The Effect of Lake Beseka Discharge on Irrigation Water Quality of Awash River

Belayneh Yirdaw Kelemu

A Thesis Submitted to the department of Water Resources Engineering,

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master in Water Resources Engineering (Specialization in Irrigation Engineering)

Office of Graduate Studies

Adama Science and Technology University

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April, 2018

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Co-Advisor:- Dr. Rogelio Belleza Paguntalan

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Approval of Board of Examiners

We, the undersigned, members of the Board of Examiners of the final open defense by Belayneh Yirdaw Kelemu have read and evaluated his/her thesis entitled "The Effect of Lake Beseka Discharge on Irrigation Water Quality of Awash River " and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the Degree of Master's in Irrigation Engineering.

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Declaration

I hereby declare that this MSc Thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

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This M.Sc Thisis has been submitted for examination with our approval as thesis advisors

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Date of submission __________________

Advisors approval sheet

To: **Water Resources Engineering Programme**

Subject: **Thesis Submission**

This is to certify that the thesis entitled “The Effect of Lake Beseka Dischrge on Irrigation Water Quality of Awash River “submitted in partial fulfillment of the requirements for the degree of Master of Science in Irrigation Engineering, and has been carried out by Belayneh Yirdaw , ID.No GSR/5924 /06 -, under my/our supervision. Therefore, I/we recommend that the student has fulfilled the requirements and hence hereby he/she can submit the thesis to the program.

Dr.Boja Mekonnen (Ph.D) _________________________ _________________

Major Advisor Signature Date

Dr. Rogelio Belleza Paguntalan ___________________________ _____________

(Professor)

Co-Advisor Signature Date

Dedication

I dedicate this thesis manuscript to my wife Bogalech Jima , and to my family.

Biographical Sketch

The author was born in Goha-Tsion (W/Jarso), Dec 15, 1975 G.C. He attended his primary and secondary school in Goha-Tsion between the years 1981 to 1995 G.C. Then he completed his high school education in 1994 G.C

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He joined the School of Graduate Studies of the Adama Science and Technology University in the academic year 2014 G.C as a graduate student of the Master of Science degree program in Irrigation Engineering.

Acknowledgment

First of all, I praise God, for guiding me throughout the course of this study.

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I never forget to appreciate Bogalech (my wife) and Kalkidan (my daughter), who never complained when I use their time for this study.

List of Acronyms

AwBA	Awash Basin Authority
Do	Dissolved oxygen
EC	Electrical Conductivity
FAO	Food and Agriculture Organization
l	liter
mg	milligram
MoWIE	Ministry of Water, Irrigation & Electricity
pH	Concentrator of Hydrogen Ions
SAR	Sodium Absorption Ratio
TDS	Total Dissolved solids
Temp.	Temperature

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Abstract

The quality of water deteriorates due to different natural event and human activity is major challenge of irrigation. When the quality of irrigation water is not safe, it affect the soil, production as well as the entire economy. In Ethiopia, Awash River is the main irrigation water source for mechanized farms and small land farmers established in the Basin for the last few decades. Even Awash River serves as a source of drinking water, hydropower, industrial consumption, irrigation and disposal of waste water, A major user and consumer of the surface water is irrigated agriculture through numerous private and government irrigation farms and small holders those found in the middle and lower Awash. Recently Irrigation activity of middle and lower Awash area affect by lake Beseka water. Lake Beseka is the rift Valley Lake which expanding at an astounding rate for the last four decade. This expansion has a significant effect on the surrounding and downstream area including irrigation activities. This study was conducted with the primary objective of assessing the effect of Lake Beseka discharge on the irrigation water quality of Awash River. Nine sample sites were chosen to make representative in respect to irrigation development; additionally the mix of Lake Beseka and Awash River water with ratio of 5:95, 10:90 and 15:85 were used to determine the mix ratio of Lake Beseka water to Awash River. The physicochemical parameter like pH, EC, TDS &TSS, CO_3^-, HCO_3^-, *Cl^-, Na^+ and,* K^+ *compared with the standard of FAO. Result showed that $P^{H,}$ EC, Alkalinity, TDS & TSS,* CO_3^- *&* HCO_3^-*, Chloride and sodium higher in Lake Beseka than Awash River water. The SAR value of Awash River water ranges 1.43 to 11.32, which has low to medium hazard level, where as SAR value of Lake Beseka >50, which very high hazard level. From the result obtained, it is concluded that the discharging of Lake Beseka water to Awash River water has an effect on irrigation water quality as well as productivity of downstream. So mix ratio of Lake Beseka water to Awash River water should be 5:95, When this was well done the physicochemical parameter of Awash River goes to fulfill FAO standards for irrigation water quality and to build a trust among upstream and downstream users .*

Key Words: Awash River, Irrigation water, Lake Beseka, water quality,

1. INTRODUCTION

1.1 Background

Water is one of the most resources on the earth and life cannot exist without it. The quality of water is central to the entire role that water plays in our lives. From the beauty of nature water ways teeming with wildlife, to the vital livelihoods that clean river and stream support to the essential role that safe water plays in any of its use. Water is the source of life on the earth and human civilizations blossomed where there was reliable and clean fresh water for drinking, washing and other uses.Numerous human and natural processes affect the biological, physical and chemical characteristics of water. Contaminations of water make the water unsuitable for any specific use. Fresh water ecosystem is one of the most degraded resources on the planet, and has suffered proportionally greater species and habitat losses than terrestrial or marine ecosystem (Revenga et.al, 2000). Livelihood such as agriculture, fishing and animal husbandry all rely on good water quality as well as quantity. Women, children and the economically disadvantaged are the most affected by poor water quality. Plants, animals and habitats that support biological diversity also need clean water.

Water quality is a term used here to express the suitability of water to sustain various uses or processes. Any particular water use has a certain requirement of physical, chemical and biological characteristic of water. Water quality is affected by change in nutrients, sedimentation, temperature, heavy metals, non-metals, toxins, persistent organics, pesticides and biological factors. It is very essential and important to test the quality of water before it is used for drinking, domestic, agricultural and industrial purposes. The utility of river water for various purposes is governed by physicochemical and biological quality of water (Singh et.al, 2013). Salty water discharge to fresh water need to control in order to regulate its effect on downstream areas. One of the main criteria for irrigation is that the quality of water. The development of irrigation has been important contributors to food security, particularly in arid areas. Which are always be set with land, water salinity and other environmental problems.

The use of salinized and sodic water for irrigation poses risk to agriculture and the environment. Salinity is very important in evaluating irrigation water quality (Ghassemi, 1995). High salt concentrations prevent the uptake of water by plants causing crop yield reductions. This occurs when salt accumulate in the root zone to such an extent that the crop is no longer able to extract sufficient water from saline soil solution, resulting in water stress for significant period (FAO, 1994). If the water uptake power of the plant is reduced, the plant slows its rate of growth and reduced production.

Another important variable in relation to irrigation water quality is sodicity. Sodicity refers to the presence of a high proportion of sodium (Na^{+}) ions relative to calcium (Ca^{2+}) and magnesium (Mg^{2+}) ion in soil or water, Sodicity degrades soil structure by breaking down clay aggregates, which results in more easily eroded soil that is less permeable to water and retards plant growth. The consequences of land sodicity and precursors of land salanization is water logging. This creates imbalance between the amount of water and air in the soil. Due to this imbalance of water and air in the soil the healthy growth of plant is damaged and production is adversely affected. The environmental and agricultural damage also may imply economic loss. There are different causes both natural and human that can induce accumulation of salt in soils and water resources. Discharging of salty water from different sources to the water source used for irrigation is one of the causes of salinity, and sodicicty problems. These saline and sodic water bodies are found in the regions with complex meteorological and climatological characteristics.

The main Ethiopian rift valley system is a part of east Africa which is a region of extremely complex meteorological and climatological phenomena and coupling mechanisms, possibly one of the most complicated in the continent. The topography of the rift valley of exerts a strong influence on microclimate, drainage system and local ecosystems. Lake Beseka is one of the surface water bodies found within the northern end of main Ethiopia Rift valley in the Awash basin. The lake is one of the most highly mineralized lake water (Bedilu, 2005). Moreover, it has been expanding in Volume as a result of which a critical social, economic as well as environmental factors have been under threat (Tenalem,2005; Bedilu, 2005; Tamiru, 2000; MoWR, 1999). During the last five decades the lake level and surface area have been increasing contentiously (MoWR,2000). This continuous expansion of Lake Beseka poses risk to Awash River because of its saline water. The expansion of lake affects the surface and ground water dynamics and soil properties of the region and threatens the sustainability of Matahara Sugar Estate, Matahara town in particular, and Awash river basin in general (Megersa et al., 2009). This would be disastrous. Considering that agricultural development downstream would be at risk (Eleni, 2009).

In 1978, Sir Willian Halcrow and partners studied the existing condition of lake Beseka, and ground that the lake covered an area of $3km^2$ up to the year 1964. In 1972, the area of the lake had reached $11km^2$ (Halcrow, 1978); in 1988 the area increased to 40 km^2 with maximum depth of 11m (MoWR, 1999). At present the lake area is expected to be more than 40 km^2. This change in volume was found to be related to the shift in water balance caused by the ground water inflow through open rift faults from the surrounding over irrigated fields and the regulated Awash River (Tenalem, 2005). It was found that the nearby Metahara Sugar Estate and Abadir farm, which dispose their excessive irrigation water into the lake, and the presence of hot-and-cold springs which supply the lake, the chemistry of the lake has been changing (Tamiru. et la, 2005).The drastic expansion of the lake has led to many problems in the surrounding area, and threatens the wellbeing of the indigenous people and the economic welfare of the nation in general.

To overcome this problem, the Ministry of Water and Energy (MoWE) has so far spent 35 million ETB to dig drainage channels, discharging water into the Awash River (2% of Awash River by volume) from the lake water. The diluted Awash River water is discharged to the downstream irrigation farms; however this cannot be a solution because of two reasons. First, the lake water rises much higher than the amount of discharging water into the river. Second the physiochemical property of the lake water changes periodically detailed hydrologic investigation is needed.

1.2 Statements of the Problem

Accelerated water quality changes due to anthropogenic and natural process are one of the major environmental concerns in Ethiopia. Growing trends in the water quality of surface water bodies due to growing industrialization, agricultural activities, natural phenomena and others have raised concern about pollution of water bodies. The quality of surface water around rift valley is influence by the complex geological activities which increase the concentration of chemical constituents in surface water to undesirable levels by transferring from deep ground water in thermal spring and others. As a result, the surface water bodies are characterized by high fluoride, bicarbonate and chloride concentration far above the recommended level. The Areas around Lake Besake are characterized by recent extertiental faults which are associated with geothermal fields discharging hot springs and famaroles (Tamiru et al, 2005).

There are hot springs situated in the southern and south-western end of Lake Beseka which affect the physicochemical properties of the lake (MoWR 1999). Trace metals also affect water quality, the natural properties of water, aquatic ecosystem, humans, animals and birds in terms of toxicity.Lake Beseka is in less than 3 km from the Awash River, which is the source of drinking water and irrigation for millions of people downstream. If the lake continues to expand at the current rate and other influencing factors remain the same, the lake will cross the natural water divide and invade the town of Addis Ketema and join the Awash River. This would be disastrous because the polluted water with threaten the ecosystem and development downstream of Lake Beseka.

Many studies show that the Awash River has a maximum flow during the wet season of July, August and September. During these months the average flow of the river is about 89.1 m^3 /sec. Discharging Lake Beseka to Awash River with 1 to 12 ratios can be safe. Combining the mix ratio model and Awash River peak flow during wet season, Lake Beseka could discharge up to 10 m^{3}/sec in July, August and September. (MoWR 1999)

This recommendation may reduce the effect of Lake Beseka in surroundings areas, but it may aggravate its impact on downstream user. Discharging Lake Beseka water to Awash river is an environmental and social issues, This is because of social diversity around the Lake, different uses of Awash River water downstream such as irrigation, domestic, recreation including wildlife. In depth study is required to understand the impact of discharging appropriate mix ratio of waters from the lake and Awash River poses on the main challenge for water resource planners and irrigation engineers in the area. The special issue arising from this problem need to be understood.

1.3 Objectives of the Study

1.3.1 General objective

The general objective of this research was to assess the effect of Lake Beseka discharge on the irrigation water quality of Awash River.

1.3.2 Specific objectives

The specific objectives of this study were as follows:-

1) To determine the physicochemical characteristics of water at Lake Besaka and Awash River,
2) To determine the effect of blending of Lake Besak to Awash River on the water quality for irrigation
3) To determine the appropriate mix ratio of the Lake Beseka and Awash River for irrigation, and
4) To assess the social impact of discharging Lake Beseka water to Awash River in upstream and downstream users.

1.4 Research Questions

1) What are the physicochemical characteristics of water at Lake Besaka and Awash River?
2) What is the effect of discharging Lake Beseka on Awash River water quality for irrigation?
3) What is the appropriate mix ratio of Lake Beseka and Awash River for irrigation?
4) What is the social impact of discharging Lake Beseka water to Awash River?

2. LITERATURE REVIEW

2.1 Hydrological System of Lake Beseka and Its Impact

The Awash Basin divided in to seven zones with their own specific characteristics; of these seven zones upper valley is the area of the basin between Koka dam and Awash station with an elevation of between 1500 m and 1000 m and mean annual rainfall ranges from 600 mm to 800mm (Halckro, 2006). This eventually has made the water resource in the area mainly originated from rain fall. Moreover on the surface the rainfall being accumulates and drains to the lake. The other source of lake water is the ground water in different direction of the lake. A portion of the rainfall can eventually flow as a runoff. If it exceeds the infiltration capacity of the soil due to its salinity, consequently the lake turns gradually discharged into the Awash River, and similarly above open water the rainfall exceed the evaporation rate the level of the lake is maintained by a net flow surface water and ground water.

The ground water flows from the south and northwestern part of the watershed towards the Lake, the ground water level is high in the south and northwestern part of watershed and become lower towards Lake Beseka and eastern part of watershed. The ground water level is at its lowest east of Lake Beseka, around the Metehara town area, and this may induced ground water outflows from the Lake .part of the basin around the lake is characterized by wind spread hot spring. (Eleni, 2009). Changing water levels and result shifts in location of shoreline and grazing and woodland area has been inundated during the last four decades. In other words the local pastoral people had lost about more than 40 km^2 their valuable land. On the development side on area 161.55 ha has been affected from Metehara sugar factory which of 55.55 ha been totally inundated or completely lost while the remaining 106 ha is very poor in sugarcane production due to in efficient mechanical operations caused by high water table and high sodium salt deposit. The study also show that if immediate remedial measure are not taken to stop the lake level rise before lake water unrestrictedly flows in to Awash river it will inundated an additional area of 175 ha. This would increase an affected farmland to 336.55 ha which would be great lose for Metehara sugar factory (MoWR).

