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ASSESSSMENT OF DOWNSTREAM POLLUTION PROFILE OF HAWASSA CITY MUNICIPAL WASTEWATER AND ITS INFLUENCE ON LAKE HAWASSA

BY

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As a thesis research advisor, I hereby certify that I have read and evaluated this thesis prepared, under my guidance, by Temesgen Tarekegn entitled as "Assessment of Downstream Pollution Profile of Hawassa city Municipal Wastewater and Its Influence on Lake Hawassa''. I recommended the paper to be submitted as fulfilling the requirement for the degree of MSc in environmental science.

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ACRONYMS

AAWSA	Addis Ababa Water and Sewerage Authority
AAU	Addis Ababa University
ANOVA	Analysis of variance
APHA	American Public Health Association
BOD	Biological Oxygen Demand
BOD5	Five Day Biological Oxygen Demand
CCME	Canadian Council of Minster for environment
COD	Chemical Oxygen Demand
CW	Constructed Wetland
DO	Dissolved Oxygen
EC	Electrical Conductivity
EPA	Environmental Protection Authority
EEPA	Ethiopian Environmental Protection Agency
EU	European Union
FAO	Food and Agriculture Organization
GIS	Geographic Information System
GPA	Global Program me of Action
NTU	Nephelometric Turbidity Unit
OECD	Organization for Economic Co-operation and Development
pH	Power of Hydrogen

QSAE	Quality and Standards Authority of Ethiopia
PPM	Parts Per Million
SNNPR	South Nations Nationalities and People Region
SPSS	Statistical Package for Social Science
SS	Suspended Solid
TDS	Total Dissolved Solid
TN	Total Nitrogen
TSS	Total Suspended Solids
UNEP	United Nations Environment Program
UNESCO	United Nations Educational Scientific and Cultural Organization
WBG	World Bank Group
WHO	World Health Organization
WWSP	Waste Water Stabilization Pond
^{O}C	Degree Celsius
Mg/L	milligram per Liter
µS/cm	micro-Siemens per centimeter

ABSTRACT

Assessment of Downstream Pollution Profile of Hawassa city Municipal Wastewater and Its Influence on Lake Hawassa

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Addis Ababa University, 2015

Lake Hawassa is used for a variety of purposes like fishing, recreation, swimming, drinking water supply by the communities surrounding it and cultivation of vegetables. However, it is exposed to wastewater discharge from the city and polluting the aquatic ecosystem. The objective of this study was characterization of municipal wastewater of Hawassa city and its impact on the receiving lake water quality. Five sites were selected from Wastewater channel and on the lake. A total of 20 grab samples were collected on two week basis for physio-chemical analysis. Samples were examined using standard procedure over the duration of May 2013 to July 2013. The significant pollution parameters for these effluents include a COD mean concentration ranged from (13.28±2.00mg/l -75.48±3.48), BOD_5 concentration of (6.03±1.74 mg/l -26.97±3.56mg/l). Chloride and total hardness concentrations with mean values ranged from (12.44±4.14-18.58±14.88) and (292.75±438.21mg/l- 49.50±14.46) respectively. Ammonia and total nitrogen concentrations were with mean values of ranged (0.52±0.25mg/l -4.39±0.99 mg/l) and (10.00±1.63-32.75±2.75mg/l) respectively. The mean phosphorus, nitrate and nitrite content of the effluent were also found to be 0.34±0.06mg/l -4.20±0.14, 0.41±0.25mg/l-3.77±0.34 and 0.11±0.15mg/l- 0.27±0.17 mg/l respectively. The concentration of nitrite was negligible when the value compared with other parameters investigated. The pH values were 7.36±0.52-8.31±0.28 indicating alkalinity of the wastewater. Total Dissolved solids, electrical conductivity and Total Suspended Solids of the effluent wastewaters were (513.00±45.77-755.25±162.70) mg/l, (865.00±66.73-1287.75±297.23) (µS/cm) and (21.75±23.89 - 276.75±109.76) mg/l, respectively. The investigation of temperature and turbidity ranged from 21.50±2.69 - 23.00 ±2.7 ^{O}C. and 23.28±21.10NTU -226.00±35.56 NTU respectively. The values of most parameters were significantly different among sites, at 0.05 significant level of post Hoc ANOVA.

