ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

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DEPARTEMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

TITLE: - ASSESSMENT OF SURFACE WATER QUALITY IN UPPER AWASH RIVER BASIN

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Certificate

This is to certify that the thesis prepared by Shaka Nugusu, entitled: **Assessment of Surface water quality in Upper Awash River Basin,** and submitted in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering (major in Water Supply and Environmental Engineering).

As a member of the board of examiners of the MSc, Thesis open defense examination, we certify that we have read, evaluated the thesis prepared by Shaka Nugusu and examined the candidate. We recommend that the thesis be accepted as fulfilling the thesis requirement for the degree of Master of Science in Civil Engineering (Major in Water Supply and Environmental Engineering).

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Abstract

The present study focuses on the analysis of physicochemical and biological water quality parameters: electrical conductivity, nitrate, phosphate, COD, BOD, DO, turbidity , total dissolved solids, total alkalinity, total hardness, trace elements and biological parameters like E- Coli and total coliform in the upper Awash River basin. Awash River is in a great environmental concern because most of its tributaries streaming from the different catchment area of the basin contain several pollutants. The main threat to the surface water quality in upper Awash River basin is environmental pollution derived from domestic, Industrial and Agricultural activities. Due to inadequacy of controlled waste management strategies and waste treatment plants, people are forced to discharge wastes both on open surface and within water bodies. Improper waste disposal has deteriorated the quality of Awash River by changing the physical, chemical and biological properties of river water. Twelve samples of river water from different selected points during dry and wet season were collected and taken to Addis Ababa Environmental protection laboratory and Oromia water quality laboratory for identification of surface water quality status. physicochemical and bacteriological analysis of the samples during the dry and wet season along the streams show that the level of unwanted chemical and biological constituents are higher than the maximum permissible limit of Ethiopian and WHO standards. Therefore, this study aims to assess the quality of Upper Awash River Basin surface water quality based on physicochemical and bacteriological parameters and figure out if there are environmental and health risk associated with the use of these water sources. The result indicated that the range of BOD (7.6-216mg/l), Ammonia (0.12- 44.8mg/l), phosphate (0.28-9.64mg/l), turbidity (104- 5100mg/l) and alkalinity (40- 438mg/l). Total coliform and E-Coli present in the samples were at levels indicative of fecal pollution. It also exceeded all the guidelines for human use whether for personal contact, drinking, washing and cooking. Therefore this indicates that there is a serious health risk from the use of these water sources. The lack of industrial and municipal wastewater treatment plant of the towns in the basin has caused the Awash River to suffer from a serious pollution.

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Abbreviations

AAU	Addis Ababa University
AAEPA	Addis Ababa Environmental protection Authority
APHA	American Public Health Association
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
EC	Electrical Conductivity
EEPA	Ethiopian Environmental Protection Authority
EPA	Environmental Protection Authority
FAO	Food and Agricultural Organization
FEPA	Federal Environmental protection Authority
GPS	Global positioning system
mg/l	milligram per litter
NH_3	Ammonia
TDS	Total Dissolved Solids
UN	United Nation
WHO	World Health Organization
MoWIE	Ministry of water, Irrigation and Energy

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1. Introduction

Water is the most abundant substance on earth. Comprising over 70% of the earth's surface it is the principal component of all living things and a major force constantly shaping the surface of the earth. The need for water is strongly ascending, which is not only important for domestic purpose but also vital for the development activities in both agricultural and industrial sectors. The need of water is more complex due to population growth, urbanization and industrialization. Any developmental activity is related, either directly or indirectly, with water utilization. The natural physicochemical properties of water render its vital importance to sustain the living planet Earth and every form of life on its face, including human beings. Its vital role in many human activities including agriculture, industry, domestic, electric power generation, transport and recreation shows that to what extent water is an integral part of human's life. The normal functioning of a natural system such as a human body depends entirely on the availability of adequate quantity and quality of water.

Water pollution is the contamination of water bodies (lakes, rivers, oceans, aquifers and groundwater) or any physical, chemical, or biological change in water quality that has a harmful effect on living organisms or makes water unsuitable for desired uses. Sewage, industrial chemicals, heavy metals from industrial processes, and house hold cleaners are examples of materials commonly discharged into streams and rivers. Additional water pollutants include chemicals, pesticides, fertilizers, motor oil, litter, and other components of polluted runoff. In short Water pollution occurs when pollutants are directly or indirectly discharged into water bodies without adequate treatment to remove harmful compounds.

This day's water pollution resulted from industrialization, urbanization and population explosion has become a global problem. Our country, Ethiopia is also facing the problem of water quality degradation, however, the extent and degree of severity of water pollution is more pronounced in major cities, like Addis Ababa where the problem is at its peak currently. Although humans recognize this fact, they disregard it by polluting rivers, lakes, ground waters and oceans. In order to reduce and eventually overcome water pollution, one must understand the problems and become part of the solution (Abdulshikur, 2006; Chapman, 1996)

Rivers are the most important freshwater resource for man. Unfortunately, river waters are being polluted by indiscriminate disposal of sewage, industrial waste and surfeit of human activities, which affects the River water physicochemical characteristics and microbiological quality. Increasing numbers and amounts of industrial, agricultural and commercial chemicals discharged into the aquatic environment have led to various lethal effects on aquatic organisms. Aquatic organisms, including fish, accumulate pollutants directly from contaminated water and indirectly **via** the food chain.

Owing to the large quantity of effluent discharged to the receiving waters, the natural processes of pathogen reduction are inadequate for protection of public health. In addition, industrial wastes that alter the water pH and provide excessive bacterial nutrients often compromise the ability of natural processes to inactivate and destroy pathogens.

The extent of discharge of domestic and industrial effluents is such that rivers receiving untreated effluent cannot provide the dilution necessary for their survival as good quality water sources.

Disposal of sewage wastes into a large volume of water could increase the biological oxygen demands to such a high level that all the available oxygen may be removed, consequently causing the death of all aerobic species, e.g., fish. Prevention of river pollution requires effective monitoring of physicochemical and microbiological parameters.

Generally Water quality refers to the characteristics of a water supply that will influence its suitability for specific use i.e. how well the quality meets the needs of the user; quality is defined by certain physical, chemical, and biological characteristics (FAO, 1998). Good quality water is very important for general use, drinking, cooling, cleaning, irrigated agricultural crops, washing and processing equipment's. Water quality of rivers is best in the headwaters, where rainfall is frequent. Water quality often declines as rivers flow through regions where land use and water use are intense and pollution from intensive agriculture, large towns, industry and a recreation area increases (Bedelu, 2005). Similarly, the uncontrolled and excessive use of fertilizers and pesticides has long-term effects on ground and surface water resources (Chapman, 1996). Water quality alteration constitutes a major environmental impact of many water use and water development activities the most obvious source of quality alteration is the discharge of municipal and industrial water, addition of toxic substances to natural water is a change of special significance (Tamiru, 2011). Water quality is closely linked to the surrounding environment and land use. The quality of water is strongly influenced by community uses such as agriculture, urban and industrial use, and recreation.

1.1. Statement of the problem

In Ethiopia so far there is no well-organized water quality monitoring system, centralized water quality database, systematic and comprehensive River water quality assessment is lacking. However few available reports and studies made so far showed that there is no significant water quality pollution problem in most of the country's river basins except Awash River basin (Source Ministry of Water, Irrigation and Energy). The Awash River Basin is facing land and wetland degradation, soil erosion due to deforestation and overall water quality declines (*Taddesse et al., undated*). Awash River is the most threatened river from industrial waste, agricultural and urban domestic waste. The upper Awash River had low water quality status which is likely to be due to poor farming, untreated effluents from factories and poor provision of sanitation facilities to the riparian communities (Fasil, 2013). The Awash basin liquid waste resulting from the factories is not properly treated as per the standard set for waste water discharge (Melkame and Kasahun, 2013). The Awash River is prone to various types of pollution with wastewater, of which most originates from the urban agglomeration of Addis. Much of the wastewater, both domestic and industrial, produced in that area reaches the Awash river untreated, seriously polluting the water course (Rooigen and Taddesse, 2009). All of these issues can be accounted either directly or indirectly to growing population pressure and human activities in the basin. The ministry of water, Irrigation and energy is responsible for safeguarding the water environment, utilization and efficient allocation of these resources and promoting a sustainable water resources development in the country. Based on this, among the various river basin in the country, Awash River basin should have attracted considerable attention.

Therefore this study tried to assess the Surface Water quality of upper Awash River Basin and potential sources of pollution by determining the physicochemical and bacteriological parameters of surface water quality indicators by taking into account the spatial and temporal variations.

1.2. *Research questions*

- What are the major pollution sources?
- What is the status of Upper Awash River Basin surface water quality with respect to WHO, FAO, and Ethiopian water quality standards?
- Is there a variation in water quality from sampling station to station from dry season to wet season?
- What is the trend of surface water quality in the upper Awash River basin?

1.3. Objective

1.3.1. General objective

The general objective of this study is the assessment of surface water quality of the Upper Awash River Basin by analyzing some physicochemical and biological characteristics of the water.

1.3.2. Specific objectives

- To identify major sources of pollution
- To assess the water quality status and trends of the study area
- To assess the spatial and temporal water quality of the study area

1.4. Scope and limitation of the study

The research is focused only on the upper part of Awash River up to Koka reservoir /lake and it is based on limited number of samples because of financial limitations. Like any other research work, this study has also faced a number of limitations in the process of convening the work. The main obstacles were:

- The absence of time series data that could showed successive trends of awash pollution.
- The absence of centralized environmental data base
- Limited number of literatures specific to the objectives set in this project and the study area.

2. Literature review

Water quality is a term used here to express the suitability of water to sustain various uses or processes. Any particular use will have certain requirements for the physical, chemical or biological characteristics of water; for example limits on the concentrations of toxic substances for drinking water use, or restrictions on temperature and pH ranges for water supporting invertebrate communities. Consequently, water quality can be defined by ranges of variables which limit water use. Although many uses have some common requirements for certain variables, each use will have its own demands and influences on water quality.

Quantity and quality demands of different users will not always be compatible, and the activities of one user may restrict the activities of another, either by demanding water of a quality outside the range required by the other user or by lowering quality during use of the water. Efforts to improve or maintain a certain water quality often compromise between the quality and quantity demands of different users. There is increasing recognition that natural ecosystems have a legitimate place in the consideration of options for water quality management. This is both for their intrinsic value and because they are sensitive indicators of changes or deterioration in overall water quality, providing a useful addition to physical, chemical and other information.

The composition of surface and groundwater is dependent on natural factors (geological, topographical, meteorological, hydrological and biological) in the drainage basin and varies with seasonal differences in runoff volumes, weather conditions and water levels.

Large natural variations in water quality may, therefore, be observed even where only a single watercourse is involved. Human intervention also has significant effects on water quality. Some of these effects are the result of hydrological changes, such as the building of dams, draining of wetlands and diversion of flow. More obvious are the polluting activities, such as the discharge of domestic, industrial, urban and other wastewaters into the water course (whether intentional or accidental) and the spreading of chemicals on agricultural land in the drainage basin.

Water quality is affected by a wide range of natural and human influences. The most important of the natural influences are geological, hydrological and climatic, since these affect the quantity and the quality of water available. Their influence is generally greatest when available water quantities are low and maximum use must be made of the limited resource. Thus, although water may be available in adequate quantities, its unsuitable quality limits the uses that can be made of it.

Although the natural ecosystem is in harmony with natural water quality, any significant changes to water quality will usually be disruptive to the ecosystem.

Generally the quality of natural water in rivers, lakes and reservoirs and below the ground surface depends on a number of interrelated factors. In its movement on and through the surface of the earth, water has the ability to react with the minerals that occur in the soil and rocks and to dissolve a wide range of materials, so that its natural state is never pure. It always contains a variety of soluble inorganic, soluble organic and organic compounds. In addition to these, water can carry large amounts of insoluble materials that are held in suspension. Both the amounts and type of impurities found in natural water vary from place to place and by time of year and depends on a number of factors. Moving water dilutes and decomposes pollutants more rapidly than standing water, but many rivers and streams are significantly polluted all around the world. In Ethiopia, human activities such as land use and modification, urbanization, human settlement and other practices associated with rapid population growth are the major water quality degrading factors (Fasil, 2013). A primary reason for this is that all three major sources of pollution (industry, agriculture and domestic) are concentrated along the rivers. Industries and cities have been located along Upper Awash Rivers Basin because of this the Awash River is the most polluted river in Ethiopian. The western, southern and southwestern parts of Addis Ababa are among the highly populated urban as well as industrial centers in the country consequently a considerable amount of waste is generated every day from different sources (Abdulshikur, 2007). With a rapidly expanding human population and a growing trend of industrial development, problems related to management of industrial waste have become of considerable magnitude in Ethiopia (Getachew, 2006).

The Awash River Basin is facing land and wetland degradation, soil erosion due to deforestation and overall water quality declines (*Taddesse et al., undated*). All of these issues can be accounted either directly or indirectly to growing population pressure and human activities in basin. The Awash River is prone to various types of pollution with wastewater, of which most originates from the urban agglomeration of Addis Ababa city. In the case of Addis Ababa, the waste collection system (solid and liquid) did not proportion to its expansion and consequently the impact of these waste on the water environment is increasing (Tamiru, 2011). Much of the wastewater, both domestic and industrial, produced in that area reaches the Awash river untreated, seriously polluting the water course. Since downstream river water is being used for various purposes such as drinking water supply (Adama City) and irrigation; public health risks are high, not only in the urban area but in the rural area.

The AAWSSA report shows that Addis Ababa (Akaki) wastewater treatment capacity is Less than ten percent (10%) of the urban area is Sewered while in the major part of the remaining area pit latrines are used that dispose their wastewater in the storm water drainage network (*AAWSSA, 2008*). With a rapidly expanding human population and a growing trend of industrial development, problems related to the management of industrial waste have become of considerable magnitude in Ethiopia. The problem is more severe in the capital city, Addis Ababa, where most of the industrial establishments of the country have been taking place. At present nearly all industries operating in the city do not implement any pollution abatement activities (Getachew, 2006).

Addis Ababa city has two sewage treatment plants, the first one, is called Kality treatment plant, runs under its designed capacity of 7,600 m^3/day or 200,000 population equivalents, while it treats on average 5,200 m^3/day. The other treatment plant, called Kotebe treatment plant, receives only sludge from vacuum trucks that empty septic tanks, with an estimated annual volume of 85,000m^3(*Rooijen and Girma,, 2009*). Therefore, the remaining wastewater is discharged directly into natural watercourses of the little and great Akaki River, which eventually joins the Awash River. The little and great Akaki River is an important source of water for small scale farmers in and around Addis Ababa who are producing vegetables and fodder for livestock. The River serves as an important drainage system that disposes of abundant runoff and wastewater into the Awash River. The upper Awash River had low water quality status which is likely to be due to poor farming, untreated effluents from factories and poor provision of sanitation facilities to the riparian communities (Fasil, 2013).

2.1. Physiochemical water quality

Water has a wide range of physical and chemical characteristics that affects its quality and treatability (Hutton, 1996). Physical and Chemical testing of drinking water is necessary to assure that treated water is safe and palatable and to monitor the various water treatments for safe drinking water supply and also Physicochemical testing of raw water is helpful to determine treatment techniques and chemical dosage.

Turbidity is a measure of the cloudiness of water and is used to indicate water quality and filtration effectiveness. Turbidity of natural water is caused by the presence of compounds such as clay, mud, organic matter, bacteria, and algae. The flow rate of river water, soil erosion, building and Road Construction, Mining, Urban Runoff, wastewater and Septic System Effluent, decaying plants and animals are some factors that increase the turbidity of water (WHO, 1993). Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria (APHA, 1998). These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.

PH is one important water quality parameter, the pH of water, affects the biochemical process in water (Chapman, 1996). The WHO guide level for pH in drinking water quality is 6.5 to 8.5 (WHO, 1993). Most drinking water have a pH from 4 to 9 and the majority are slightly alkaline due to carbonates and bicarbonates of calcium and magnesium dissolved in water with variable pH are most likely contaminated and indicating the introduction of industrial wastes (Hutton, 1996).

Total dissolved solids (TDS) in waters constitute mainly carbonates, bicarbonates, chlorides, sulfates, calcium, magnesium, potassium, dissolved metals, dissolved organics and other substance account for a small portion of the dissolved residues in water. Dissolved solids and residues in drinking water tend to change the waters physical and chemical nature of drinking water (WHO, 2004).

Water with high dissolves solids is not preferred by consumers in drinking, the presence of harmful dissolved compounds arsenic, mercury can be dangerous in water even where the total solid concentration is relatively low with their health effects (AWWA, 2000). The WHO recommended limit of TDS concentration of drinking water should be 1000mg/l (Hutton, 1996).

Electrical Conductivity is the ability of aqueous solution to carry an electric current, this ability depends on the Electrical conductivity presence of ion and waters with high inorganic compounds are relatively good conductors indicates water quality. Electrical conductivity of the water is related to total concentration of ions in the water, their valence charge and mobility. Changes in conductivity of water sample may signal changes in mineral composition of water seasonal variation in reservoirs and pollution of water from industrial wastes (AWWA, 2000).

Hardness is measure of concentration of calcium and magnesium salt in water, is important variable for drinking water quality. They are generally present as carbonate and bicarbonate salts. Calcium and magnesium salts in natural water is due to the passage of rain water or over deposits of calcium and magnesium rich rock such as limestone, dolomite and gypsum or cementing material are the major sources of water hardness.

Calcium in natural water is due to the passage of rain water through over deposited of calcium rich rocks such as lime stone dolomite and gypsum or cementing materials in other rocks, is one important component in water quality. Depending on the water source and treatment of water the range of calcium concentration in river water ranges from zero to several hundreds of milligram.

Magnesium is common constituent of natural waters which is important components in water quality, its concentration ranges from zero to several 100mg/l, the major sources of magnesium in water is the chemical weathering of rocks such as dolomite, manganite and also silicate mineral found in igneous rocks (Hutton, 1996). It is the major contributor to hardness and like calcium, concentration of magnesium above 150mg/l especially if present with sulfate can cause gastrointestinal irritation and diarrhea, some salts of magnesium in water are toxic by ingestion or inhalation, concentration of magnesium greater than 125mg/l also can have a cathartic and diuretic effect (WHO, 1993).

The presence of sodium ion in drinking water is important factor in related with its health complications .The abundance of sodium in the earth crust is 2.5percent in soil it is 0.02 to 0.62 percent in streams is 6.3mg/l and in ground water is generally greater than 5mg/l. The ratio of sodium in water is important in agriculture and human physiology, soil permeability can be harmed by a high sodium ratio, in large concentration of sodium has health effects that may affect persons with cardiac difficulties, the recommended limit for sodium in drinking water is about 20mg/l (WHO, 1993).

The alkalinity of water is a measure the water capacity to neutralize an acid and it's related to the water buffering capacity. Alkalinity has little known significance with regard to human health however highly alkaline waters are unpalatable and also affect the efficiency of coagulation process. Alkalinity of water is caused by the presence of carbonates, bicarbonates and hydroxides. In most river waters the principal ion is bicarbonate, phenolphetlin alkalinity is usually due to carbonates or hydroxides which is the indicator of industrial pollution in surface water (APHA, 1980).

Trace amount of ammonia are found in most natural water and Sewerage contains large amount of ammonia formed by bacterial decay of nitrogenous organic wastes. Surface water showing a sudden increasing in the ammonia content may indicate sewage pollution or industrial pollutions from dairies, abattoirs, tanneries or chemical plant rural run off, excretion of wastes etc. The nature of ammonia is combined as ammonium $NH4^+$ ion above the pH 7 the percentage of free ammonia increasing rapidly. Ammonia in water is an indicator of possible bacterial, sewerage and animal waste pollution, source reduction of nitrogenous wastes (WHO, 2004).