Figure 1:- Inundation of social Institution

Source : (MoWR)

It is obvious as the lake water and swampy area are approaching to human settlement area the prevalence of water borne and water related diseases may increase. The impact of lake level rise on the Awash National park is mainly indirect that the expansion of lake has inundated considerable area of grazing land and watering points of the surrounding pastorals, mainly kereyu. Therefore, these pastorals societies are forced to look for alternative grazing and watering sites and they encroached into the park area. As a result the park area has been pressurized and stability of wild and domestic animal in the same park may reduce tourist attraction and may also result in the transmission of communicable disease between the wild and domestic animals.

Soil salinity and sodicity assessment of the study area revealed that, substantial parts of Amibara farm areas were consistently and continuously affected by salinity problem.

Significant proportion of the irrigated land has been abandoned or soon will be abandoned mainly because of secondary salinization resulted from shallow saline groundwater table. With regard to water quality assessment, spatial variability was observed in the Awash River along the courses due to inflows from other tributaries and natural thermal springs. But from the analysis it can be concluded that, Awash River water can be considered as suitable for irrigation purpose, with moderate salinity and low sodicity class. (Frew, 2012). The discharge rate of Beseka water into Awash River will affect its quality and aggravate the soil salinity and reduce cotton yield. Moreover the result revealed that Beseka Lake is a great source of pollution for down streams agricultural farm and it is a great environmental concern than need immediate attention. (Elias k., Brook A. and Tilahun H. 2003)

2.3 Irrigation water Quality

Irrigation water quality refers to its suitability for use. A good quality water has the potential to allow maximum yield under good soil and water management practices. However, with poor quality water, soil and cropping problems can be expected to develop which will reduce yields unless special management practices are adopted to maintain or restore maximum production capability under the given set of conditions. The suitability of water, from a quality standpoint, is determined by its potential to cause problems and is related to the special management practices needed or the yield reduction caused. Solution in most cases is at the farm level, meaning the evaluation must be done in terms of the specific use and potential hazard to crop production under the existing management capability and farm situation. (FAO, 1998).

One of the main problem in irrigation practice is salinity, this is because of all irrigation water contain soluble salts. The composition of salts in water varies according to the source of water and properties of constitute chemical compounds. The salt which found in the irrigation water may include substances gypsum (Calcium Sulphate, $CaSO_4$, $2H_2O$), table salt (Sodium Chloride, NaCl) and baking soda (Sodium bicarbonate ,$NaHCO_2$). When these salts dissolved in water, salts separate in to ions, for example sodium chloride break down into Sodium and Chloride ions. Thus it is customary to refer to ions rather than salts.

The application of irrigation water to the soil introduces salts in to a root zone. plant roots take in to water but absorb very little salt from the soil solution, in a similar way when water evaporates from the soil surface, the salt remain behind. Gradually accumulation of salts in the root zone occurred. This happens even when the water has low salinity. The problems that result from using poor quality water will vary both as to kind and degree but the most common are:-

Salinity: - A salinity problem related to water quality. if the total quantity of salts in the irrigation water is high enough that salts accumulate in the crop root zone to the extent that yields are affected. If excessive quantities of soluble salts accumulate in the root zone, the crop has extra difficulty in extracting enough water from the salty soil solution. This reduced water uptake by the plant can result in slow or reduced growth and may also be shown by symptoms similar in appearance to those of drought such as early wilting. Some plants exhibit a bluish-green colour and heavier deposits of wax on the leaves. These effects of salinity may vary with the growth stage and in some cases may go entirely unnoticed due to a uniform reduction in yield or growth across an entire field. This mechanism of water uptake has been studied extensively and it now appears the plant takes most of its water from and responds more critically to salinity in the upper part of the root zone than to the salinity level in its lower depths when using normal irrigation practices (Bernstein and Francois, 1973). Thus, managing this critical upper root zone may be as important as providing adequate leaching to prevent salt accumulation in the total root zone.

Permeability: A permeability problem related to water quality occurs when the rate of water infiltration into and through the soil is reduced by the effect of specific salts or lack of salts in the water to such an extent that the crop is not adequately supplied with water and yield is reduced. The poor soil permeability makes it more difficult to supply the crop with water and may greatly add to cropping difficulties through crusting of seed beds, water logging of surface soil and accompanying disease, salinity, weed, oxygen and nutritional problems. It is evaluated firstly, from total salts in the water since low salt water can result in poor soil permeability due to the tremendous capacity of pure water to dissolve and remove calcium and other soluble in the soil and, secondly, from a comparison of the relative content of sodium to calcium and magnesium in the water. Furthermore, carbonates and bicarbonates can also affect soil permeability and must be evaluated.

The adverse influence of sodium on soil permeability has been recognized for many years. But in many cases the evaluation of the sodium influence alone has proven to be in error basically because the interaction of three factors determines water's long term influence on soil permeability. These factors are I) sodium content relative to calcium and magnesium; 2) bicarbonate and carbonate content, and 3) the total sail concentration of the water. A simultaneous analysis of these has been applied to soils before but only recently has been applied to estimating the permeability hazard of irrigation waters to soils (Rhoades 1972).

Toxicity: - A toxicity problem occurs when certain constituents in the water are taken up by the crop and accumulate in mounts that result in a reduced yield. This is usually related to one or more specific ions in the water namely Boron, Chloride and Sodium.

Miscellaneous: - Various other problems related to irrigation water quality occur with sufficient frequency that they should be specifically noted. These include excessive vegetative growth, lodging and delayed crop maturity resulting from excessive nitrogen in the water supply, white deposits on fruit or leaves due to sprinkler irrigation with high bicarbonate water and suspected abnormalities indicated by unusual pH of the water. (FAO, 1996).

Sodium adsorption ratio (SAR) Sodium adsorption ratio is a measure of the amount of sodium (Na) relative to calcium (Ca) and magnesium (Mg) in the water extract from saturated soil paste. It is the ratio of the Na concentration divided by the square root of one-half of the Ca + Mg concentration. It is an irrigation water quality parameter used in the management of sodium-affected soils and an indicator of the suitability of water for use in agricultural irrigation, as determined from the concentrations of the main alkaline and earth alkaline cations present in the water. It is also a standard diagnostic parameter for the sodicity hazard of a soil, as determined from analysis of pore water extracted from the soil. SAR allows assessment of the state of flocculation or of dispersion of clay aggregates in a soil. Sodium and potassium ions facilitate the dispersion of clay particles while calcium and magnesium promote their flocculation. The behavior of clay aggregates influences the soil structure and affects the permeability of the soil whose directly depends the water infiltration rate.

SAR is only one factor in determining the suitability of water for irrigation, in general, the higher the sodium adsorption ratio, the less suitable the water is for irrigation. Irrigation using water with high sodium adsorption ratio may require soil amendments to prevent long-term damage to the soil. If irrigation water with a high SAR is applied to a soil for years, the sodium in the water can displace the calcium and magnesium in the soil. This will cause a decrease in the ability of the soil to form stable aggregates and a loss of soil structure and tilth. This will also lead to a decrease in infiltration and permeability of the soil to water, leading to problems with crop production. According to United State Soil Laboratory Staff (1954), irrigation water classified into four hazard classes as S1, S2, S3 and S4 to signify low, medium, high and very high hazard levels based on the amount of SAR content. The ranges in this system are <10, 10-18, 18-26 and >26 for the low, medium, high and very high hazard levels respectively.

2.4 Water Quality Criteria and Standards

Numerous sets of water quality standards, or guidelines for water quality, have been issued during the course of time by various agencies and authorities (e.g. United States Environmental Protection Agency (EPA), World Health Organization (WHO), European Union (EU), and other countries) intending to define the maximum acceptable limit of water pollution by various pollutants. Standards for ambient water quality are commonly designated according to the intended use of the water resource (e.g. drinking water, fishing water, irrigation etc.).

The concentrations above which water pollutants adversely affect a particular water use may differ widely. Water quality requirements, expressed as water quality criteria and objectives, are use-specific or are targeted to the protection of the most sensitive water use among a number of existing or planned uses. In establishing water quality standards for a given water body, site-specific physical, chemical, hydrological and biological conditions are taken into consideration. Such conditions may be related to the overall chemical composition (hardness, pH, dissolved oxygen), physical characteristics (turbidity, temperature, mixing regime), type of aquatic species and biological community structure, and natural concentrations of certain substances (e.g. metals or nutrients). These site-specific factors may affect the exposure of aquatic organisms to some substances or the usability of water for human consumption, livestock watering, irrigation and recreation. Water quality criteria are based on scientific information about the effects of water pollutants on a specific water use. They describe water quality requirements for protecting and maintaining an individual use. Many water quality criteria set a maximum level for the concentration of a substance in water which will not be harmful when the specific medium is used continuously for a single, specific purpose.

For some other water quality variables, such as dissolved oxygen, water quality criteria are set at the minimum acceptable concentration to ensure the maintenance of biological functions. The protection and maintenance of the water uses usually impose different requirements on water quality and, therefore, the associated water quality criteria are often different for each use. Water quality criteria have been widely established for a number of traditional water quality variables such as pH, dissolved oxygen, biochemical oxygen demand (BOD), chemical oxygen demand (COD) and nutrients. Such criteria guide decision makers, especially in countries with rivers affected by severe organic pollution, in the establishment of control strategies to decrease the potential for oxygen depletion.

Water quality criteria for irrigation water generally take into account, amongst other factors, such characteristics as crop tolerance to salinity, sodium concentration and phytotoxic trace elements. The effect of salinity on the osmotic pressure in the unsaturated soil zone is one of the most important water quality considerations because this has an influence on the availability of water for plant consumption. Sodium in irrigation waters can adversely affect soil structure and reduce the rate at which water moves into and through soils. Sodium is also a specific source of damage to fruits. Phytotoxic trace elements such as boron, heavy metals and pesticides may stunt the growth of plants or render the crop unfit for human consumption or other intended uses. (WWF-Pakistan). At the international level, Food and Agriculture Organization of the United Nations (FAO, 1998) guidelines have been extensively used to evaluate irrigation water quality guidelines.

2.5 The Role of plant nutrient in plant growth

Plants convert light energy into biomass through photosynthesis and produce various products of economic value (grain, fibre, tubers, fruits, vegetables and fodder) among others. To do this, plants need sufficient light, suitable temperature, substances such as water, CO2, oxygen, and a number of nutrients. Available nutrients in the soil solution can be taken up by the roots, transported to the leaves and used according to their functions in plant metabolism.

Plants, like all other living things, need food for their growth and development. Plants require 16 essential elements. Carbon, hydrogen, and oxygen are derived from the atmosphere and soil water. The remaining 13 essential elements (nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, zinc, manganese, copper, boron, molybdenum, and chlorine) are supplied either from soil minerals and soil organic matter or by organic or inorganic fertilizers. Each type of plant is unique and has an optimum nutrient range as well as a minimum requirement level. Below this minimum level, plants start to show nutrient deficiency symptoms. Excessive nutrient uptake can also cause poor growth because of toxicity. Therefore, the proper amount of application and the placement of nutrients are important. Soil and plant tissue tests have been developed to assess the nutrient content of both the soil and plants, (FAO, 2006).

Nitrogen (N):- it is available to plants as nitrate (NO_3^-), and ammonium (NH_4^+) ions. Nitrogen is biologically combined with C, H, O, and S to create amino acids, which are the building blocks of proteins. Amino acids are used in forming protoplasm, the site for cell division and thus for plant growth and development. Since all plant enzymes are made of proteins, N is needed for all of the enzymatic reactions in a plant. N is a major part of the chlorophyll molecule and is therefore necessary for photosynthesis. N is a necessary component of several vitamins. N improves the quality and quantity of dry matter in leafy vegetables and protein in grain crops.

Stunted growth may occur because of reduction in cell division. Pale green to light yellow color (chlorosis) appearing first on older leaves, usually starting at the tips. Depending on the severity of deficiency, the chlorosis could result in the death and/or dropping of the older leaves. This is caused by the translocation of N from the older to the younger tissues. Reduced N lowers the protein content of seeds and vegetative parts. In severe cases, flowering is greatly reduced. N deficiency causes early maturity in some crops, which results in a significant reduction in yield and quality.

Phosphorus (P):- available to plants as orthophosphate ions ($HPO_4 2^-$, H_2PO_4–). In photosynthesis and respiration, Phosphorus plays a major role in energy storage and transfer as ADP and ATP (adenosine di- and triphosphate) and DPN and TPN (di- and triphosphopyridine nucleotide). Phosphorus is part of the RNA and DNA structures, which are the major components of genetic information. Seeds have the highest concentration of Phosphorus in a mature plant, and Phosphorus is required in large quantities in young cells, such as shoots and root tips, where metabolism is high and cell division is rapid. Phosphorus aids in root development, flower initiation, and seed and fruit development. Phosphorus has been shown to reduce disease incidence in some plants and has been found to improve the quality of certain crops.

Phosphorus is needed in large quantities during the early stages of cell division; the initial overall symptom is slow, weak, and stunted growth. Phosphorus is relatively mobile in plants and can be transferred to sites of new growth, causing symptoms of dark to blue-green coloration to appear on older leaves of some plants. Under severe deficiency, purpling of leaves and stems may appear. Lack of Phosphorus can cause delayed maturity and poor seed and fruit development.

Potassium (K):- available to plants as the ion K^+. Unlike Nitrogen and Phosphorus, Potassium does not form any vital organic compounds in the plant. However, the presence of Potassium is vital for plant growth because Potassium is known to be an enzyme activator that promotes metabolism. Potassium assists in regulating the plant's use of water by controlling the opening and closing of leaf stomata, where water is released to cool the plant. In photosynthesis, Potassium has the role of maintaining the balance of electrical charges at the site of ATP production. Potassium promotes the translocation of photosythates (sugars) for plant growth or storage in fruits or roots. Through its role assisting ATP production, Potassium is involved in protein synthesis, and it has been shown to improve disease resistance in plants, improve the size of grains and seeds, and improve the quality of fruits and vegetables. Potassium is needed in photosynthesis and the synthesis of proteins, plants lacking Potassium will have slow and stunted growth. In some crops, stems are weak and lodging is common if Potassium is deficient. The size of seeds and fruits and the quantity of their production is reduced.