Key Words: *Municipal Wastewater, Pysico-chemical, Pollution.*

CHAPTER I

1. INTRODUCTION

1.1 Background of the study

Water pollution is a serious environmental problem in the world. It is the degradation of the quality of water that renders water unsuitable for its intended purpose. Anything which degrades the quality of water is termed as pollutant. Water pollutants can be broadly classified as major categories namely organic, inorganic, suspended solid and sediments, heavy metals, radioactive materials and heat (Botikin and Keller, 1995). Water pollution has an effect on oceans and inland water bodies. Most of our water resources are gradually becoming polluted due to the addition of foreign materials from the surroundings. Rapid urbanization and industrialization with improper environmental planning often lead to discharge of industrial and sewage effluents into lakes. The Lakes have a complex and fragile ecosystem, as they do not have self- cleaning ability and then readily accumulate pollutant (Simachew Dires, 2008). From spatial perspective, the sources of pollution can be divided as point and non-point sources. As the name implies, point source pollution represents those activities where wastewater is routed directly into receiving water bodies by, for example, discharge pipes, where they can be easily measured and controlled. In contrast, non-point source pollution arises from a broad group of human activities for which the pollutants have no obvious point of entry into receiving watercourses (Demelash, 2008).

Wastewater is any water that has been adversely affected in quality by anthropogenic influence. It comprises liquid waste discharged by domestic residences, commercial properties, industry, and/or agriculture and can encompass a wide range of potential contaminants and concentrations. In the most common usage, it refers to the municipal wastewater that contains a broad spectrum of contaminants resulting from the mixing of wastewaters from different sources (http://en.wikipedia.org/wiki/Wastewater, 2009). Together with discharges from industry, domestic, agricultures can cause an impact on environmental condition in river and coastal waters. Eutrophication is an accelerated growth of algae on higher forms of plant life caused by the enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorus and inducing an

undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned (European Communities and WHO, 2002). Eutrophication of fresh water ecosystem is one of the most prevalent environmental problems responsible for water quality degradation on a world –wide scale (Wetzel et al., 2001).
There is at present hardly any infrastructure for the effective treatment of sewage in developing countries. Municipal sewerage and the extent of domestic and industrial wastewater treatment are inadequate in most urban situations. When there is a municipal sewerage network in place, the coverage is usually incomplete and the treatment level is insufficient. Even when treatment facilities exist, poor maintenance and operation often results in failing treatment processes, causing pollution of the effluent receiving surface waters. The risk of water borne diseases may actually increase in developing countries as a result of the introduction of a conventional sewerage scheme, since it is usually not accompanied by effective end-of-pipe treatment (UNEP/GPA, 2004). Untreated effluent contains high concentrations of salts, total suspended solids, chemical oxygen demand, nitrogen and phosphorous and toxic compounds, such as heavy metal and chlorinated organic compounds. Industrial effluents can seep into the aquifer and pollute groundwater or where it is discharged without proper treatment can affect the physico-chemical properties of the receiving water and consequently its biota. Currently an estimated 245 000 km^2 of marine ecosystems are affected with impacts on fisheries, livelihoods and the food chain. It is also reported that surface water bodies in developing countries are under serious threat as a result of indiscriminate discharge of polluted effluents from industrial, agricultural, and domestic activities (Kambole, 2003).

Water is one of the most important natural resource, which is abundant in nature and covers about two-thirds the surface of the Earth. It is used in both terrestrial and aquatic environment for various activities, balancing the ecological system of global environment. It is know that alteration of water quality conditions (e.g., temperature, pH, dissolved oxygen, flow) may directly affect the abundance and diversity of aquatic organisms Thus it is paramount importance to evaluate the impact of municipal wastewater particularly on water bodies using physio-chemical as pollution indicator factor. In present study, the ecological impact of municipal wastewater on an immediate environment and the receiving water body or Lake Hawassa was investigated.

1.2. STATEMENT OF THE PROBLEM

Municipal wastewater consists of a mixture of domestic wastewater, effluents from commercial and industrial establishments and urban run-off (UNEP/GPA, 2004). Municipal wastewater effluent is a concern because of its composition and the total volume discharged. A range of typical emerging contaminants are found in municipal wastewater effluent discharged into environment. In addition to metal contaminants, newly emerging contaminants such as pharmaceutical, personal care products, endocrine disrupting compounds and brominated flame retardants are growing cause of concern. As a result of complexity of the effluent mix, a broad range of chemicals, physical, and biological changes to ecosystem occur resulting ecological degradation. Impacts to social (including human health) and economic system also result (CCME, 2006). Municipal wastewater, which is 99% liquid, consists of suspended and dissolved solids, both organic and inorganic, and includes large numbers of microorganisms. (Alberta Environment, 2000).Industrial effluents and domestic sewage contribute large quantities of nutrients and toxic substances that have a number of adverse effects on the water bodies and the biota (Zinabu Gebre-Mariam and Zerihun Desta, 2002).