Fluoride is found naturally in much water, it is also added in many water systems to reduce tooth decay. Optimum fluoride concentration in drinking water varies with climate, because more water is consumed in warmer climate, fluoride concentration should be lowered. Excessive fluoride concentration can because teeth become stained or mottled (Sandra, 1996). This is true where the natural fluoride content is above 2.4mg/l the concentration of fluoride in drinking water is critical when considering the strength of growing teeth and bones. Waters low in fluoride sometimes has fluoride added to bring the concentration to recommended level. Higher than

2mg/l bones are brittle, staining teeth and crippling in old women. The WHO guide level of fluoride is 1.5mg/l (WHO, 1993).

Chlorine as the chloride ion is the major constituent in water and waste water with a wide range of concentration from few mg/l in clean rain to 10 of mg/l in supersaturated, hot saline ground water. Chloride may be increased in surface water since it is concentrated in human and animal urine reaching water courses. Human urine may contain 1-1.5% of NaCl. An increase in the chloride contents 30-300mg/l in natural waters may be caused by pollution by sewage. A related health problem of chlorine contamination in drinking water includes Eye/nose irritation; Anemia; infants and young children: nervous system effects (Sandra, 1996). Paper works, galvanizing paints, softening plants and another industries may also discharge effluents containing chlorides and also run-off from heavily fertilized filed. The WHO guide level of chloride is 250mg/l (WHO, 1993).

Nitrate is an end product of the decay of nitrogenous material such as nitrate fertilizers or animal and human excreta (Hutton, 1996). Its presence in a water supply usually denotes bacterial activity as a result of recent or on-going pollution, often from sewerage. In developing countries especially there is risk of ground water pollution by onsite sanitation. Nitrogen fertilizers are causing high level of nitrates in water supplies (WHO, 1993). The level of nitrogen in surface water fluctuates with the seasons, influencing algae and plant growth rate which can degrade river and lake water quality. Health hazards of high nitrate level in drinking water include shortness of breath and blue-baby syndrome and other disorders (WHO, 2004). The WHO guide level of chloride is 50mg/l (WHO, 1993).

Sulfates occur in most natural water in wide range of concentration. High values of sulfate above 200mg/l can lead to attack of diarrhea especially in new comers to the high sulfate water supply. The WHO and Ethiopian guide level of sulfate is 250mg/l. Waters in contact with sulfate rocks such as gypsum often have high sulfate values, acid mine water particularly from sulfide bearing ores and industrial wastes may also contribute large amount of sulfate to natural water. In developing countries drinking water containing high sulfate can contributes to problem of sewer corrosion and related health hazards (Hutton, 1996).

Phosphate commonly occurs in natural water and is often added in water treatment chemicals. Excessive amount of phosphate actually constitute pollution usually by infiltration of waste water from domestic and industrial sources or agricultural runoff phosphate derived from detergent, hardness treatment. Phosphorus are often the limiting nutrients for growth of organisms in water, and too much phosphate can lead to rapid eutrophication especially in lakes reservoirs and ponds where other nutrients such as nitrate may be present. Such rapid growth in hot climate where the dissolved oxygen in water is already low can create problem of taste and odor (WHO, 2004).

Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) are two common measures of water quality that reflect the degree of organic matter pollution of a water body. BOD is a measure of the amount of oxygen removed from aquatic environments by aerobic micro-organisms for their metabolic requirements during the breakdown of organic matter, and systems with high BOD tend to have low dissolved oxygen concentrations. COD is a measure of the oxygen equivalent of the organic matter in a water sample that is susceptible to oxidation by a strong chemical oxidant, such as dichromate (Chapman, 1996).

3. Methodology

3.1. Descriptions of the whole basin

The Awash River basin with a total area of 110,000 km^2 drains the northern part of the rift valley in Ethiopia. It has no outlet to the oceans, the terminal point being Lake Abe on the border with Djibouti. The basin is almost entirely within the boundaries of Ethiopia, the portion within Djibouti being negligible. The river rises at an elevation of about 3,000 m in the central highlands, West of Addis Ababa and flows north-east wards along the Rift Valley. The main river length is about 1,200 km. The basin lies between longitude 7°52′12″N and 12°08′24″N and latitude 37°56′24″E and 43°17′2″E.

The Awash River Basin is divided into four major spatial stretches on the basis of altitudinal variation (Halcrow, 1989):

1. The Upper Basin - from its head water up to Koka Dam (>1,500 masl);
2. The Upper Awash Valley - from Koka Dam up to Awash Station (1,500 – 1,000 masl);
3. The Middle Awash Valley - from Awash Station up to Gewane (1,000 – 500 masl), and;
4. The Lower Awash Valley - from Gewane up to Lake Abe (<500 masl).

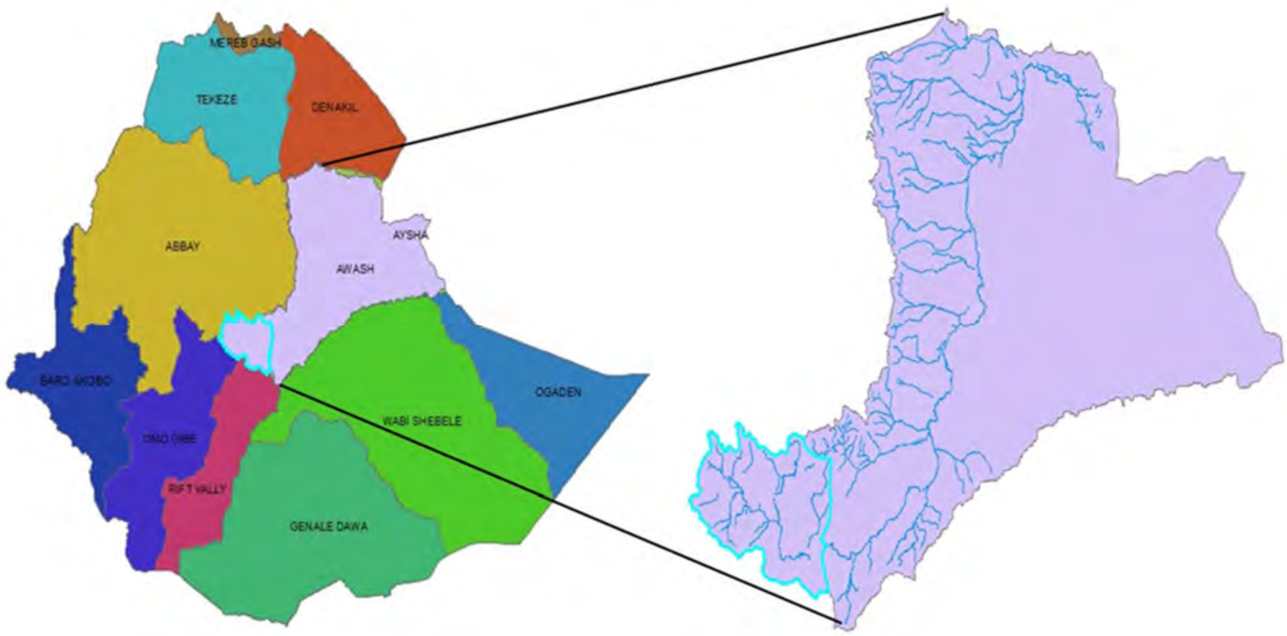

Figure 1. Ethiopian river basin, Awash River basin and location of upper Awash River basin

3.1.1. Description of the Particular study area (Upper Awash river basin)

This research was undertaken on the upper part of the Awash River Basin in Ethiopia, which lies upstream of Koka dam and it is located between latitudes of 8°16’ and 9° 18’ and longitudes of 37° 57’ and 39°17’. It covers about 7240 km². Upper Awash basin is one of the hydrological zones in the basin with high demand level water supply, irrigation and Hydropower due to its suitable natural resources (land, water and accessible conditions). The elevation of the riverine area ranges from 3000m and 1500m amsl. The mean annual rainfall generally lies between 800mm and 1500mm. The area is dominated by cropland, shrub land, and urban area. Because of the land use the area is more susceptible to agricultural, industrial and municipal pollution of river water. The regional location of the study area lies within administration region of Oromia and Addis Ababa City.

3.1.2. Sampling time and location

Twelve sampling site of Awash River and its tributaries were selected to represent the water quality variations. The sampling points were located by GPS and are shown in Figure 2. The sampling points were selected based on the rate of human interference, industrial and agricultural activities that have been taking place in the study area. These twelve sampling points were taken to show the relative surface water quality changes in the Upper Awash River Basin (study area).

3.1.2.1. Sampling time

Temporal variation of the physicochemical and biological quality of water body can be described by studying the relative concentration and biodegradation rate of the water. The temporal span of the field investigations was meant to cover both dry (for three days from07/05/14 to 09/05/2014) and wet season (for three days from 18/08/14 to 20/08/14) in order for the study to take variations due to the changes in the seasonality of flow of the Awash River and its tributaries occasioned by variations in rainfall.

3.1.2.2. Sampling location

Essentially, site selection decision with regard to diffuse sources of pollution is based on the potential of assortment of sample sites to yield a fair picture of the environmental performance of Awash River and its tributaries at different points. In addition to suitability and appropriateness in terms of yield requirements of the study, site selection was based on ease of accessibility of any of the sample sites. The sample sites are indicated in Figure 2. Also see Annex III for absolute locations and the elevations of these sites.

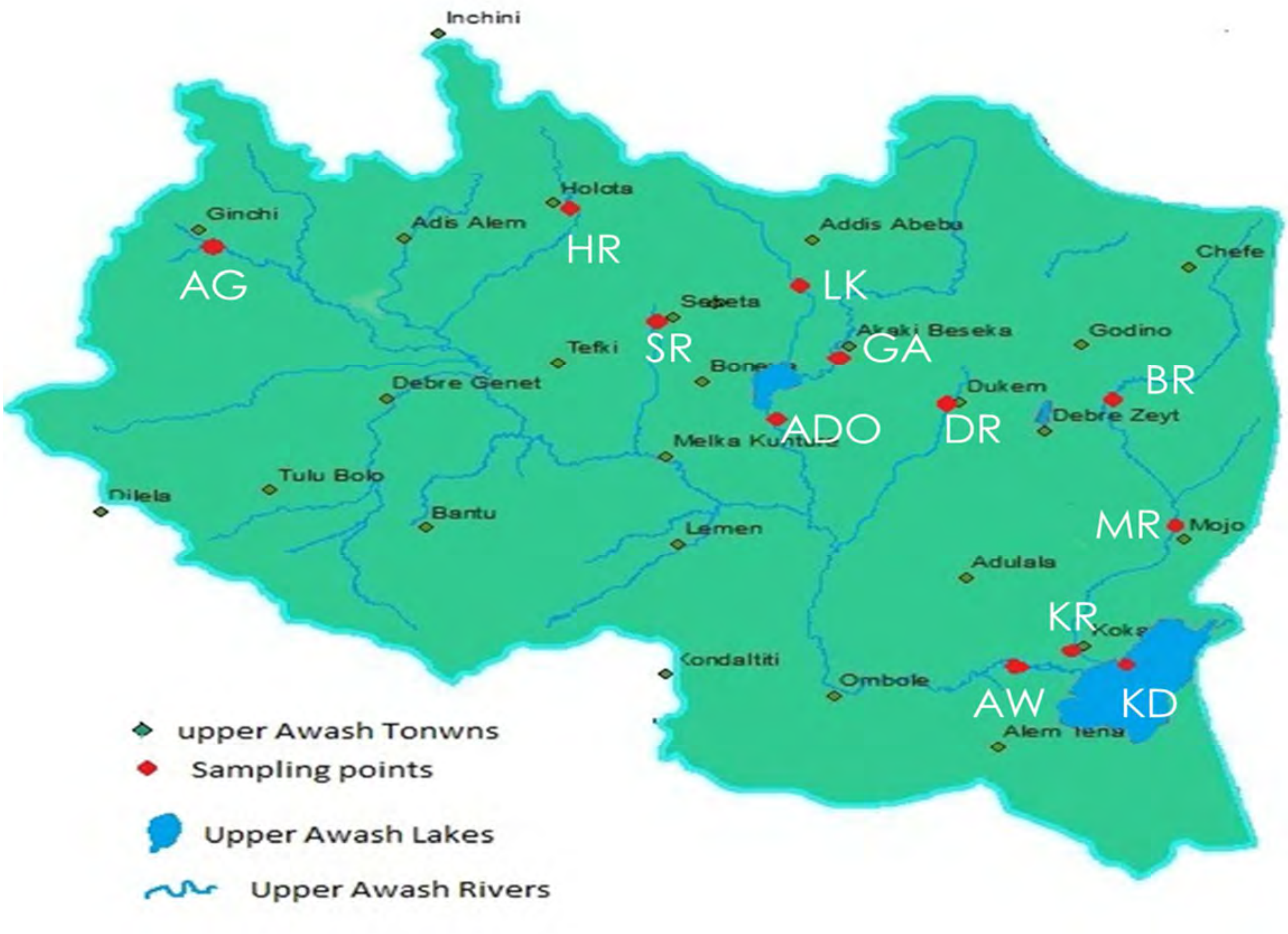

Figure 2. Upper Awash river basin, town's location and water sampling points

3.2. Method of data collection

An orderly field work was carried out for the collection of primary and secondary data on various aspects of water quality of the Awash River. A total of 12 water samples, (2 from reservoirs and 10 from river) during both dry and wet season were collected using 2000ml polyethylene plastic bottles for different physicochemical parameters. Water samples from each of the twelve sampling points was collected by direct immersion of bottles in the water. Water sampling and preservation techniques followed the standard methods of water sampling and preservation techniques (APHA, 1998). The sampling sites were characterized based on physical, chemical and land use information. It was decided to take a sample from tributary rivers downstream of towns which are expected the sources of pollution. Samples were collected from well-mixed section of the river (main stream) water surface using a washed plastic with concentrated nitric acid and distilled water to avoid contamination.

Samples from Aba Samuel reservoir site was collected from the outgoing canal and for case Koka reservoir the sample was collected from the upstream side, directly from the reservoir at which the local farmer withdrawn a water for irrigation by suction pump.

Secondary data such as effluent of some industrial waste, existing surface water quality, and watershed characteristics were collected from responsible agencies such as Ministry of Water, Irrigation and Energy, Oromia water, mine and energy water quality control department and Ethiopian environmental protection agency (EEPA).

3.2.1. Analysis of physicochemical parameters

To assess surface water quality the collected sample had been tested in Addis Ababa environmental protection authority laboratory and Oromia central water quality laboratory. Parameter like Temperature, Turbidity, pH, EC, total dissolved solids (TDS), Total Alkalinity, Total hardness, Chloride, Fluoride, manganese, calcium, magnesium, sodium, potassium, Ammonia, Nitrates, phosphates, sulfate, COD, BOD, DO and bacteriological like total coliform and E-Coli had been determined with their respective methods or procedures and instruments. Selected heavy metals: Fe, Pb, Cr, and Zn, which are expected in industrial effluents released to the rivers catchments analyzed following the standard methods. The pH, temperature, total dissolved solids (TDS) and Electric Conductivity (EC) were determined at the time of sampling by Cyberscan PC300 PH/conductivity/TDS/Temperature meter having the respected electrodes. These probes were immersed in the sample water and the measured parameters were displayed on the LCD screen of the instrument.

The physicochemical test is performed using DR/2004 spectrophotometer. A reagent chemical is dissolved in 10 ml of water sample in a cylindrical cell and allowed to react. Colour develops with intensity proportional to the amount of the target element to be measured. Each element has a unique maximum absorption wavelength (λ) at which the spectrophotometer is adjusted. Light is allowed to pass through the sample cell so that light is absorbed at the required wavelength. The results are displayed on the LCD screen as mg/l in proportion to the amount of light absorbed at that particular wavelength. Ammonia, Nitrate, sulphate, fluoride, iron, manganese, chromium and zinc amount of collected water sample were analysed using the above mentioned spectrophotometer. The dissolved oxygen (DO) content in the samples was estimated by Winkler method. Sodium and potassium content in the samples were determined using atomic absorption spectrophotometer.

Determination of total Alkalinity, total hardness, calcium, magnesium, chloride and total acidity were carried out by titration methods.

3.3. Data Analysis and Interpretation

The water quality criteria standards were used to interpret water quality characterization. The most common national requirements are suitability of water for domestic, drinking and irrigation purposes. The analyzed laboratory result taken from twelve sample point values for each physiochemical and biological values and compared with the WHO, FAO and the Ethiopian drinking water quality standards and interpreted in accordance with the result obtained from the samples with the maximum allowable limits. Any impact or deviation from standard were discussed and interpreted in relation with the corresponding activities.

4. Result and Discussion

4.1. *Physical and chemical quality of upper Awash River water*

4.1.1. Electrical Conductivity

Electrical conductivity is the measure of the ability of water to conduct an electric current and depends upon the number of ions or charged particles in the water, and is measured by passing a current between two electrodes (a known distance apart) that are placed into a sample of water. The unit of measurement for electrical conductivity is expressed in either micro Siemens per centimeter (µS/cm) or milli Siemens per centimeter (mS/cm). Low values are characteristic of high-quality, low-nutrient waters and High values of conductance can be indicative of salinity problems. Very high values are good indicators of possible polluted sites. A sudden change in electrical conductivity can indicate a direct discharge or other source of pollution into the water. However, electrical conductivity readings do not provide information on the specific ionic composition and concentrations in the water. The WHO standers for electric conductivity for drinking water is 500 µS/cm and Food and Agriculture Organization (FAO) guidelines for the evaluation of water quality for irrigation and suggests that there need be: no restrictions on the use of irrigation water with an EC of 0.7 dS/m (700 µS/cm).The electric conductivity of the sample stations for both dry and wet seasons are shown below in the following figure. The figure shows that the temporal concentration of electrical conductivity in dry season had crossed the threshold value of the World Health organization (WHO) at Koka river station (KR), Little Akaki river (LK), Awash at Koka (at the bridge), Sebata river (SR), Modjo river, Great Akaki River (GA) and Aba Samuel dam outlet (ADO) the same is true for FAO standard except Awash at Koka and Great Akaki river. During wet season high Electrical Conductivity was recorded only at Sebata River (SB) which was above the WHO limit. The higher values within the sampling point have resulted from different domestic wastes, untreated sewerage and mostly untreated industrial effluent. However comparing the seasonal variation along the river sampling point the dry season showed relatively higher concentration peaks which could be due to the small flow during the dry season and the higher evaporation rate that leaves salt behind. The Ethiopian Environmental Protection Authority (EEPA, 2003) the stream waters guideline set an Electric conductivity in a range of 100- 1000µS/cm. only little Akaki and Koka River was above 1000 µS/cm during dry season.