Calcium (Ca):- available to plants as the ion Ca^{2+}. Calcium has a major role in the formation of the cell wall membrane and its plasticity, affecting normal cell division by maintaining cell integrity and membrane permeability. Calcium is an activator of several enzyme systems in protein synthesis and carbohydrate transfer. Calcium combines with anions including organic acids, sulfates, and phosphates. It acts as a detoxifying agent by neutralizing organic acids in plants. Calcium is essential for seed production in peanuts. Calcium indirectly assists in improving crop yields by reducing soil acidity when soils are limed.

Calcium is not mobile and is not translocated in the plant, so symptoms first appear on the younger leaves and leaf tips. The growing tips of roots and leaves turn brown and die. Calcium deficiency is not often observed in plants because secondary effects of high acidity resulting from soil calcium deficiency usually limit growth, precluding expressions of Calcium deficiency symptoms. Without adequate Calcium, which in the form of calcium pectate is needed to form rigid cell walls, newly emerging leaves may stick together at the margins, which causes tearing as the leaves expand and unfurl. This may also cause the stem structure to be weakened. In some crops, younger leaves may be cupped and crinkled, with the terminal bud deteriorating. Buds and blossoms fall prematurely in some crops.

Magnesium (Mg):- available to plants as the ion Mg^{2+}. The predominant role of Magnesium is as a major constituent of the chlorophyll molecule, and it is therefore actively involved in photosynthesis. Magnesium is a co-factor in several enzymatic reactions that activate the phosphorylation processes. Magnesium is required to stabilize ribosome particles and also helps stabilize the structure of nucleic acids and it assists the movement of sugars within a plant.

Magnesium is a mobile element and part of the chlorophyll molecule. The deficiency symptom of interveinal chlorosis first appears in older leaves. Leaf tissue between the veins may be yellowish, bronze, or reddish, while the leaf veins remain green. Corn leaves appear yellow-striped with green veins, while crops such as potatoes, tomatoes, soybeans, and cabbage show orange-yellow color with green veins. In severe cases, symptoms may appear on younger leaves and cause premature leaf drop. Symptoms occur most frequently in acid soils and soils receiving high amounts of Potassium fertilizer or Calcium.

Sulfur (S):- available to plants as the sulfate ion, $SO4^{2-}$. Sulfur is essential in forming plant proteins, because it is a constituent of certain amino acids. It is actively involved in metabolism of the B vitamins biotin and thiamine and co-enzyme A. Sulfur aids in seed production, chlorophyll formation, nodule formation in legumes, and stabilizing protein structure.

Younger leaves are chlorotic with evenly, lightly colored veins. In some plants (e.g., citrus) the older leaves may show symptoms first. However, deficiency is not commonly found in most plants. Growth rate is retarded and maturity is delayed. Plant stems are stiff, thin, and woody. Symptoms may be similar to Nitrogen deficiency and are most often found in sandy soils that are low in organic matter and receive moderate to heavy rainfall.

Boron (B):- is necessary in the synthesis of one of the bases for RNA formation and in cellular activities. Boron has been shown to promote root growth. Boron is essential for pollen germination and growth of the pollen tube. Boron has been associated with lignin synthesis, activities of certain enzymes, seed and cell wall formation, and sugar transport.

Boron deficiency causes stunted growth, first showing symptoms on the growing point and younger leaves. The leaves tend to be thickened and may curl and become brittle. In many crops, the symptoms are well defined and crop-specific, such as: peanuts: hollow hearts; celery, crooked and cracked stem. Beets: black hearts. Papaya: distorted and lumpy fruit. Carnation: splitting of calyx. Cabbage, broccoli, and cauliflower pith in hollow stem.

Chlorine (Cl):- available to plants as the chloride ion, Cl^{-} Chlorine is essential in photosynthesis, where it is involved in the evolution of oxygen. Chlorine increases cell osmotic pressure and the water content of plant tissues. Chlorine is found in many bacteria and fungi. Chlorine reduces the severity of certain fungal diseases.

Iron (Fe):-Iron is essential in the heme enzyme system in plant metabolism (photosynthesis and respiration). The enzymes involved include catalase, peroxidase, cytochrome oxidase, and other cytochromes. Iron is part of protein ferredoxin and is required in nitrate and sulfate reductions. Iron is essential in the synthesis and maintenance of chlorophyll in plants. Iron has been strongly associated with protein metabolism.

Manganese (Mn) :- available to plants as Mn^{2+}, Mn^{3+} Manganese primarily functions as part of the plant enzyme system, activating several metabolic functions. It is a constituent of pyruvate carboxylase. Manganese is involved in the oxidation-reduction process in photosynthesis. Manganese is necessary in Photosystem II, where it participates in photolysis. Manganese activates indole acetic acid oxidase, which then oxidizes indole acetic acid in plants.

Manganese Deficiency, first appear as chlorosis in young tissues. Unlike Iron chlorosis symptoms, in dicots Manganese chlorosis shows up as tiny yellow spots. In monocots, greenish-grey specks appear at the lower base of younger leaves. The specks may eventually become yellowish to yellow-orange. In legumes, necrotic areas develop on the cotyledons, a symptom known as marsh spots. (R. Uchida).

Plants require nutrients in balanced amounts depending on their stage of development and yield levels. For optimal nutrition of crops, a sufficient concentration of the individual nutrients should be present in the plant leaves at any time. The nutrient concentrations required in plants, or rather in the active tissues, are usually indicated on a dry-matter basis, as this is more reliable than on a fresh-matter basis with its varying water content. Leaves usually have higher nutrient concentrations than do roots. (FAO, 2006).

2.6 Conflict on Water Resource

It is known that water is an essential element for individual security, so water is a fundamental and irreplaceable resource in all society ,its necessity also the same for human, based on this facts it is not surprising that the water management is complex and that water related interests are frequently contested. Access to the water in sufficient quantity and quality can drive competition among stakeholder where interests are perceived as incompatible, it can also foment cooperation where stakeholders may have a common interest and understanding.

Most environmental conflicts, including water-related ones, spring from three sources (White, 1986). The first source is an actual or prospective human intervention in the environment that provokes changes in natural and societal systems. The conflict arises when one or more of the stakeholder groups see the activity as disturbing the complex interaction between physical, biological, and social processes. The second source is disagreement over the management of water supply at one location as it affects the use of it elsewhere. The third source is where climatic variability and change independent of any human activity places new stresses on the water resources and generates fresh adaptations to available resources. In a River Basin that traverses an international border, a political regional boundary, or a general boundary of different jurisdiction, the basis of a conflict is the implementation of developments by a stakeholder concerned within its territory. Such implementation impacts at least one of its neighbors during water shortage conditions, and usually leads to a number of water conflicts. The key indicators or the water conflicts are related to a number of issues including water quantity, water quality, management of multiple use, political divisions, geopolitical setting, level of national development, the hydro-political issue at stake, and institutional control of water resources (Wolf, 1998).

There are 276 Trans boundary river basins in the world and 256 (or 92.7 percent) of them are shared by two to four countries (UN-Water 2013). Within that realm of shared water there are extensive opportunities for potential disputes within, between, and among states and water-users. In terms of understanding the risk of large-scale violent conflict over these resources, reviews of historical evidence show that armed interstate “water wars” are exceedingly rare. However, as demand grows and global freshwater resources become ever more stressed, practitioners must be aware of changing risks and opportunities and adapt their interventions accordingly. This includes careful consideration of the ways in which water may be a dimension of political conflict at international, national, and local levels as well as the relationships between those dynamics. Localized disputes between users and domestic water interests often influence politicians and policy decisions, which fuels international political agendas and Localized informs relations between countries. Conversely, interstate water politics and tensions can have ripple effects that affect the ability of national institutions and local users to effectively manage water for domestic needs. Technical, political, local, and international concerns are often inseparable, for good and for ill. Therefore, it is important that both diplomatic and development interventions, at all scales, consider dimensions of hydro politics in order to manage and prevent conflict escalation while harnessing opportunities for collaboration and peace building. (USAID, 2014)

The call for appropriate conflict identification is a pragmatic one. If one correctly identifies the type of conflict, one can predict the "actors, goals, perceptions, recruitments, structures, and other key political features involved" (Frey, 1993). If true, it could provide a useful tool to understand environmentally-related water conflicts as well as to predict the prospects for cooperation.

Water-related violent conflicts often occurs on the local rather than the international level, and the intensity of conflict is generally inversely related to geographic scale, and, while conflicts often remain local, they can also impact on stability at the national and regional levels (Carius *et al.*, 2005).

The Awash River is one area where continuous local conflicts are occurring mainly in relation to water utilization, grazing, land use, politics and related matters. The root cause of local conflict over water may be conflicts over a limited resource, conflicts over the control of the distribution, conflicts over the quality of the resource, and conflicts in large infrastructure projects. Thomasson (2005)

Lake Beseka brings a major salinity challenge to the irrigation development downstream. It will not be possible to provide a full fledged solution in this project for it but to question the current management strategy. Given, the vast expanses of the irrigation development downstream of the lake the current dilution strategy need to be questioned. The management to dimension Lake Beseka challenge need to be seen in relation to improvement of the water management practices in the upstream irrigation developments. A hydrodynamic modeling of the long-term effect of the current dilution practice in the irrigation developments should be made to minimize potential conflict scenarios which may emerge. (Asie, et al., 2016)

3. MATERIALS AND METHODS

3.1 Description of the Study Area

Ethiopia is a developing country which is endowed with a number of lakes and large rivers which gives immense value to overall economic development. Awash River is one of the largest rivers in the country. Awash River Basin is the fourth largest catchment in Ethiopia by area, but only the seventh in terms of water resources (Fig.1). The river discharges about 4.9 billion m^3 of water annually and its catchment area is 115,000 km^2. A Large part of the eastern catchment only nominally contribute to the river flow and in most years runoff percolates into the plain before it reaches the river. The river rises from the central highlands of Ethiopia above 3,000 meters A.S.L near Ginchi and flows in a north easterly direction through the northern end of the rift valley to eventually discharge into Lake Abe near the Djibouti border, a distance of 1200 km from its principal source.

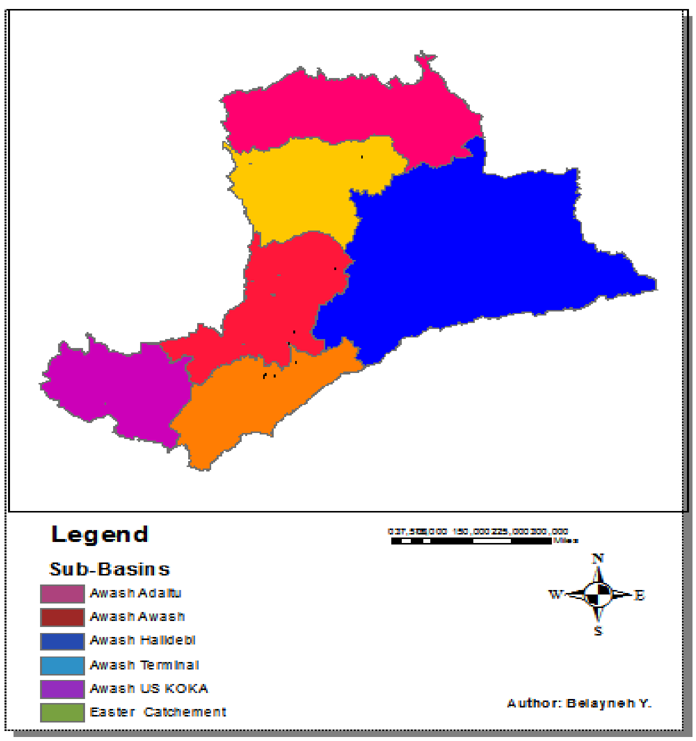

Figure 2:-Map of Awash Basin

The whole river basin lies within the central-eastern borders of Ethiopia and as such there are no international agreements regulating the use and management of the water. Due to strategic location, good access to facilities and availability of the land and water resources, it is the most developed river basin in Ethiopia with respect to irrigation development. Currently almost 200,000ha is irrigated in the entire basin. From this 21,128 ha irrigated in Amibara to Gewane (AwBA, 2016).

The main crops in the area include cotton, maize, sugarcane and vegetables (Table 2)

Table 1:-Types of crops grow downstream of Lake Beseka (Worda, Hectar)

No	Type of crop	Amibara	Gelealo	Gewane	Total
1	Cotton	5201	1206	2665	9072
2	Maize	1045	143	1575	2763
3	Sugarcane	6017			6017
4	Vegetables	1171	434	1671	3276
	Total	13434	1783	5911	21128

The increasing lake water level threatens to cut the strategically important road and rail links to Djibouti. The high water level in the lake is also increasing the ground water level in the vicinity which resulted to reduced sugarcane yield (Halcro, 2006). The continuous increase of the lake size and the damage experienced has attracted the attention of community, governmental organization especially the Ministry of Water Resource. To respond to the challenge the Ministry of Water Resource initiated and set a budget and project office that is responsible to undertake integrated studies and come up with remedial measure (MoWR).

The Awash Basin is part of the Great Rift Valley in Ethiopia bounded by geographic coordination $7^{o}52'12$-$12^{o}08'24''$N latitude and 37o56’24-$43^{o}17'24''$E longitude. It covers a total area of about 116,000 km^2. According to the Strategic Basin Plan, Awash Basin is divided into six planning areas (sub-basin). These are Awash Upstream of koka, Awash Awash, Awash Halidebi, Awash Adayitu, Awash Terminal and Eastern sub basin (Figure 2).

Administratively, the basin covers parts of Afar, Amhara, Oromia , SNNPR and Ethiopia Somali Regional States, Addis Ababa, and Dire Dawa city Administrations.

The population of the basin is estimated to be 14.8 million and distributed into Addis Ababa (22.73%), Afar (9.85%), Amhara (18.74%), Dire Dawa (2.71%), Oromia (37.5%), SNNPR (0.9%) and Somali (7.55%). The main population centers lie in the upper part of the basin mainly above an elevation of 1,500m above sea level. The main population centers and industrial zones of the country which include Addis Ababa, Dire Dawa, Adama ,Kombolcha and Bishoftu are located in this basin. (AwBA, 2014)

Because of the accessibility of Awash River and availability of land the basin is the most developed with respect to irrigation. The expansion of large, medium and small scale irrigation, urbanization and Lake Beseka are the main causes of water scarcity & quality problem in the area.