Surface and ground water are being polluted with different pollutants. Some pollutants are directly discharged from industrial effluents and municipal sewage, and others come from polluted runoff in urban and agricultural areas. This situation has been exacerbated as a result of the rapid growth of population, increased urbanization and expansion of irrigation that more likely use different fertilizers, pesticides and herbicides, and other modern agricultural practices as well as lack of environmental regulations (FAO, 1992). In a series of regional consultative meetings with government designated experts, UNEP's Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (UNEP/GPA) has identified wastewater-related problems as one of the major problems in coastal zones throughout the world. In particular municipal wastewater discharges are considered as one of the most significant threats to sustainable coastal development affecting human health as well as environmental quality aspects, both resulting in economic losses (UNEP/GPA, 2004).An estimated 90 % of wastewater in developing countries is still discharged directly into rivers and streams without any waste treatment or after retention period of sometime in stabilization ponds. Such discharges are part of the reason why de-oxygenated dead zones are growing rapidly in the seas and oceans (Shu et al., 2005). Environmental pollution derived from domestic and industrial activities is the main threat to the surface and groundwater qualities in Ethiopia (EPA, 2003).

A series of hygienic studies conducted in Awassa city demonstrated that poor service and uncollected domestic refuse, often mix with human and animal excreta piles up on the streets or is dumped in drainage system or surrounding areas. These pose not only a serious health risk to the population but also lead considerable environmental degradation. (Shiferaw and Belay, 1993). Lake Hawassa is a fresh closed Lake playing an important role in the lives of many people in the region. It is the source of commercial fishery. It serves for recreation purpose and also is used for drinking water supply by the communities surrounding it. It is influenced by human activities such as agricultural practice, deforestation, industrialization and discharging of domestic sewages (Zenebe Yirgu ,2011). Municipal wastewater of Hawassa city directly discharged into the Lake Hawassa. The Lake which receives the Municipal wastewater from the city is used for a variety of purposes like fishing, recreation, swimming, drinking water supply by the communities surrounding it and cultivation of vegetables for the community of Hawassa. The lake also increases the economy of the locality in particular and the country in general by attracting tourists and investors. The indiscriminate disposal of this Municipal wastewater to Lake Hawassa can cause an impact on environmental condition in the Lake .This is mainly because untreated wastewater usually contain other contaminants, nutrients mainly nitrogen and phosphorus that can stimulate the growth of aquatic plant ,which in turn result in eutrophication problem to the lake (Muhammad,2009). The chemicals may also have a tendency to accumulate in aquatic organisms and may pose risk of human exposure through consumption of fishes. Therefore, studying the characteristics of Municipal wastewater composition of Hawassa city can provide baseline information in relation to the impact of the effluent on the receiving lake ecology.

1.3 Objective of the Study

1.3.1 General Objective

- ✓ The main objective of this study was to determine the physio-chemical characteristics of Municipal Wastewater of Hawassa City.

1.3.2 Specific Objectives

- ➢ To indicate possible impacts of Municipal Wastewater of Hawassa City on the water quality of the receiving lake around Municipal Wastewater site.
- ➢ To address wastewater compliance issue of discharge with the available guideline or standard.
- ➢ Give base line information about the pollution profile of wastewater of the City.

CHAPTER II

2. REVIEW OF RELATED LITERATURE

2.1 Municipal Waste Water, and Its Composition

2.1.1 Municipal waste water

Wastewater is a complex mixture of natural inorganic and organic material mixed with manmade substances. In its broadest sense, wastewater can be classified as domestic (sanitary) wastewater also known as sewage, including agricultural wastes and municipal wastewater, which is a mixture of the former two (Gray, 1999). Domestic wastewater consists of effluent discharges from households, institutions and commercial buildings. Industrial waste water is the effluent discharged by manufacturing units and food processing plants. In addition to domestic wastewater and industrial wastewater, storm water, groundwater seepage entering to the municipal sewage network also adds the volume of a municipal wastewater. As it is known that Municipal wastewater is a discharge of a complex mixture of chemicals (both inorganic and organic wastes, from the production processes in a municipality) and its effects can affect the composition of healthy water physico-chemistry over time. This variation can alter other parameters such as the concentrations of suspended solids, biological oxygen demand (BOD), conductivity, temperature, color and odor of the receiving water bodies (UNESCO/WHO/UNEP, 1996).

