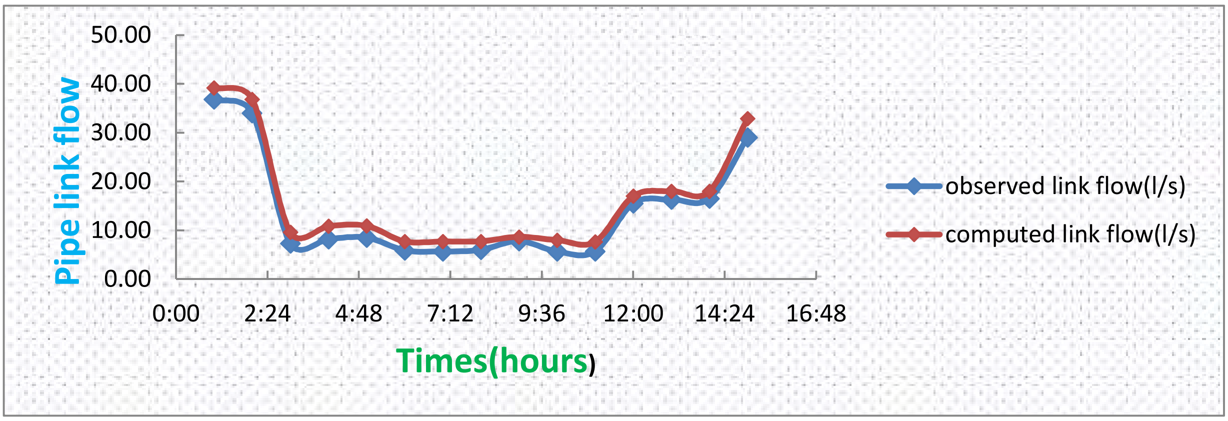
4.8.6. Tank level and Link flow calibration



R^2 = 0.835068

Figure 4-15: Tank level and Link flow calibration

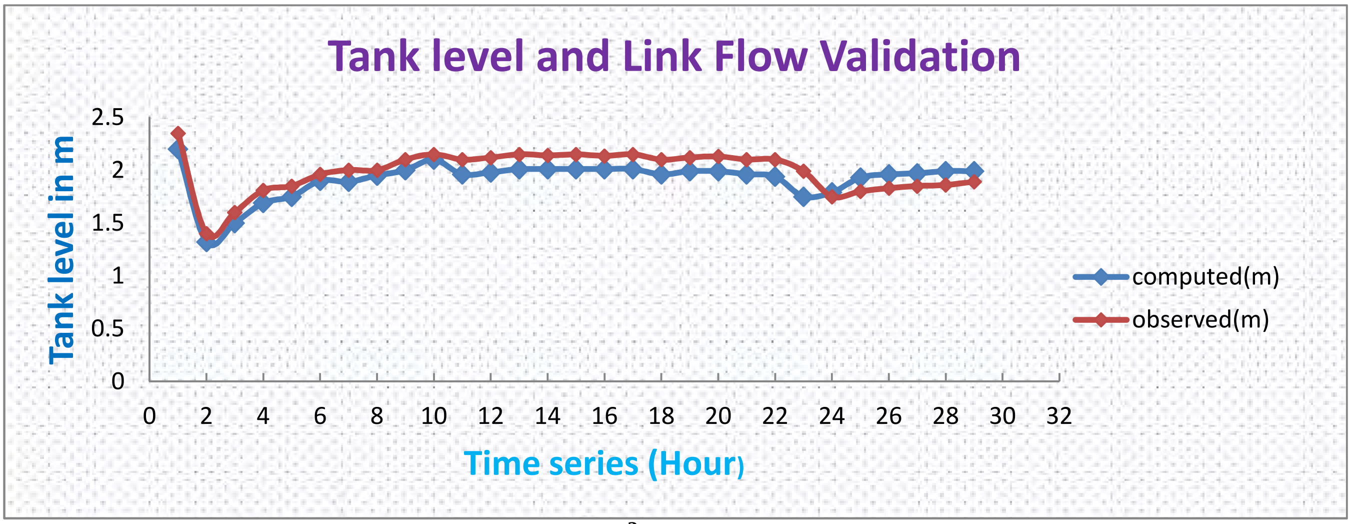
Figure 38 shows graphical method of comparing observed versus simulated tank level and link flow during calibration at peak hourly demand. The result shows that value of 84%. Figure 4-16 shows that the graphical plot of observed versus computed at pipe main truck out from the tank during calibration process. The result shows that value of 97.7%. This implies that the computed pressures are within the acceptable limit recommended by (Thomas et al., 2003).



R^2 = 0.976837

Figure 4-16: Pipe main tracks Node-ATWS41 link flow calibration at peak hour demand

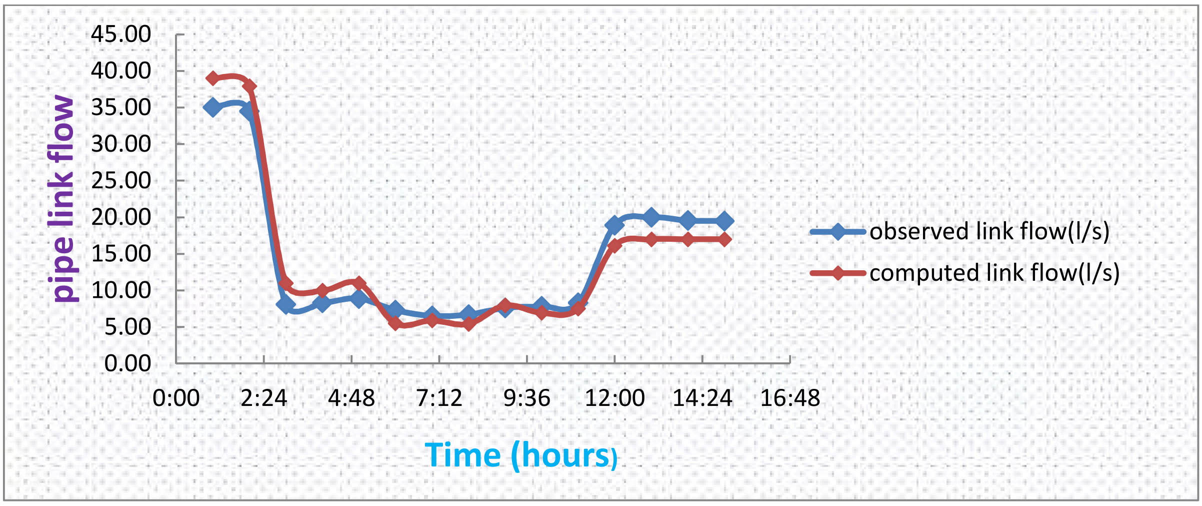
4.8.7. Tank level and link flow time series **Validation**



R^2 = 0.85591

Figure 4-17: Tank level and link flow time series validation

Figure 4-17 shows graphical method of comparing observed versus simulated tank level and link flow during validation at low hour demand. The result shows that value of 86%. Figure 4-18 shows that the graphical plot of observed versus computed at pipe main truck out flow from the tank during validation. The result shows that value of 99.82%. This implies that the computed pressures are within the acceptable limit recommended by (Thomas etal.2003).



R^2 = 0.998156

Figure 4-18: Pipe main track at No-ATWS41 link flow validation at low flow demand

4.8.8. Model Performance Evaluation Methods

There are many ways to judge on the performance of model calibration. The evaluation was made by calculating the squared relative difference between observed and simulated pressure for each test.The evaluation criteria used was statistical method using correlation coefficient and root mean square Error (RMS) and graphical method.

$$\frac{\Sigma}{\sqrt{\Sigma * \Sigma}}$$

Where = correlation coefficient, are measured and simulated values respectively and average values of measured and simulated respectively.