Lake Beseka is one of the rift valley lakes situated at the center of the Ethiopian rift valley about 190 km east of Addis Ababa. The lake watershed lies between $39^0$43'- $39^0$59'E longitude and 8^0 41'-$9^0$0' north latitude (Elenni, 2009).The area is located in the center of Ethiopia, is influenced by two moisture sources, and characterized by two rainy seasons in summer (July-September) and spring (March-April). The climate is semi-arid with a mean annual temperature of 25^0c and a total mean annual rainfall 534mm.

The area is characterized by an average daily maximum and minimum temperature of 33^0C and 17^0C, respectively. The lowest temperature is between November and January, while May and June are characterized by higher temperatures. Relative humidity is high during the main rainy season. Wind speed are maximum during the months of June and July, and at a minimum volume during October, long term average sunshine hours in the study area is 8.4hr, and the lowest sunshine hours being the main rainy season. Potential evapotranspiration exceeds monthly rainfall in nearly all months. Thus, the climate of the area can be defined as semi-arid (FAO, 1984).

Topography of the area ranges from flat to undulating plains and from hill to the high in mount Fentale. Most of the watershed is characterized by flat to undulating plains with altitudes ranging from 940m to 1100 m.a.s.l Plains with small and high gradient are located in the north western and western part of the watershed.

Land use and land cover characteristics can play a significant role in causing the lake level change and physiochemical of the lake water. Land use land cover map of the lake were developed in the year 1973 and 2003 from satellite images following standard principle and procedure of image classification (Lillesand, Met,al 1999). Water body, shrub land, active volcanic area, grass land, cultivated land and degraded lands are the major land use and land cover units in the Beseka catchment.

3.2 Sampling Sites Location and Selection

Sampling site from both Lake Beseka and Awash River were selected. The sampling area from Lake Beseka, the representative of Lake Water and the water that flows to Awash River. The sampling area of Awash River started at Awash upstream of Lake Beseka (Lake Beseka before joining Awash) and extends up to Awash at Adayitu, This was based on the assumption that the sampling site requires consideration to make representative in respect to irrigation development, which is very important for the water quality analysis and to evaluate the water quality changes.

Based on the above facts the nine sampling sites were chosen in relatively indicate different water qualities (Table 2). Figure 3 shows the map of the basin showing the location of the water sampling site.

Table 2:-Location of Sampling Site in Awash River & Lake Beseka

NO	Sampling Site Name	Symbol	Coordinate		Elevation (masl)	Sub basin
			Easting	Northing		
1	Awash Before Beseka	SR_1	600365	978746	952.4	Awash Awash
2	Awash After Beseka	SR_2	609824	979426	943.4	Awash Awash
3	Awash at Awash 7Kilo	SR_3	629912	995525	812	Awash Awash
4	Awash at Melkasedi	SR_4	622986	1017802	760	Awash Awash
5	Awash at Melkawarer	SR_5	629088	1030185	738.9	Awash Halidebi
6	Awash at Meteka	SR_6	666527	1103137	567.6	Awash Halidebi
7	Awash at Adayitu	SR_7	692534	1230795	457.6	Awash Adayitu
8	Lake Beseka	SL_1	598989	980653	957.8	Awash Awash
9	Lake Beseka at canal	SL_2	600911	982395	958	Awash Awash

The following are the description of each sampling site:

1. SR_1- Awash River water before mixing with Lake Beseka, this sample point may help to evaluate the water quality of Awash River without the effect of Lake Beseka water.
2. SR_2-Awash River water after mixing with Lake Beseka, this sample point may help to evaluate the water quality of Awash River that immediately after Lake Beseka water joining it.
3. SR_3-Awash River water located around Awash 7 kilo, this sample point may help to evaluate the quality of Awash River around Awash 7 kilo which is the river after Awash fall.
4. SR_4-Awash River water located around Melkasadi (weir of Amibara Irrigation), this point may help to evaluate the quality of Awash River before kesem River joining Awash River and the quality of water release to Irrigation by Amibara diversion weir.

5. SR_5-Awash River water located around Amibara (Head Quarter of AwBA), this sample point may help to evaluate the quality of Awash River After kesem River joining Awash River and the water quality. This water serves for irrigation around Amibara .
6. SR_6- Awash River water located around Gewane, Awash before joining Lake Gedabasa, this sample point may help to evaluate the quality of Awash River water that is use for irrigation around Gewane and Buremodaytu woreda .
7. SR_7 –Awash River water located around Adayitu (the sample area found below Lake Gedabasa), this sample point may help to evaluate the quality of Awash River water after Lake Gedabasa water joining to it and vice-versa.
8. SL_1-Lake Beseka water, this sample point may help to evaluate the water quality of Lake Beseka .
9. SL_2-Lake Beseka water at the canal, this sample may help to evaluate the quality of Lake Beseka water that discharging to Awash River. These samples were collected started from downstream and finalized at the samples around Lake.

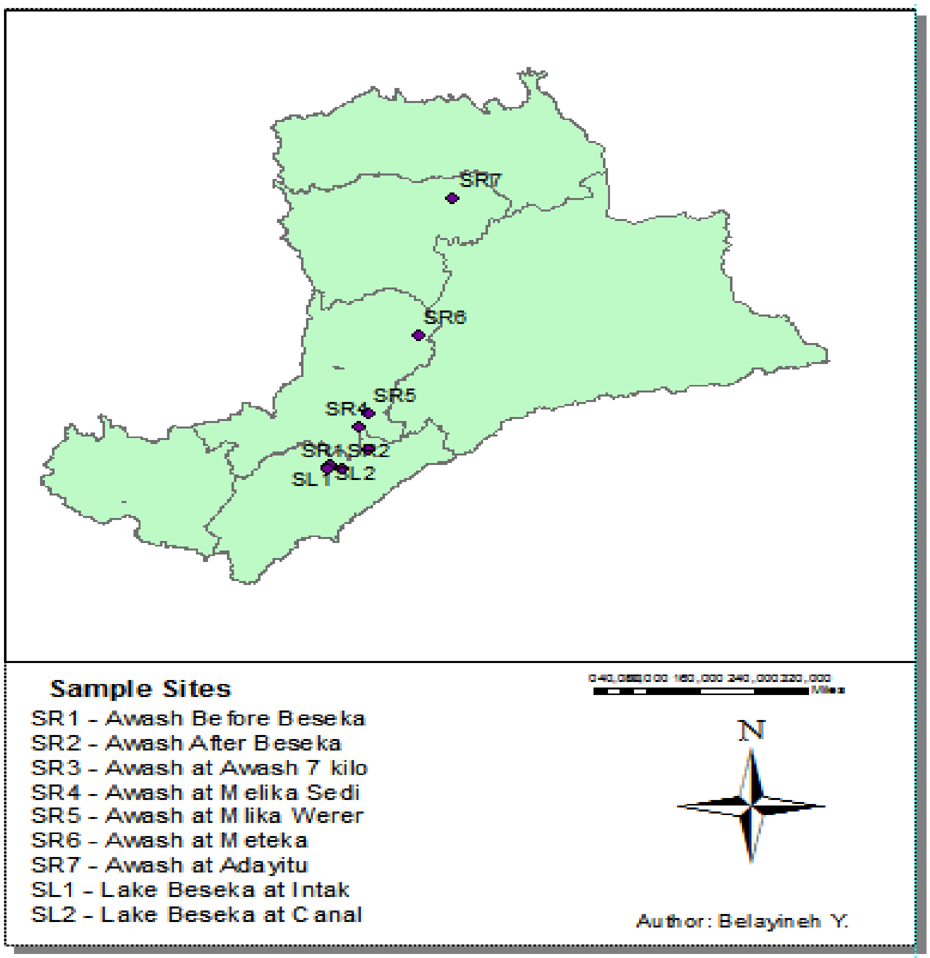

Figure 3:- Map showing the sampling site for the study

3.3 Mix Ratios Used in the Study

The proportion selected was based on the previous studies and implementation of discharging Lake Beseka water to Awash River, on the first Study the lake water discharged 2% by volume based on the flow of Awash River (MoWE, 2014). The second study proposes discharging 7.7 % of Lake Beseka water with respect to Awash River flow. For this study the mix ratio of Lake Beseka to Awash River 5:95, 10:90 and 15:85 were used.

Table 4:- Mixing Ratio of Awash River & Lake Beseka water used in this study.

NO	Sampling Name	Symbol	Awash River (%)	Lake Beseka water (%)
1	Treatment 1	SL_5	95	5
2	Treatment 2	SL_{10}	90	10
3	Treatment 3	SL_{15}	85	15

The three recommended mixes ratios were:-

1. SL_5 -The mix of Lake Beseka water (SL_1) and Awash River water (SR_1) with a proportion of 5:95, this means the mix contain 5% and 95% of Lake Beseka water and Awash River water respectively.
2. SL_{10} -The mix of Lake Beseka water (SL_1) and Awash River water (SR_1) with a proportion of 10:90, this means the mix contain 10% and 90% of Lake Beseka water and Awash River water respectively.
3. SL_{15} - The mix of Lake Beseka water (SL_1) and Awash River water (SR_1) with a proportion of 15:85, this means the mix contain 15% and 85% of Lake Beseka water and Awash River water respectively. The samples were taken for three consecutive months from October ,November and December the mean value taken for analysis

For the social impact of discharging Lake Beseka water to Awash River water, formal and informal discussion with community representative, minutes of different forum , letters written by different bodies as a complain were discussed with the concept of conflict and conflict resolution. A total of 10 representatives of the community participate (5 from the community around the Lake and 5 from downstream of Lake Beseka) to understand their attitude about discharging of the Lake Beseka water to Awash.

3.4 Equipment used in the study

Water samples were collected from each sampling points by using polyethylene and glass bottles, Water sample collection was mostly carried out on the material that collects water, procedures, and timing and transportation rate physiochemical water sample collection were employed. Samples were collected in 100ml polyethylene plastic to evaluate different physiochemical parameters

The collection and handling of samples were made in accordance with the standard procedure, before sample collection bottles were washed with concentrated nitric acid and distilled water to avoid contamination. Bottles containing samples were preserved using ice box and transported to laboratory within 6-8 hrs after collection.

The samples were transport to the laboratory in dark boxes containing water from the same source to maintain the temperature of the samples close to that of the in situ temperature and to analyze for their physical and chemical parameter immediately. The mixing ratio was done in soil and water laboratory of Awash Basin Authority and Identification of physiochemical characteristics of the sample under take in Ethiopian Construction Design and Supervision Works Corporation laboratory. In the laboratory EC meter and pH meter were used to measure EC and pH respectively, to measure Sodium, Potassium, Flame photo was used. UV Spectro was used to measure Chloride and Bicarbonate.

3.5 Data Analysis and Interpretation

Irrigation water quality criteria, standard and related legislation were used to interpret water quality characterization. The standards for irrigation water of Food and Agriculture Organization (FAO) was used in this study. (Appendix Table 2)

The collected water samples were subjected for the analysis of pH, EC, dissolved cations (Ca, Mg, Na and K), alkalinity ($HCO_3^-$and $CO_3$2-) and Cl^- contents in the laboratory. EC and pH of the water samples were measured in the laboratory within 24 hours using conductivity meter and a digital pH meter, respectively, (Richards, 1954) with appropriate conversion factors for temperature. Ca and Mg ions were measured using atomic absorption spectrophotometer, while Na and K were analyzed using flame photometer.

For analysis, the results of sample points were categorized in three groups, the first group contained seven sample points those found along Awash river (SR_1, SR_2, SR_3, SR_4, SR_5, SR_6 and SR_7), as shown in Table 5. This group helped to investigate the quality of Awash River water. The second group contain two samples (SL_1, and SL_2), as shown in Table 6. This group helped to determine the characteristics of Lake Beseka water. The third group contain three samples of mixed water (SL_5, SL_{10} and SL_{15}), as shown in Table 7 .This group helped to determine the mix Ratio of Lake Beseka water to Awash River. The results of the first group were also compared to with the result of year 2009 to 2013, which prepared as an average of the year. Any deviations from the FAO standards were discussed with area and condition. The results of interview were analyzed with tally of the given answer for each question by the target group and changed in percent.

4. RESULTS AND DISCUSSIONS

4.1 Physical and Chemical Parameters

The result of Physiochemical characteristics of Awash River water are given in Table 4. The laboratory result 2009-2013 for the physicochemical parameters of all Awash River sample site and Lake Beseka water are also annexed as appendices (see Appendix Table 3 to 10).

The result of Physiochemical characteristics of Lake Beseka Water sample and mixed water are given in Table 5 and Table 6, respectively.

4.1.1 pH

pH is an essential parameter which shows the acidity or basicity of the water. It is measured with hydrogen ion. It expressed as pH<7.0 acidic, pH >7.0 basic and pH =7.0 neutral. The normal pH range for irrigation water is from 6.5 to 8.5.

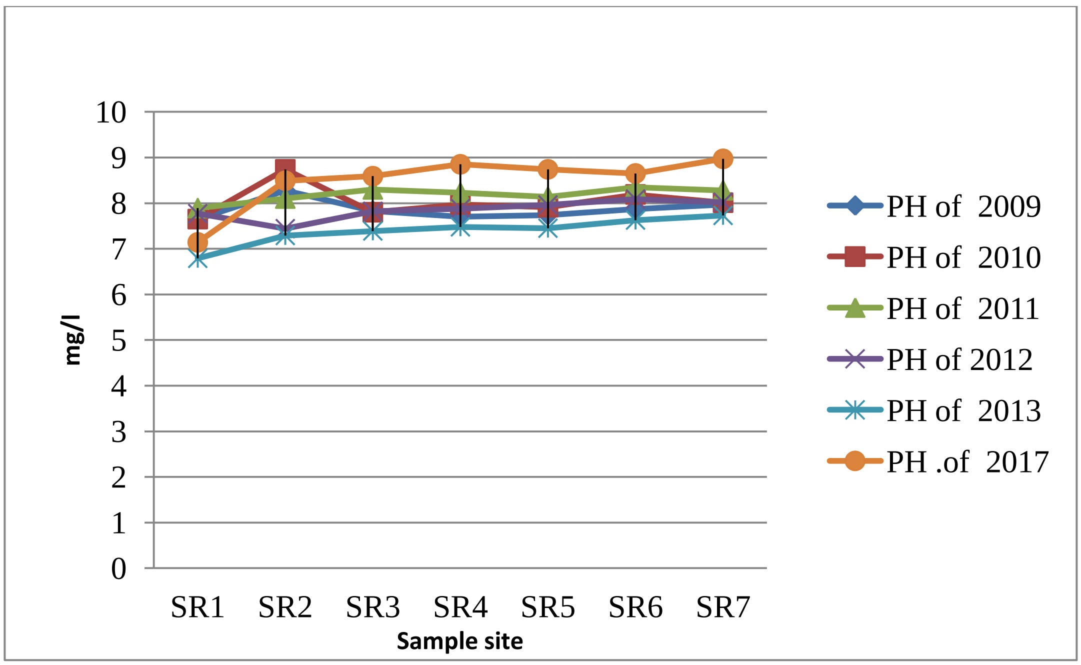

Figure 4:- pH level of selected site from 2009 to 2013

The pH of Awash River Water ranges 7.14 to 8.97, Awash River water sample before Beseka (SR_1) and after Lake Beseka (SR_2) falls within this range. All the rest are beyond the upper limit. The lowest and the highest value recorded at sample of Awash River water Before Lake Beseka and Awash River at Adayitu, respectively. The general trend in pH variation along the flow of Awash River is that the upstream is lower than the downstream from Awash River water before Beseka to Awash River water at Melkasedi. From Awash River water at Melkasedi to Awash River water at Meteka the pH value decreases and it also increases again at Awash River water at Adayitu.