Ethiopia is naturally endowed with abundant water resources that help to fulfill domestic requirements such as irrigation and hydropower. With its current per-capita fresh water resources estimated at 1924m^3, the country is one of the sub-Saharan African countries endowed with the largest surface fresh water resource. However; only 2% of the potential is annually utilized (Mo WR, 1999). Water quality refers to the characteristics of a water supply that will influence its suitability for specific use *i.e.* how well quality meets the needs of the user. Quality is defined by certain physical, chemical, and biological characteristics (FAO, 1998). Good quality water is very important for general use, drinking, cooling, cleaning, irrigating agricultural crops, washing and processing equipments. Water quality of rivers is best in the headwaters, where rainfall is frequent. Water quality often declines as rivers flow through regions where rainfall is frequent. Water quality often declines as intensive agriculture, large towns, industry and a recreation area increases (Rhonades, 1993). Similarly, the uncontrolled and excessive use of fertilizers and pesticides has long-term effects on ground and surface water resources (Chapman, 1996). Water quality alteration constitutes a major environmental impact of many water use and development activities. The most obvious source of quality alteration is the discharge of municipal and industrial water, and also addition of toxic substances to natural water (Tamiru Alemayehu, 2001).

At national level or international level according to some organization like EPA, World Bank Group, WHO and other environmental and health protection agencies set environmental quality standards with a goal of safeguarding public health and protecting the environment by indicating pollution limits. But most of the guidelines and the limits are stated only to specific source pollution i.e., for factories, industrial discharges, and hotels. For municipal and other non point source domestic wastes the limit's sated are very rear. Internationally accepted guide line showing standard limits for proceeded wastewater, domestic sewage and polluted storm water discharged to surface water for general application is given in (Table 1) (World Bank Group; 2006, WHO 2003).

Table1. Processed wastewater limit values for discharges to water bodies (World Band Group, 2006; WHO 2003) and (EPA, 2003) (pH given by pH scale)

Parameters	(Ethiopia EPA,2003)	(World Band Group, 2006; WHO 2003)
Temperature	40 ^{0}C	-
pH	6 – 9	6-9
BOD5 at 20 ^{0}C	50 mg/l	50mg/1
Total dissolved solid	80mg/l	80mg/m1
Total suspended solid	-	50mg/l
Total nitrogen (as N)	40 mg/l	10mg/l
S^{-2}	-	1mg/1
COD (mg O_2 /l)	150 mg/l	125 mg/l
Total phosphorus (as P)	10 mg/l	-
PO_4^{-3}	-	<1mg/1
NO_3^{-2}	-	50 mg/1
NH_3	20mg/l	-
Suspended solids	30 mg/l	-
Mercury (as Hg)	0.001 mg/l	0.5 mg/1
Nickel (as Ni)	2 mg/l	0.1 mg/1
Lead (as Pb)	0.5 mg/l	0.01 mg/1

2.1.2 Composition of Municipal Wastewater

Assessment for composition of municipal water reveals many components including organic matter, nutrients (Nitrogen, Phosphorus, and Potassium), inorganic matter (dissolved minerals), toxic chemicals (heavy metal and pesticides), pathogens, total solids, dissolved solids and suspended solids. For an effective and economic waste management program characterization of wastes according to their composition is essential. It helps in the choice of treatment methods, deciding the extent of treatment, assessing the beneficial uses of wastes and utilizing the purification capacity of natural bodies of water in planned and controlled manner. Wastewater is characterized in terms of its physical, chemical, and biological composition. It should be noted that many of the physical properties and chemical and biological characteristics are interrelated. For example, temperature is a physical property, which affects both the amounts of gases dissolved in the wastewater and the biological activity in the wastewater (Metcalf & Eddy, 2003). Other physical parameters include color, odor, solids (residues) and turbidity. Solids can be further classified into suspended and dissolved solids (size and settle ability) as well as organic (volatile) and inorganic (fixed) fractions. Chemical parameters associated with the organic content of wastewater include the biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon, and total oxygen demand.

Inorganic chemical parameters of wastewater are salinity, hardness, pH, acidity, alkalinity, composition of ions (iron, manganese, chlorides, sulfates, sulfides), heavy metals (mercury, lead, chromium, copper, and zinc), and nitrogen (organic ammonia, nitrite, and nitrate). Bacteriological parameters include coli forms, specific pathogens, and viruses (Canter, 2000). Understanding how the wastewater is produced is as important as knowing what contaminates are present (Irene Mohammed et al., 2004).

2.1.3 Impact of a Municipal Wastewater on Environment

Environmental pollution is an inevitable consequence of economic development and people's desire to improve their quality of life (Kumar, 2000). There are a wide range of potential environmental impacts caused by municipal wastewater. Those impacts are landscape change, habitat loss, loss of flora and fauna and stability problem, noise health security problem, effect on the amount and quality of water, and high traffic materials (Gerhard and Yandora, 2003). The descriptions of some of the impacts are as follow.