4.8.9. Pressure and flow Calibration and Validation

As pressure conditions calibration was 85% of the pressure field test measurements should be with in ±0.5 mor±5% of the maximum head loss across the system of the simulated pressure, which ever is greater according to (Thomas etal.2003). According to (Thomas 2003), for the smaller water supply system having less than or equal to 600mm diameters, the model should be accurately predict hydraulic grade line (HGL) to with in 1.5–3m depending on size of the system at calibration data points during fire flow tests and to the accuracy of the elevation and pressure data during normal demands.

It should also reproduce tank water level fluctuations to with in for EPS (exetend period simulation) runs and match treatment plant/ pump station/ well flows to with in 10–20 present. But for master planning of larger water supply systems which as greater than or equal to 600mm diameters,the model also should be accurately predict HGL with in 1.5–3m during times of peak velocities and to the accuracy of the elevation and pressure data during normal demands. It should also reproduce tank water level fluctuations to with in (1–2m) for EPS runs and match treatment plant, and pump station flows to within 10–20 percent (Thomas et.al, 2003).

A) Pressure **calibration** using time series along pipe distribution networks.

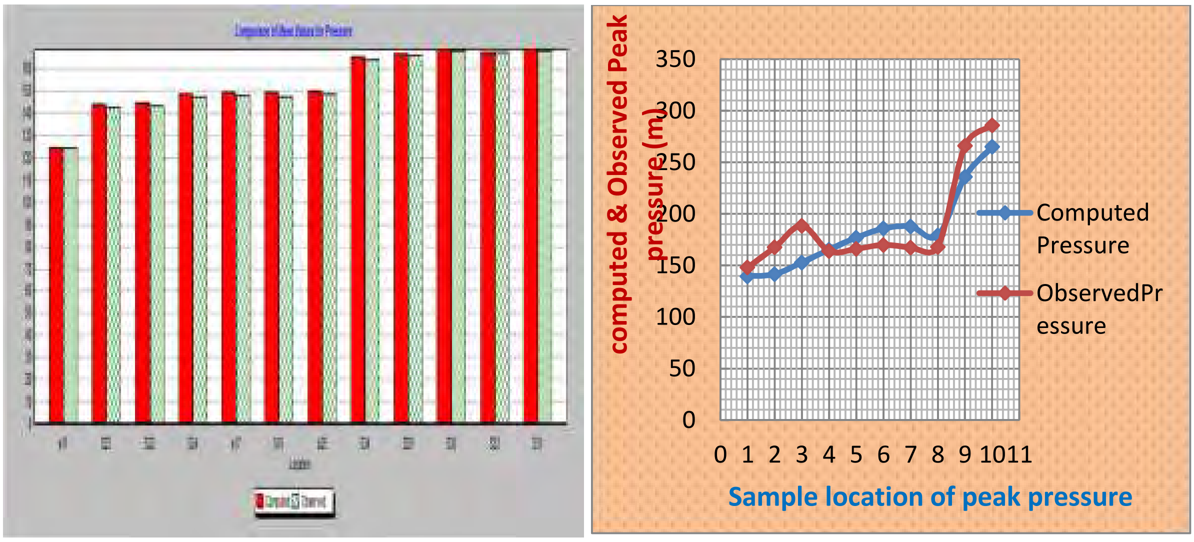
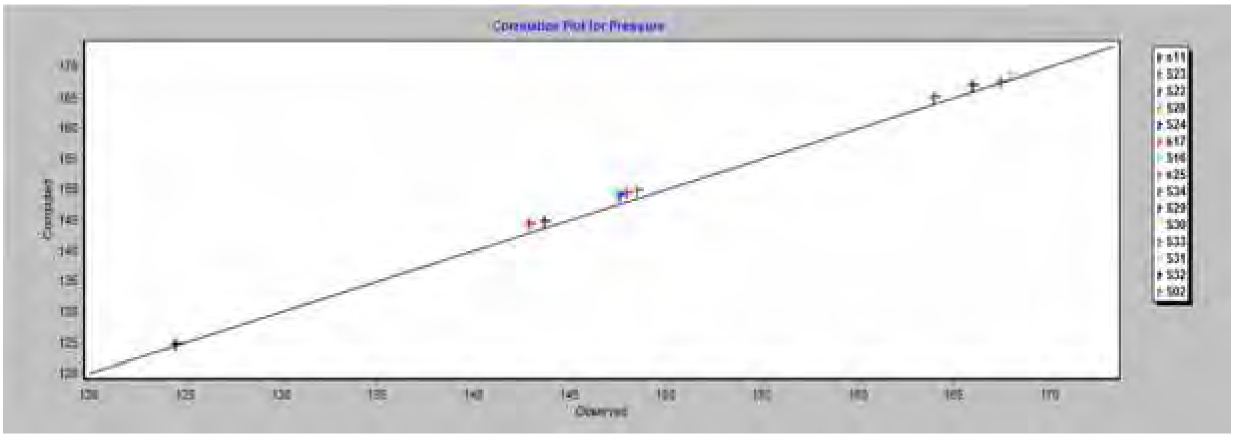


Figure 4-19: Observed versus Computed Pressure during calibration

The calibration of pressures was done both graphical and statistical method. Figure 4-19 shows **the graphical representation** of measured and computed pressure at different locations and time series. Figure 4-20 shows that **the statistical correlation plots** of observed versus computed pressure during calibration process. The results show that value of **89.82%.** This implies that the computed pressures are within the acceptable limit recommended by (Thomas et al., 2003).



R^2 = 0.8982

Figure 4-20: Correlated plot of computed versus observed pressure during calibration

B) The Pressure **Validation** using time series along pipe distribution networks.

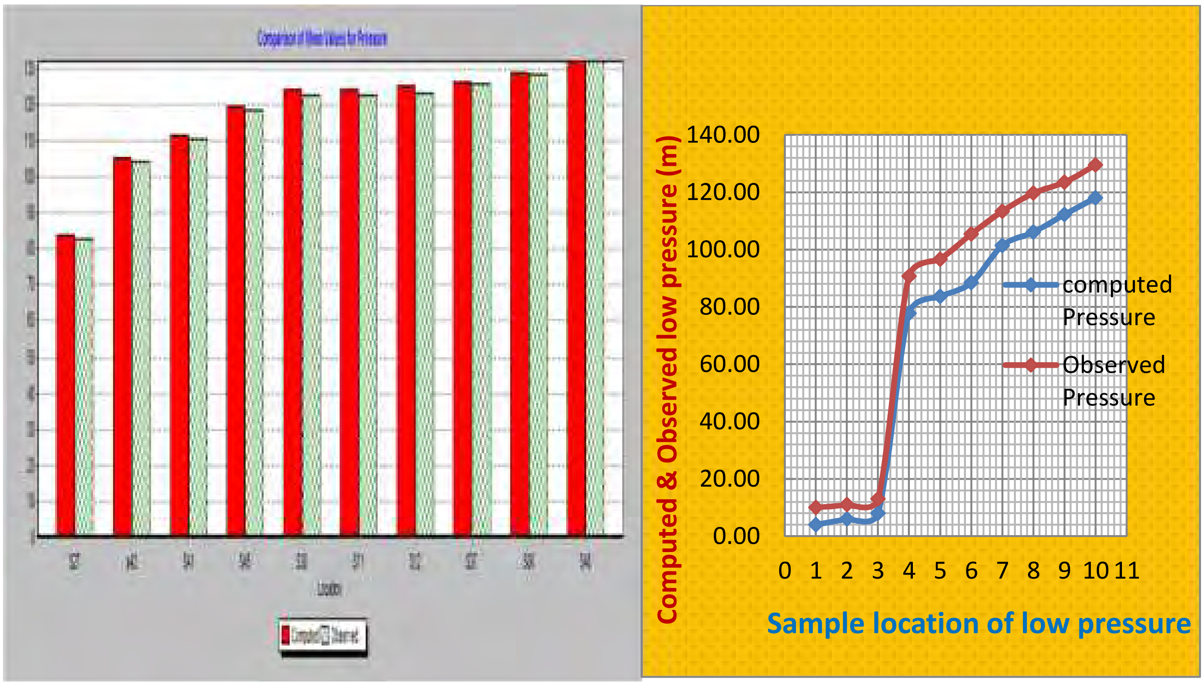
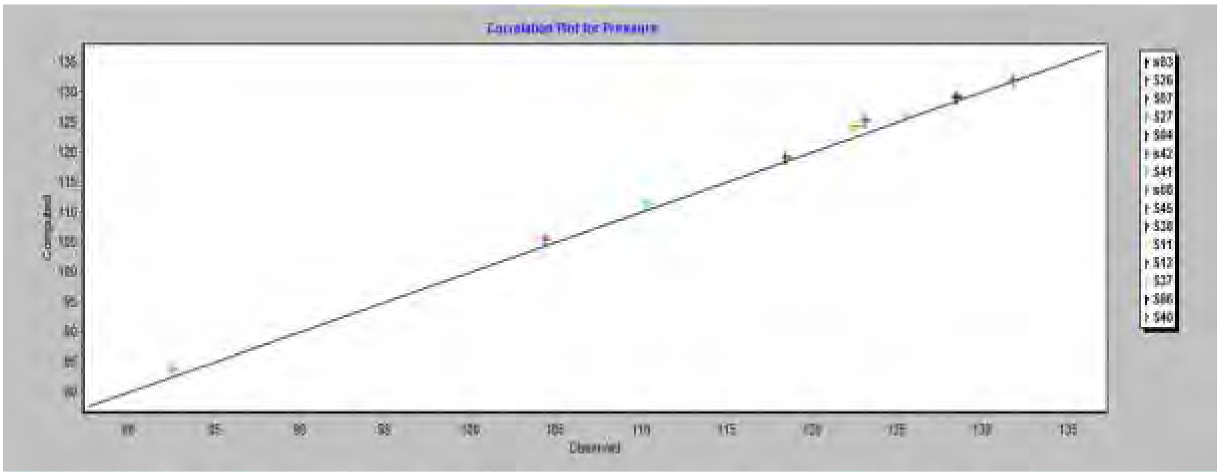