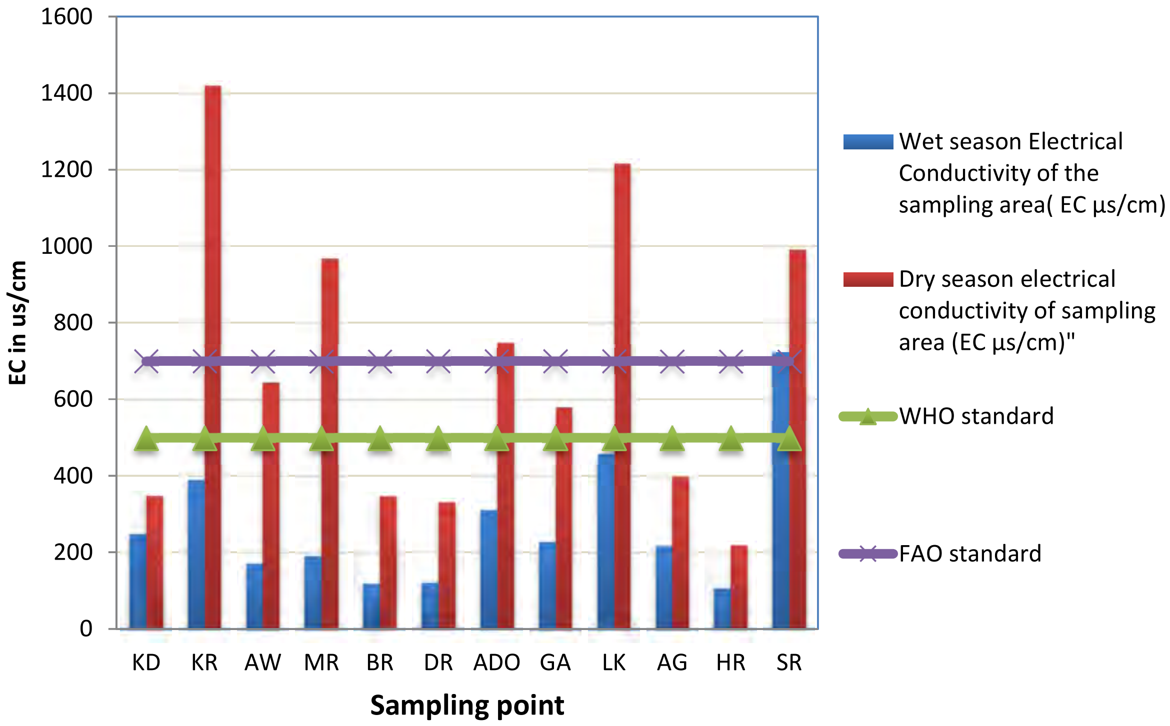

Figure 3. Electric conductivity values of various river water sample stations

4.1.2. Turbidity

Turbidity is a measure of the clarity of a water body and is an optical measurement that compares the intensity of light scattered by a water sample with the intensity of light scattered by a standard reference suspension. It is commonly recorded in nephelometric turbidity units (NTUs). Turbidity in water is caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, and plankton and other microscopic organisms. It is also due to Sediment which comes largely from shoreline erosion and from the resuspension of bottom sediments due to wind mixing. The Turbidity of the sampling stations for dry and wet season ranges from 199 to 1760 NTU and 104 to 5100 NTU respectively. The WHO states that appearance of water with a turbidity of less than 5 NTU is usually acceptable to consumers, although this may vary with local circumstances. The Ethiopian drinking water quality standard limit for turbidity is 5NTU but FAO has no guide line for irrigation water turbidity. Apparently all the sample water for both dry and wet season laboratory results were above the standard limits. Provided, that water samples collected from different river sampling sites of awash river exceed the acceptable range of both WHO and Ethiopian standards for both dry and wet season. This high turbidity value is due erosion, domestic waste and industrial effluents discharge into the river. Comparing the dry season and wet season result the wet season result is higher than dry season for sampling point like Koka River, Awash at Bridge, Modjo River and Great Akaki River, this is because turbidity come from suspended sediment such as silt or clay (from erosion), inorganic materials. For the remaining samples the dry season turbidity was higher than the wet season which was due to suspended sediment such as silt, inorganic materials, or organic matter such as algae, plankton and decaying material. In addition to these suspended solids, turbidity can also include colored dissolved organic matter like, colored dissolved organic material (CDOM), fluorescent dissolved organic matter (FDOM) and other dyes.

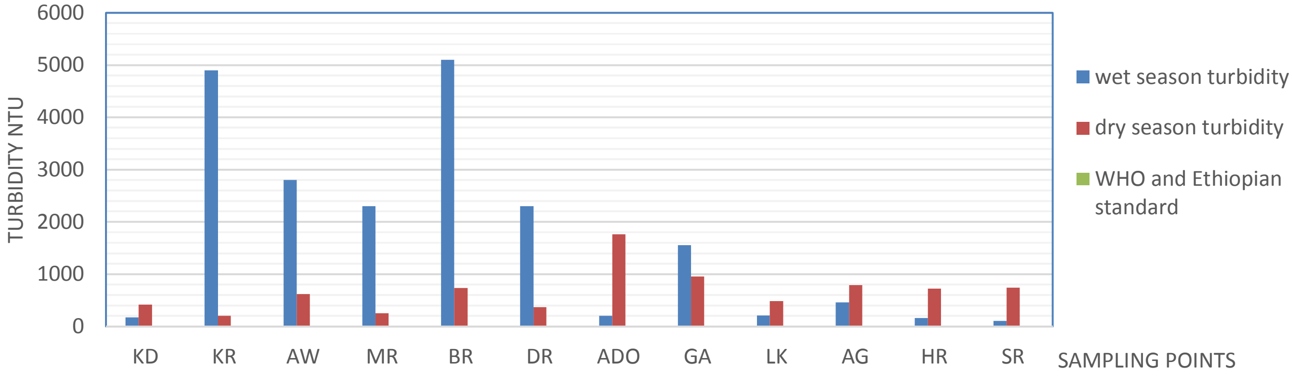

Figure 4. Turbidity values of various river water sample stations

4.1.3. Total dissolved solid (TDS)

Total Dissolved Solid comprises inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates) and small amounts of organic matter that are dissolved in water. Concentrations of TDS in water vary considerably in different geological regions owing to differences in the solubility's of minerals. The WHO and Ethiopian drinking water quality guide lines for TDS is 1000 mg/l. In the study area TDS of the samples for both dry and wet season ranges from 109 (at Holeta River) to 712mg/l (at Koka river) and 53.1(at Holeta river) to 361mg/l(at Sebata river) respectively which is below the maximum limits of WHO and Ethiopian standard. Regarding to the seasonal variation dry season shows higher concentration than wet season for all sampling points. This is due to the dilution of inorganic and organic salts during the dry season.

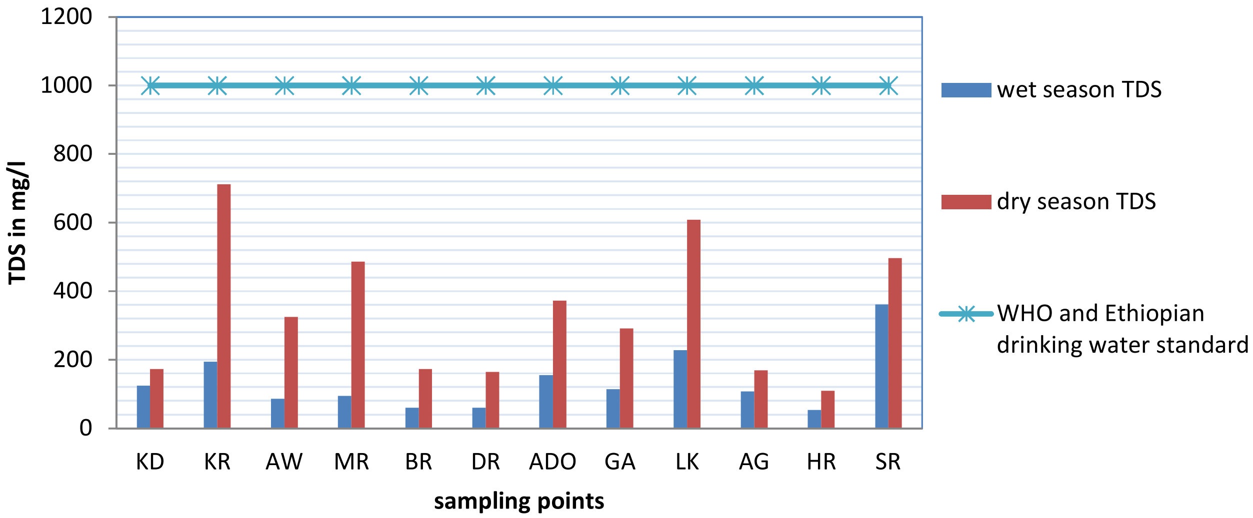

Figure 5. Total dissolved solid values of various river water sample stations

4.1.4. PH

The pH of a solution is the concentration of hydrogen ions, expressed as a negative logarithm. It reflects the acidity or alkalinity of a solution, Water with a pH of 7 is neutral; lower pH levels indicate increasing acidity, while pH levels higher than 7 indicate increasingly alkaline solutions. It is important to consider the effects of pH on other potential toxicants; e.g. the bioavailability of heavy metals. In present study area the dry and wet season PH value ranged from 6.57 (Holeta river) to 8.19 (Sebata river) and 7.32(great Akaki river) to 7.84 (Sebata river) respectively. The WHO, Ethiopian water quality standard and FAO water quality standard for PH ranges from 6.5 to 8.5. The PH of all the samples fulfills the above standard for both dry and wet season. Comparing seasonal variation the dry season PH of the samples were higher than a wet season for a Koka dam, Koka river, Modjo river, aba Samuel dam, great Akaki and Sebata river sampling points and vice versa for the remaining sample points as shown on Figure 6. This was because of the alkalinity and acidity contents of the samples from different sources.

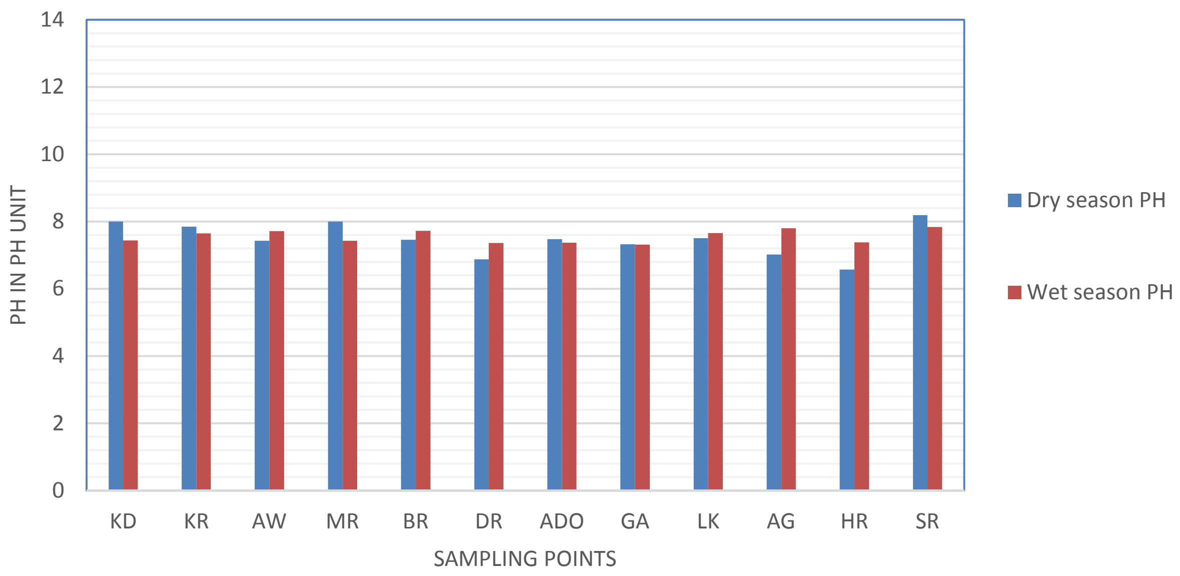

Figure 6. The PH values of different sample points

4.1.5. Temperature

Temperature can be measured using a thermometer with a range of 0–50°C or a suitable electronic thermometer. Since the solubility of dissolved oxygen decreases with increasing water temperature, high water temperatures limit the availability of dissolved oxygen for aquatic life. In addition, water temperature regulates various biochemical reaction rates that influence water quality. Heat sources and sinks to a water body include incident solar radiation, back radiation, evaporative cooling and heat conduction, thermal dischargers (e.g. cooling water from power plants), tributary inflows and groundwater discharge. The variation in temperature of the sample stations during dry season was from 21.4 to 29.7^{o}C and wet seasons from 18.3 to 23.5^{o}C. Comparing the seasonal variation except the little Akaki and great Akaki river sample for all the samples site the dry season temperature was higher than the wet season. For the two site the sample were collected at the morning during the dry season that is why the dry season shows less value. The variations from sample to sample and season was directly related to the weather temperature of time of sampling.

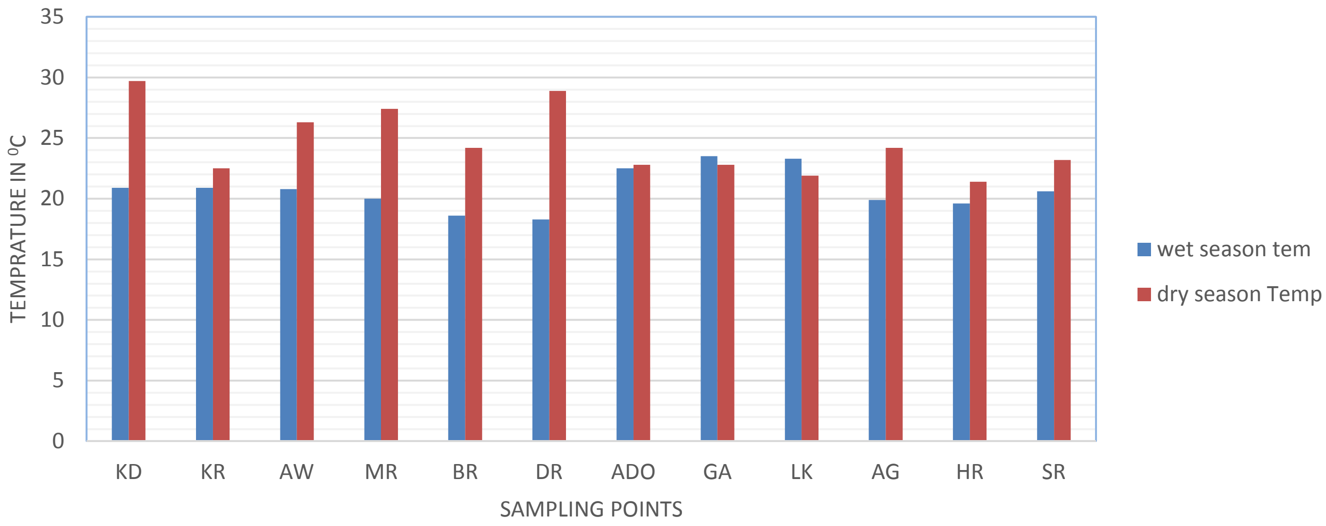

Figure 7. Temperature values of various water sampling

4.1.6. Total Alkalinity and Acidity

Alkalinity is the name given to the quantitative capacity of an aqueous solution to neutralize an acid. This capacity is commonly known as "buffering capacity." For example, if you add the same weak acid solution to two vials of water - both with a pH of 7, but one with no buffering power (e.g. zero alkalinity) and the other with buffering power (e.g. an alkalinity of 50 mg/l), - the pH of the zero alkalinity water will immediately drop while the pH of the buffered water will change very little or not at all. The pH of the buffered solution would change when the buffering capacity of the solution is overloaded.

A buffer is a solution to which an acid can be added without changing the concentration of available H+ ions (without changing the pH) appreciably. It essentially absorbs the excess H+ ions and protects the water body from fluctuations in pH. Measuring alkalinity is important in determining a stream's ability to neutralize acidic pollution from rainfall or wastewater. It is one of the best measures of the sensitivity of the stream to acid inputs. There can be long-term changes in the alkalinity of streams and rivers in response to human disturbances. Alkalinity does not measure the same property as the pH (namely basicity). The main sources of natural alkalinity are rocks, which contain carbonate, bicarbonate, and hydroxide compounds, borates, silicates, and phosphates may also contribute to alkalinity. Total alkalinity is the total concentration of bases in water expressed as parts per million (ppm) or milligrams per liter (mg/l) of calcium carbonates ($CaCO_3$). These bases are usually bicarbonates (HCO_3^-) and carbonates ($CO^{2-}{}_3$), and they act as a buffer system that prevents drastic changes in PHs, Water with high total alkalinity is not always hard, since the carbonates can be brought into the water in the form of sodium or potassium carbonate. Comparing total alkalinity with total hardness, except Dukem river sample for all sampling site total Alkalinity concentration were higher than the total hardness (figure 9) which results PH above 7, But for the case Dukem River during dry season total Hardness were above the alkalinity of the water which results the PH of the water sample below 7. The WHO and Ethiopia Water quality standards, desirable limit of total alkalinity is 200mg/l as $CaCO_3$. The total alkalinity of the study area was ranged from 40 to 438 mg/l in dry season and from 44 to 126mg/l in a wet season. Except to Dukem sampling point a higher concentration of Alkalinity was observed in dry season than in wet season across the sampling point. In dry season alkalinity was observed above the standards at Koka River, Modjo River, and Aba Samuel dam, Awash at Koka Bridge, Awash at Ginchi, great Akaki, little Akaki and Sebata river sampling site. This is because the alkalinity of natural water is determined by the soil and bedrock through which it passes. The main sources for natural alkalinity are rocks which contain carbonate, bicarbonate, and hydroxide compounds. Borates, silicates, and phosphates also may contribute to alkalinity. Limestone is rich in carbonates, so waters flowing through limestone regions or bedrock containing carbonates generally have high alkalinity - hence good buffering capacity. Only four sampling points namely; Bushoftu, Koka dam, Dukem and Holeta River sampling points are below the WHO and Ethiopian standards during a dry season. The alkalinity level for all sample sites in wet season is acceptable as they are well below the WHO and Ethiopian guide line.

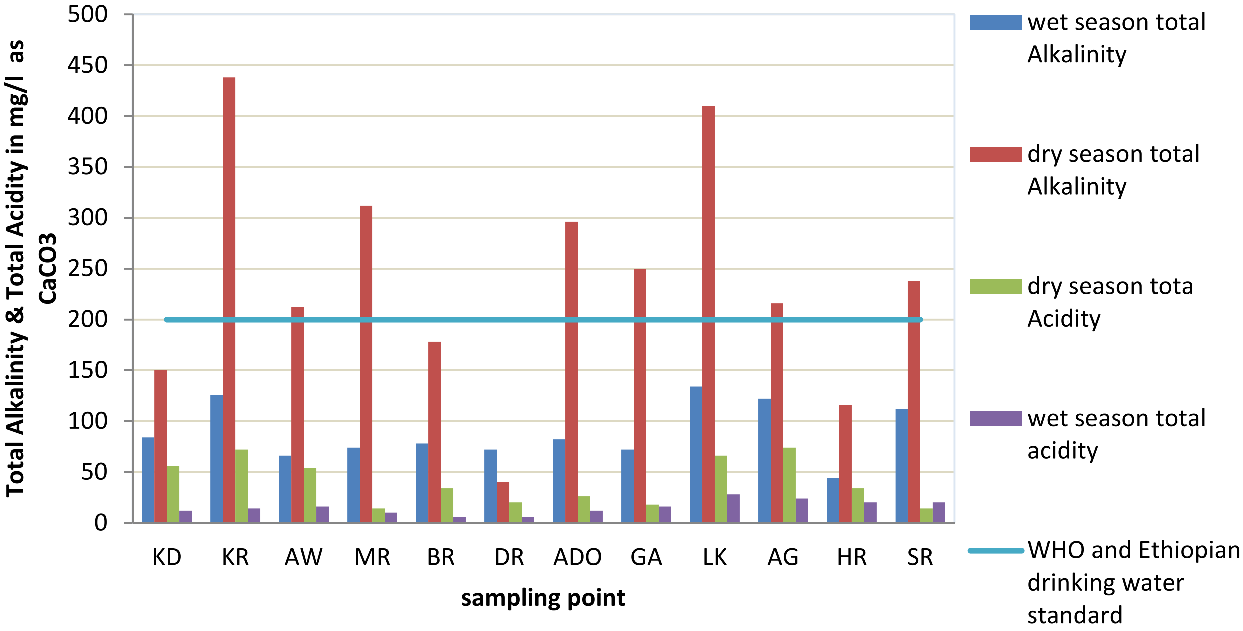

Figure 8. Total Alkalinity and Acidity values of various River water sample stations