Table 4:- FAO standard on irrigation water quality & 2017 physiochemical characteristics of water at the sampling sites in Awash River. (2017)

NO	Parameter	Unit	FAO standards	SR_1	SR_2	SR_3	SR_4	SR_5	SR_6	SR_7
1	P^H		6-8.5	7.14	8.49	8.59	8.85	8.74	8.65	8.97
2	Electrical Conductivity	µs/cm	0-3000	420.00	900.00	959.00	1021.00	1272.00	1257	1060.00
3	Tolal solids $105^{O}C$	mg/l		476.00	724.00	696.00	720.00	966.00	976	988.00
4	Total dissolved Solid $105^{O}C$	mg/l	0-2000	304.00	524.00	530.00	592.00	758.00	732	688.00
5	Turbidity	Ntu		169.00	178.00	161.00	125.00	205.00	241	298.00
6	Total Hardness	mg/l		140.00	112.00	72.00	56.00	82.00	112	86.00
7	Alkalinity	mg/l	5-400	174.30	403.20	329.70	336.00	443.10	434.7	345.00
8	Ammonia	mg/l	0-5	0.77	0.62	0.67	0.62	0.59	0.6	0.32
9	Phosphate	mg/l	0-2	0.10	0.29	0.44	0.51	0.46	0.41	0.19
10	Nitrate	mg/l	0-10	2.27	2.59	0.76	0.67	0.65	0.71	1.02
11	Nitrite	mg/l	0-1.6	0.036	0.020	0.025	0.022	0.022	0.028	0.018
12	Calcium	mg/l	0-400	43.20	32.00	20.80	12.00	24.00	30.4	17.60
13	Manganese	mg/l		Trace	Trace	Trace	Trace	Trace	Trace	Trace
14	Magnesium	mg/l	0-600	7.68	7.68	4.80	6.24	5.28	8.64	10.08
15	Sodium	mg/l	0-920	46.00	184.00	190.00	210.00	275.00	257.5	227.50

NO	Parameter	Unit	FAO standards	SR_1	SR_2	SR_3	SR_4	SR_5	SR_6	SR_7
16	Potassium	mg/l	0-2	25.80	6.60	29.00	33.00	30.50	27	22.50
17	Sulphate	mg/l	980	35.49	49.88	7.07	38.12	42.50	44.89	98.26
18	Total Iron	mg/l		0.13	0.42	0.69	0.66	0.52	0.58	0.66
19	Chloride	mg/l	0-106.5	19.83	15.11	74.60	86.88	109.54	99.15	93.49
20	Fluoride	mg/l		1.16	3.06	2.26	3.24	4.55	3.48	3.24
21	Carbonate	mg/l	6	Nill	52.92	55.44	73.08	95.76	75.6	84.00
22	Bicarbonate	mg/l	610	212.65	384.30	289.51	261.32	345.87	376.61	250.10

Table 5:- FAO standard on irrigation water quality & 2017 physiochemical characteristics of water sample in Lake Beseka water. (2017)

No	Parameter	Unit	FAO standards	SL_1	SL_2
1	P^H		6-8.5	9.50	9.34
2	Electrical Conductivity	µs/cm	0-3000	3440.00	3370.00
3	Tolal solids 105^{O}C	mg/l		2320.00	2014.00
4	Total dissolved Solid 105^{O}C	mg/l	0-2000	2292.00	1964.00
5	Turbidity	Ntu		25.00	46.00
6	Total Hardness	mg/l		24.00	34.00
7	Alkalinity	mg/l	5-400	1209.00	1008.00
8	Ammonia	mg/l	0-5	0.52	0.50
9	Phosphate	mg/l	0-2	0.55	1.16
10	Nitrate	mg/l	0-10	1.56	2.92
11	Nitrite	mg/l	0-1.6	0.021	0.012
12	Calcium	mg/l	0-400	6.40	8.00
13	Manganese	mg/l		Trace	Trace
14	Magnesium	mg/l	0-600	1.92	3.36
15	Sodium	mg/l	0-920	840.00	830.00
16	Potassium	mg/l	0-2	82.00	8.90
17	Sulphate	mg/l	980	286.40	226.66
18	Total Iron	mg/l		0.06	0.12
19	Chloride	mg/l	0-106.5	325.51	272.90
20	Fluoride	mg/l		15.50	6.92
21	Carbonate	mg/l	6	327.60	335.16
22	Bicarbonate	mg/l	610	809.59	548.27

According to table 5, the pH of Both Lake Beseka water samples are beyond the pH range, but the pH of Lake Beseka water which taken from the Lake Beseka is higher than that of the pH of Lake Beseka water which taken from the canal.

As shown in Appendix table the pH value of Awash River from 2009 to 2013 ranges from 6.79 at Awash River water before Beseka (2013) to 8.74 at Awash River water after Beseka (2010), the only value which beyond the FAO standard is also Awash River water after Beseka (2010). Figure 3 shows that the trend of pH level of Awash River water from 2009 to 2011 increase and from 2011 to 2013 decrease.

4.1.2 Electrical Conductivity

Electrical conductivity of the water is the most important parameter for assessing the suitability of irrigation water, because the concentration of salt content in irrigation water estimated in terms of this parameter. When the EC of water is high the crop gets inability to compete with ions in the soil solution, simply higher the EC lesser in the water available to plant. The most influential water quality on crop productivity is the salinity hazard which measured EC.

The allowable concentration for electrical conductivity as per FAO standards is 0-3000 μs/cm, As shown in table 4, all the values of Electrical conductivity (EC) of Awash River water are below the maximum limit, but the value of EC along the flow of Awash River increase, except the declination of Awash River at Meteka and Adayitu. The lowest value of EC recorded at Awash River before Beseka which is 420 and the highest value recorded at Melkawerer which is 1272. Electrical conductivity of Lake Beseka water is out of range, but like that of pH the EC of Lake Beseka water at the canal lower than Lake Beseka water.

As indicated in the appendix tables from 2009 to 2013 year data, 276 is the lowest value of EC recorded at Awash River at Awash 7 kilo (2010) and 2969.3 is the highest value of EC recorded at Awash River after Beseka (2010). As shown in figure 4, the trend of EC value increased from 2009 to 2010, decreased from 2010 to 2011 and again increased 2011 to 2013.

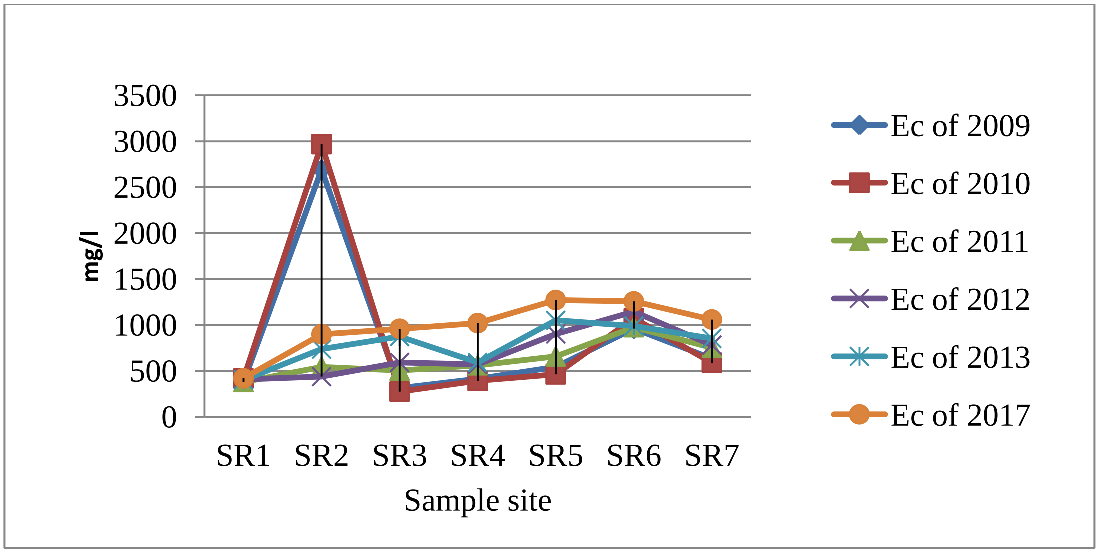

Figure 5:-Electrical conductivity level of Selected Sites from 2009 to 2013

4.1.3 Total Dissolved Solids / Total Soluble Solids

The allowable TDS concentration of FAO is from 0 to 2000, as shown in table 4, the total amount of dissolved chemical species (TDS) at Awash River water varies between 304 and 758.

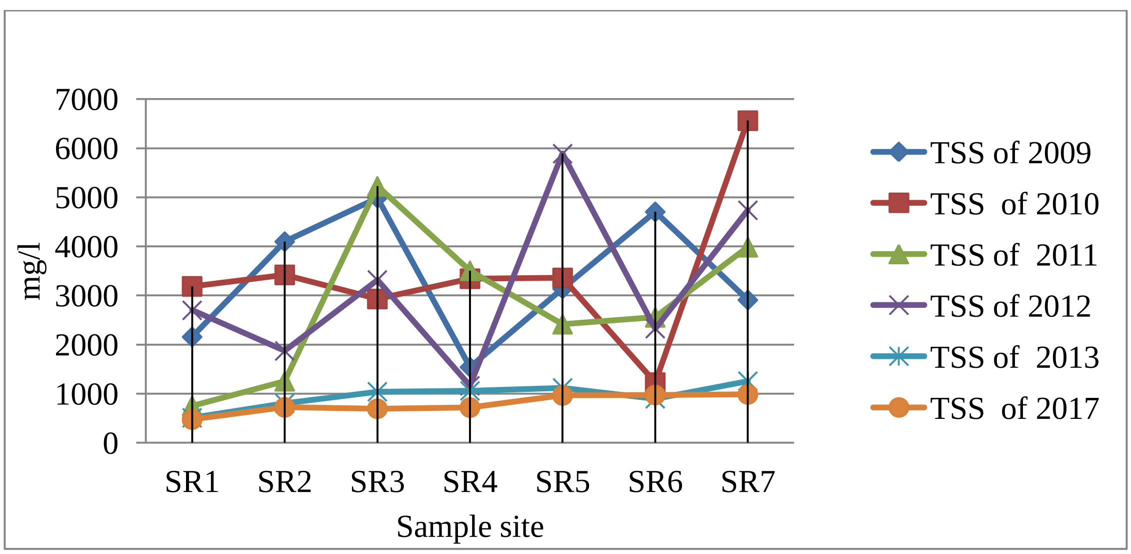

Figure 6:- Total Soluble Solids level of selected site from 2009 to 2013

The TDS concentration is more pronounced at Awash River, especially after discharging of Lake Beseka , the trend of TDS/TSS along the down course of Awash River similar trends, i.e. increase from Awash upstream of Lake Beseka to Awash River at Meteka, then decrease to Adayitu .

From table 5, the TDS values of Lake Beseka water and Lake Beseka canal water are 2292 and 1964 respectively, from these Lake Beseka water is beyond the limit. As shown in the appendix tables, from2009 to 2013 data, only Awash River water after Beseka (2010) with a value 2062 and Awash River at Melkawerar (2012) with a value 5144.4 are beyond the upper limit.

4.1.4 Carbonate and Bicarbonate

According to the FAO standards of irrigation water the maximum limit of Carbonate & Bi carbonate are 6 mg/l and 610 mg/l respectively. As shown in table 4, the carbonate of Awash River Water before Lake Beseka is nil, but the values of the rest are out of the maximum limit, which ranges from 52.92 to 95.76. As shown in Appendix tables Awash River water before Lake Beseka from 2009 to 2013, at Awash 7 Kilo from 2009 to 2010, at Melkasedi in 2013, at Melkawerar from 2009 to 2010 and at Adayitu 2010, Values of Carbonate are nil.

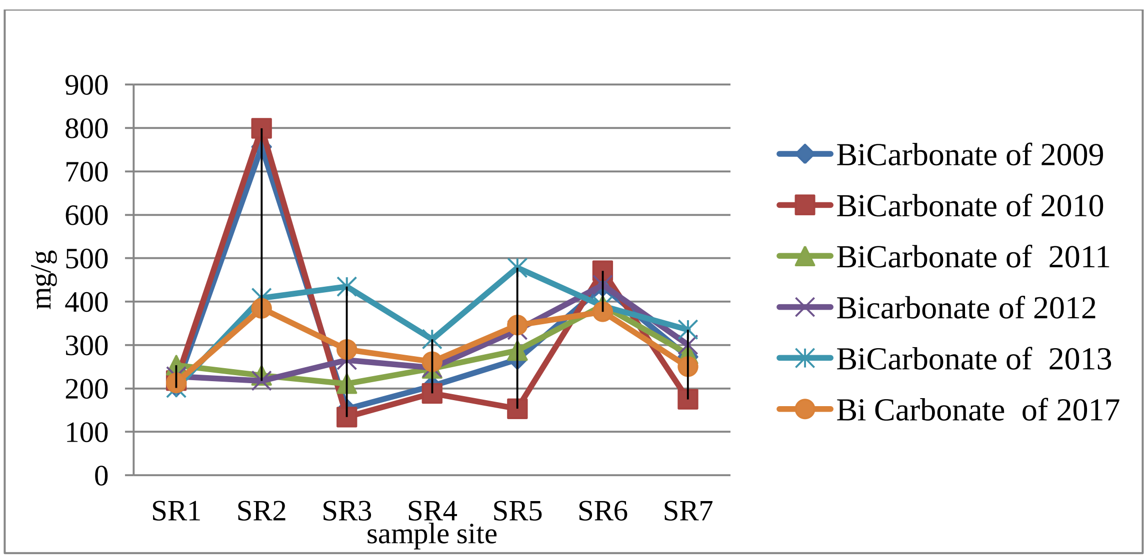

Figure 7:-Bicarbonate level of selected sites from 2009 to 2013

Awash River after Lake Beseka from 2009 to 2010, Awash River at Melkasedi and Meteka in 2009 are below the maximum limit. Bicarbonate of Awash River is below the maximum limit and it ranges 212.65 to 384.3.but Bicarbonate of Lake Beseka and Lake Beseka canal water are beyond the maximum limit. As shown in the appendix tables, only 2009 to 2010 Awash River water after Lake Beseka is beyond the maximum limit.