2.1.3.1 Impact on land scape and land stability

A land scape comprises the visual feature if an area of land including physical elements such as land form, living elements of flora and fauna, abstract elements such as lighting and weather conditions and human elements (human activity) or the built environment (Gerhard, and Yandora, 2003). The primary natural landscape could be lost little by little. This is against the widely accepted idea that "every untouched corner in the nature is beautiful." Removing of a rocky hill for the running way of liquid wastewater removal has a relation the land and it will damage the different landscape elements that give scenic value and tranquility (harmony and silence). The natural condition of the land could be changed due to of excavation and construction of the wastewater canals. This leads to unstable slope, land slide, rock fall and erosion. The slope will be deteriorated and become unstructured which results sliding, plane and wedge mode of failures (OECD, 1998).

2.1.3.2 Impact on the atmosphere

The effect of air pollution on health and the environment is of growing concern worldwide. Increasingly rigorous legislations combined with powerful societal pressures is escalating our need for impartial and authoritative information on the quality of the air we all breathe. Different gases released due to the chemical alteration in a wastewater result in deterioration of air quality in the surrounding area and negative effects to the health and wellbeing of nearby residents (OECD, 1998).

2.1.3.3 Impact on water resource

The impact of sewage has become a severe environmental problem in the protection of water resources and aquatic ecological environment, threatened the economical development, drinking water safety and ecological environment and seriously hampered the sustainable development of society and ecological (Zinabu Gebre- Mariam and Zerihun Desta, 2002). The impact level can spread at surface and ground water.

2.1.3.4 Surface water and ground water impacts

Both surface and Groundwater are being polluted from various sources. These are grouped as 1) recharge of groundwater via infiltration from river and irrigation channels; 2) infiltration of municipal wastewater into groundwater from septic tanks; 3) agricultural activities, principally irrigation and fertilizer application; and 4) toxic chemicals, gasoline tanks, liquid propane gas, hydrocarbons and oil explorations spillage. But it is being more polluted by untreated industrial and municipal wastewater on its route through the urban areas (Richard et al., 1999). This incidence of ground water and surface water and surface water contamination impact is a potent source of spread of water borne diseases. Other serious problem is effects related to eutrophication and accumulation of heavy metal.

2.1.3.5 Impacts on biodiversity

An estimated 90% of wastewater in development countries is still discharged directly into rivers and streams without any treatment or after retention period of sometime in stabilization ponds. Most of these effluents have organic and inorganic chemicals, which are much higher than the allowable limits and extremely harmful to aquatic flora and fauna and through food chains to human beings (Zinabu Gebre-Mariam and Zerihun Desta, 2002).

2.1.3.6 Social impacts

Characterization of social, economic, and cultural impacts of municipal wastewater are relatively straight forward and consists of an assessment of past and current impacts and projected future effects of municipality wastewater management. Wastewater has impacts on the society by creating odor, nuisance, poor environmental quality, etc, which deteriorates the life of the society. The society may develop risk perception on the impacts (Hassan et al., 2005)

A vicious cycle of health impacts is established when human waste is not treated properly. Bacteria, viruses and parasites that are present in human excreta enter the environment, where they might remain for some time in water or soil. By drinking contaminated water, or eating food that has been irrigated with untreated water, these micro-organisms infect people, who in turn will contaminate the environment via their faeces and/or urine.

Economic losses result from increased health care costs, additional treatment costs for drinking water, loss of income because of loss of productive days, drop in fish production, tourism etc. (UNEP/GPA, 2004).

2.2. An Impact Assessment of a Municipal Wastewater by Using Some Aspects

2.2.1 Physico-chemical aspect assessment for physical and chemical quality

Water has a wide range of physical and chemical characteristics that affects its quality and treatability (Hutton, 1996). Their uncontrolled discharge into the environment has caused lots of hazards to man, other organisms and the environment itself. Rapid urbanization, industrialization and population growth have been the major causes of stress on the environment leading to problems like human health problems, eutrophication and fish death, coral reef destruction, biodiversity loss, ozone layer depletion and climatic changes (Bay et al., 2003). Determination of adverse effects of various elements upon human health and the ecosystem has been gaining momentum recently, especially on scientific, social and emotional grounds. Hence, there is a presumption that sound scientific data base is needed to define maximum exposure levels of specific chemical compound(s) of health implications (Fortner and Witt man, 1983).