Figure 4-21: Observed and Computed Pressure during validation

The validation of pressures was done both graphical and statistical method. Figure 4-21 shows the **graphical representation** of measured and computed pressure at different locations and time series. Figure 4-22 shows that the **statistical correlation plots** of observed versus computed pressure during calibration process. The results show that value of

95.74%. This implies that the computed pressures are within the acceptable limit recommended by Thomas et al., 2003.



R^2 = 0.9574

Figure 4-22: Correlated plot of observed versus computed pressure during validation

4.9. Variantion of pressure with residual chlorine in system

The analysis of the effects of pressure changes on the residual chlorine in water transimission main and distribution systems are carried out by installing pressure gauge at selected sampling location such as, treatment plant, public fountains, customer tap, water reservoirs and other sampling points. In order to assess the relationship between the pressure and residual chlorine concentration in the system, the measured pressures and chlorine residual collected at different locations were used for calibration and validation of EPANET water quality model.

The residual chlorine concentration in the distribution system decreases from the distribution reservoir to dead end of the pipe network. This can be due to high residence time, turbidity of water, and increase in the pressure especially at lowest elevation in the study area.The increase in pressure in pipe networks indirectly affect the residual chlorine by increasing the turbidity of water as shown in figure 4-23 below In Adama case the treated water is travelled 11km long distance in transimission main by high pressurized pumps.The pressure is decreases the chlorine residual due to long distance travelled and high residence time in the distribution systems.Therefore, the residual chlorine concentration is lost in the transmission main and in the distributin network.See table 4-3, page 56.

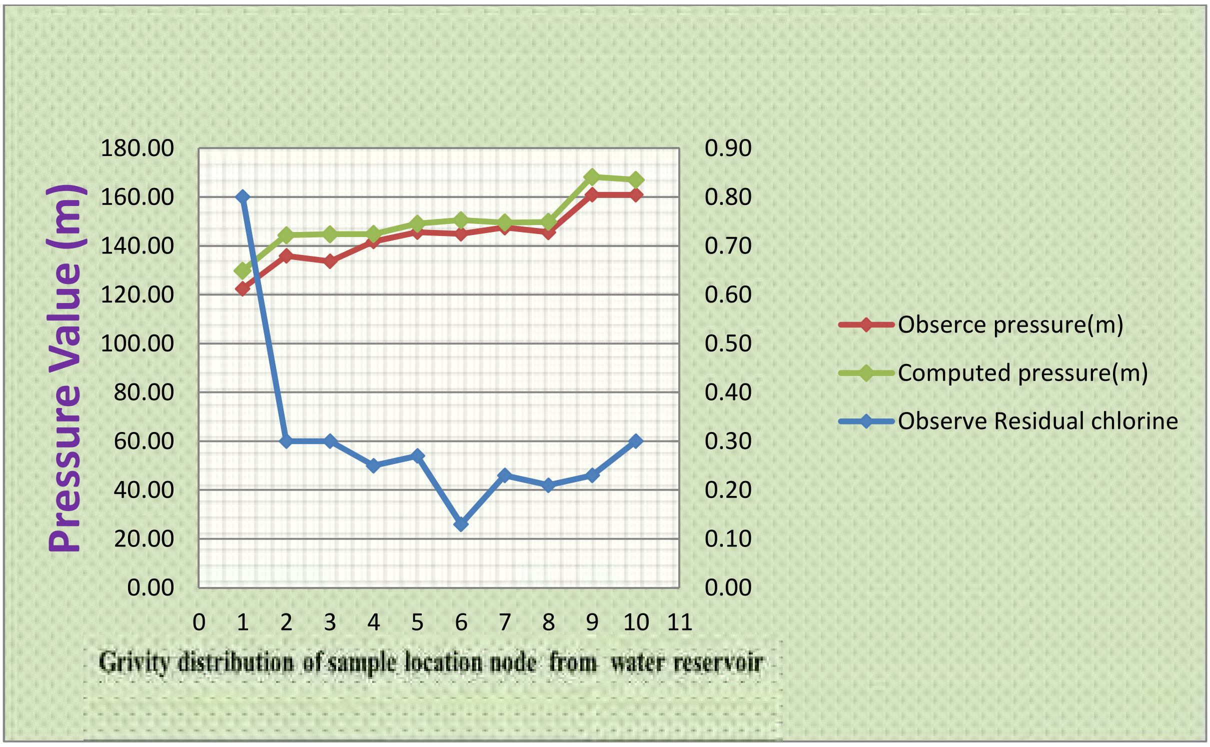


Figure 4-23: Relationship between pressure changes with residual chlorine in the distribution network system

The figure above shows that the Variantion of pressure with residual chlorine in ystem.When we see the residual chlorine graph it is decreases down when node points increases and the pressure graph is increases to positive direction, when node points increases. This analysis result is the approval of pressure effect on residual chlorine in the Water supply system.

Chapter-5

5. Conclusions and Recommendation

5.1. Conclusions

The assessment current situation of Adama Town water quality modeling was found appropriate technique and accordingly modeling efforts were carried out for case study of the Adama water supply system. Classification and analysis of drinking water quality parameters were done using a total of 45 samples representative drinking water from different locations of the water supply system of the Adama Town. Comparison of the water quality parameters with the permissible limit of the WHO (2012) and Ethiopian recommended values (Girma, e tal. 2011) guidelines were made concerning with safe and acceptable level of potable water for users. Bacteriological tests such as faecal coliforms and total coliforms were analyzed in relation to the health occurrence of water associated diseases. The most physico-chemical parameters considered for study include color, turbidity, pH, electrical conductivity, total dissolved solids, total hardness, total alkalinity, calcium, potassium, magnesium, copper, iron, manganese, chromium (hexavalent), chloride, fluoride, nitrate, phosphate, residual chlorine, dissolved oxygen (DO) and Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD).