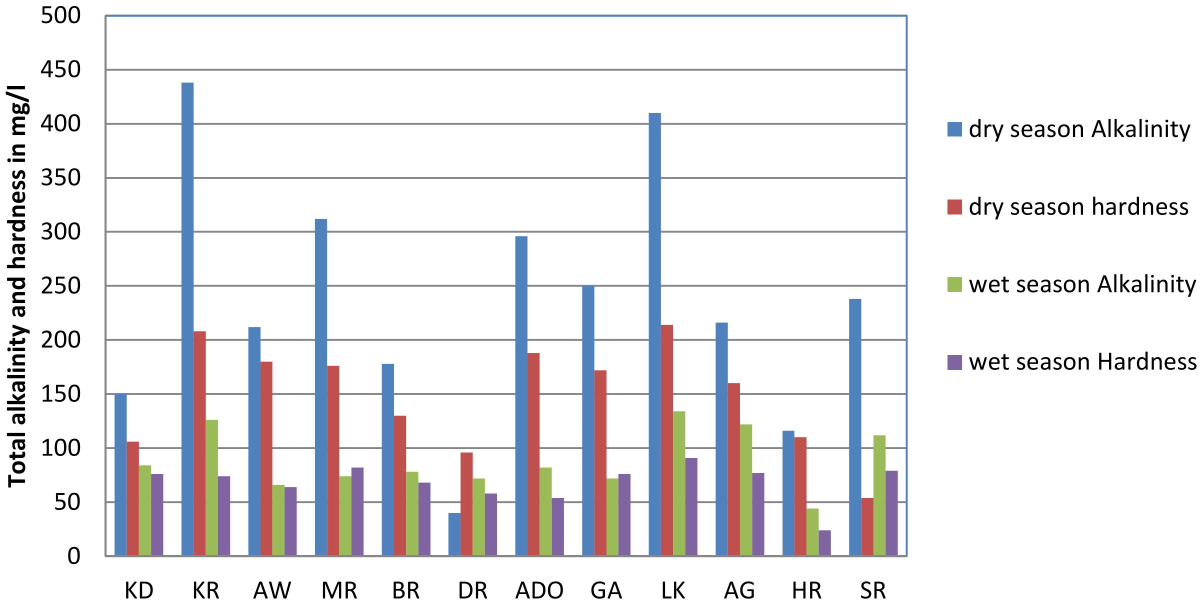

Figure 9. Total Alkalinity and Hardness values of various River water sample stations

4.1.7. Nitrate (NO_3^-)

Nitrate forms naturally in soil from transformations of nitrogen, nitrogen containing fertilizers, manure, or urea. Direct surface runoff of waters from agricultural areas and discharge from wastewater treatment facilities can also contribute to elevated nitrate concentrations and degrade the quality of stream water. Human ingestion of water with nitrate concentrations in excess of the MCL (10 mg/L) can lead to a sometimes fatal blood disorder in infants called methemoglobinemia or "blue-baby syndrome."(WHO, 2008). The Ethiopian and WHO maximum limit of nitrate standard for drinking water is 50mg/l. The nitrate concentrations along the sampling points during wet and dry season are ranged from 0.44mg/l at Awash at Ginchi to 28.2mg/l at Aba Samuel Dam outlet and 15.4mg/l at Holeta River to 77.4mg/l at Mojo River respectively. All the wet season sampling station has shown below the standard. However the dry season result shows above the standards for three samples, which are Awash River at the bridge, Modjo River and Sebata River, again it shows us Sebata and Modjo are more polluted by industrial effluent which contains high concentration of nitrate where as for the case of Awash at Bridge the source of Nitrates might the surrounding floriculture due to a discharge of nitrogen containing chemical and fertilizer into the river. Comparing the seasonal variation along the river sampling points except aba Samuel dam outlet all the dry season showed relatively higher concentration peaks which could be due direct discharges of industrial effluent and domestic waste to the river channel and the small flow during the dry season which results high concentration of Nitrate. The wet season Aba Samuel dam outlet sampling point nitrate concentration might be a result of runoff from the surrounding agricultural land with application of nitrate containing fertilizer.

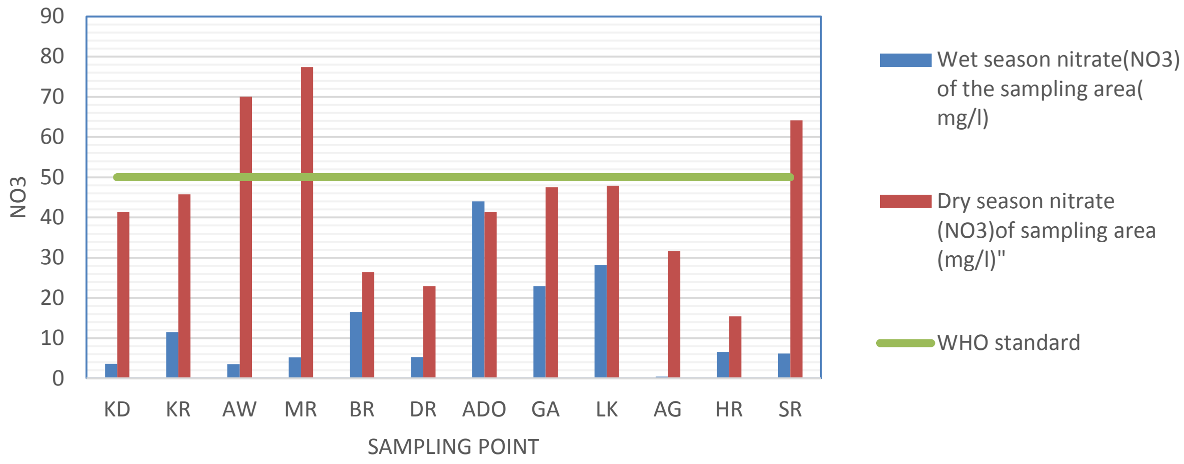

Figure 10. Nitrate concentration of various water sample stations

4.1.8. Phosphate (PO_4)

Phosphate, PO_4 load appeared to be high in the analyzed water samples. PO4 forms are produced by natural processes, but major man-influenced sources include: partially treated and untreated sewage, runoff from agricultural sites, and application of some lawn fertilizers. The concentration of phosphate in both seasons shows a high variation, both seasons result showed us a concentration above the maximum permissible of WHO limit 0.1mg/l and below the usual range of PO_4 in irrigation water 0-2 me/l or 20.66 mg/l. The dry season samples result shows us a maximum reading was at little Akaki river with a concentration of 6.45mg/l and a minimum value was 0.38mg/l at Mojo River but For wet season the maximum value was at Ginchi sample which was 9.64mg/l and a minimum was 0.28mg/l at Koka Dam. The seasonal variation shows us for three sampling stations (Bushoftu River, Awash at Ginchi and Holeta River) wet season result was greater than a dry season. This is because of most catchment of this three sampling points are agricultural land, also the existence of floriculture and agricultural demonstration center which shows us there was an excessive use of phosphate fertilizer. The remaining sampling point shows that the dry season concentration is higher than the wet season, this indicates that disposal of phosphate from industrial and domestic sewage as a washing powder, intensive rearing of livestock and the use of phosphate containing fertilizer for irrigation around Dukem, Little Akaki and great Akaki River and relatively because of small water flow during a dry season.

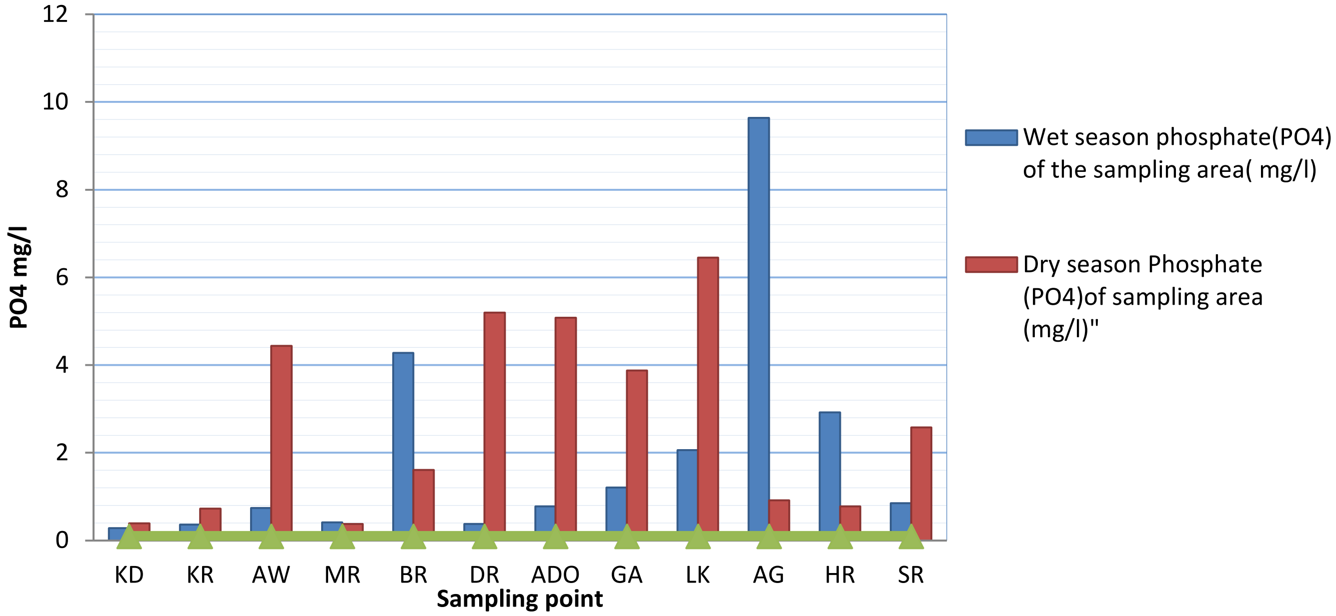

Figure 11. Phosphate concentration values of various river water sample stations

4.1.9. Sulphate (SO_4)

Sulfates occur naturally in numerous minerals and are used commercially, mainly in the chemical industry. They are discharged into water in industrial wastes and through atmospheric deposition; however, the highest levels usually occur in groundwater and are from natural sources. The concentration of sulfate along the river sampling station for both dry and wet season varied from 5mg/l at Holeta River to 108mg/l at Koka river and2mg/l Awash at bridge to 56mg/l at Ginchi respectively. Regarding seasonal variation excluding awash at Ginchi and Holeta River in all the sample the dry season sulfate concentration was higher than the wet season. The result tell us the possible source of sulfate is from industrial effluent but for case of the two sample Holeta and Ginchi there might be the natural source. The Ethiopian and WHO guide line for drinking water, maximum limit of sulfate concentration is 250 mg/l thus all the river water satisfy the standard regarding sulfate.

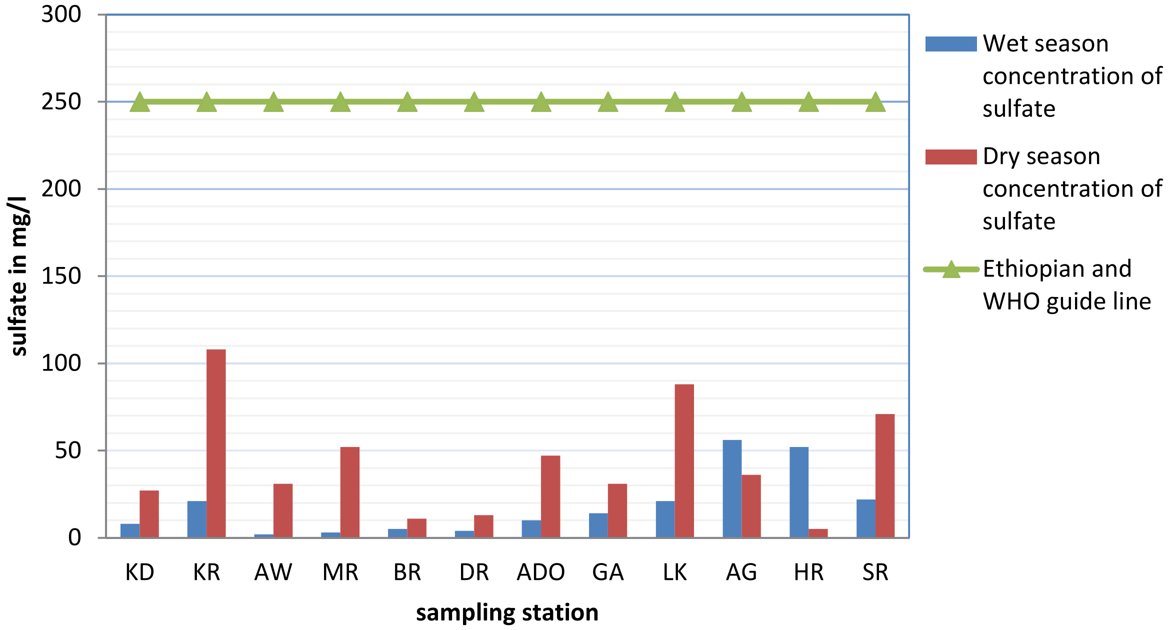

Figure 12. Sulphate values of various river water sample stations

4.1.10. Fluoride

Fluoride in waters at a concentration of 3 mg/l will cause mild fluorosis (mottling of teeth), but will also result in teeth with less wear and fewer cavities than if the water had lower fluoride concentration. According to WHO and Ethiopian water quality standard the safe upper concentration limit of Fluoride is 1.5 mg/l. However, the water quality results obtained from River sampling points was below WHO and Ethiopian guidelines. The wet season fluoride concentration along the sampling point was very low, It was found only in four sampling points Koka dam, Koka river, little Akaki river and Sebata River with a maximum of 0.7mg/l whereas dry season fluoride concentration was in a range of 0.053mg/l to 1.25mg/l.

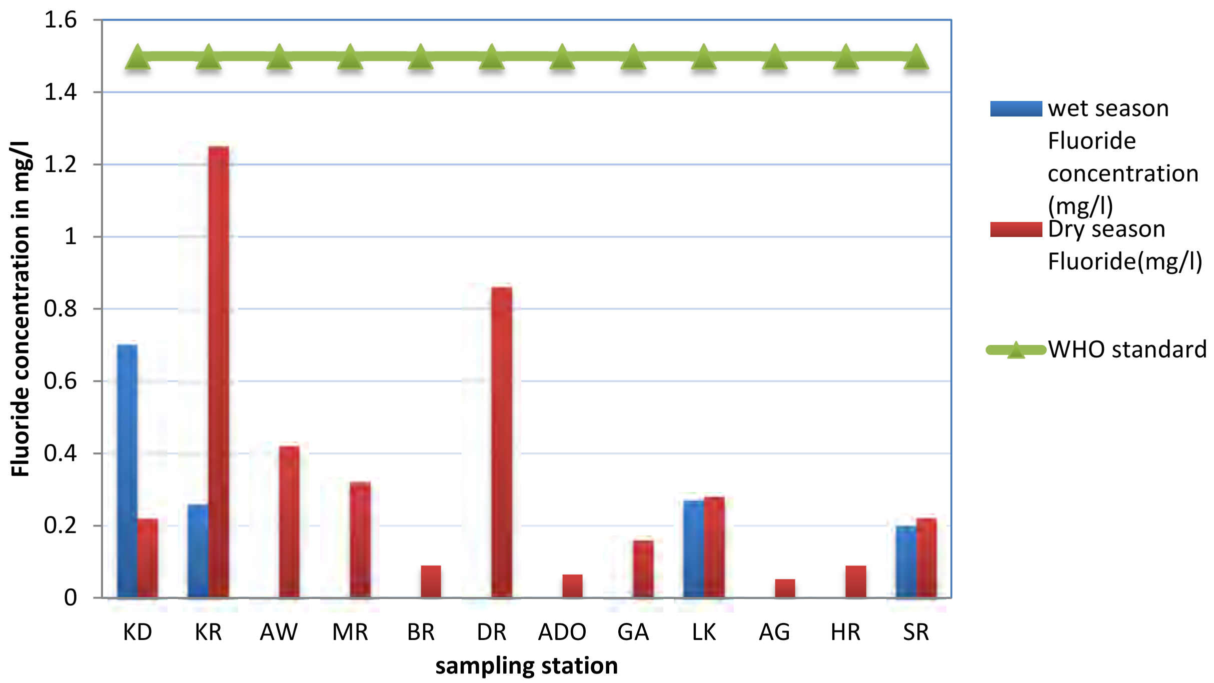

Figure 13. Fluoride values of various river water sample stations

4.1.11. Dissolved Oxygen (DO)

Dissolved Oxygen is the most important water quality parameter which shows the amount of oxygen present in water. It gets there by diffusion from the surrounding air, aeration of water that has jumbled over falls and rapids; and as a waste product of photosynthesis. Rapidly moving water contains more dissolved oxygen than slow or stagnant water and colder water contains more dissolved oxygen than warmer water. The optimal DO concentration for fish health is 5 mg/l and most species become distressed when levels drop to 4 -2 mg/l. Dissolved oxygen is also important for the microbial breakdown of waste in the water and for chemical reactions and also as DO level falls the objectionable odors, tastes and colors reduce the acceptability of water. Generally the low levels of DO in the samples indicate high levels of pollution. In the studied water samples DO value both dry and wet season ranged from 0.7 (little Akaki) to 4.8mg/l (Awash at Ginchi) and 2.7 at Mojo River to 4.9mg/l at Awash at Ginchi respectively. The stream water must have a DO value of 4mg/l (EEPA, 2003). Based on this standard a sample of Koka dam, Awash at Ginchi, Holeta River and wet season Sebata River results satisfy the guide line value this tells us the amount of oxygen consumed by microorganism was less.

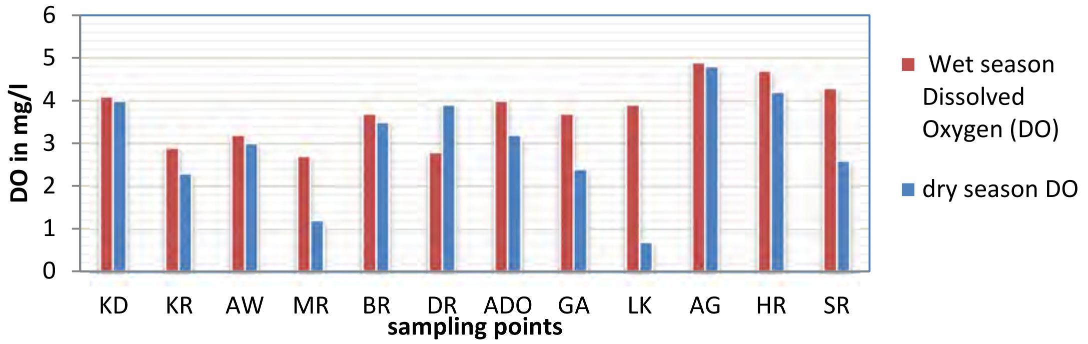

Figure 14. Dissolved Oxygen values of various river water sample stations

4.1.12. Biological Oxygen Demand (BOD_5)

The most widely used parameter to measure water quality and used in the design of effluent treatment plants is 5-day Biochemical Oxygen Demand (BOD_5). The determination of BOD_5 involves the measurement of the DO used by microorganisms in the biochemical oxidation of organic matter. In the upper Awash River samples the dry season BOD_5 values were found to be in the range from nil (at Dukem River sampling point) to 216mg/l (at Little Akaki river sampling point) whereas the wet season result along the sampling points ranges from 7.96mg/l (at Koka dam) to 16.8mg/l (at Little Akaki River). Thus Little Akaki River sampling station has greater BOD for both seasons. Generally Little Akaki River is the most polluted tributary followed by

Mojo River. According to EEPA stream water quality standard the BOD of the stream should be less than 5mg/l, but none of the sample sites result comply with this standard.