2.2.1.1 Some of major physic-chemical aspects of municipal wastewater

Physicochemical is helpful to determine state of the wastewater, its treatment techniques and chemical dosage (APHA, 1996). Major physicochemical factors which directly or indirectly can affect an abundance and distribution of biodiversity and so should be assessed to determine their effect are pH, temperature, electrical conductivity, nutrients, TDS, turbidity, BOD, dissolved oxygen, heavy metals and flow velocity.

pH is a measure of the acidity or alkalinity of the water on a scale from 1-14 (1 is very acidic, 7 neutral and 14 very alkaline). If the pH of water is too high or too low, the aquatic organisms living within it will die. The majority of aquatic creatures prefer a pH range of 6.5-9.0, though some can live in water with pH levels outside of this range. As pH levels move away from this range (up or down) it can stress animal systems and reduce hatching and survival rates. The further outside of the optimum pH range a value is, the higher the mortality rates. The more sensitive a species, the more affected it is by changes in pH. In addition to biological effects, extreme pH levels usually increase the solubility of elements and compounds, making toxic chemicals more "mobile" and increasing the risk of absorption by aquatic life (EPA, 2012). There are many factors that can affect pH in water, both natural and man-made. Most natural changes occur due to interactions with surrounding rock (particularly carbonate forms) and other materials. pH can also fluctuate with precipitation (especially acid rain) and wastewater or mining discharges (EPA, 2012). In addition, CO_2 concentrations can influence pH levels. The alkalinity of natural water is controlled by the concentration of hydroxide and represented by a pH greater than 7. This is usually an indication of the amount of carbonates, and bicarbonates that shift the equilibrium producing $[OH^-]$. This is happening due to the amount Carbon dioxide in water will be converted into H_2CO_3 which acidify the water to a pH of about 6. If any alkaline earth metals (sodium, calcium and magnisum, etc) are present, the carbonate and bicarbonate formed from solubilisation of CO_2 will interact with alkaline earth metals increasing the alkalinity shift the pH up over 7. Other contributors to an alkaline pH include boron, phosphorous, nitrogen containing compounds and potassium (Bellingham, 2008). Photosynthesis, respiration and decomposition all contribute to pH fluctuations due to their influences on CO_2 levels. The extremity of these changes depends on the alkalinity of the water, but there are often noticeable diurnal (daily) variations Point source pollution is a common cause that can increase or decrease pH depending on the chemicals involved (Washington State Department of Ecology, 1991).

Temperature: Many of the physical and biological characteristics of waterways are directly affected by temperature. Temperature is highly dependent on the depth of the water, season, time of the day, cloudiness of the sky and the air temperature. Discharges can also affect temperatures, e.g., cooling water. Changes in temperature alter dissolved oxygen. (Higher temperatures mean the water holds less dissolved oxygen). The distribution and number of aquatic species also changes as temperature varies. A short period of high temperatures each year can make the water body unsuitable for sensitive species even through during the rest of the year the temperature is acceptable (Chapman, 1996).

Electric conductivity: The electric conductivity is the ability of a substance to conduct electricity. The conductivity of water is a more-less liner function of the concentration of dissolved ions. Conductivity itself is not a human or aquatic health concern, but because it is easily measured, it can serve as an indicator of other water quality problems (It is used to give an indication of the amount of inorganic materials in the water including. Calcium, bicarbonate, nitrogen, phosphorus, iron, sulfur and others), if the conductivity of a stream suddenly increases, it indicates that there is a source of dissolved ions in the vicinity. Typically, excessive EC level indicates excessive amounts of nutrients (salt) in the wastewater. Therefore, conductivity measurements can be used as a quick way to locate potential water quality problems (Kenneth, 2003; Masters et al., 2005).Conductivity is measured in terms of conductivity per unit length, and meters or micro Siemens/cm. storm water runoff, sewage effluent, catchments geology and agricultural effluent running into streams have a significant influence on the conductivity of stream water (Aguado et al., 2006).

Nutrients: Urbanization generally leads to higher nutrient concentration in storm runoff (Omernik, 1976). Nutrients such as phosphorous and nitrogen are essential for the growth of algae and other plants. Aquatic life is dependent upon these photo synthesizers, which usually occur in low levels in surface water. Excessive concentrations of nutrients, however, can over stimulate aquatic plant and algae growth. Bacterial respiration and organic decomposition can use up dissolved oxygen, depriving fish and invertebrates of available oxygen in the water (Smith et al., 1999).