4.1.5 Chloride

The maximum allowable of chloride for irrigation water is 106.5 mg/l as a FAO standard. From the sample of Awash River only Awash at Melkawerar beyond the upper limit which is 109.54. Chloride of Lake Beseka water and Lake Beseka canal water is out of the FAO range. As shown in the appendix tables all the chloride value from 2009 to 2013 is within the acceptable range. But as shown in figure 8, it has increasing trend from 2009 to 2013.

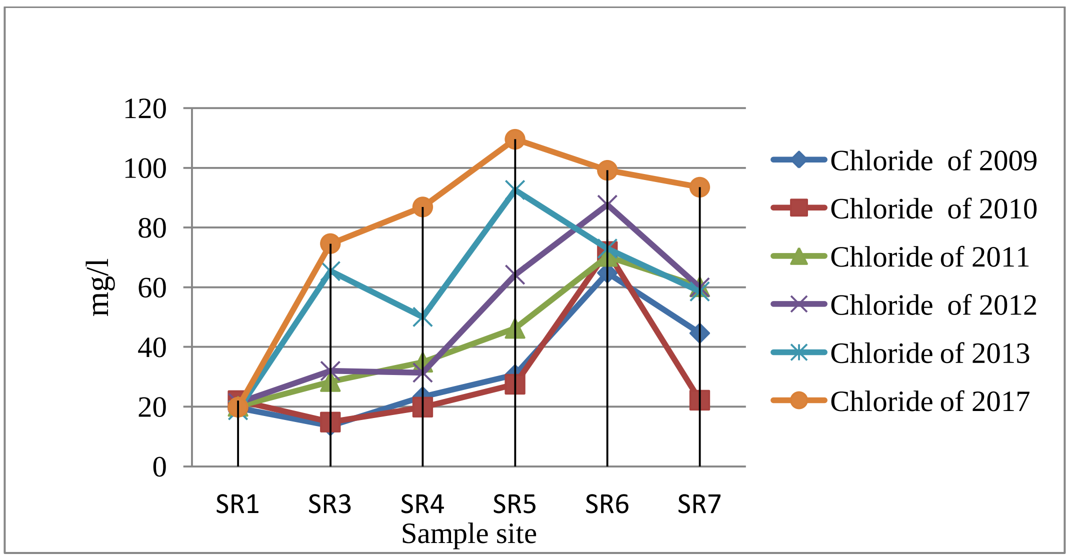

Figure 8:- Chloride level of selected sites from 2009 to 2013

4.1.6 Sodium

According to the FAO standards the range of Sodium for irrigation water is between 0 and 920 mg/l, the concentration of sodium at all Awash River water below the maximum limit which ranges 46 to 275. Sodium of Lake Beseka water and Lake Beseka canal water also within the allowable ranges of FAO, but these values are much higher than that of the values of Awash River. As shown in figure 9, the trend of sodium from 2009 to 2013 is increases.

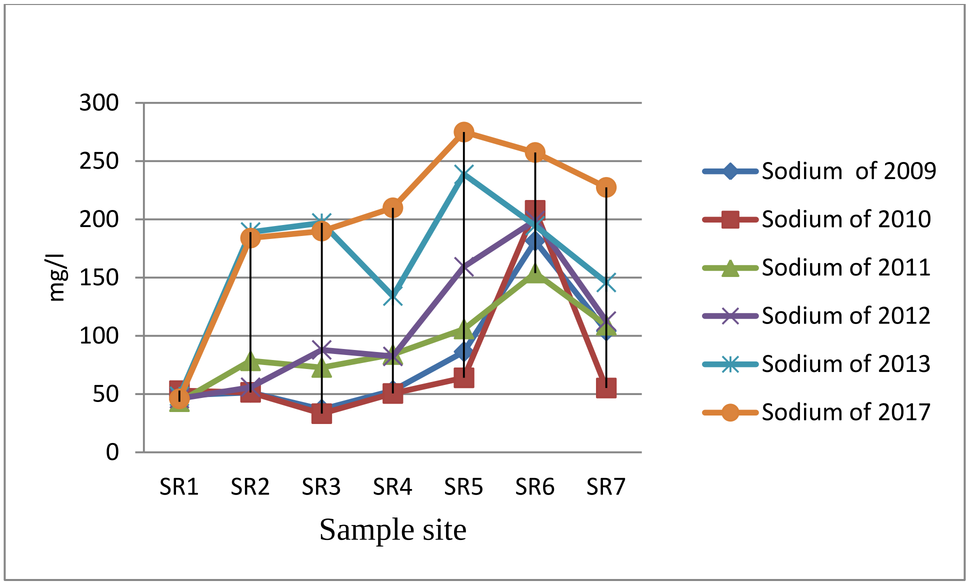

Figure 9:- sodium level of selected sites from 2009 to 2013

4.1.7 Potassium

FAO standards range of Potassium for irrigation water is between 0 and 2 mg/l, the concentration of potassium of Awash River, Lake Beseka and Lake Beseka canal water are above the maximum limit. All values of Potassium from 2009 to2013 also beyond the maximum limit with increasing trend. (Appendix tables and figure 10)

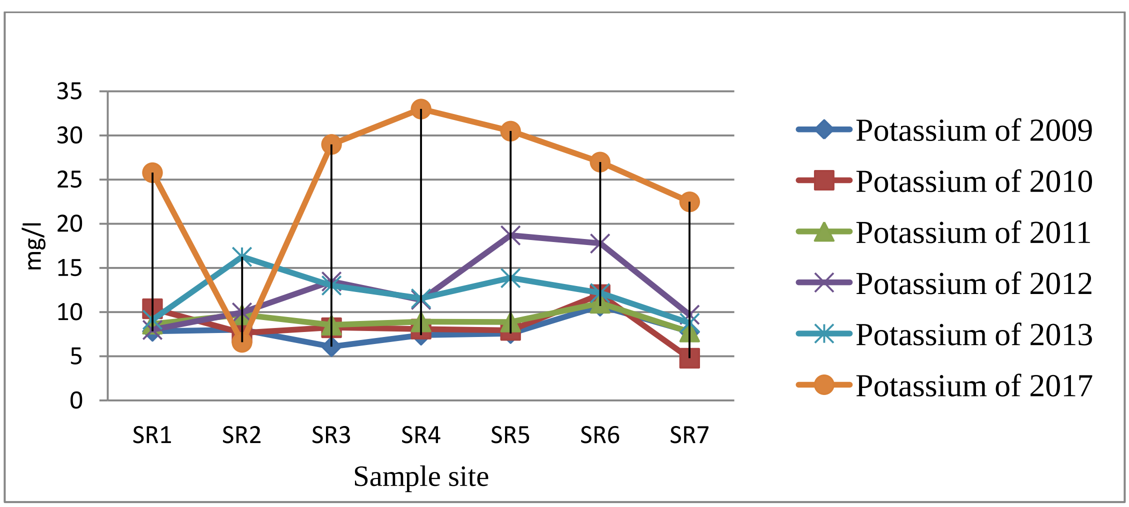

Figure 10:- Potassium level of selected sites from 2009 to 2013

4.1.8 Sodium Absorption Ratio (SAR)

Sodium Adsorption Ratio is also used to evaluate the suitability of water for irrigation. The values obtained for all Awash River at sampling Points, except Melkasadi and Melka Werer (2017), belongs to low hazard level (Figure 11). Melkasadi and Melka Werer sampling points were grouped under medium hazard level. At all sampling site the level of SAR value has increasing trends from 2009 to 2013. Very high SAR values were recorded with in Lake Beseka and Lake Beseka canal water, which is not suitable for irrigation purpose.

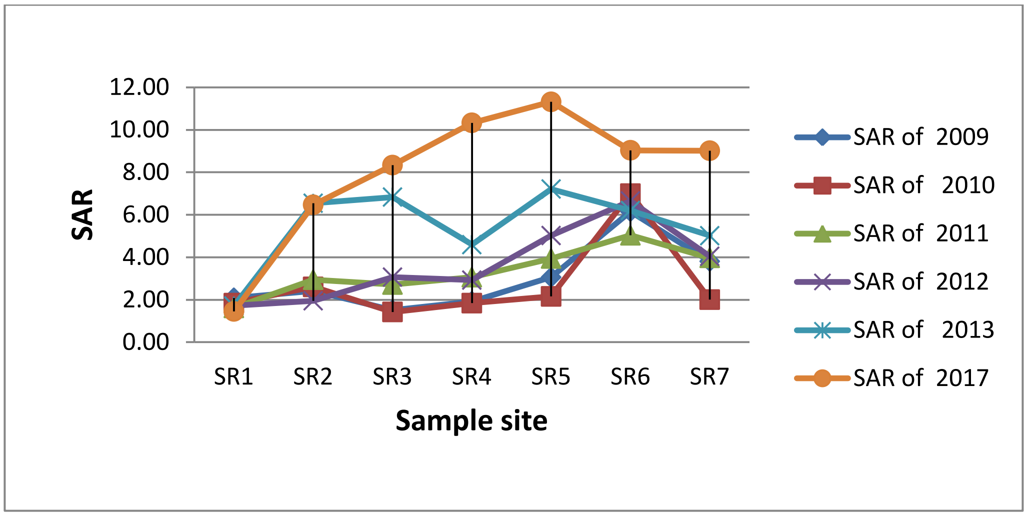

Figure 11:- SAR level of selected sites from 2009 to 2013

4.2 Physicochemical characteristics of Different Mixed Ratio

The three mixed ratio water, SL_{5}, SL_{10} and SL_{15} contain the ratio of Lake Beseka water to Awash River water 5:95, 10:90 and 15:85 with a volume basis respectively.

Table 6:- FAO standard on irrigation water quality & physiochemical characteristics of water sample of different mix ratio.

No	Parameter	Unit	FAO standards	SL_5	SL_{10}	SL_{15}
1	P^H		6-8.5	7.76	8.53	8.69
2	Electrical Conductivity	µs/cm	0-3000	642.00	782.00	947.00
3	Tolal solids 105^{O}C	mg/l		524.00	600.00	752.00
4	Total dissolved Solid 105^{O}C	mg/l	0-2000	442.00	516.00	636.00
5	Turbidity	Ntu		80.00	80.00	112.00
6	Total Hardness	mg/l		136.00	108.00	1080.00
7	Alkalinity	mg/l	5-400	241.50	273.00	319.87
8	Ammonia	mg/l	0-5	0.38	0.65	0.64
9	Phosphate	mg/l	0-2	0.12	0.89	0.34
10	Nitrate	mg/l	0-10	1.10	2.59	1.77
11	Nitrite	mg/l	0-1.6	0.008	0.040	0.039
12	Calcium	mg/l	0-400	36.00	35.20	32.00
13	Manganese	mg/l		Trace	Trace	Trace
14	Magnesium	mg/l	0-600	11.04	4.80	6.72
15	Sodium	mg/l	0-920	86.00	160.00	205.00
16	Potassium	mg/l	0-2	23.50	28.50	35.00
17	Sulphate	mg/l	980	96.79	41.70	57.25
18	Total Iron	mg/l		0.21	0.40	0.45
19	Chloride	mg/l	0-106.5	33.99	73.04	91.07
20	Fluoride	mg/l		1.38	3.42	9.09
21	Carbonate	mg/l	6	Nill	25.20	50.27
22	Bicarbonate	mg/l	610	294.63	281.82	288.04

The result shows that the value of pH higher when the ratio of Lake Beseka water increase in the mix ratio, the highest value recorded from the treatment (SL_{15}) which is 8.69 and followed by 8.53 from the treatment (SL_{10}). But only the value treatment (SL_5) meets the allowable range of FAO irrigation water standard. By adding 5% lake Beseka water the PH of Awash River raise from 7.14 to 7.76 the difference is 0.62, when the amount of Lake Beseka water increase to 10 % the PH value raise from 7.76 to 8.53 the difference is increase to 0.77, in the same manner when the ratio of Lake Beseka water increase to 15% the pH value increase from 8.53 to 8.69 but the difference decrease to 0.14.

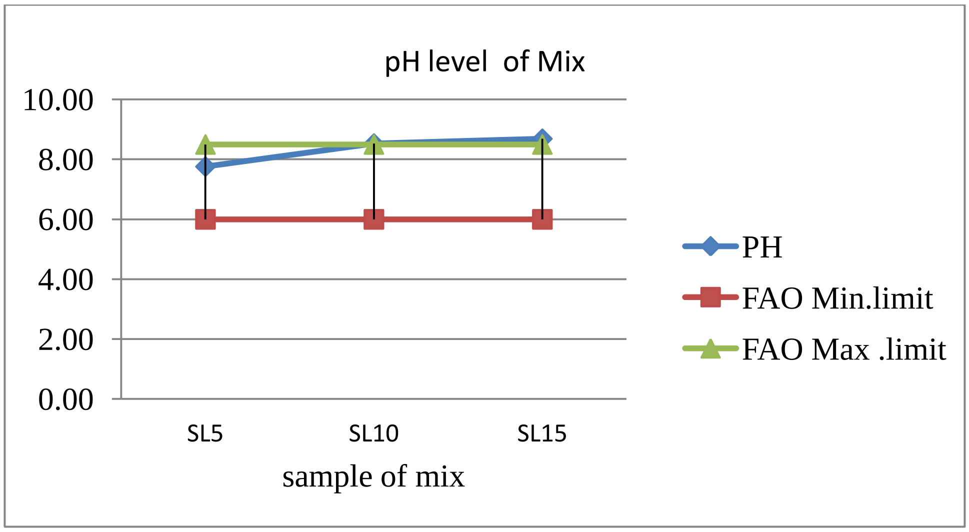

Figure 12:-comparison of pH level three mixed water and FAO standards

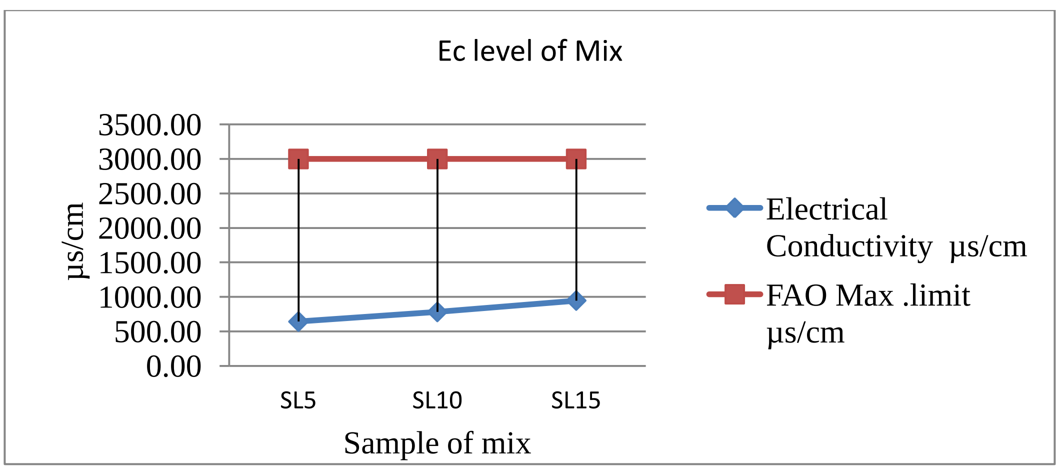

Figure 13: -comparison of EC level of three mixed water and FAO standards

In the case of EC all the mixed water is below the maximum limit, but EC also increase when the ratio of Lake Beseka water increase in the mixed water.