Adama Town Water Supply have shown that free residual chlorine samples were taken two timce laboratory tests and results were the following: In frist round when we were taking 45 samples from sensitive location and tested in laboratory except Koka treatment plant all results with no free residual chlorine in Town Water distribution system net work. In second round after we construct temporary Constant-Head drip chlorinator on Lugo reservoirs, when take samples second round and test in laboratory the result of free residual chlorine is 0.02-0.3mg/l at the end users tap and at reservoirs give 0.8mg/l; so after constant head-drip on operation the drinking water of Adama town is free from bacteriological. Among the physico- chemical parameters, heavy metals and the remaining all parameters were less than permissible limit of WHO guide lines and Ethiopian recommended values concerning the safety and acceptability level (Grima etal, 2011) for the end users except color and Iron, the results of Color concentration during Wet and Dry seasons were found between the ranges of 9-17 TCU.This result is greater than WHO maximum permissible limit values and less than Ethiopian maximum permissible limit values. Iron is a very common problem in drinking water and has a strong relationship with water hardness typically with both hardness and iron increasing at the same time. Based on aesthetic reasons the WHO Guide lines Drinking Water Quality recommended that their on levels should be kept below 0.3mg/l. However, the Adama Town Water Supply Samples laboratory test results were equal to WHO maximum permissible limit value. So need some adjustment and also Iron result was increasing during Wet season than that of dry season.

Pressure established hydraulic performance evaluation indicated that acceptable minimum and maximum pressures have not been met. During peak hour flow, parts of the distribution system receive water with low pressure and under some circumstances risk of obtaining no water is observed because of the pressure in the distribution system is below permissible minimum requirement. In line with this, a lot of the nodes in the distribution system are disposed to undesirable pressures which exceed maximum allowable pressure. As a result, the distribution system is exposed to risks of high leakage and repeated pipe breakage during high flows. Disinfection modeling result showed that the distribution system lack of ability to fully distribute microbiologically safe water due to absence of minimum allowable residual chlorine with in the system. In water quality calibrations the wall reaction coefficient (Kw) has an inverse relation with the C-factor.

5.2. Recommendations

To improve of the current situation of Adama water supply system, both design and operational modifications are necessary. From the assessment under taken and modeling result the following sets of recommendations are drawn to permanently modify the Water quality in full distribution system and the hydraulic performance of the sub-system, the design needs to be reviewed and pressure zones which serve customers situated in nearly equivalent elevation has to be established:

- To improve drnking Water in Adama Town proper disinfections with higher doses of chlorine at the treatment plant and permanently at Lugo resrvoirs all ways needed. Pressure breaker is required at high pressure zones in order to regulate pressure within the permissible limit to avoid over mixing of residual chlorine in the system. These consequent measures may improve the efficiency to kill different pathogens at different point use of the community through out of the water supply distribution system.

- Water quality modeling shall include modeling of disinfection by product as to fully understand water quality transformations in water distribution system. Impacts of various development activities on performance of water distribution system
- Modification in current flushing program which only targets storage reservoirs cleaning per year is necessary. Periodic flushing of system elements associated with long water age may also minimize water quality degradation by removal of pipe scales and sediment associated with disinfectant consumption.
- Hydraulic modeling effort of the subsystem shall consider different scenario; which involves impacts of excessive pressure in the system since most of the nodes obtain water by gravity system.
- In the USB rapid sand filiter Alge plant is highly growth, this Alge plant is produced more Bacteria in the treatment plant. It must be clean monthly and additional used chemical, which protect the treatment plant.
- To use additional dosage of coagulant (alum) and through filtration process during the summer season to reduce the turbidity and colour within the permissible limit.
- As much as possible the oldest galvanized steel pipes should be replaced by either PVC pipes or HDPE pipes. This is helpful to avoid the rusting problems in the system as well as to some extent solve the colour and turbidity problems of the source supply.

Chapter - 6

6. References and Appendices

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6.2. Appendixs

Table: 1-First round Samples collected and laboratory test Results

S.No	Sampling Code	Sample Location			Date	Residual Chlorine, mg/l	FCC/100ml	TCC/100ml	Sample test Results
		Easting (X)	Northing (Y)	Altitude (Z)					
1	ATWS 01	519730	937132	1556	8/3/2016	0.0	250	TNTC	Non-potable
2	ATWS 02	519810	937324	1570	8/3/2016	0.6	Nil	Nil	Potable
3	ATWS 03	529031	940541	1765	8/3/2016	0.0	1250	TNTC	Non-potable
4	ATWS 04	527319	943424	1684	8/3/2016	0.0	1000	TNTC	Non-potable
5	ATWS 05	529931	945125	1632	8/3/2016	0.0	650	TNTC	Non-potable

6	ATWS 06	529943	945427	1640	8/3/2016	0.0	98	15	Non-potable
7	ATWS 07	530600	948142	1720	8/3/2016	0.0	107	TNTC	Non-potable
8	ATWS 08	529638	944478	1633	8/3/2016	0.0	Nil	63	Non-potable
9	ATWS 09	529852	944429	1631	8/3/2016	0.0	560	TNTC	Non-potable
10	ATWS 10	529801	944442	1632	8/3/2016	0.0	38	98	Non-potable
11	ATWS 11	530640	945072	1646	8/3/2016	0.0	150	TNTC	Non-potable
12	ATWS 12	530634	945083	1644	8/3/2016	0.0	210	TNTC	Non-potable
13	ATWS 13	531685	944664	1635	8/3/2016	0.0	96	5	Non-potable
14	ATWS 14	529572	943582	1629	8/3/2016	0.0	78	23	Non-potable
15	ATWS 15	529767	942783	1632	8/3/2016	0.0	TNTC	350	Non-potable
16	ATWS 16	530094	942655	1620	8/3/2016	0.0	100	32	Non-potable
17	ATWS 17	530588	943943	1620	8/3/2016	0.0	45	65	Non-potable
18	ATWS 18	530005	94439	1630	8/3/2016	0.0	TNTC	650	Non-potable
19	ATWS 19	529850	944388	1629	8/3/2016	0.0	66	95	Non-potable
20	ATWS 20	529889	944733	1631	8/3/2016	0.0	TNTC	150	Non-potable
21	ATWS 21	529224	944763	1627	8/3/2016	0.0	117	TNTC	Non-potable
22	ATWS 22	528800	944749	1626	8/3/2016	0.0	165	TNTC	Non-potable
23	ATWS 23	527759	944712	1625	9/3/2016	0.0	2	18	Non-potable
24	ATWS 24	528832	944230	1622	9/3/2016	0.0	2	17	Non-potable
25	ATWS 25	526832	940536	1620	9/3/2016	0.0	21	13	Non-potable
26	ATWS 26	526641	946109	1750	9/3/2016	0.0	Nil	68	Non-potable
27	ATWS 27	529031	940541	1687	9/3/2016	0.0	Nil	1	Non-potable

28	ATWS 28	528665	941719	1626	9/3/2016	0.0	Nil	2	Non-potable
29	ATWS 29	531687	943970	1603	9/3/2016	0.1	18	Nil	Non-potable
30	ATWS 30	532795	943674	1601	9/3/2016	0.0	Nil	Nil	Potable
31	ATWS 31	532819	943636	1600	9/3/2016	0.0	Nil	35	Non-potable
32	ATWS 32	533909	944671	1551	9/3/2016	0.0	1	TNTC	Non-potable
33	ATWS 33	530599	942150	1601	9/3/2016	0.0	3	8	Non-potable
34	ATWS 34	530944	942722	1604	9/3/2016	0.0	1	5	Non-potable
35	ATWS 35	531891	946668	1705	9/3/2016	0.0	Nil	Nil	Potable
36	ATWS 36	529672	944676	1635	9/3/2016	0.0	Nil	1	Non-potable
37	ATWS 37	529415	944838	1643	9/3/2016	0.0	Nil	17	Non-potable
38	ATWS 38	529310	945116	1646	9/3/2016	0.0	3	7	Non-potable
39	ATWS 39	529090	944029	1633	10/3/2016	0.1	30	Nil	Non-potable
40	ATWS 40	529976	944076	1637	10/3/2016	0.0	Nil	18	Non-potable
41	ATWS 41	528883	946833	1658	10/3/2016	0.0	2	3	Non-potable
42	ATWS 42	528798	947819	1664	10/3/2016	0.0	Nil	23	Non-potable
43	ATWS 43	528007	943630	1628	10/3/2016	0.0	5	4	Non-potable
44	ATWS 44	527306	941779	1631	10/3/2016	0.0	1	5	Non-potable
45	ATWS 45	527807	945555	1650	10/3/2016	0.0	Nil	6	Non-potable

N.B:-TNTC = Too Numerous To Count (>300 coliforms/100ml), FCC= Faecal Coliform Count, TCC= Total Coliform Count, ATWS = Adama Town Water Supply.