Phosphorus: Phosphorus occurs naturally in low concentrations and is essential for all forms of life. It comes from processes such as weathering of rock and the decomposition of organic matter. Phosphorus indicates nutrient status, organic enrichment and the consequent health of the water body. Increased levels may result from erosion, discharge of sewage or detergents, urban runoff, and rural runoff containing fertilizers, animal and plant matter (European Communities and WHO, 2002). When concentrations are too high problems such as algal blooms, excessive weed growth and the loss of species diversity can occur. Abundant plant growth such as algal blooms leads to increased pH and turbidity and sometimes to the production of toxins and odor (Carpenter et al., 1998; Donald et al., 2002).

Nitrogen: Nitrogen in urban runoff/streams occurs in three forms: Gaseous form (Nitrogen and Ammonia), Inorganic form (Nitrates, nitrites and Ammonium), organic form (biological material, e.g., protein) Natural breakdown of vegetation, run-off from lawn and crop fertilizers and effluent can contain nitrates. Run-off from feedlots can have concentrated ammonia and nitrates. Inadequately treated sewage, poor septic tank systems and streams fed by nitrate rich groundwater can all increase nitrogen in waterways. Ecosystems can be affected when nitrogen concentrations become too high. This may result in algal blooms and an overabundance of oxygen-dependant bacteria that deplete the water of oxygen. Nitrate in high concentrations may be harmful to stock. High concentrations of ammonia are also very toxic to aquatic animals (Washington State Department of Health, 2005).

Total Dissolved solids: “Dissolved solids” refer to any minerals, salts, metals, cations or anions dissolved in water. This includes anything present in water other than the pure water molecule and suspended solids. Suspended solids are any particles/substances that are neither dissolved nor settled in the water (William, 1993). In general, the total dissolved solids concentration is the sum of the cations (positively charged) and anions (negatively charged) ions in the water. Parts per million (PPM) is the weight to weight ratio of any ion to water. Conductivity is usually about 100 times the total cations or anions expressed as equivalents. Total dissolved solids (TDS) in mg/1 usually range from 0.5 to 1.0 times the electrical conductivity. Some dissolved solids come from organic source such as leaves, silt, plankton, and industrial waste and sewage (APHA, 1996). Other sources come from runoff from urban areas, and fertilizers and fertilizers and pesticides used on towns and farms. Dissolved solids also come from inorganic materials such as rocks and air that may contain calcium bicarbonate, nitrogen, iron phosphorus, sulfur, and other minerals (Tenagn Adisu, 2009).

BOD/COD: - Natural organic detritus and organic waste from urban and agricultural runoff, waste water treatment plants, and failing septic systems acts as a food source for water-borne bacteria. Bacteria decompose these organic materials using dissolved oxygen, thus reducing the DO present for fish (Micheal et al., 2001). Biochemical oxygen demand (BOD) is a measure of the amount of oxygen that bacteria will consume while decomposing organic matter under aerobic conditions. Biochemical oxygen demand is determined by incubating a sealed sample of water for five days and measuring the loss of oxygen from the beginning to the end of the test. Samples often must be diluted prior to incubation or the bacteria will deplete all of the oxygen in the bottle before the test is complete. The main focus of wastewater treatment plants is to reduce the BOD in the effluent discharged to natural waters. Wastewater treatment plants are designed to function as bacteria farms, where bacteria are fed oxygen and organic waste. The excess bacteria grown in the system are removed as sludge, and this “solid” waste is then disposed on land. Chemical oxygen demand (COD) does not differentiate between biologically available and inert organic matter, and it is a measure of the total quantity of oxygen required to oxidize all organic material into carbon dioxide and water. COD values are always greater than BOD values, but COD measurements can be made in a few hours while BOD measurements take five days (Barnes et al., 1998).

If effluent with high BOD levels is discharged into a stream or river, it will accelerate bacterial growth in the river and consume the oxygen levels in the river. The oxygen may diminish to levels that are lethal for most fish and many aquatic insects. As reviver re-aerates due to atmospheric mixing and as algal photosynthesis adds oxygen to the water, the oxygen levels will slowly increase downstream. The drop and rise in DO levels downstream from a source of BOD is called the DO sag curve. These are some of the major water physico-chemical parameters which can be assessed concerning wastewater especially.