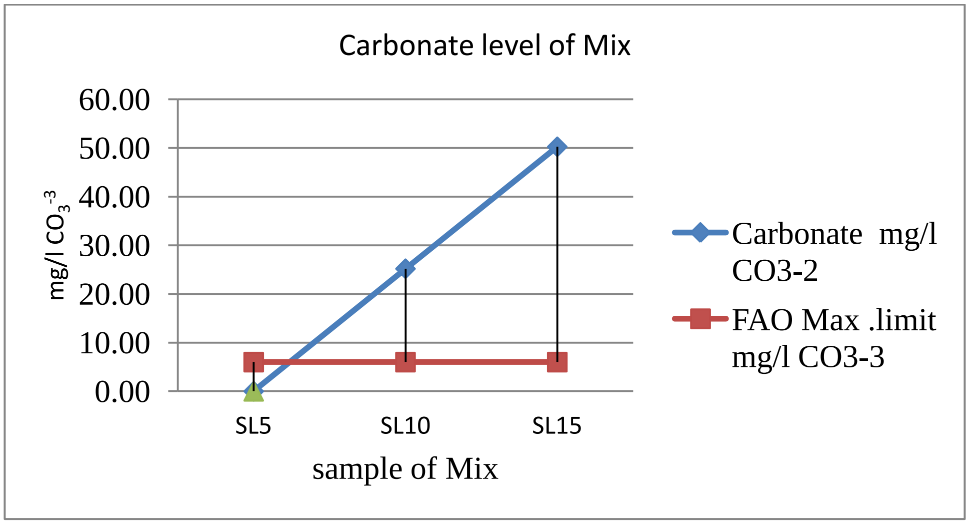

Figure 14:- comparison of Carbonate level of three mixed water and FAO standards

SAR values of all the mixed water have low level of hazard but the value increases when the ratio of Lake Beseka water increases in the mixed water.

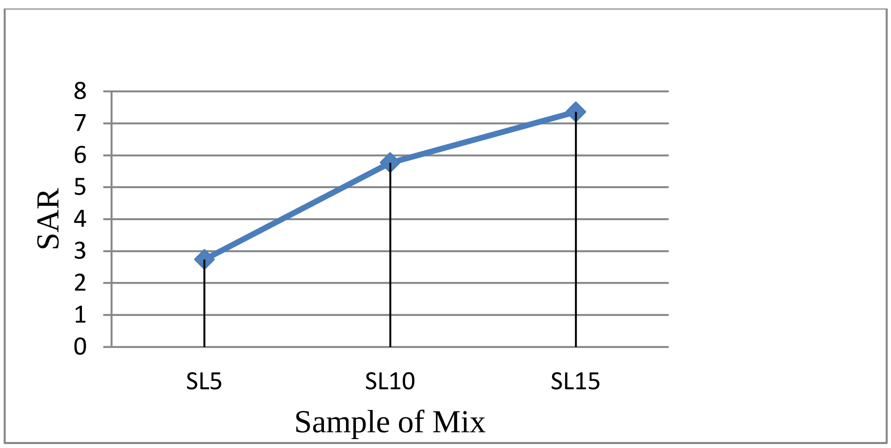

Figure 15:- SAR value of Mixed water

Generally except potassium, all physiochemical parameters in the treatment of (SL_5) are in the range of FAO irrigation water quality standard. In the treatment of (SL_{10}) pH is slightly higher than the maximum limit of FAO, Potassium and carbonate is beyond the upper limit. The rest physiochemical parameters are within the range of FAO standards. In the treatment of (SL_{15}) PH, potassium and carbonate are beyond the upper limit. The rest physiochemical parameters are within the range of FAO standards. So it is possible to conclude the mix ratio of Lake Beseka water to Awash River water for irrigation is 5:95.

4.3 Social Impact

Now a day's one of the conflict arise between upstream and downstream society is discharging of Lake Beseka water to Awash River, Based on the Answer given in questioner (see Appendix form 1) the entire respondent i.e. 10 (100%), agrees as Lake Beseka water has an effect on the irrigation. The entire downstream target group (i.e. 50% of all) didn't agree the discharging of Lake Beseka to Awash River but all the target group around the Lake agree on the discharging of Lake. The community Around the Lake Beseka(i.e 5 or 50 %) think (or strongly agree) that the Lake water become fresh than the earlier, but the target group from downstream area didn't accept (disagree) on this idea .

On the mitigation measure, according the target group around the Lake, the discharging of Lake Beseka to Awash River with appropriate mix ratio take as first prioritize solution, but the downstream target group other solution without discharge to Awash River is preferred.

From different non published document and discussion with community Lake Beseka is one of the main causes for the expansion of salt affected land. Because of this they think that discharging of Lake Beseka to Awash River is for the protection of upstream community.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In the world as well as in our country irrigation has a significant role on both social and economic development, one of the main concern in relation to irrigation is that the quality of water, Awash river water susceptible for both natural and human induced problem. Among these problems Lake Beseka is the main challenge of irrigation water quality. As a result the irrigated land exposed to salinity, reduction of production. If it continue in this trend many hectare of land may get abounded.

Water quality assessment on Awash River was conducted based on selective water quality parameters which are relevant to indicate the suitability of water for irrigation purposes. Present investigation concludes that physicochemical parameters concentrations of Awash River water, before Lake Beseka water joining it were found to be below the recommended limit of standards for irrigation waters. On the other hand physicochemical parameters concentrations of Lake Beseka water were found to be above the recommended limit of standards for irrigation waters.

In some parameter like pH, Electrical conductivity, Alkalinity, Chloride, Carbonate and Bicarbonate the quality of Lake Beseka water far from the maximum limit of irrigation water quality. The physiochemical property of Awash River automatically changed after Lake Beseka mix with it.

The discharge rate of Lake Beseka water into Awash River will affect its quality for irrigation and aggravate the soil salinity and reduce agricultural yield. Moreover, the result revealed that Lake Beseka is a great source of pollution for down streams agricultural farm and it is great environmental concerns that need immediate attention.

From the three mix ratios of Awash River and Lake Beseka water the ratio 95:5 would be suitable for irrigation. The other two mixed water (SL_{10} and SL_{15}) have a result of beyond the upper limit of irrigation water quality standard. As seen on the sample of Awash at Meteka (SR_6) the effect expands up to the irrigation area around Gewane.

Generally, discharging of Lake Beseka to Awash River has an impact on the water quality of Awash River for irrigation, since the discharge of Lake Beseka water increasing the area which affected by irrigation water quality also increase. In addition to this the social effect will raised through time.

5.2 Recommendation

- The water quality of Awash River will get out of the allowable maximum limit as the discharging of Lake Beseka water continues. It is necessary strengthening monitoring and controlling of discharging of Lake Beseka to Awash River.
- The mixed ratio of Lake Beseka to Awash River is safe, if it is 5 % based on the flow of Awash River.
- Efficient utilization of Irrigation systems on the downstream is necessary to mitigate the long term effect of lake Beseka .
- In order to mitigate the effect of Lake Beseka water on both around the Lake and downstream area it is better to use desalinization of Lake Beseka water and reuse.
- The study was conduct within a short period of time it may lack integrity and comprehensiveness. Further studies should be conduct in different season and considering the other parameter like diluting rate and underground water quality.

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7. APPENDIX

Appendix Form 1:- Questioner for assessment of social impacts

1. Do you think that discharge of Lake Beseka water to Awash River has an effect on downstream irrigation activities? Strongly Agree ☐ Agree ☐ Dis Agree ☐ None ☐

2. Do you think that discharge of Lake Beseka water to Awash River a solution for controlling of Lake Beseka rise ? Yes , it is ☐ No, it isn't ☐

3. Do you think that Lake Beseka water become fresh than earlier?

   Yes, it is ☐ No, it isn't ☐

4. Downstream community leaders explain their complain on discharging of Lake Beseka water to Awash River water, what is your opinion? Strongly ☐ Agree ☐ Dis Agree ☐ None ☐

5. There are different mitigation measure to control the rise of Lake Beseka water ,from this solution put a number as apriority .

   ☐ Desalinization without Discharging to Awash River

   ☐ Desalinization with Discharging to Awash River

   ☐ Only Discharging to Awash River

Appendix Table 1:- Principal Ions present in irrigation water (FAO, 1996)

Ions	Chemical Symbol	Equivalent weight
Anions (Acidic ions)		
Chloride	Cl^-	35.5
Sulphate	$SO4^-$	48
Carbonate	$CO3^-$	30
Bicarbonate	$HCO3^-$	61
Nitrate	$NO3^-$	62
Cations (Basic ions)		
Sodium	Na^+	23
Potassium	K^+	39.1
Calcium	Ca^{++}	20
Magnesium	Mg^{++}	12.2

Appendix Table 2:-Irrigation water quality standard of FAO (1998)

Parameter	Unit	FAO min. & Max. limit
P^H		6-8.5
Electrical Conductivity	µs/cm	0-3000
Tolal solids 105^{O}C	mg/l	
Total dissolved Solid 105^{O}C	mg/l	0-2000
Turbidity	Ntu	
Total Hardness	mg/l	
Alkalinity	mg/l	5-400
Ammonia	mg/l	0-5
Phosphate	mg/l	0-2
Nitrate	mg/l	0-10
Nitrite	mg/l	0-1.6
Calcium	mg/l	0-400
Manganese	mg/l	
Magnesium	mg/l	0-600
Sodium	mg/l	0-920
Potassium	mg/l	0-2
Sulphate	mg/l	980
Total Iron	mg/l	
Chloride	mg/l	0-106.5
Fluoride	mg/l	
Carbonate	mg/l	6
Bicarbonate	mg/l	610

Appendix Table 3:- Laboratory result Awash River water Before Lake Beseka sample point (2009 to 2013)

Sample Location	Month	Parameter	Unit	2009	2010	2011	2012	2013
Before Beseka	Average	Turbidity	Ntu	384.2	657.77	277.9	1063.2	413.4
		Tolal solids $105^{O}C$	mg/l	2158.7	3188	754.55	2700.3	511.3
		Total dissolved Solid $105^{O}C$	mg/l	248.9	275	238.73	644.8	232.1
		EC	µs/cm	380.99	419	380.36	408.8	401.4
		P^{H}		7.65	7.65	7.89	7.77	6.79
		Ammonia	mg/l NH_3	0.41	0.81	0.86	0.84	1.28
		Sodium	mg/l Na^{+}	49	53	43.54	46.18	48.2
		Potassium	mg/l K^{+}	7.84	10.4	8.66	8	9.15
		Total Hardness	mg/l $CaCO_3$	101.27	114	102.01	100.5	102.8
		Calcium	mg/l Ca^{+2}	31.54	30.67	32.12	30.6	31.8
		Magnesium	mg/l Mg^{+2}	-	9.03	5.12	5.81	7.55
		Total Iron	mg/l Fe^{+3}	0.09	0.28	0.51	0.18	0.76
		Manganese	mg/l Mn^{+2}	0.03	0.02	-	0.43	0.01
		Fluoride	mg/l F^{-}	1.47	1.46	1.16	1.23	0.99
		Chloride	mg/l Cl^{-}	19.53	22.03	20.1	21.24	18.8
		Nitrite	mg/l NO_2^{-3}	-	0.29	0.14	0.061	0.09
		Nitrate	mg/l NO_3^{-2}	3.59	1.82	2.91	3	2.2
		Alkalinity	mg/l $CaCO_3$	167.02	178.83	150.15	170.8	166.5
		Carbonate	mg/l CO_3^{-2}	Nill	Nill	Nill	Nill	Nill
		Bicarbonate	mg/l HCO_3^{-}	203.76	218.05	253.43	227.6	201.1
		Sulphate	mg/l SO_4^{-2}	15.86	21.39	15.4	22.4	24.5
		Phosphate	mg/l PO_4^{-3}	0.33	0.39	0.76	0.73	0.41

Source :(AwBA)

Appendix Table4:- Laboratory result Awash River water after Beseka sample point (2009 to 2013)

Sample Location	Month	Parameter	Unit	2009	2010	2011	2012	2013
Awash After Beseka	Average	Turbidity	Ntu	1702	1670.47	449.2	1404	334
		Tolal solids $105^{O}C$	mg/l	4099	3422	1256.2	1873.4	807
		Total dissolved Solid $105^{O}C$	mg/l	1838	2062	337.2	285	446
		EC	μs/cm	2692	2969.3	544.42	437.4	737.9
		P^{H}		8.28	8.74	8.1	7.44	7.29
		Ammonia	mg/l NH3	0.39	1.06	0.9	0.93	1.2
		Sodium	mg/l Na+	51.54	51.54	78.6	55.95	189.2
		Potassium	mg/l K+	8	7.65	9.7	9.98	16.28
		Total Hardness	mg/l CaCO3	63.42	54.25	99.5	114.11	104.99
		Calcium	mg/l Ca+2	19.5	15.2	30.6	33.59	32.44
		Magnesium	mg/l Mg+2	3.6	3.87	5.5	7.24	8.28
		Total Iron	mg/l Fe+3	0.04	0.425	0.45	0.27	0.46
		Manganese	mg/l Mn+2	0.07	-	-	1.21	0.04
		Fluoride	mg/l F-	1.73	1.45	1.54	1.14	1.74
		Chloride	mg/l Cl-	22.19	20.46	37.63	21.5	61.32
		Nitrite	mg/lNO2-3	0.13	0.1	0.14	0.2	0.09
		Nitrate	mg/lNO3-2	3.7	3.43	3.31	4.6	2.52
		Alkalinity	mg/lCaCO3	174.6	165.2	202.4	181.1	337.62
		Carbonate	mg/l CO3-2	4.8	5.32	16.7	17.64	24
		Bicarbonate	mg/lHCO3-	756.4	799	229.93	217.7	408.45
		Sulphate	mg/l SO4-2	20.02	27.23	31.24	30.8	64.35
		Phosphate	mg/l PO4-3	1.41	1.84	0.69	0.69	0.66