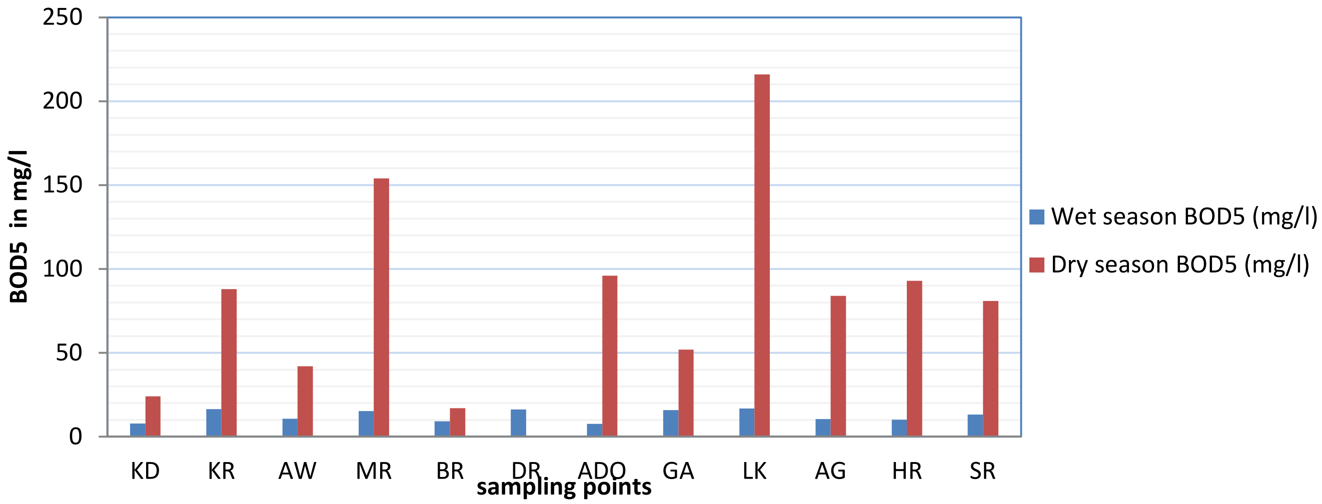

Figure 15. BOD5 of various sample stations water

4.1.13. Chemical Oxygen Demand (COD)

Chemical oxygen demand (COD) is often measured in addition to or instead of BOD5 as it has the advantage that it can be measured in a couple of hours and in many “known” waters (e.g. fresh water or municipal wastewater) can be used to roughly calculate the BOD. The COD test is used to measure the oxygen equivalent of the organic material in wastewater that can be oxidized chemically using dichromate in acid solution (Metcalf and Eddy 2003).

The COD values in the rivers sample taste ranged from 21mg/l (Dukem river) to 460mg/l (little Akaki) during a dry season and 21(at Aba Samuel dam) to 151mg/l (little Akaki) during a wet season. As with BOD, COD is substantially higher in the little Akaki River than in the Modjo and the other river sampling points which imply that little Akaki River is more polluted than any other river in the study area. From EEPA stream water quality standard the COD of the stream should be less than 150mg/l. From the sample sites dry season results of Modjo river, Aba Samuel Dam outlet, Awash at Ginchi, Sebata river and little Akaki river were above the standard but during a wet season only little Akaki river result was above the standard which is directly related to the municipal and industrial sources of untreated liquid and solid wests.

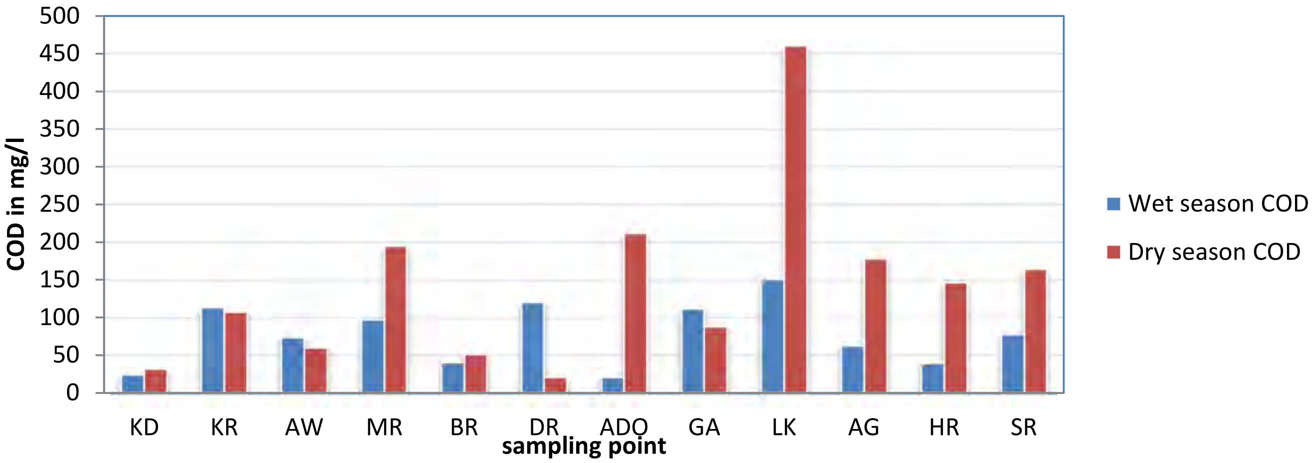

Figure 16. COD values of various river water sample stations

4.1.14. Calcium Hardness

Calcium hardness is sometimes confused with the terms water hardness and total hardness. Too little calcium hardness and the water is corrosive and too much calcium hardness and the water is scale forming. High levels can cause scale buildup and Low levels can cause etching and equipment corrosion. The WHO drinking water maximum permissible limit of calcium hardness is 100 mg/l. The value of sampling stations for both dry and wet season ranged from 16 mg/l as $CaCO_3$ (Dukem river) to 206 (Little Akaki river) mg/l as $CaCO_3$ and 18 mg/l as $CaCO_3$ (Holeta river) to 72mg/l as $CaCO_3$ (Koka Dam, Little Akaki and Awash at Ginchi) respectively. Thus Little Akaki River sampling station has greater calcium hardness for both seasons.

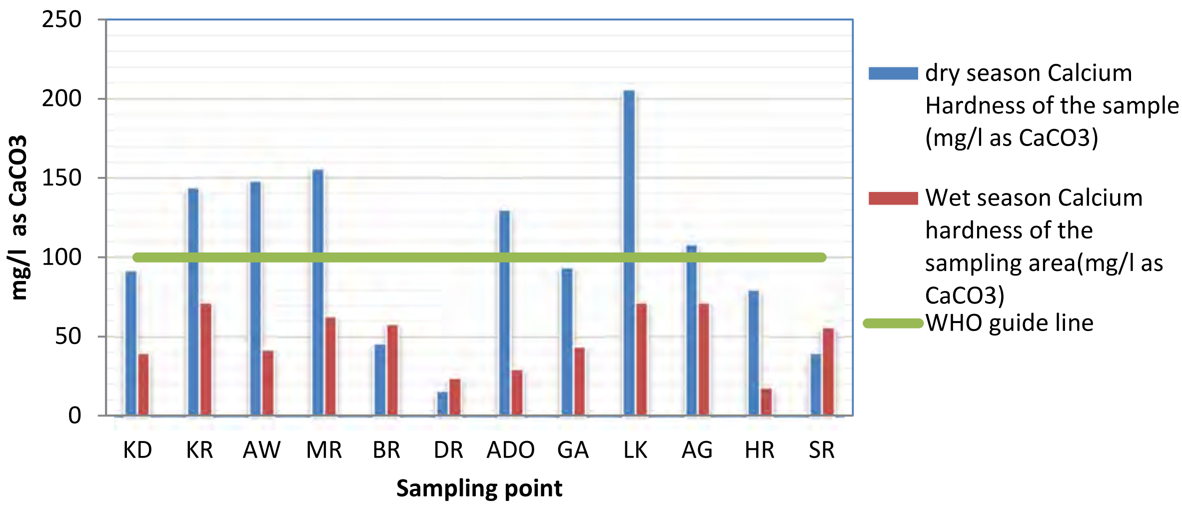

Figure 17. Calcium concentration of water sample stations

4.1.15. Total Hardness

The total hardness is the sum of the hardness formers in water (Ca and Mg ions) in mmol/l. originally hardness was understood to be a measure of the capacity of water to precipitate soap. Soap is precipitated chiefly by the calcium and Mg ions present. WHO and Ethiopian maximum limit of hardness in drinking water is 200 mg/l and 300mg/l as $CaCO_3$ respectively. Total hardness is measured in parts per million (ppm). The total hardness value of the study area ranges for dry and wet season ranged from 54 (Sebata river) to 214(little Akaki river) mg/l as $CaCO_3$ and 24(Holeta river) to 91mg/l $CaCO_3$ (at little Akaki river) respectively. Only Koka River and little Akaki River site dry season results are above the WHO limiting value the remaining are below the limiting value. The high value of total hardness is due to industrial effluent especially tannery industries. Excluding Sebata River sampling point all the sampling point's dry season hardness is greater than wet season hardness.

Table 1. Water hardness classification

Hardness	
Description	Hardness range(mg/l as CaCO3)
soft	0 – 75
Moderately hard	75 – 100
Hard	100 – 300
Very Hard	>> 300

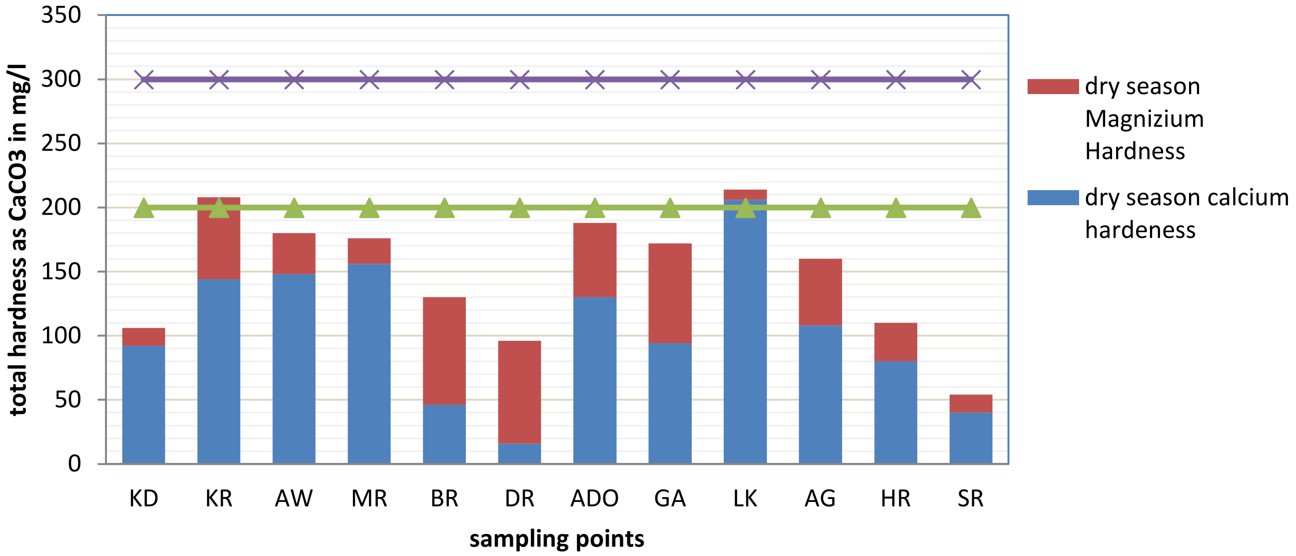

Figure 18. Dry season Total Hardness values of various river water sample stations

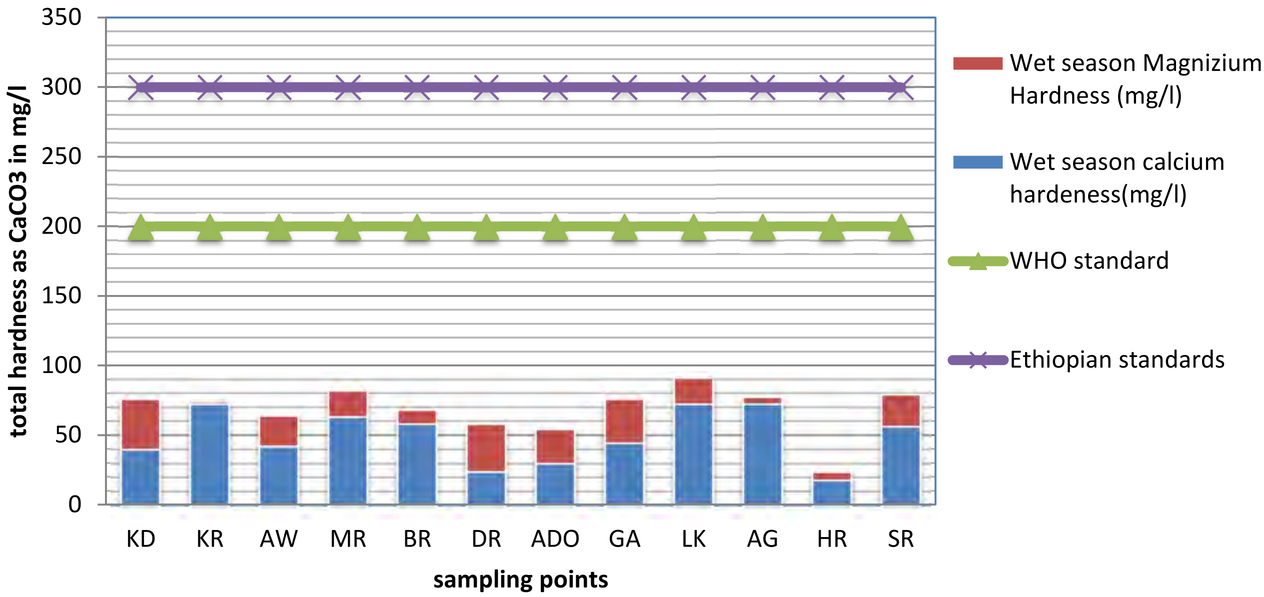

Figure 19. Wet season Total Hardness values of various river water sample stations

4.1.16. Chloride

Chloride is an anion which found in all natural waters, although the concentration may vary widely with the maximum in brackish water reaching up to 350 mg/L. Due to considerable amount of chlorides contained in both domestic and some industrial wastes (such as from tanneries), the measure of chloride in receiving waters indicates the level of salt pollution and thus the degree by which the beneficial use of water for agriculture can be affected. The Ethiopian drinking water quality standard and WHO have pegged the chloride limit for drinking water at 250 mg/L and no restriction up 4me/l (142mg/l) by FAO standard. From lab result the dry and wet season chloride concentration along the sampling site was ranged from nil (0) to 96mg/l and from 0 to 6mg/l respectively. Thus all the sample result for both dry and wet season is below the standards whatever the source is the river water has low chloride concentration.

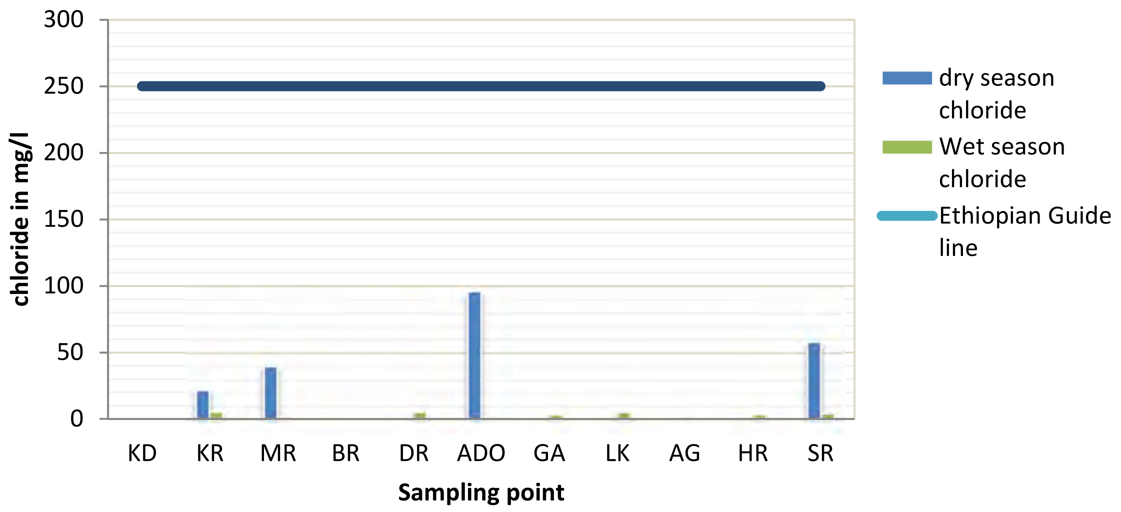

Figure 20. Chloride values of various river water sample stations

4.1.17. Ammonia

The term ammonia includes the non-ionized (NH_3) and ionized (NH_4^+) species. Ammonia in the environment originates from metabolic, agricultural and industrial processes and from disinfection with chloramines. Natural levels in groundwater and surface water are usually below 0.2 mg/l (WHO, 2008). Intensive rearing of farm animals can give rise to much higher levels in surface water. Ammonia in water is an indicator of possible bacterial, sewage and animal waste pollution. Ammonia is a major component of the metabolism of mammals. Exposure from environmental sources is insignificant in comparison with endogenous synthesis of ammonia. In the 1993 WHO Guidelines, no health-based guideline value was recommended, but the Guidelines stated that ammonia could cause taste and odor problems at concentrations above 35 and 1.5 mg/l, respectively and Ethiopia guide line specification of ammonia for drinking is 2mg/l. The concentration of ammonia ranged from just 0.42 mg/l to 44.8 mg/1 in the sampling water of dry season and 0.99mg/l to 40.5mg/l for wet season (Figure 19). According to EEPA stream water quality standard the ammonia concentration in stream should be less than 0.025mg/l, but none of the sample sites result fulfill this standard. This is because of ammonia originates from municipal, agricultural and industrial sources.

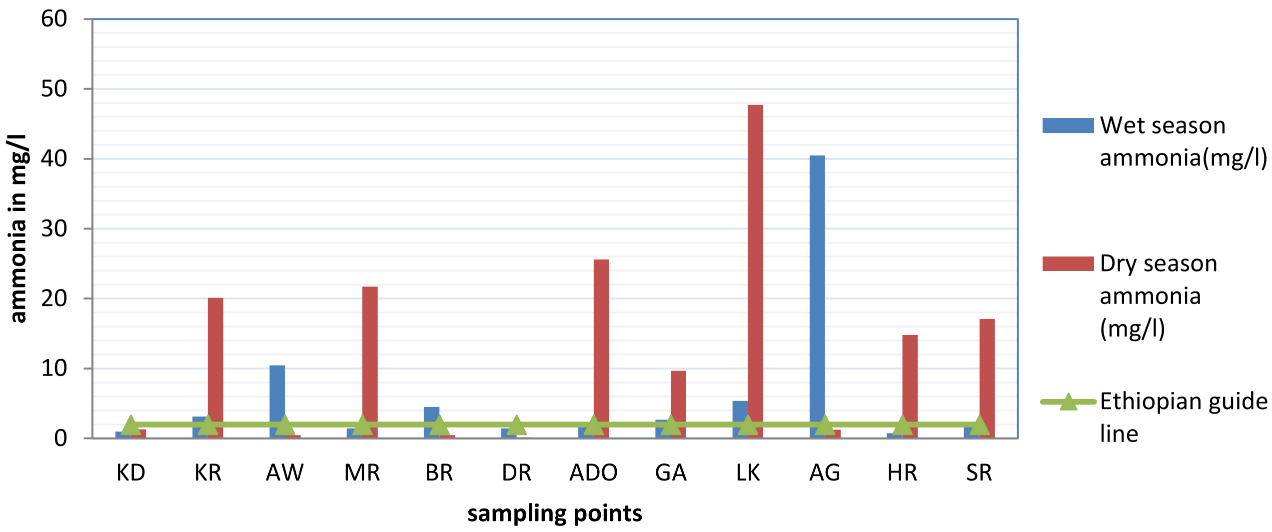

Figure 21. Ammonia Concentration of various river water sample stations

4.2. Metallic constituents

Trace quantities of many metals can be found in wastewaters, particularly industrial waste but also arising from domestic waste, for example form household cleaning products. Many of these metals are necessary for growth of biological life but only in trace concentrations; if the required concentrations are exceeded they can become toxic and thus interfere with the potential beneficial uses of wastewater (Metcalf and Eddy 2003). It is important to note however, that metals will only be absorbed by plants once a threshold concentration has been reached in the soil and the metal is in a mobile phase, hence the concentration in irrigation water is not a direct reflection of the uptake of crops. Metals are bound to soils with pH above 6.5 or with high organic matter content. Below this pH, adsorption sites are saturated and metals become mobile (WHO 2006).

All the samples were analyzed for a selected metals that either likely to cause damage to crops or impact on human health, these included: calcium (as Ca^{2+}); magnesium (as Mg^{2+}); potassium (as K^{+}); sodium (as Na^{+}); iron (as Fe); Zinc (as Zn); chromium (as Cr), Manganese (Mn) and lead (as Pb).