Table 2: Second round Samples collected and laboratory test Results

Sampling Code	Sample Location			Date	Residual Chlorine, mg/l	FCC/100ml	TCC/100ml	Sample test Results
	Easting (X)	Northing (Y)	Altitude (Z)					
ATWS 01	519730	937132	1556	10/4/2016	0.0	2530	4612	Very high Risk
ATWS 02	517461	936589	1570	10/4/2016	0.6	Nil	Nil	Potable
ATWS 03	529031	940541	1765	10/4/2016	0.80	Nil	Nil	Potable
ATWS 04	527319	943424	1685	10/4/2016	0.30	Nil	Nil	Potable

ATWS 05	529931	945125	1632	10/4/2016	0.30	Nil	Nil	Potable
ATWS 06	529943	945427	1640	10/4/2016	0.25	Nil	Nil	Potable
ATWS 07	530600	948142	1720	10/4/2016	0.27	Nil	Nil	Potable
ATWS 08	529638	944478	1633	10/4/2016	0.13	Nil	Nil	Potable
ATWS 09	529852	944429	1631	10/4/2016	0.23	Nil	Nil	Potable
ATWS 10	529801	944442	1632	10/4/2016	0.17	Nil	Nil	Potable
ATWS 11	530640	945072	1646	10/4/2016	0.21	Nil	Nil	Potable
ATWS 12	530634	945083	1644	10/4/2016	0.23	Nil	Nil	Potable
ATWS 13	531685	944664	1635	10/4/2016	0.30	Nil	Nil	Potable
ATWS 14	529572	943582	1629	11/4/2016	0.24	Nil	Nil	Potable
ATWS 15	529767	942783	1632	11/4/2016	0.18	Nil	Nil	Potable
ATWS 16	530094	942655	1620	11/4/2016	0.20	Nil	Nil	Potable
ATWS 17	530588	943943	1620	11/4/2016	0.21	Nil	Nil	Potable
ATWS 18	530005	94439	1630	11/4/2016	0.22	Nil	Nil	Potable
ATWS 19	529850	944388	1629	11/4/2016	0.16	Nil	Nil	Potable
ATWS 20	529889	944733	1631	11/4/2016	0.30	Nil	Nil	Potable
ATWS 21	529224	944763	1627	11/4/2016	0.20	Nil	Nil	Potable
ATWS 22	528800	944749	1626	11/4/2016	0.20	Nil	Nil	Potable
ATWS 23	527759	944712	1625	11/4/2016	0.18	Nil	Nil	Potable
ATWS 24	528832	944230	1622	11/4/2016	0.23	Nil	Nil	Potable
ATWS 25	526832	940536	1620	11/4/2016	0.30	Nil	Nil	Potable
ATWS 26	526641	946109	1750	12/4/2016	0.20	Nil	Nil	Potable
ATWS 27	529031	940541	1687	12/4/2016	0.25	Nil	Nil	Potable
ATWS 28	528665	941719	1626	12/4/2016	0.30	Nil	Nil	Potable
ATWS 29	531687	943970	1603	12/4/2016	0.30	Nil	Nil	Potable
ATWS 30	532795	943674	1601	12/4/2016	0.22	Nil	Nil	Potable
ATWS 31	532819	943636	1600	12/4/2016	0.26	Nil	Nil	Potable
ATWS 32	533908	944671	1551	12/4/2016	0.30	Nil	Nil	Potable
ATWS 33	530599	942150	1601	12/4/2016	0.20	Nil	Nil	Potable
ATWS 34	530944	942722	1604	12/4/2016	0.17	Nil	Nil	Potable
ATWS 35	531891	946668	1705	12/4/2016	0.23	Nil	Nil	Potable
ATWS 36	529672	944676	1635	13/4/2016	0.30	Nil	Nil	Potable
ATWS 37	529415	944838	1643	13/4/2016	0.21	Nil	Nil	Potable
ATWS 38	529310	945116	1646	13/4/2016	0.30	Nil	Nil	Potable
ATWS 39	529090	944029	1633	13/4/2016	0.12	Nil	Nil	Potable
ATWS 40	529976	944076	1637	13/4/2016	0.21	Nil	Nil	Potable
ATWS 41	528883	946833	1658	13/4/2016	0.30	Nil	Nil	Potable
ATWS 42	528798	947819	1664	13/4/2016	0.21	Nil	Nil	Potable
ATWS 43	528007	943630	1628	13/4/2016	0.20	Nil	Nil	Potable
ATWS 44	527306	941779	1631	13/4/2016	0.19	Nil	Nil	Potable
ATWS 45	527807	945555	1650	13/4/2016	0.23	Nil	Nil	Potable

N.B:-TNTC = Too Numerous to Count (>300 coliforms/100ml), FCC= Faecal Coliform Count, TCC= Total Coliform Count, ATWS = Adama Town Water Supply.

Table: 3- Test Method and Laboratory instruments

S/N	Parameter Tested	Method used to measure the parameter
1	Temperature	CyberscanPC300PH/Conductivity/TDS Temperature meter
2	PH	CyberscanPC300 PH/Conductivity/TDS/Temperature meter
3	Total Dissolved Solids(TDS)	CyberscanPC300 PH/Conductivity/TDS/Temperature meter
4	Electrical conductivity(EC)	CyberscanPC300 PH/Conductivity/TDS/Temperature meter
5	Total hardness as$CaCo_3$	EDTA, Titration
6	Calcium hardness as CaCo3	EDTA, Titration
7	Turbidity	Palintest, 8000
8	Color	Palintest,8000
9	Sulfate	8051, SulfaVer 4
10	Iron, Total	8008,FerroVer
11	Chloride	Mercuric Nitrate titration
12	Chlorine, Free	8021,DPD method
13	Chromium, Hexavalent	8023, 1,5-Diphenylcabohydazide(ChromaVer 3)
14	Copper	8143,Porphyrin method
15	Fluoride	8029,SPADNS method
16	Manganese	8034,Periodate Oxidation
17	Nitrate	8039,Cadmium Reduction
18	Nitrite	8507,Diazotization method
19	Nitrogen, Ammonia	8038, Nessler method
20	Chemical Oxygen Demand	8000,Reactor Digestion method
21	Phosphorus, reactive	8048,PhosVer 3 (Ascorbic acid) method
22	Potassium	8049, Tetraphenylborate method

23	Zinc	8009,Zincon method
24	Bacteria colony	Membrane Filtration method
	determination	
25	Dissolved Oxygen/DO	Thiosulfate Titration method
26	Biochemical Oxygen Demand	Thiosulfate Titration method
27	Total Alkalinity	Titration

Table: 4- Bottle tests of data arrangement for determination of Bulk coefficient determination