Source :(AwBA)

Appendix Table 5:- Laboratory result Awash River water at Awash 7 kilo sample point (2009 to 2013)

Sample Location	Month	Parameter	Unit	2009	2010	2011	2012	2013
Awash at 7 Kilo (water Supply)	Average	Turbidity	Ntu	4538	1125	749.1	1234	503.9
		Tolal solids $105^{O}C$	mg/l	4987	2931	5225	3318.4	1042
		Total dissolved Solid $105^{O}C$	mg/l	204	193	316	382	530.8
		EC	µs/cm	315	276	503.6	593	873.8
		P^{H}		7.83	7.8	8.3	7.82	7.39
		Ammonia	mg/l NH_3	0.55	1.12	0.88	0.59	1.11
		Sodium	mg/l Na^{+}	37	33.25	72.92	88	197
		Potassium	mg/l K^{+}	6.1	8.25	8.54	13.48	13.03
		Total Hardness	mg/l $CaCO_3$	82.95	75.1	100.69	114	104.4
		Calcium	mg/l Ca^{+2}	25.62	20.88	31.21	33.66	31.04
		Magnesium	mg/l Mg^{+2}	4.59	5.49	5.44	7.26	8.88
		Total Iron	mg/l Fe^{+3}	0.06	0.63	0.38	0.26	0.31
		Manganese	mg/l Mn^{+2}	0.05	-	-	-	0.07
		Fluoride	mg/l F^{-}	1.23	1.41	1.27	1.57	2.15
		Chloride	mg/l Cl^{-}	13.62	14.83	28.41	31.96	65.4
		Nitrite	mg/l NO_2^{-3}	-	0.24	0.16	0.1	0.06
		Nitrate	mg/l NO_3^{-2}	3.5	4.57	4.27	3.12	2.36
		Alkalinity	mg/l $CaCO_3$	124.95	109.7	191.61	199.59	360.6
		Carbonate	mg/l CO_3^{-2}	Nill	Nill	19.37	22.7	19.2
		Bicarbonate	mg/l HCO_3^{-}	152.44	133.82	210.97	265.5	434.41
		Sulphate	mg/l SO_4^{-2}	19.61	20	27.41	51.82	75.56
		Phosphate	mg/l PO_4^{-3}	0.37	0.78	0.53	0.46	0.73

Source :(AwBA)

Appendix Table 6:-Laboratory result Awash River water at Melka sedii sample point (2009 to 2013)

Sample Location	Month	Parameter	Unit	2009	2010	2011	2012	2013
Awash at Melka sedii (Weir)	Average	Turbidity	Ntu	288	389.2	423	424.5	1122.2
		Tolal solids 105^{O}C	mg/l	1542	3344	3506	1164	1059.4
		Total dissolved Solid 105^{O}C	mg/l	553.5	259	349	356	461
		EC	µs/cm	414	392	562	571	591.5
		P^{H}		7.7	7.97	8.23	7.88	7.48
		Ammonia	mg/l NH_3	0.51	0.78	0.7	0.76	1.26
		Sodium	mg/l Na^{+}	53.1	50.56	84	82.4	134.2
		Potassium	mg/l K^{+}	7.4	8.1	8.91	11.4	11.56
		Total Hardness	mg/l $CaCO_3$	106.8	96.16	104.9	109	108.8
		Calcium	mg/l Ca^{+2}	33.9	33.17	31.83	31	32.17
		Magnesium	mg/l Mg^{+2}	5.3	5.41	6.07	7.75	8.97
		Total Iron	mg/l Fe^{+3}	0.12	0.42	0.34	0.26	0.54
		Manganese	mg/l Mn^{+2}	0.03	0.02	-	-	0.05
		Fluoride	mg/l F^{-}	2.14	1.47	1.77	1.3	4.88
		Chloride	mg/l Cl^{-}	23.31	19.84	34.89	31.4	50.05
		Nitrite	mg/l NO_2^{-3}	0.005	0.26	0.56	0.16	0.12
		Nitrate	mg/l NO_3^{-2}	4.21	5.74	3.45	4.72	2.31
		Alkalinity	mg/l $CaCO_3$	169.4	159.4	213.3	218	288.69
		Carbonate	mg/l CO_3^{-2}	4.8	24	23.05	18.1	Nill
		Bicarbonate	mg/l HCO_3^{-}	205.8	188.36	246.1	247.7	313.42
		Sulphate	mg/l SO_4^{-2}	26.43	24.2	30.6	37.4	74.3
		Phosphate	mg/l PO_4^{-3}	0.38	0.512	0.6	0.66	0.66

Source :(AwBA)

Appendix Table 7:- Laboratory result Awash River water at Melka werar sample point (2009 to 2013)

Sample Location	Month	Parameter	Unit	2009	2010	2011	2012	2013
Awash at Melka werer (Office Area)	AVERAGE	Turbidity	Ntu	2493.11	1327	921.82	2362.8	418.7
		Tolal solids 105^{O}C	mg/l	3138.9	3360	2418	5889.8	1120.6
		Total dissolved Solid 105^{O}C	mg/l	359.99	337	410.14	5144.4	592.3
		EC	µs/cm	542.4	463	658.2	902.7	1050.5
		P^{H}		7.74	7.91	8.14	7.96	7.45
		Ammonia	mg/l NH_3	0.38	1.305	0.7	1.294	1.4
		Sodium	mg/l Na^+	86.44	64	105.95	159.36	238.7
		Potassium	mg/l K^+	7.59	7.95	8.9	18.7	13.87
		Total Hardness	mg/l $CaCO_3$	111.2	122.75	100.4	94.74	164.7
		Calcium	mg/l Ca^{+2}	35.69	30.7	29.79	45.344	29.78
		Magnesium	mg/l Mg^{+2}	5.404	10.57	6.22	6.64	17.6
		Total Iron	mg/l Fe^{+3}	0.58	0.23	0.327	0.21	0.46
		Manganese	mg/l Mn^{+2}	0.04	0.07	-	0.165	0.05
		Fluoride	mg/l F^-	2.08	2.15	1.84	1.79	2.49
		Chloride	mg/l Cl^-	30.72	27.5	46.21	64.19	92.57
		Nitrite	mg/l NO_2^{-3}	0.005	0.42	0.123	0.1	0.17
		Nitrate	mg/l NO_3^{-2}	3.99	4.16	3.46	3.05	1.98
		Alkalinity	mg/l $CaCO_3$	218.5	177.7	245.33	326.6	410.66
		Carbonate	mg/l CO_3^{-2}	Nill	Nill	11.98	19.92	12
		Bicarbonate	mg/l HCO_3^-	266.6	152.99	287.13	334.65	477.8
		Sulphate	mg/l SO_4^{-2}	43.93	36.2	35.65	52.92	97.2
		Phosphate	mg/l PO_4^{-3}	0.34	0.7	0.534	0.55	0.88

Source :(AwBA)

Appendix Table 8:- Laboratory result Awash River water at Meteka sample point from (2009 to 2013)

Sample Location	Month	Parameter	Unit	2009	2010	2011	2012	2013
Awash at Meteka	Average	Turbidity	Ntu	577.19	290.5	302.02	1271.74	153.82
		Tolal solids $105^{O}C$	mg/l	4705.7	1228.3	2557.3	2326.9	899.14
		Total dissolved Solid 105OC	mg/l	626.5	707.7	595.6	710	669.25
		EC	µs/cm	959.8	1071.8	976.7	1147.3	989.34
		P^{H}		7.87	8.19	8.35	8.09	7.63
		Ammonia	mg/l NH_3	0.317	0.44	0.58	0.653	0.85
		Sodium	mg/l Na^{+}	181.5	207.8	154	199.2	194.57
		Potassium	mg/l K^{+}	10.69	12	11.02	17.78	12.17
		Total Hardness	mg/l $CaCO_3$	118.23	120.82	115.04	109.52	120.83
		Calcium	mg/l Ca^{+2}	28.414	31.45	36.11	31.96	32.14
		Magnesium	mg/l Mg^{+2}	11.475	10.23	9.38	10.4	12.95
		Total Iron	mg/l Fe^{+3}	0.0425	0.2	0.21	0.143	0.2
		Manganese	mg/l Mn^{+2}	0.0275	0.02	-	-	0.01
		Fluoride	mg/l F^{-}	2.33	2.42	2.33	1.81	1.89
		Chloride	mg/l Cl^{-}	64.78	71.95	70.3	87.59	72.93
		Nitrite	mg/l NO_2^{-3}	0.005	0.07	0.06	0.14	0.075
		Nitrate	mg/l NO_3^{-2}	1.798	4.7	1.602	2.32	1.0614
		Alkalinity	mg/l $CaCO_3$	358.47	405.3	338.12	374.8	355.06
		Carbonate	mg/l CO_3^{-2}	6	23.2	11.96	31.16	-
		Bicarbonate	mg/l HCO_3^{-}	434.8	470.9	390.9	438.4	389.58
		Sulphate	mg/l SO_4^{-2}	72.11	62.5	43.3	81.19	99.14
		Phosphate	mg/l PO_4^{-3}	0.41	0.55	0.64	0.79	0.877

Source :(AwBA)

Appendix Table 9:-Laboratory result Awash River water at Adayitu sample point (2009 to 2013)

Sample Location	Month	Parameter	Unit	2009	2010	2011	2012	2013
Awash at Adaitu	Average	Turbidity	Ntu	1570.2	2457.3	1361.2	1961.6	575.63
		Tolal solids $105^{O}C$	mg/l	2909.8	6562	3986	4737.8	1258
		Total dissolved Solid $105^{O}C$	mg/l	412.9	284	460.5	479.3	492.1
		EC	µs/cm	633.2	589.91	753	781.6	853.8
		P^{H}		7.97	8.01	8.28	8.02	7.73
		Ammonia	mg/l NH_3	0.47	0.96	0.85	0.71	1.138
		Sodium	mg/l Na^+	104.3	55.25	109.2	112.74	145.88
		Potassium	mg/l K^+	7.79	4.8	7.77	9.72	8.79
		Total Hardness	mg/l $CaCO_3$	103.74	104.5	83.99	108.06	105.9
		Calcium	mg/l Ca^{+2}	30.43	28.12	31.37	32.48	33.19
		Magnesium	mg/l Mg^{+2}	6.74	8.19	6.4	6.44	8.2
		Total Iron	mg/l Fe^{+3}	0.06	0.465	0.22	0.33	0.42
		Manganese	mg/l Mn^{+2}	0.03	-	-	0.54	0.03
		Fluoride	mg/l F^-	1.57	0.405	1.73	1.05	1.08
		Chloride	mg/l Cl^-	44.6	22.16	60.15	59.94	58.58
		Nitrite	mg/l NO_2^{-3}	0.02	0.175	0.18	0.16	0.108
		Nitrate	mg/l NO_3^{-2}	2.84	4.37	3.4	6.15	2.35
		Alkalinity	mg/l $CaCO_3$	234.95	143.4	240.6	230.76	284.47
		Carbonate	mg/l CO_3^{-2}	11.52	Nill	13.68	22.8	18
		Bicarbonate	mg/l HCO_3^-	272.62	174.95	279.21	300.5	335.53
		Sulphate	mg/l SO_4^{-2}	37.79	46.89	52.54	64.85	78.75
		Phosphate	mg/l PO_4^{-3}	0.48	0.63	0.95	0.65	0.89

Source :(AwBA)

Appendix Table 10: - Laboratory result Lake Beseka water sample point (2009 to 2013)

Sample Location	Month	Parameter	Unit	2009	2010	2011	2012	2013
Lake Beseka	Average	Turbidity	Ntu	44.1	49.2	42.1	74.04	47.2
		Tolal solids $105^{O}C$	mg/l	4308	4404	3644.5	3623.8	3497.8
		Total dissolved Solid $105^{O}C$	mg/l	4225.6	4074.7	3513.2	3383.2	3017.1
		EC	µs/cm	6067.8	5510	5382	5292	4934.2
		P^{H}		9.39	9.47	9.51	9.32	9.21
		Ammonia	mg/l NH_3	0.49	0.67	0.77	0.85	1.22
		Sodium	mg/l Na^{+}	1595	1613.3	1218	1286	1196.3
		Potassium	mg/l K^{+}	58.98	48.76	46.79	46.86	44.33
		Total Hardness	mg/l $CaCO_3$	15.24	17.73	17.96	21.67	21.55
		Calcium	mg/l Ca^{+2}	4.48	5.6	4.55	5.34	6.92
		Magnesium	mg/l Mg^{+2}	1.33	0.9	1.56	1.99	4.31
		Total Iron	mg/l Fe^{+3}	0.06	0.3	0.23	0.15	0.15
		Manganese	mg/l Mn^{+2}	0.04	-	-	0.72	0.05
		Fluoride	mg/l F^{-}	33.58	6.9	20	16.96	179.1
		Chloride	mg/l Cl^{-}	554.3	422.2	437.5	437.4	411.6
		Nitrite	mg/l NO_2^{-3}	-	0.04	0.08	0.09	0.12
		Nitrate	mg/l NO_3^{-2}	1.29	1.3	1.08	1.04	1.03
		Alkalinity	mg/l$CaCO_3$	2205	2100.2	2932	1754.2	1542.8
		Carbonate	mg/l CO_3^{-2}	538.8	365.3	460	546.8	503.9
		Bicarbonate	mg/lHCO_3^{-}	1594.7	1556.5	1306	1028.3	891.6
		Sulphate	mg/l SO_4^{-2}	553.5	792	427	373.92	473
		Phosphate	mg/l PO_4^{-3}	2.84	2.73	2.33	2.48	2.08

Source :(AwBA)