4.2.1. Iron (Fe)

Iron is micronutrients which help plant growth and development but can be detrimental if threshold levels are exceeded. The concentration of iron ranged from 0.12 mg/l to 3.60 mg/1 in the sampling water of dry season and 0.14mg/l to 5.4mg/l for wet season. The FAO recommended maximum concentration of iron for crop production is 5 mg/1 and one sample has exceeded this level which was Dukem River during a wet season. The Ethiopian and WHO maximum limits for concentration of iron is 0.3 mg/l. when we see the seasonal variation the dry season concentration was high for the some sample site, Sebata River, Awash at Ginchi, little Akaki river, Great Akaki river, aba Samuel dam and Koka dam and the wet season concentration of iron was high for the remaining sample sites. This variation is may be related to domestic, industrial waste and mostly the naturally occurrences of iron in the soil deposit.

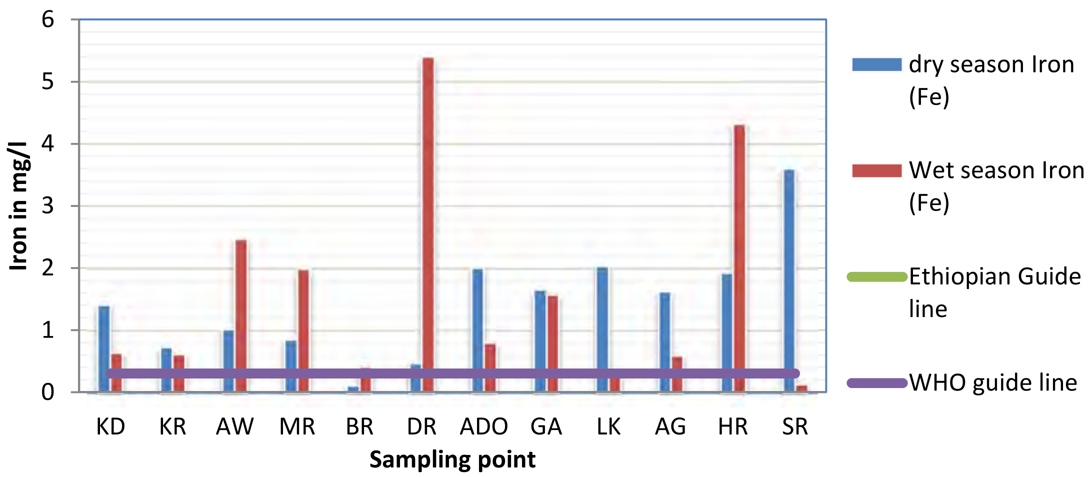

Figure 22. Iron (Fe) values of various river water sample stations

4.2.2. Lead (pb)

Lead is used principally in the production of lead-acid batteries, solder and alloys. The organo-lead compounds tetraethyl and tetra-methyl lead have also been used extensively as antiknock and lubricating agents in petrol, although their use for these purposes in many countries is being phased out. Owing to the decreasing use of lead containing additives in petrol and of lead-containing solder in the food processing industry, concentrations in air and food are declining, and intake from drinking-water constitutes a greater proportion of total intake. The health effect of lead is toxic to both the central & peripheral nervous systems, including neurological effects. The 1993 WHO, FAO and Ethiopian drinking water Guidelines proposed a health-based guideline value of 0.01mg/l, 5mg/l and 0.01mg/l respectively. The results of the samples show us the concentration of lead for dry and wet season ranges from 0.41 to 1.18mg/l and from 0.14 to 5mg/l respectively. This shows us the river water has high concentration of lead which mean above the standards at all sampling stations for both dry and wet season. This might be the existence of lead in industrial, municipal and natural existence of lead in the mineral.

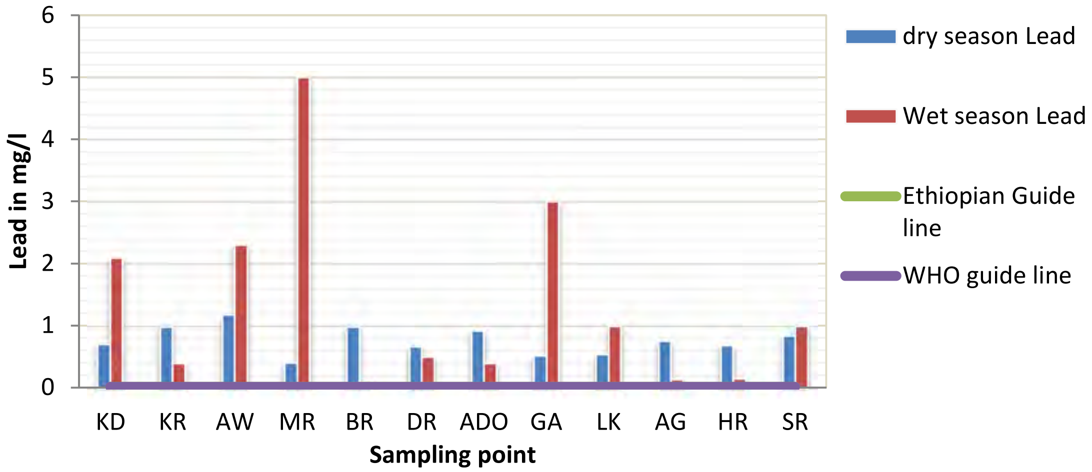

Figure 23. Lead concentration of various river water sample stations

4.2.3. Zinc

Zinc is an essential trace element found in virtually all food and potable water in the form of salts or organic complexes. The WHO, FAO and Ethiopian drinking water guide line for maximum limit of Zink is 3mg/l, 2mg/l and 5mg/l respectively. From the sample result the concentration of Zink was very nil (<0.0001mg/l) during a dry season in sampling point but during a wet season it was varied from 0 to 2.8mg/l (Dukem sampling point) which is ok because it is below the maximum limit of WHO and Ethiopian standard.

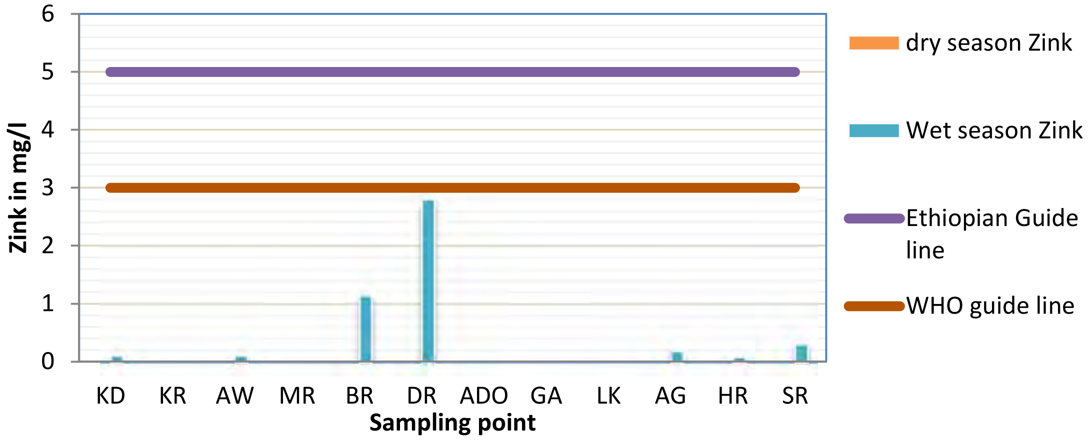

Figure 24. Zink concentration of various river water sample stations

4.2.4. Chromium

Chromium is potentially toxic to humans and animals at low concentrations. The maximum allowable concentration in river water should not exceed 0.05mg/l. The national drinking water quality, WHO and FAO limits available is 0.05mg/l. the laboratory analysis shows us except Holeta river all the remaining sample's dry season chromium concentration was above the standard limits and during a wet season only Awash at Ginchi was above the standard. The pollution sources of chromium might be industrial effluent and natural occurrences of the chromium in the soil deposit.

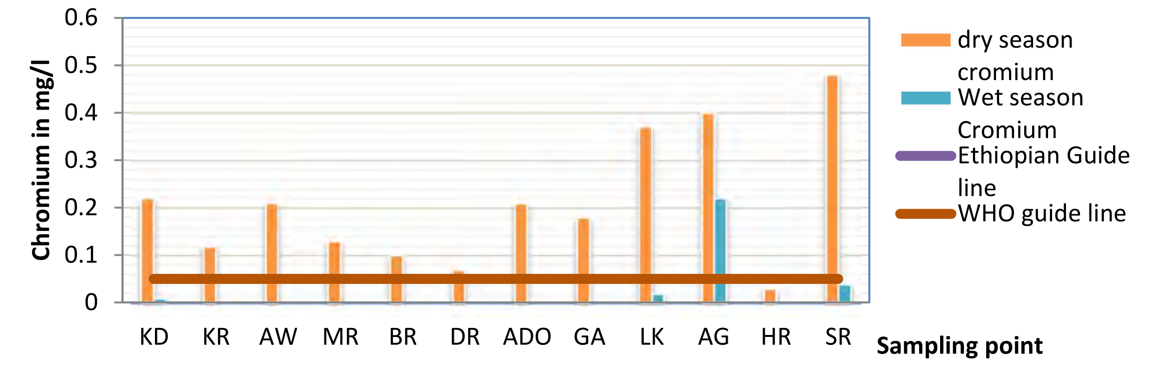

Figure 25. Chromium concentration of various river water sample stations

4.2.5. Magnesium

The laboratory result of samples for both season dry and wet season shows very far below from the Ethiopian drinking water guide line for magnesium of 50mg/l. even if the dry season magnesium concentration was higher than a wet season for most of the sample the water still satisfies the standard for all sampling points for magnesium case.

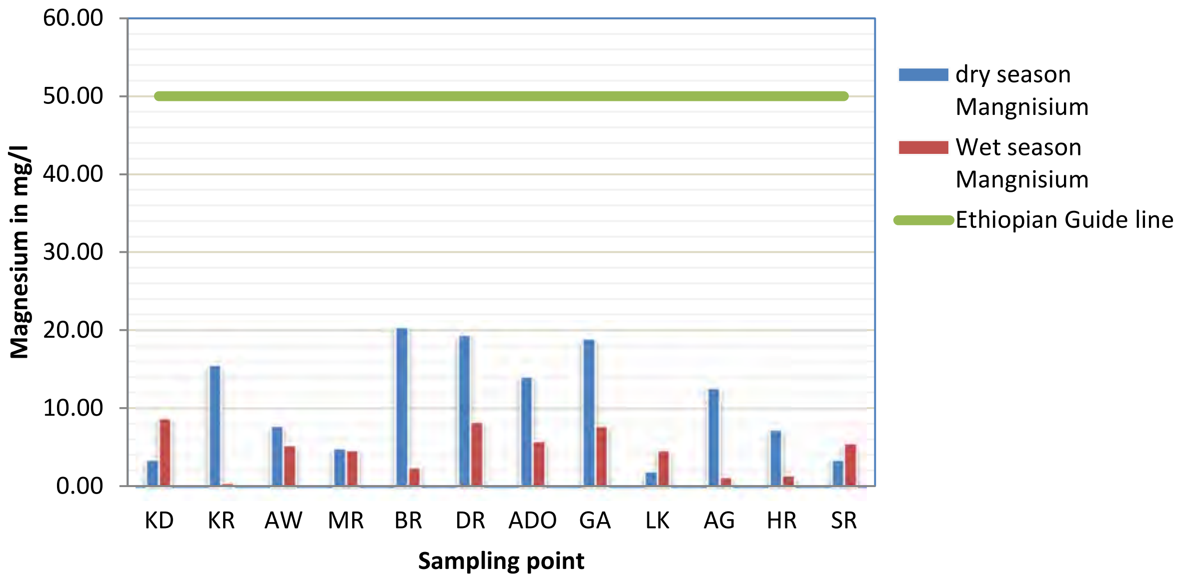

Figure 26. Magnesium concentration of various river water sample stations

4.2.6. Calcium

The laboratory analysis for calcium concentration of samples for both dry and wet season ranges from 6.4to 82.4 and 7.2 to 28.8mg/l respectively. The Ethiopian drinking water guide value for calcium is 75mg/l. only little Akaki dry season sampling result is above the standard which shows us little Akaki river is more polluted than others. Comparing the seasonal variations except Bushoftu River, Dukem River and Sebata River the remaining sampling point's dry season concentration of calcium was high.

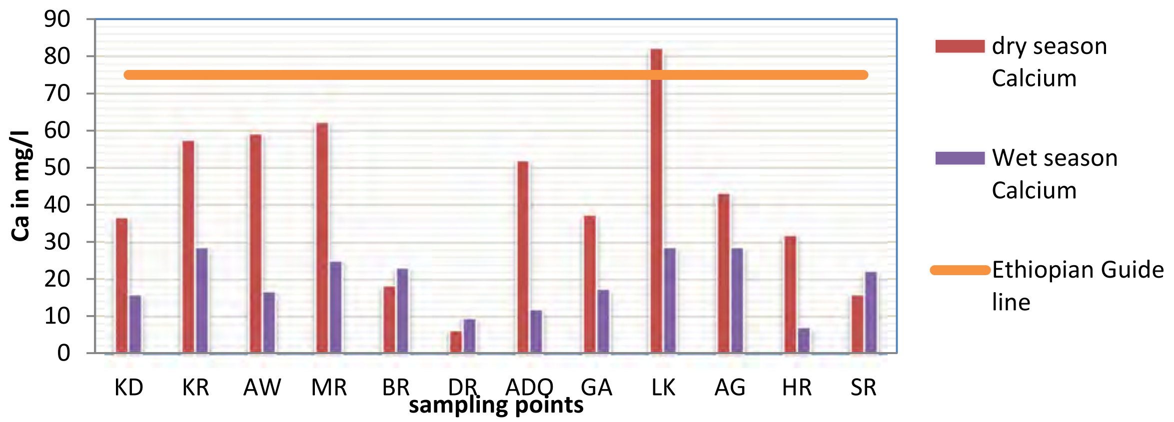

Figure 27. Calcium concentration of various river water sample stations

4.2.7. Manganese

Manganese is one of the most abundant metals in the Earth's crust, usually occurring with iron. It is used principally in the manufacture of iron and steel alloys, as an oxidant for cleaning, bleaching and disinfection as potassium permanganate and as an ingredient in various products. Manganese is an essential element for humans and other animals. Adverse effects can result from both deficiency and overexposure. Manganese is known to cause neurological effects following inhalation exposure, particularly in occupational settings, and there have been epidemiological studies that report adverse neurological effects following extended exposure to very high levels in drinking-water (WHO, 2008). The WHO, FAO and Ethiopian drinking water quality guideline standard value is 0.1mg/l, 0.2mg/l and 0.5

mg/l respectively. The manganese concentration in the Awash River samples for both dry and wet season ranges from 0.1 to5.5mg/l and 0.02 to 0.7mg/l respectively. The dry season concentration of manganese was above the WHO and Ethiopian standard at a sample of, Sebata river, Holeta river, great Akaki River, little Akaki River, Aba Samuel Dam, Awash River at the bridge, Koka River and Koka Dam. This could be related to industrial waste and domestic waste which contains manganese and natural existence in the soil deposit. Except Awash at Ginchi which was above the WHO and Ethiopian guide line for both season the remaining wet season manganese concentration fulfill the Ethiopian and WHO standards.

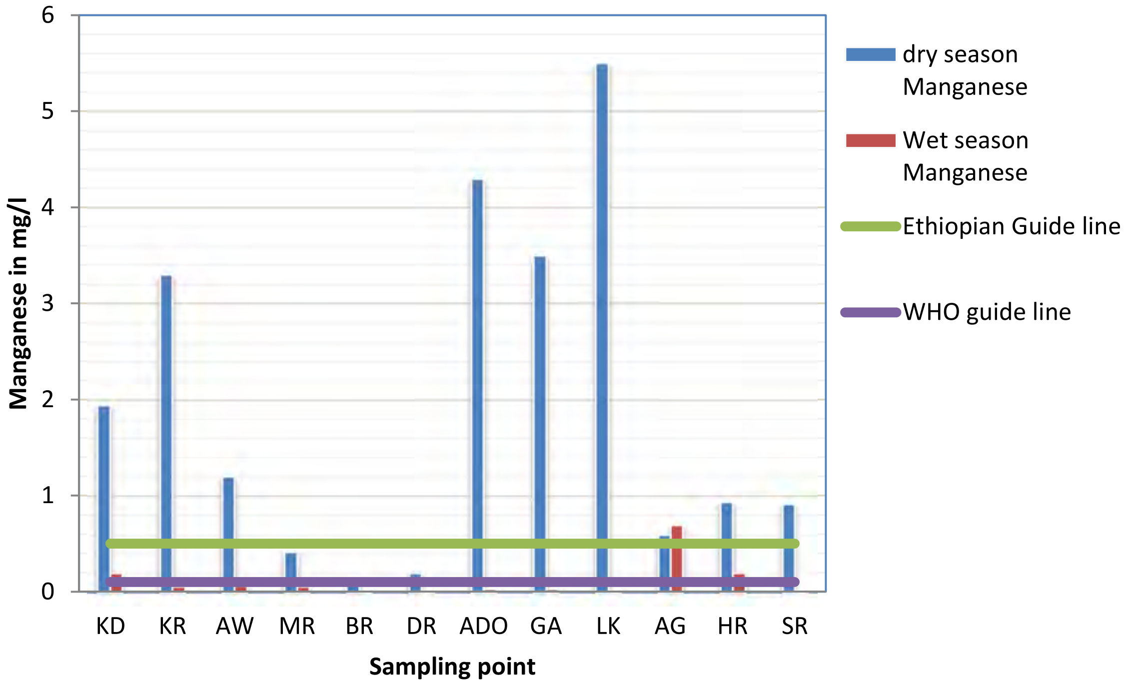

Figure 28. Manganese concentration of various river water sample stations

4.2.8. Copper

The concentration of Copper in the study are varies from 0.05 to 1.89mg/l in dry season and 0.14 to 0.96mg/l during wet season. The WHO, FAO and Ethiopian drinking water guide line for maximum limit of copper is 1mg/l, 0.2mg/l and 2mg/l respectively. From the sample result the concentration of copper was below the WHO and Ethiopian standards during a wet season. But during a dry season the concentration of copper was above the WHO standards in awash at Ginchi (1.89), little Akaki River (1.63) and aba Samuel dam outlet (1.53) sampling point. Based on Ethiopian standard all the sample water was ok for both dry and wet season because it was below the maximum guideline but above the FAO standards for irrigation which stated as toxic to a number of plants at 0.1 to 1.0mg/l in nutrient solutions. This might be one of the problems that the farmers face in the basin.

Figure 29. Copper concentration of various river water sample stations

4.2.9. Potassium

From the figure below the potassium vale for the analyzed water sample for both dry and wet season ranges from 1.1 to 32.13 and 0.2 to 10.5mg/l respectively. Comparing the season variation the dry season concentration of potassium was higher than the wet season. The Ethiopian drinking water standard for potassium is 1.5mg/l but there is no standard sated by WHO. Except to Awash River at Koka the remaining dry season potassium concentration was above the Ethiopian standard. The wet season potassium concentration was also above the standard at Koka River, Awash at Koka, little Akaki and Sebata River. Comparing each sampling point the little Akaki River was the most polluted than the other for both dry and wet season. The Couse's of this high potassium concentration is related to domestic, industrial and natural sources.