Date	Time	1st Bottle test data set	
		Sample code	Observed Residual Chlorine (mg/l)
10/4/2016	8:00AM	ATWS 03(Lugo Cl.W.Tank)	0.80
10/4/2016	8:30AM	ATWS 04	0.6
10/4/2016	9:00AM	ATWS 05	0.50
10/4/2016	9:30AM	ATWS 06	0.43
10/4/2016	10:00AM	ATWS 07	0.36
10/4/2016	10:30AM	ATWS 08	0.30
10/4/2016	11:00AM	ATWS 09	0.25
10/4/2016	11:30AM	ATWS 10	0.22
10/4/2016	12:00AM	ATWS 11	0.18
10/4/2016	12:30PM	ATWS 12	0.14
Date	Time	2nd Bottle test data set	
		Sample code	Observed Residual Chlorine (mg/l)
11/4/2016	10:00AM	ATWS 03(Lugo Cl.W.Tank)	0.80
11/4/2016	10:30AM	ATWS 04	0.6
11/4/2016	11:00AM	ATWS 05	0.55
11/4/2016	11:30AM	ATWS 06	0.47
11/4/2016	12:00AM	ATWS 07	0.40
11/4/2016	12:30PM	ATWS 08	0.32
11/4/2016	1:00PM	ATWS 09	0.25
11/4/2016	1:30PM	ATWS 10	0.22
11/4/2016	2:00PM	ATWS 11	0.14
11/4/2016	2:30PM	ATWS 12	0.07

Date	Time	3rd Bottle test data set	
		Sample code	Observed Residual Chlorine (mg/l)
12/4/2016	1:00PM	ATWS03(Lugo Cl.W.Tank)	0.80
12/4/2016	2:00PM	ATWS 04	0.60
12/4/2016	3:00PM	ATWS 05	0.50
12/4/2016	4:00PM	ATWS 06	0.40
12/4/2016	5:00PM	ATWS 07	0.33
12/4/2016	6:00PM	ATWS 08	0.28
12/4/2016	7:00PM	ATWS 09	0.24
12/4/2016	8:00PM	ATWS 10	0.20
12/4/2016	9:00PM	ATWS 11	0.14
12/4/2016	10:00PM	ATWS 12	0.12

Table: 5- Time Series Table Link tank level **first data** arrangement **calibration** at peak flow hourly demand

First data Water Tank level Calibration data's			
Time	Tank level		
Time (hours)	computed(m)	observed(m)	difference(m)
1:00	2.17	2.16	0.01
2:00	1.33	1.46	-0.13
3:00	1.46	1.66	-0.20
4:00	1.71	1.82	-0.11
5:00	1.86	1.99	-0.13
6:00	1.91	2.00	-0.09
7:00	1.92	2.02	-0.10
8:00	1.94	2.03	-0.09
9:00	1.94	2.10	-0.16
10:00	1.99	2.10	-0.11
11:00	1.97	2.10	-0.13
12:00	2.04	2.13	-0.09
13:00	2.1	2.17	-0.07
14:00	2.09	2.20	-0.11
15:00	2.095	2.20	-0.11
16:00	1.99	2.13	-0.14
17:00	2.09	2.20	-0.11
18:00	1.99	2.14	-0.15
19:00	2.1	2.15	-0.05
20:00	1.98	2.09	-0.11

21:00	1.88	2.09	-0.21
22:00	1.89	1.89	0.00
23:00	1.95	1.83	0.12
24:00	1.94	1.83	0.11
25:00	1.99	1.87	0.12
26:00	1.97	1.90	0.07
27:00	1.98	1.89	0.09
28:00	1.99	1.90	0.09
29:00	2.00	1.91	0.09

$$R^2 = \frac{(x-x^{-})\,(y-y^{-})}{\sqrt{\Sigma(x-x^{-})^2 \sum (y-\bar{} \; y^{-2})}} = 84\%$$

Where: x and y sample means of average array1 and array2 respectively and R^2 Correlation mean square in percent.

Table: 6- Time Series Table Link tank level **second data** arrangement validation at low flow hour demand

Pipe Link no-5 Flow Calibration data's			
Time(Hour)	observed link flow(l/s)	computed link flow(l/s)	differences(l/s)
1:00	35.00	39.00	4.00
2:00	34.50	37.90	3.40
3:00	8.10	11.00	2.90
4:00	8.30	10.00	1.70
5:00	8.90	11.00	2.10
6:00	7.30	5.50	-1.80
7:00	6.53	5.90	-0.63
8:00	6.70	5.42	-1.28
9:00	7.60	7.95	0.35
10:00	7.85	6.95	-0.90
11:00	8.30	7.54	-0.76
12:00	18.90	16.13	-2.77
13:00	20.00	16.99	-3.01
14:00	19.55	16.99	-2.56
15:00	19.50	16.99	-2.51

$$R^2 = \frac{(x-x-)\,(y-y-)}{}$$

Z:VUB

$$\sqrt{\sum(x - \bar{x})^2 \sum(y - \bar{y})^2}$$

Table: 7-Time Series Table Link tank level **second data** arrangement **validation** at low flow hour demand

Water Tank level Validation data's			
Time	Tank level		
Time (hours)	computed(m)	observed(m)	difference(m)
1	2.2	2.35	-0.15
2	1.32	1.4	-0.08
3	1.5	1.6	-0.1
4	1.69	1.81	-0.12
5	1.75	1.85	-0.1
6	1.9	1.96	-0.06
7	1.89	2.0	-0.11
8	1.95	2	-0.05
9	2	2.1	-0.1
10	2.1	2.15	-0.05
11	1.96	2.1	-0.14
12	1.98	2.12	-0.14
13	2.01	2.15	-0.14
14	2.01	2.14	-0.13
15	2.01	2.15	-0.14
16	2.01	2.135	-0.125
17	2.01	2.15	-0.14
18	1.96	2.1	-0.14
19	1.99	2.12	-0.13
20	1.99	2.13	-0.14
21	1.96	2.1	-0.14
22	1.94	2.1	-0.16
23	1.75	1.99	-0.24
24	1.79	1.75	0.04
25	1.93	1.8	0.13
26	1.96	1.83	0.13
27	1.97	1.85	0.12
28	1.99	1.86	0.13
29	1.99	1.89	0.1

$$R^2 = \frac{(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-x)^2 \sum(y-y)^2}} = 98\%$$

Table: 8- Second data arrangement the pipe link flow for **validation** at low hourly demand

Pipe Link no-5 Flow Validation data's			
Time(hr)	observed link flow(l/s)	computedlink flow(l/s)	differences(l/s)
1:00	37.00	39.2	2.20
2:00	36.00	36.8	0.80
3:00	8.30	9.6	1.30
4:00	8.20	9.85	1.65
5:00	9.50	10.9	1.40
6:00	5.90	6.71	0.81
7:00	6.23	6.72	0.49
8:00	5.99	6.73	0.74
9:00	7.80	8.64	0.84
10:00	6.67	7.98	1.31
11:00	6.65	7.64	0.99
12:00	15.50	16.99	1.49
13:00	16.30	18	1.70
14:00	16.50	18	1.50
15:00	29.00	32.86	3.86

$$R^2 = \frac{(x-x^-)(y-y^-)}{\sqrt{\sum (x - x)^2 \sum (y - y)^2}}$$

Where x is represented pipe link flow demand (l/s) Y is represented pipe link flow demand (l/s)

R^2 is correlation mean square in present

x^-&y^- Is sample of means average array 1 and array2 respectively

Table:-9 Observed of the residual chlorine and pressure relationship data

S.No	Location of SamplePoints			Time(Hours)	Sample point Nodes	Observed residual chlorine	Observed pressure(m)	Computed pressure(m)
	X(m)	Y(m)	Z(m)					
1	530640	945072	1646	1:00	ATWS11	0.8	124.50	124.82
2	527759	944712	1625	2:00	ATWS23	0.3	142.90	144.35
3	528800	944749	1626	3:00	ATWS22	0.3	143.69	144.77
4	528665	941719	1626	4:00	ATWS28	0.25	141.82	141.82
5	528832	944230	1622	5:00	ATWS24	0.27	147.62	149.05
6	530588	943943	1620	6:00	ATWS17	0.13	147.97	149.52

7	530094	942655	1620	7:00	ATWS16	0.23	147.48	149.53
8	526832	940536	1620	8:00	ATWS25	0.21	148.55	149.82
9	528832	944230	1622	9:00	ATWS34	0.23	163.94	165.21
10	531687	943970	1603	10:00	ATWS29	0.3	165.97	167.05

Table: 10 Concentration of Dissolved Oxygen laboratory test Result

DO concentration of Dissolved Oxygen					
Sample Date & Time		Sample Location			Laboratory
Date	Time	X(m)	Y(m)	Z(m)	Result in mg/l
24/03/2016	8:00am	512620	951928	1772	3.27
24/02/16	9:00 aM	502935	931848	1612	2.43
24/02/16	10:00am	512002	949919	1758	4.53
24/02/16	11:00am	502390	929357	1600	3.7
25/02/16	12:00am	517224	936235	1604	5.47
25/02/16	01:10pm	502389	929357	1600	4.7
26/02/16	02:10pm	519730	937132	1556	4.63
27/02/16	03:10pm	450797	929357	1600	4.53

Table: 11 Observed of the BOD Concentration laboratory test Result

BOD Concentration						
Sample Date & Time		Sample Location			BOD Concentration	
Date	Time	X(m)	Y(m)	Z(m)	in Dry season	in wet season
15/04/2016	10:00am	512620	951928	1772	68.5	84.9
15/04/2016	11:00am	502935	931848	1612	8.7	10.2
15/04/2016	12:00am	512002	949919	1758	31.3	39.4
15/04/2016	02:00pm	502390	929357	1600	6.9	9.3
16/04/2016	03:00pm	517224	936235	1604	3.2	4.0
16/04/2016	04:00pm	502389	929357	1600	4.1	6.2
16/04/2016	05:00pm	519730	937132	1556	5.3	8.12
16/04/2016	06:00pm	450797	929357	1600	3.9	6.15

Table: 12. Observed of the COD Concetration laboratory test Result

COD Concetration						
Sample Date & Time		Sample Location			COD Concentration	
Date	Time	X(m)	Y(m)	Z(m)	in Dry season	in wet season
15/04/2016	1:00	512620	951928	1772	98	117
15/04/2016	2:00	502935	931848	1612	156	949
15/04/2016	3:00	512002	949919	1758	102	401
15/04/2016	4:00	502390	929357	1600	89	186
16/04/2016	5:00	517224	936235	1604	21	46
16/04/2016	6:00	502389	929357	1600	12	60
16/04/2016	7:00	519730	937132	1556	9	18
16/04/2016	8:00	450797	929357	1600	5	16

Table 13: Copper Laboratory Result

Samples No	Easting (X)	Northing (Y)	Altitude (Z)	Copper, mg/l
S-1	519730	937132	1556	0.1
S-2	519810	937324	1570	0.08
S-3	526891	943400	1653	0.040
S-4	528773	943551	1573	0.03
S-5	529931	945125	1632	0.02
S-6	529943	945427	1640	0.03
S-7	530634	946190	1656	0.20
S-8	529638	944478	1633	0.06
S-9	529852	944429	1631	0.05
S-10	529801	944442	1632	0.041

Table 14: Chromium(Cr+6) Laboratory Result

Samples No	Easting (X)	Northing (Y)	Altitude (Z)	Chromium (Cr+6)
S-11	530640	945072	1646	0.01
S-12	530634	945083	1644	0.01
S-13	531685	944664	1635	0.01
S-14	529572	943582	1629	0.02
S-15	529767	942783	1632	0.01
S-16	530094	942655	1620	0.01

S-17	530588	943943	1620	0.01
S-18	530005	94439	1630	0.01
S-19	529850	944388	1629	0.03
S-20	529889	944733	1631	0.01

Table15: Lead(Pb) Laboratory Result

Samples No	Easting (X)	Northing (Y)	Altitude (Z)	Lead(Pb)
S-21	529224	944763	1627	0.01
S-22	528800	944749	1626	0.01
S-23	527759	944712	1625	0.012
S-24	528832	944230	1622	0.008
S-25	526832	940536	1620	0.01
S-26	524261	945553	1750	0.003
S-27	529031	940541	1687	0.01
S-28	528665	941719	1626	0.009
S-29	531687	943970	1603	0.011
S-30	532795	943674	1601	0.004

Table 16: Alkalinity Laboratory Result

Samples No	Easting (X)	Northing (Y)	Altitude (Z)	Alkalinity
S-1	519730	937132	1556	145
S-2	519810	937324	1570	121
S-3	526891	943400	1653	134
S-4	528773	943551	1573	129
S-5	529931	945125	1632	131
S-6	529943	945427	1640	140
S-7	530634	946190	1656	133
S-8	529638	944478	1633	141
S-9	529852	944429	1631	127
S-10	529801	944442	1632	140

Table 17: Total Hardness in mg/l Laboratory Result

Samples No	Easting (X)	Northing (Y)	Altitude (Z)	Total Hardness in mg/l
S-1	519730	937132	1556	145
S-2	519810	937324	1570	112
S-3	526891	943400	1690	123
S-4	528773	943551	1573	136
S-5	529931	945125	1632	133
S-6	529943	945427	1640	116

S-7	530634	946190	1656	122
S-8	529638	944478	1633	142
S-9	529852	944429	1631	132
S-10	529801	944442	1632	118

Table 18: Manganese (Mn++) Laboratory Result

Samples No	Easting (X)	Northing (Y)	Altitude (Z)	Manganese (Mn++)
S-21	529224	944763	1627	0.31
S-22	528800	944749	1626	0.23
S-23	527759	944712	1625	0.38
S-24	528832	944230	1622	0.29
S-25	526832	940536	1620	0.41
S-26	524261	945553	1750	0.45
S-27	529031	940541	1687	0.36
S-28	528665	941719	1626	0.40
S-29	531687	943970	1603	0.27
S-30	532795	943674	1601	0.42

Table 19: Sulphate(SO4) Laboratory Result

Samples No	Easting (X)	Northing (Y)	Altitude (Z)	Sulphate(SO4)
S-21	529224	944763	1627	30
S-22	528800	944749	1626	28
S-23	527759	944712	1625	38
S-24	528832	944230	1622	30
S-25	526832	940536	1620	21
S-26	524261	945553	1750	128
S-27	529031	940541	1687	24
S-28	528665	941719	1626	22
S-29	531687	943970	1603	35
S-30	532795	943674	1601	20

Table 20: First Data arrangement for Pressure **calibration** and time series with pressure networks

Fist Data Peak pressure for Calibration							
No	Easting (X)	Northing (Y)	Altitude (Z)	Nodes	Times (Hours)	Computed Pressure	ObservedPressure
1	530640	945072	1646	S11	1:00	124.82	124.50
2	527759	944712	1625	S23	2:00	144.35	142.90

3	528800	944749	1626	S22	3:00	144.77	143.69
4	528665	941719	1626	S28	4:00	141.82	141.82
5	528832	944230	1622	S24	5:00	149.05	147.62
6	530588	943943	1620	S17	6:00	149.52	147.97
7	530094	942655	1620	S16	7:00	149.53	147.48
8	526832	940536	1620	S25	8:00	149.82	148.55
9	530944	942722	1604	S34	9:00	165.21	163.94
10	531687	943970	1603	S29	10:00	167.05	165.97
11	532795	943674	1601	S30	11:00	168.79	167.95
12	530599	942150	1601	S33	12:00	167.73	167.47
13	532819	943636	1600	S31	13:00	168.96	167.96
14	533909	944671	1551	S32	14:00	215.96	215.96
15	519810	937324	1570	S02	15:00	245.00	245.00