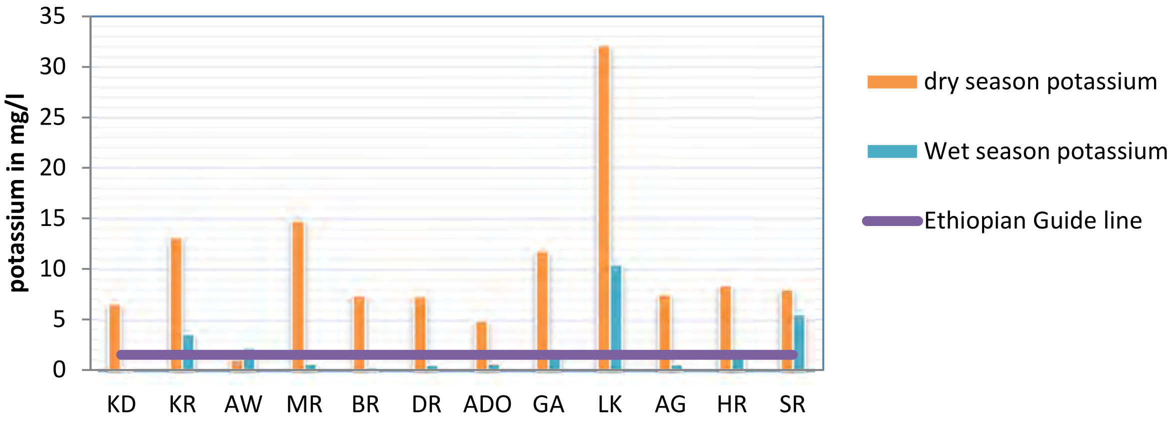

Figure 30. Potassium concentration of various river water sample stations

4.2.10. Sodium

The variation of sodium concentration in the analyzed sample for dry and wet season was from 10.61 to 195.19mg/l and 10.33 to 52.84mg/l respectively. The WHO and Ethiopian drinking water standards for sodium is 200mg/l. all sample water for both season are below the maximum allowable limit. Even if it is less than the standards the dry season sodium concentration for the samples like Koka River, Modjo River and Little Akaki River were relatively high. The occurrence of high concentration of sodium is because industrial effluent which contains sodium ion, especially in tannery industries.

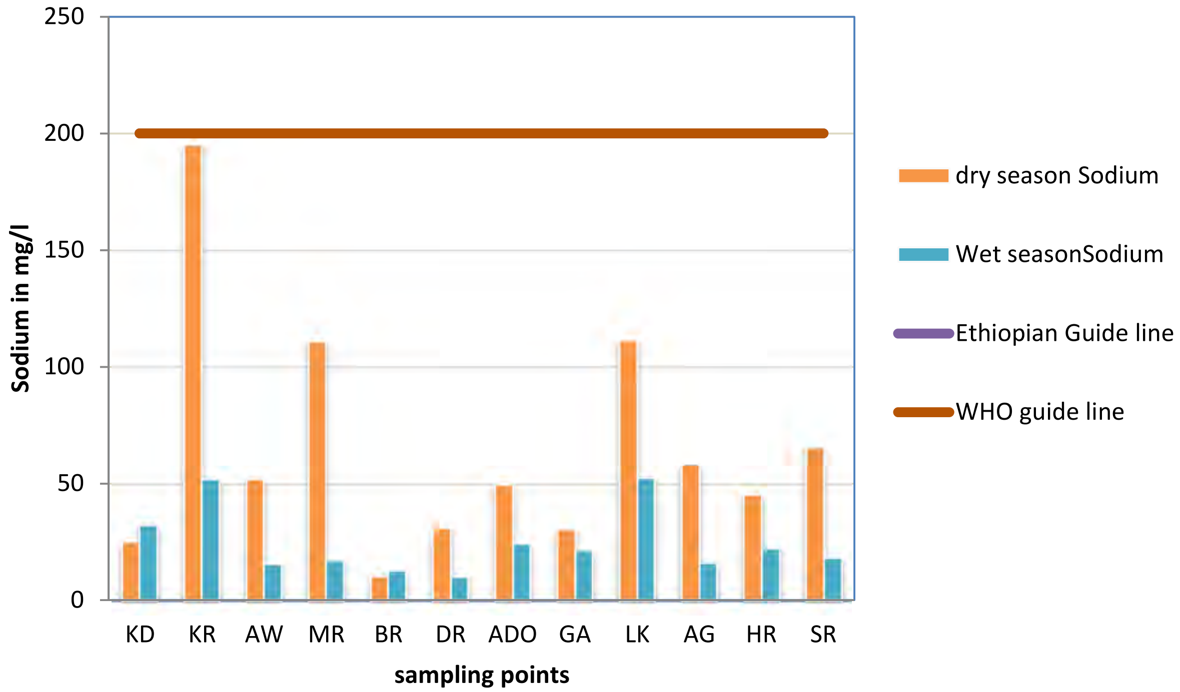

Figure 31. Sodium concentration of various river water sample stations

4.2.11. Sodium Adsorption Ratio

Not only is the total salt concentration in irrigation water extremely important for agriculture but so too the relative proportion of sodium to other cations, because sodium has a unique effect on soils. When present in its exchangeable form sodium changes the physicochemical properties of the soil and has the ability to disperse soil particles when above a certain threshold value, relative to the concentration of total dissolved salts, this dispersion results in reduced air and water infiltration to the soil and the formation of a hard crust when the soil is dry (Pescod, 1992).

The relative concentration of sodium is determined by the sodium adsorption ratio (SAR).

This index quantifies the proportion of sodium ion (Na^+) to calcium ions (Ca^{2+}) and magnesium ions (Mg2+) in a sample using either of the two equations below.

Calculation of sodium adsorption ratio

$$SAR = \frac{Na}{\sqrt{(Ca+Mg)/2}}$$ where concentrations are in meq/l

$$SAR = \frac{Na^{+}}{\sqrt{(Ca^{2+}+Mg^{2+})/2}}$$ where ionic concentrations of each are in mmol/l

This ratio is important because calcium and sodium have different effects on the soil: calcium will flocculate (hold together), while sodium disperses (pushes apart) soil particles. Water with low salinity content (<0.5 dS/m) leaches the soluble minerals and salts. If calcium is leached, soil structure can be destabilized and fine soil particles become dispersed and clog the pour spaces, leading to reduced water infiltration, soil crusting and crop emergence problems (Ayres and Westcot 1985). The high salinity water will increase infiltration, whereas low salinity water or water with high sodium to calcium ratio will decrease infiltration: both factors may also operate at the same time, therefore it is important to consider both EC and SAR, and for this reason guideline for potential irrigation problems relating to infiltration include both (Table 2).

Table 2. Guidelines for potential irrigation problems of infiltration rate of water to soil (source: Ayres and Westcot, 1985)

SAR	No restriction	Moderate restriction	Sever restriction
	EC µS/cm		
0-3	>700	700-200	< 200
3-6.0	> 1200	1200-300	< 300
6-12.0	> 1900	1900-500	< 500
12-20.0	>2900	2900-1300	< 1300
20-40	>5000	5000-2900	< 2900

The calculated SAR for all the river water sample were between 0.4 and 5.9. Based on the FAO guideline Koka Dam, Aba Samuel Dam outlet, little Akaki River and Sebata River sampling point's falls under no restriction for irrigation but the remaining sample sites Koka River, Awash River at Bridge, Modjo River, Bushoftu River, Dukem River, great Akaki River, Awash at Ginchi and Holeta River are under moderate restriction.

Table 3. Calculated SAR value for the dry season sampling points

sample site	KD	KR	AW	MR	BR	DR	ADO	GA	LK	AG	HR	SR
SAR	1.1	5.9	1.7	3.6	0.4	1.4	1.6	1.0	3.3	2.0	1.9	3.9
EC µS/cm	348	1420	646	968	347	331	747	581	1217	398	219	992

4.3. Biological water quality of Awash River

The biological characteristics of water and wastewater are of fundamental importance to human health, in controlling diseases caused by pathogenic organisms of human origin, and because of the role that they play in the decomposition of waste.

Untreated wastewater that includes waste contains a variety of excreted organisms including pathogens at very high concentrations. Microbial evidence can therefore be used to indicate that a hazard to human health exists in the environment. There is not however a perfect indicator organism for wastewater as excreted organisms ranges from bacteria to helminthes, protozoa and viruses (WHO, 2006). The most common indicator organisms used when monitoring water quality are total Coli forms and E-Coli. Despite this, it was necessary to use total Coli forms and E-Coli because of the availability of laboratories to perform the tests. From laboratory result the level of total coli form and E-Coli for both dry and wet season ranges from 10 to above 300(too numerous to count) and above 300/100ml respectively. The result both dry and wet season in the entire samples did not comply with both WHO and Ethiopian water quality standards which is 0/100ml for both. Based on the results for both seasons of all the samples, the river water had a high level of total coli form and E-Coli. The Farmers and residents around the river use this water for other proposes such as washing clothes and use for cooking as well as agriculture, therefore they are in primary contact with wastewater.

4.4. Sources of pollution

The water quality analysis on surface water were presented in the previous section. Naturally water bodies can contain limited portions of a certain chemicals and these water quality parameters can increase in concentration due to natural process such as evaporation, transpiration and deposition. Moreover, external pressures as domestic, municipal and industrial waste effluent, fast population growth and rapid industrialization, and lack of sewage networks and poor living condition have caused the deterioration of surface water quality in the upper Awash River basin. This eventually could lead to an increase in the concentration of a certain water quality parameters above potential natural levels and even above WHO acceptable levels. The pollution levels where parameter levels go above WHO levels are seen in all River samples and can potentially be attributed to many sources. The major sources of water pollution are likely from industries and municipalities. Moreover, the water pollution from agriculture and natural activities also aggravate the water quality. For the current study the following discussion presents an overview of that are believed to be a general potential source of pollution due to the results presented and their spatial and temporal variability.

4.4.1. Industrial sources

This is mainly point source pollution because the pollution source is easily traceable and result from a single pipe or series of pipes. Industrial effluent is concentrated towards the northwestern and southwestern sections of the Addis Ababa and Town like Sebata, Bushoftu, Modjo and Dukem. Due to rapid urbanization of Addis Ababa and the surrounding towns there is an expansion of many industries in this area. The majority of industrial activities in the Awash River Basin are concentrated in and around Addis Ababa. Out of the industrial establishments that are found in Ethiopia, more than 65% are situated in Addis Ababa city (EPA, 2003). However, the majorities are food and beverage, Textiles, Tanneries, Chemicals, rubber and plastics, paper and paper products, metallic and nonmetallic mineral products and wood industries. Among the Industries located in the city 90% of them discharge their wastes without any treatment into the adjoining water coarse and open spaces (EPA, 2000 and EPA, 2003). Industrial effluent is concentrated towards the northwestern and southwestern sections of the city. As compared to the Great Akaki River, which predominantly passes through residential and commercial areas in the northeastern and southeastern parts of the city, Little Akaki remains to be the primary recipient of most of the industrial effluents discharged within the city. The major exposure of Great Akaki River to industrial effluents appears in its lower catchment when it crosses industrial town, Akaki. According to Melkame and Kasahun, (2013) wastewater test result through the largest conducted at Industry located at Mojo, Akaki, Sebata and Koka town the industrial effluent wastewater quality is above the Ethiopian effluent limit. Similarly during field visit of the study area Upper Awash River basin it has been observed that nearly all industries have no functional treatment plant and hence they discharge their effluent directly to the Mojo, Koka, Akaki and Sebata River which results the Awash River water quality degradation. Some of the industries found in the basin consist of tanneries, gypsum, textile mills, distilleries, breweries, food-processing agroindustries, floriculture, beverage, chemicals, metal and paper processing or manufacturing industries.

4.4.2. Municipal sources

Ethiopia is one of the developing countries, where urban population growth is very fast. Especially, in Addis Ababa, the growth is faster than any other cities (town). It is obvious that when the population increases the municipal solid and liquid wastes generation also increases.

In addition to that the city's municipal waste (solid and liquid) collection coverage is limited to minor proportion of the residents and is less efficient as a result it greatly contributes to the pollution of streams especially during the rainy seasons when the surface runoff gets higher. Even if the capacity of its the waste water treatment is not sufficient, Addis Ababa city is the only city in the basin which has a wastewater treatment, the remaining towns in the upper awash river basin have no wastewater treatment which means domestic liquid waste from overflowing and seeping pit latrines, septic tanks, public and communal toilets, open ground excreta defecation include the municipal liquid waste is directly discharged to the river or the streams. Even though the Addis Ababa city has a centralized sewerage system (sewer line) and two WWTPs (i.e. the kotebe and kality) plants, they are currently operating bellow their capacities of, 350 and 7500 cubic meters per day respectively due to inefficient waste collection. It is estimated that approximately 100,000 cubic meter wastewater is produced in Addis Ababa per day (Mohammed, 2002) from domestic activities such as bathrooms and kitchens alone. In addition to this 30% of the city dwellers have no facility at all to dispose of their liquid waste (EPA, 1999). This adds to the volume of waste water that in one way or another drains to the little and great Akaki rivers and contributes to their pollution.

4.4.3. Agricultural activities

Fertilizers, pesticides and sediments derived from agricultural fields are major polluting agents to the Awash River. Starting from its upstream around Ginchi town to its reach at Koka Dam of Awash River and its tributaries for cultivation of vegetables, crops and floriculture is a common practice. Thus during wet seasons agricultural return flow contributes to pollution. From the wet season result the phosphate concentration was high in Holeta river, Bushoftu river and awash at Ginchi which all have a large agricultural catchment which tell us high application of phosphate fertilizers in the agricultural field. Cultural Irrigation practice have observed in some sampling points like Holeta river, little Akaki, great Akaki, Bushoftu river and awash at Koka which might be a reason for high concentration of phosphate and nitrate in these specific sampling points.

4.4.4. Natural factors

Natural factors like weathering and leaching of minerals from soils and bed rocks can contribute higher concentration of the different parameters in surface water. Natural source (such as plant die-off) contributed some to the levels in the parameters but it is likely little compared to the municipal and industrial pollution sources.

4.5. Spatial and temporal variation trends

In order to understand the different nature of pollutants, the values of certain parameters have been evaluated with respect to the acceptable permissible limits of WHO, FAO and Ethiopian standard for drinking water. This helps to indicate the pollution levels of upper Awash River basin. The temporal pollution variation and concentrations showed that during the dry season the Awash River and its tributaries had the highest pollution variation. The nitrate concentration in all the sampling points during the dry season were higher than a wet season which could be attributed to its natural occurrence in certain vegetables and usage within food industries as added preservatives to some meat and it could also be found in the native soils as part of the nitrogen cycle and favors plant growth. Whereas, the phosphate could be attributed to the use of phosphate additive in detergent formulations, which could be eroded into the river system during disposition of wastewater from different sources and leaching of fertilizers residues from agricultural farms. During a wet season the highest phosphate concentration peak were found in Awash at Ginchi, Holeta and Bushoftu River sampling point which might derived from excessive use of phosphate fertilizer but for remaining sampling points, the dry season phosphate concentration were higher and this could possibly derived from urban waste discharges, sewage effluents, and agriculture (irrigation) run-off (i.e mainly from fertilizers). The upper part of the river sampling point Ginchi and Holeta river catchment was the area with low industrial pollution and high agriculturally activity but moving down to, Sebata River, little Akaki River, great Akaki and Aba Samuel dam outlet the water has different chemistry. This change was likely induced by upstream urbanization along with, industrially areas of the catchments. This study physicochemical and biological results showed that some of the parameters measured in the rivers and dams were above the reference values, the standards set by EPA, WHO, FAO and Ethiopian drinking water quality guideline. Out of 28 parameters the sample water were above the standards at little Akaki by 67.86%, Aba Samuel Dam and Modjo River by 57.14%, Koka River by 53.57%, Awash at Ginchi, Great Akaki and Sebata River by 50%, Holeta river and Dukem river by 32.14% and Bushoftu River and Koka dam by 28.57% .

This finding deviate with Emmanuel et al. (2006) because it is found a general increase in physicochemical parameters investigated the upper part of Awash river for the little Akaki River Great Akaki, Mojo river, Awash at Koka, and Koka dam owing to a natural enrichment in electrolytes, possibly due to phenomena of mineralization or weathering of sediments, and probably largely due to discharge of industrial and domestic wastes. For instance taking phosphate and nitrate as an example, both showed a discrete concentration peaks. This could be due to short residence times in water bodies as they are taken up by phytoplankton. Phosphate further undergoes subsequent sedimentation and adsorption in parts of the river course. In addition the electrical conductivity variation could have resulted from the different quantity of the domestic, municipal and industrial wastes along the different parts of the river course, so there is likely a connection between human activity and water chemistry in this study. For example, consider electrical conductivity. While comparing the current study with previous study of Fasil et al. (2013), content of the electrical conductivity in awash at Ginchi and awash at Koka bridge has a values 327.67 and 492.87µS/cm respectively but a current study shows a slight increase. In the current study along the course of the river at the upper part of the rivers through the highlands of the study area, samples comprise the lowest levels of electrical conductivity.

The finding of Emmanuel et al. (2006) also showed that the EC at little Akaki river, great Akaki river, Modjo river, Awash at Koka and Koka dam were, 1416, 570, 795, 578 and 346 µS/cm respectively apparently. Comparing Emmanuel finding with current finding, the current finding EC during a dry season showed a decrease at a little Akaki river but there is an increases in great Akaki river, Modjo river, Awash at Koka and Koka dam, due to the accumulation of domestic, industrial effluent, sewage wastewater and also to the enrichment of electrolytes from mineralization or weathering of sediment. The temporal pollution variation and concentrations (Annex 1 and 2) showed that during the dry season the rivers sample had the highest pollution variation. The higher nitrate concentration in all the river sampling point during the dry season could be attributed to its natural occurrence in certain vegetables and usage within food industries as added preservatives to some meat. Nitrates could also be found in the native soils as part of the nitrogen cycle and favors plant growth. Whereas, the phosphate could be attributed to the use of phosphate additive in detergent formulations, which could be eroded into the river system during disposition of waste water from different sources and leaching of fertilizers residues from agricultural farms. The highest sulfate concentration peak in the little Akaki river, great Akaki river, Modjo river, awash at Koka and Koka dam is not the same with the finding of Emmanuel et al. (2006) that has also found a pronounced chloride peak at all the sampling points this could possibly derived from urban waste discharges, sewage effluents, and mostly the industrial effluent. On the contrary, the concentration of Iron (Fe), manganese, ammonia, chromium, lead and COD in the current study showed a very high range far above the range of values estimated by Emmanuel et al. (2006).

5. Conclusion and Recommendations

5.1. Conclusion

From the many findings in the study area the surface water of the Awash River basin was severely polluted. Significant pollution level of Awash river basin surface water was indicated by COD, BOD, Ammonia, phosphate, Nitrate, Turbidity, Electrical conductivity, total Alkalinity, total hardness and some metallic constituents. The variation is likely linked to the source of pollution as a result of rock and soil water interaction, industrial effluents, municipal wastes, domestic wastes and agricultural activities. The spatial and temporal results for all sampling site indicated that pH, temperature, Fluoride, chloride, magnesium, Zinc, TDS and sulphate were within the range of permissible limits of WHO and Ethiopian drinking water quality standards. High concentration and variation of pollutants along the Awash River tributaries were found in little Akaki, Great Akaki, Sebata, Koka and Modjo River. This variation likely arises due to the rapid urbanization and industrialization in the area. Out of all parameters treated in the study, the values and variation of Electrical conductivity, BOD, COD, alkalinity and hardness increases spatially and temporally in the tributaries. The areas of Holeta, Bushoftu, and Dukem River comprise the lowest peak and Awash at Ginchi, Aba Samuel Dam, Koka Dam and Awash at Koka Bridge is slight peak with treats of waste. Whereas, the little Akaki, great Akaki, Modjo, Koka, and Sebata River is responsive to high mineralization of high electrical concentration and other parameter variation.

The remaining water quality parameters: nitrate and phosphate also showed high temporal and spatial variation and concentration on surface water. All industries in the basin have no functional treatment plant and hence they discharge their effluent directly to the Mojo, Koka, Akaki and Sebata River which results the Awash River water quality degradation. Compared to all sampling points, the Little Akaki River displayed the highest peak and showed concentration variation of parameters during the dry season. The little Akaki is the recipient of most of the pollutants than Great Akaki and the other sampling points and this is likely because the great Akaki only traverse through residents and commercial centers. Whereas, the Little Akaki passes through the highly industrial, agricultural and municipal parts of Addis Ababa. The study revealed that Little Akaki River is the one which constitute higher and continuous source and sink system. Multiple sources of pollutants are discharged to the river both from point and non-point sources. The phosphate and turbidity concentration in all sampling points during both season was found above WHO limit therefore since all the sample water comprises of high mineralization and phosphate load then the water is treated as unsafe for drinking.