Table 21: Second Data arrangement for Pressure **validation** and time series with pressure networks

S.No	Easting (X)	Northing (Y)	Altitude (Z)	Nodes	Time (hours)	computed Pressure	Observed Pressure	minimum range(m) -0.5 from computed
1	526891	943400	1765	S03	1:00	6.50	6.50	6.00
2	526641	946109	1679	S26	2:00	6.80	6.80	6.30
3	530600	948142	1720	S07	3:00	7.00	7.00	6.50
4	529031	940541	1687	S27	4:00	83.78	80.63	83.28
5	527319	943424	1684	S04	5:00	86.62	86.62	86.12
6	528798	947819	1664	S42	6:00	105.41	100.37	104.91
7	528883	946833	1658	S41	7:00	111.34	106.37	110.84
8	529638	944478	1633	S08	8:00	106.67	106.67	106.17
9	527807	945555	1650	S45	9:00	119.19	116.47	118.69
10	529310	945116	1646	S38	10:00	124.05	120.51	123.55
11	530640	945072	1646	S11	11:00	124.00	120.55	123.50
12	530634	945083	1644	S12	12:00	125.24	121.12	124.74
13	529031	940541	1687	S37	13:00	126.18	123.50	125.68
14	529943	945427	1640	S06	14:00	129.09	126.51	128.59
15	529976	944076	1637	S40	15:00	132.00	129.80	131.50

Table 22. Demand pattern

Time(hr)	Demand pattern
1	0.44
2	0.94
3	1.64
4	2.04
5	0.64
6	0.34
7	0.44
8	0.94
9	1.64
10	2.14
11	0.64
12	0.34
13	0.43
14	0.93
15	1.63
16	2.03
17	0.63
18	0.33
19	0.43
20	0.93
21	1.62
22	2.02
23	0.62
24	0.32

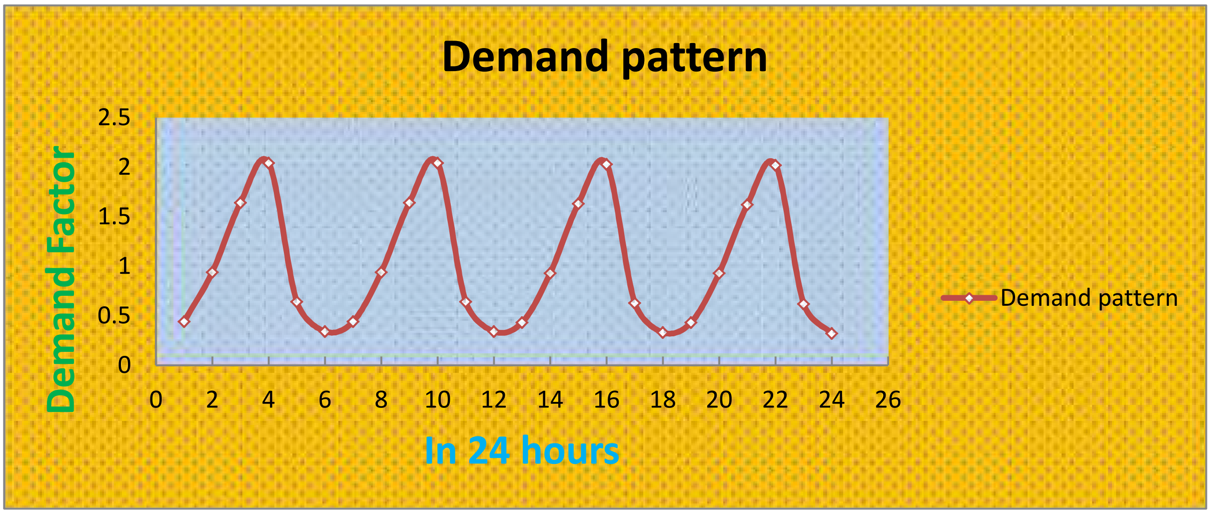

Figure6-1: Demand Factor

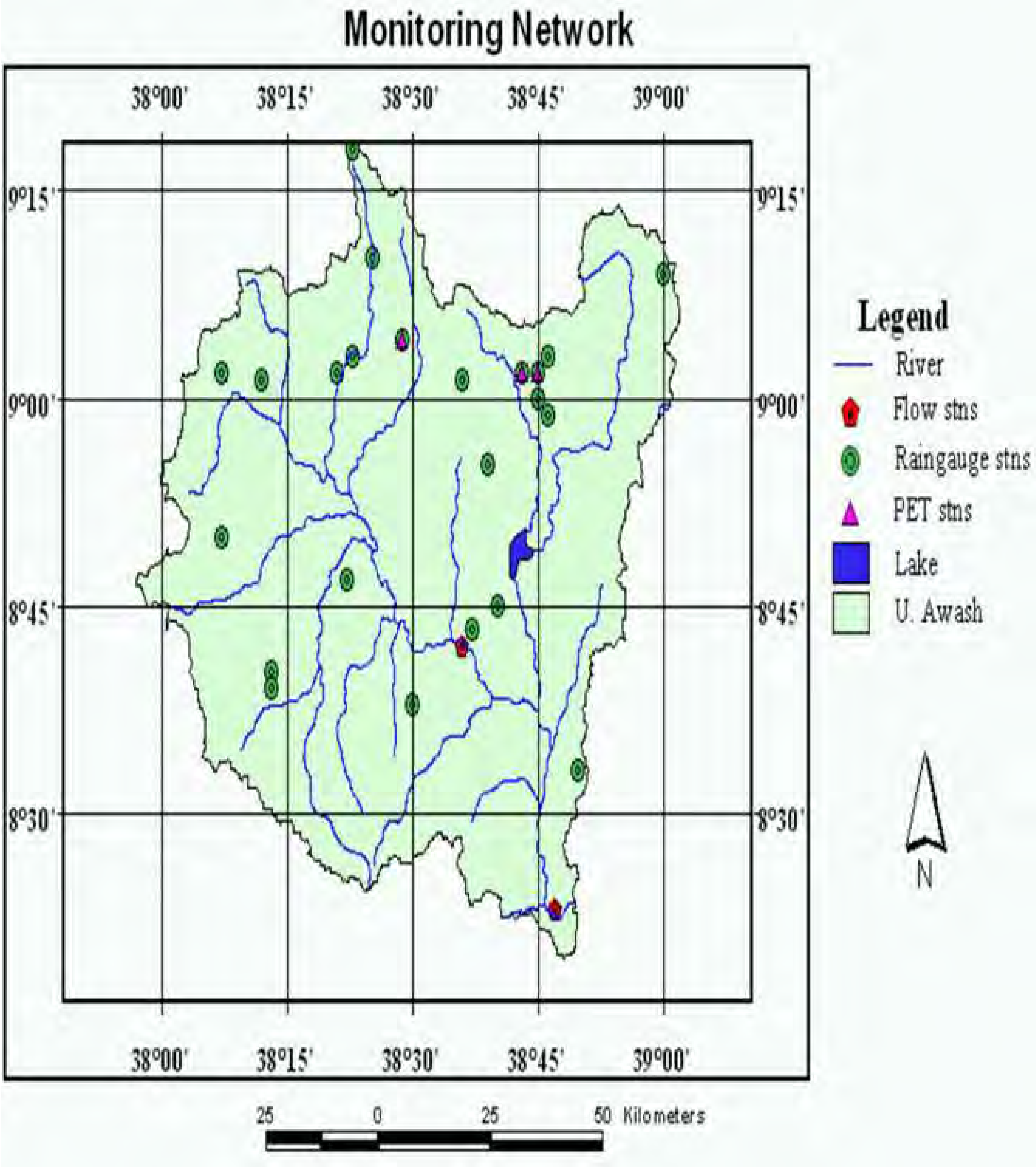

Figure6-2: The Upper Awash Basin Monitoring Network