Generally physicochemical and biological results from this study showed that some of the parameters measured in the rivers and dams were above the reference values, the standards set by EPA, WHO and Ethiopian drinking water quality guideline. Out of 28 parameters the sample water were above the standards at little Akaki by 67.86%, Aba Samuel Dam and Modjo River by 57.14%, Koka River by 53.57%, Awash at Ginchi, Great Akaki and Sebata River by 50%, Holeta river and Dukem river by 32.14% and Bushoftu River and Koka dam by 28.57% .

The concentration of ammonia, turbidity, phosphate, E-Coli and total coliform at the sampling points were above the ambient environmental standard which tell us the surface water quality of the study area was extremely deteriorated by industrial effluent, municipal waste and agricultural activities.

5.2. Recommendation

Environmental assessment and management have been recognized as effective tools for facilitating the inclusion of the principles of sustainable development into development schemes. Thus to ensure that the existing situations get improved and future developments in Awash river basin are sustainable it is essential to integrate environmental concerns into development activities.

In order to normalize the source and sink system and to establish a clean water environment, an integrated approach involving all the actors in the river basin is important.

The Federal government should contribute in the improvement of sanitary facilities to all household and restrict hazardous wastewater generating industries with in some radius of the catchment. Farther more, Addis Ababa and Oromia regional Government Environmental Protection bureau should lay ground rules and regulation in order to prevent the pollution of Awash River basin. This is possible through fixing effluent standard emissions and subsequent penalties in the form of polluter pay principles.

Improve the performance of Addis Ababa wastewater treatment plant through modification or technological upgrades and propose additional wastewater treatment for Addis Ababa city and towns in the upper Awash River basin.

It should be an urgent prerequisite to require to all industries in the basin to continuously monitor effluents and take necessary actions to change wastewater to environmentally friendly form before discharging it into the rivers. Moreover, introducing better practice to liquid and solid waste disposal into Awash River basin also prevents the water pollution. In line with this disconnecting pit latrines from entering the water system and discouraging fecal defecation in open spaces along the river side could also improve the water quality. Despite the little Akaki, Modjo and Sebata River is being contaminated with chemicals and toxic substances, it was observed that some people use the rivers for different purposes like irrigation. The local communities should be aware of the potential dangers of using such polluted water for different economic activities.

Above all, executive priority should be given to villagers at the lower catchments of the river, where their only source of water is from the polluted unsanitary Awash River. The little Akaki, Great Akaki, Sebata and Modjo River is also inhibited by farmers relying on irrigation system of the polluted river. Hence the farmers should adopt commercial fertilizers at rates matching the plant needs and different ways of marketing and practicing vegetable disinfectants in order to harvest clean and uninfected products.

An integrated water quality monitoring program and data management systems need to be developed for the Awash River Basin and the monitoring program should include discharge information.

Anthropogenic activities such as, Agricultural practices, Livestock rearing, Construction, Chemicals storage and handling and waste disposal in the project areas should be carried out in such a way that impacts to the riverine system and or the whole environment is minimal.

Moreover, Vegetation cover alongside streams has to be maintained and enhanced so as to shade the water and filter pollutants from the runoff or nonpoint sources.

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Appendix I: Dry Season physicochemical and biological analysis result of Awash River

Sampling day		**May-07-2014**	**May-07-2014**	**May-07-2014**	**May-07-2014**	**May-07-2014**	**May-07-2014**	**May-08-2014**	**May-08-2014**	**May-08-2014**	**May-09-2014**	**May-09-2014**	**May-09-2014**
Time		11:05am	10:40am	09:35am	1:40pm	03:30pm	04:20pm	09:45am	8:45am	8:15am	9:00am	10:30pm	11:10am
Air cond.		sunny	sunny	sunny	sunny	sunny	sunny	sunny	sunny	sunny	Cloudy	Rainy	sunny
Code		KD	KR	AW	MR	BR	DR	ADO	GA	LK	AG	HR	SR
S no	**Parameter**												
1	Appearance	Turbid	Turbid	Turbid	Turbid	Turbid	Turbid	Turbid	Turbid	Turbid	Turbid	Turbid	Turbid
2	Turbidity	416	199	620	254	738	369	1760	957	488	788	728	744
3	PH	8	7.85	7.43	8	7.46	7.88	7.48	7.33	7.51	7.02	6.57	8.19
4	Temperature ^{O}C	29.7	22.5	26.3	27.4	24.2	28.9	22.8	22.8	21.9	24.2	21.4	23.2
5	Total Dissolved Solution (TDS, mg/l)	173	712	325	486	173	165	373	291	609	169	109	496
6	Electro Conductivity(EC, µS/cm)	348	1420	646	968	347	331	747	581	1217	398	219	992
7	Nitrate(NO_3, mg/l)	41.4	45.8	70.1	77.4	26.4	22.9	41.4	47.5	47.9	31.7	15.4	64.2
8	Sulphate (SO_4, mg/l)	27	108	31	52	11	13	47	31	88	36	5	71
9	Iron (Fe, mg/l)	1.41	0.73	1.02	0.86	0.12	0.48	2.01	1.66	2.04	1.63	1.93	3.6

10	Manganese(Mn, mg/)	1.95	3.3	1.2	0.42	0.1	0.2	4.3	3.5	5.5	0.6	0.94	0.92
11	Phosphate (PO4, mg/l)	0.39	0.73	4.44	0.38	1.61	5.2	5.08	3.88	6.45	0.92	0.78	2.58
12	Copper (Cu, mg/l)	0.9	0.55	0.87	0.78	0.57	0.29	1.53	1.08	1.63	1.89	0.05	0.38
13	Chromium (Cr+6, mg/l)	0.22	0.12	0.21	0.13	0.1	0.07	0.21	0.18	0.37	0.4	0.03	0.48
14	Ammonia (NH_3, mg/l)	1.21	18.9	0.424	20.3	0.424	0.121	24.1	9.08	44.8	1.15	13.9	16.1
15	Ammonium (NH_4, mg/l)	1.29	20.1	0.452	21.7	0.452	0.129	25.6	9.68	47.7	1.23	14.8	17.1
16	Fluoride (F^-, mg/l)	0.22	1.25	0.42	0.32	0.089	0.86	0.064	0.16	0.28	0.053	0.09	0.22
17	Total Hardness (mg/l as $CaCO_3$)	106	208	180	176	130	96	188	172	214	160	110	54
18	Magnesium Hardness(mg/l as $CaCO_3$)	14	64	32	20	84	80	58	78	8	52	30	14
19	Calcium Hardness (mg/l as CaCO3)	92	144	148	156	46	16	130	94	206	108	80	40

20	Total Alkalinity, (mg/l as $CaCO_3$)	150	438	212	312	178	40	296	250	410	216	116	238
21	Total Acidity (mg/l as CaCO3)	56	72	54	14	34	20	26	18	66	74	34	14
22	Chloride (Cl^- mg/l)	Nil	22	Nil	40	Nil	Nil	96	Nil	Nil	Nil	Nil	58
23	Lead (pb, mg/l)	0.7103	0.9823	1.185	0.4103	0.9823	0.6696	0.9243	0.5185	0.5454	0.7583	0.6871	0.8374
24	Zink(Zn, mg/l)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
25	Magnesium (Mg, mg/l)	3.40	15.55	7.78	4.86	20.41	19.44	14.09	18.95	1.94	12.64	7.29	3.40
26	Calcium (mg/l as Ca)	36.8	57.6	59.2	62.4	18.4	6.4	52	37.6	82.4	43.2	32	16
27	Sodium(Na, mg/l)	25.41	195.19	52.16	110.7	10.61	31.5	49.76	30.88	111.4	58.75	45.69	65.78
28	Potassium(K, mg/l)	6.6	13.16	1.106	14.83	7.392	7.334	4.927	11.84	32.13	7.54	8.451	8.056
29	DO (mg/l)	4	2.3	3	1.2	3.5	3.9	3.2	2.4	0.7	4.8	4.2	2.6
30	BOD5(mg/l)	24	88	42	154	17	Nil	96	52	216	84	93	81
31	COD(mg/l)	32	108	60	195	52	21	212	88	460	178	147	165
32	E-Coli per 100ml	20	103	138	139	10	33	TNTC	TNTC	TNTC	25	30	TNTC
	Total-Coliform /100ml	TNTC	TNTC	TNTC	TNTC	101	TNTC	TNTC	TNTC	TNTC	150	175	TNTC

Appendix II: wet season physicochemical and biological analysis result of Awash River

Sample day		18-08-2014	18-08-14	18-08-14	18-08-14	18-08-14	18-08-14	19-08-14	19-08-14	19-08-14	20-08-14	20-08-14	20-08-14
Time		11:10am	10:30am	09:00am	12:40am	01:30pm	03:20pm	12:15pm	01:20pm	12:15pm	01:00pm	02:30pm	11:10am
Air cond.		Rainy	Rainy	Rainy	Rainy	Rainy	Rainy	Rainy	Rainy	Cloudy	Cloudy	Cloudy	Cloudy
Code	**parameter**	KD	KR	AW	MR	BR	DR	ADO	GA	LK	AG	HR	SR
S/ no													
1	Appearance	Turbid	Turbid	Turbid	Turbid	Turbid	Turbid	Turbid	Turbid	Turbid	Turbid	Turbid	Turbid
2	Turbidity	172	4900	2800	2300	5100	2300	200	1550	210	460	160	104
3	PH	7.44	7.65	7.72	7.43	7.73	7.36	7.37	7.32	7.66	7.8	7.38	7.84
4	Temperature ^{O}C	20.9	20.9	20.8	20	18.6	18.3	22.5	23.5	23.3	19.9	19.6	20.6
5	Total Dissolved Solution (TDS, mg/l)	124	195	86.1	95.2	60	60	155	114	228	108	53.1	361
6	Electro Conductivity(EC, µS/cm)	249	390	172.5	190.6	120	121	312	229	458	217	106.4	723
7	Nitrate(NO_3, mg/l)	3.65	11.5	3.52	5.24	16.5	5.28	44	22.9	28.2	0.44	6.6	6.16
8	Sulfate (SO_4, mg/l)	8	21	2	3	5	4	10	14	21	56	52	22
9	Iron (Fe, mg/l)	0.64	0.62	2.48	1.99	0.41	5.4	0.81	1.58	0.29	0.6	4.32	0.14

10	Manganese(Mn, mg/)	0.2	0.06	0.07	0.06	0.02	0.02	0.03	0.03	0.02	0.7	0.2	0.01
11	Phosphate (PO_4, mg/l)	0.28	0.36	0.74	0.41	4.28	0.38	0.78	1.21	2.06	9.64	2.92	0.85
12	Copper (Cu, mg/l)	0.31	1.6	0.43	1.2	1.1	0.14	0.45	0.46	0.65	0.36	0.46	0.85
13	Chromium (Cr^{+6}, mg/l)	0.01	0	0	0	0	0	0	0	0.02	0.22	0	0.04
14	Ammonia (NH_3, mg/l)	0.99	3.12	10.43	1.43	4.5	1.44	2.19	2.65	5.35	40.5	0.74	1.83
15	Fluoride (F^-, mg/l)	0.7	0.26	0	0	0	0	0	0	0.27	0	0	0.2
16	Total Hardness (mg/l as $CaCO_3$)	76	74	64	82	68	58	54	76	91	77	24	79
17	Magnesium Hardness(mg/l as $CaCO_3$)	36	2	22	19	10	34	24	32	19	5	6	23
18	Calcium Hardness (mg/l as $CaCO_3$)	40	72	42	63	58	24	30	44	72	72	18	56
19	Total Alkalinity, (mg/l as $CaCO_3$)	84	126	66	74	78	72	82	72	134	122	44	112
20	Total Acidity (mg/l as $CaCO_3$)	12	14	16	10	6	6	12	16	28	24	20	20
21	Chloride (Cl^- mg/l)	0	6	4	2	0	6	2	4	6	2	4	5
22	lead (pb, mg/l)	2.1	0.4	2.3	5	0.1	0.5	0.4	3	1	0.14	0.15	1

23	Zink(Zn, mg/l)	0.1	0	0.1	0	1.14	2.8	0	0	0	0.18	0.08	0.3
24	sodium(Na, mg/l)	32.5	52.13	15.67	17.26	13.01	10.33	24.56	21.7	52.84	16.4	22.72	18.43
25	Magnesium (Mg, mg/l)	8.748	0.486	5.346	4.617	2.43	8.262	5.832	7.776	4.617	1.215	1.458	5.589
26	Calcium (mg/l as Ca)	16	28.8	16.8	25.2	23.2	9.6	12	17.6	28.8	28.8	7.2	22.4
27	potassium(K, mg/l)	0.2	3.6	2.2	0.7	0.3	0.6	0.7	1.8	10.5	0.67	2	5.6
28	Dissolved Oxygen (mg/l)	4.1	2.9	3.2	2.7	3.7	2.8	4	3.7	3.9	4.9	4.7	4.3
29	BOD5(mg/l)	7.96	16.5	10.8	15.3	9.2	16.2	7.6	15.9	16.8	10.5	10.2	13.2
30	COD(mg/l)	25	114	74	98	41	121	21	112	151	63	40	78
31	E-Coli per 100ml	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC
32	Total-Coli form/100ml	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC	TNTC

TNTC (too numerous to count) for number >300

Appendix III: location and elevation of river water sampling point.

site nom		**Source and description**		**Latitude and longitudes**		**Altitude (meter)**
	Sample site	source	Description	Easting	Northing	
1	Koka Dam (KD)	Reservoir	Koka reservoir	508819	934113	1601
2	Koka River (KR)	River	Koka river near the bridge on Addis-Awassa road	500334	931823	1615
3	Awash River (AW)	River	awash river near the bridge on Addis-Awassa road	502338	929387	1603
4	Modjo River (MR)	River	mojo river 2km d/s of the bridge	512008	949906	1761
5	Bushoftu River (BR)	River	3 km out of Bushoftu town around the express way	501785	969997	1900
6	Dukem River (DK)	River	Near the bridge on AA- Bushoftu town road	488204	973256	1979
7	Aba Samuel dam outlet (ADO)	Reservoir	at out let of the Dam	467938	971341	2055
8	Great Akaki River (GA)	River	at the approach to Aba Samuel dam	473296	975095	2071
9	Little Akaki River (LK)	River	outside the City under the bridge	472202	982314	2070
10	Awash at Ginchi (AG)	River	Near the bridge on Addis - Ambo highway	404250	998114	2232
11	Holeta River (HR)	River	under the bridge on Addis - Ambo highway	446200	1002974	2401
12	Sebata River (SR)	River	Near the bridge downstream of the town	459384	984585	2191

Appendix IV: FAO irrigation water quality guideline

Guidelines for interpretation of water quality for Irrigation

potential irrigation problem	Units	Degree of restriction on use		
		None	slight to moderate	severe
Salinity				
EC	µS/cm	<700	700 -3000	>3000
TDS	mg/l	<450	450-2000	>2000
Infiltration				
SAR				
0-3	EC	>700	700-200	<200
3-6.0		>1200	1200-300	<300
6-12.0		>1900	1900-500	<500
12-20.0		>2900	2900-1300	<1300
20-40		>5000	5000-2900	<2900
Specific ion toxicity				
Sodium(Na)				
surface irrigation	SAR	<3	3-9.0	>9
sprinkler irrigation	me/l	<4	>3	
chloride(Cl)	me/l			
surface irrigation	me/l	<4	4-10.0	>10
sprinkler irrigation	me/l	<3	>3	
Boron(B)	mg/l	<0.7	0.7-3.0	>3
Miscellaneous effects				
Nitrate (NO_3-N)	mg/l	<5	5-30.0	>30
Bicarbonate	me/l	<1.5	1.8-8.2	>8.5
PH		Normal range 6.5-8.0		

Source: Ayres and Westcot 1985

Appendix V: Provisional Effluents permit limit for all categories of existing industries in Ethiopia (EPA 2001, Vol. 3)

Basic Parameters	Limit for discharges into surface water within 15 meters of out fall
Temperature °C	35
PH	6 -9
DO	5
Color (Lovibond Units)	7
Alkalinity	400
BOD5 @ 20oC	100
Coliform Bacteria Count MPN/100ml	400
TSS	50
TDS	2000
Ammonia	4.5
Chlorides (as Cl)	200
Hydrogen Sulphide (H2S)	0.5
Sulphate	600
Sulfide	0.2
Nitrate	45
Phosphate (as PO4)	0.7
Other Parameters	
Phenolic Compounds (as Phenol)	0.02
Arsenic (As)	0.02
Barium (as Ba)	5
Tin (as Sn)	10
Iron (as Fe)	20
Manganese (as Mn)	5
Chlorine (free)	1
Cadmium (Cd)	< 1
Chromium (as +III, or +VI) <1	< 1
Copper	< 1
Lead	< 1
Mercury	0.05
Nickel	< 1
Selenium	< 1
Silver	0.1
Zinc	< 5
Calcium	200
Magnesium	200
Boron	5

Cyanide	0.2
Detergent	1.5
Alkyl mercury compounds	10
Polychlorinated biphenyls	0.003
Alpha emmiters μc/ml	$< 0.01x10^{-7}$
Beta emmiters μc/ml	$< 0.01x10^{-6}$

Appendix VI: Drinking Water Quality Standards

Parameter	Unit	Ethiopian standard	WHO Guideline value 1993
Electrical conductivity	µS/cm	-	500
Turbidity	NTU	5	5
Color Unit	TCU	15	15
Odour and Taste		unobjectionable	unobjectionable
Calcium (as Ca)	mg/l	75	
Chloride(as Cl)	mg/l	250	250
Copper (as Cu)	mg/l	2	1
Residual free chlorine	mg/l	0.5	0.6 - 1
Sulphate (as SO_4)	mg/l	250	250
Fluoride(as F)	mg/l	1.5	1.5
Ammonia (NH_3)	mg/l	0.1	1.5
Nitrite (as NO_2)	mg/l	3	3
Iron (Fe)	mg/l	0.3	0.3
Manganese (Mn)	mg/l	0.5	0.1
Magnesium (Mg)	mg/l	50	
pH	pH meter	6.5-8.5	6.5-8.5
Total alkalinity(TA)	mg/l	200	200
Nitrate (NO_3)	mg/l	50	50
Arsenic (As)	mg/l	0.05	0.01
Potassium (as K)	mg/l	1.5	
Sodium(Na)	mg/l	200	200

Cadmium (Cd)	mg/l	0.01	0.003
Hexavalent Chromium (Cr^{+6})	mg/l	0.05	
Aluminum(Al)	mg/l	0.2	0.2
Chromium(as Cr)	mg/l	0.05	0.05
Lead (as Pb)	mg/l	0.01	0.01
Selenium(as Se)	mg/l	0.01	0.01
Boron(as B)	mg/l	0.3	0.3
Zink (Zn)	mg/l	5	3
Total mercury (Hg)	mg/l	0.001	0.001
Total Coliform	N/100ml	0	0
E. Col	N/100ml	0	0

Appendix VII: Guidelines of some physicochemical parameters for stream waters (EEPA, 2003)

Parameters	Ambient Environmental standard
BOD5	≤5 mg/l
COD	≤150 mg/l
EC	100 - 1000µS/cm@20^{0}C
NH_3-N	≤ 0.025 mg/l
NO_3-N	≤ 10 mg/l
Temperature	5 - 30^{0}C
PH	6.0 - 9.0
SO_4^{2-}	≤ 200 mg/l
PO_4^{3-}	≤ 0.005 mg/l
DO	≥4 mg/l
TSS	≤ 50 mg/l
Calcium	
Total solid	

DECLARATION

I the undersigned, declare that this thesis is my original work and has not been presented for the award of a degree in any university and all the materials used for this thesis work have duly acknowledged.

Name: Shaka Nugusu

Signature: ___________

Date and place of submission

School of Civil and Environmental Engineering, Addis Ababa University.

October, 2015.