2.3 Environment and a Need of Municipal Wastewater Treatment

2.3.1 Wastewater treatment plant

The most appropriate wastewater treatment is that which will produce an effluent meeting the recommended microbiological and chemical quality guidelines both at low cost and with minimal operational and maintenance requirements (Arar, 1988).The major function of wastewater treatment plant is to reduce the organic loading of domestic wastewater so that it can be safely discharged to the receiving stream. The effectiveness of the sedimentation process is monitored through BOD_5, COD and TSS parameter effectively by conventional wastewater treatment plant. But conventional wastewater treatment plants involve large capital investments and operating costs. Due to economical and labor constraints, these systems are not a good solution for small villages that cannot afford such expensive conventional treatment systems. However another good option used as a solution was practiced in different countries (Kyambadde, 2005). This method of treating wastewater, other than conventional method, is constructing wetlands. As a study has been conducted to understand the feasibility of a constructed wetland to treat raw wastewater, a pilot scale subsurface-flow constructed wetland was evaluated for removal efficiency of biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), total and faecal coliform and faecal streptococci bacteria from raw municipal wastewater (Ward and Stanford, 1979). The result showed that high levels of BOD, COD and TSS removal for all treatments were obtained. The best removals were obtained in those beds with the lowest hydraulic application rate and wetland vegetations suggested as. a good resource in filtering pollutant. It has another ecological advantage too. In addition to this other natural method of wastewater treatment plan is waste water stabilization pond. Pond systems are commonly employed for municipal sewage treatment, especially in developing countries, due to its cost-effectiveness and high potential of removing different pollutants (Christian et al., 2003). A World Bank Report endorsed the concept of stabilization pond as the most suitable wastewater treatment system for effluent use in agriculture. Many characteristics make WWSP substantially different from other wastewater treatment. This includes design, construction and operation simplicity, cost effectiveness, low maintenance requirements, low energy requirements, easily adaptive for upgrading and high efficiency.

2.3.2 Constructing wetlands as an alternative wastewater treatment method

Wetlands have been referred to as a "living machine" (MacDoland. 1994) and one of nature's most effective ways of cleansing polluted water (Rocky Mountain Institute. 1998). They have been termed "Kidneys of the planet" because of the natural filtration processes that occur as water passes through (Wallance, 1998). Studies of the feasibility of using constructed wetlands for wastewater treatment were initiated during the early 1950s in Germany, with the first operational horizontal subsurface flow constructed wetland appearing in 1974. In the United States, wastewater treatment using either natural or constructed wetland researches began in the late 1960s and increased dramatically in scope during 1970s (Kyambadde, 2005). During the last decades, constructed wetlands were very successful when used for wastewater, and low quality water treatment from different sources (Nicols,1983; Chris.1997).This new approach is designed based on natural processes involving complex and concerned interaction between the plants, the substrate /media the inherent microbial community to accomplish wastewater treatment in a more controlled and predictable manner through physical, chemical and biological process (Simim and Mitchell,1999; K yambadde,2005). Because they emulate natural system, Constructed Wetlands (CW) are effective, reliable, simple, environmental friendly and relatively inexpensive to install and maintain (Gersberg et al., 1985; Rogers et al., 1991). They have been successfully applied worldwide for biological treatment of municipal and industrial wastewater (USEPA, 1988; Kyambadde et al., 2005), and agricultural wastewater as well as surface runoff water (William, 1997). The economic viability of using Constructed Wetland was deduce from the total annual cost of the wetland and waste stabilization pond designed for a population in different countries such as Uganda, Tanzania, Kenya , and Ireland. It was confirmed that maintenance cost for constructed wetland was eight times lower than the conventional treatment system and also the studies have shown that constructed wetlands are very suitable for treatment of wastewater in tropical climate (Birhanu Gnet,2007). Based on the overall results of the treatment performance and costs, these researchers conclude that the application of constructed wetland can be considered both technically economically viable option for municipal wastewater treatment.

The study made by Birhanu Gnet (2007) showed that CW attracts wildlife such as birds, mammals, amphibians, and variety of dragonflies and other insects. For instance, USEPA publication (1988) indicated that more than 1,400 species of wildlife have been identified from constructed and natural treatment wetlands, of these more than 800 species were attributed to CW. Moreover, constructed wetland plants, (especially when they are planted with ornamental plant species), provide a more aesthetically pleasing alternative than other conventional wastewater treatment systems. Due to this benefits, over the past twenty years constructed wetland have been used effectively to decrease the concentration of various pollutants from different sources particularly in Europe and North America (MaDonald, 1994).

In Ethiopia, more of the country industries are found in town area. For instance more than half of the country's industries are found in Addis Ababa, but very few of them have a treatment plant or a connection to sewer. These parts of population and industries dispose their wastewater to natural watercourses and natural wetlands. In Addis Ababa, the current wastewater treatment system (stabilization pond and sewer line) serves only a small part (2%) of the population with the design capacity for 70.000 people (AAWSA, 2003). Consequently, approximately 73% of the inhabitants "disposed" feces and dirty waters in pit latrine or septic tank and a sizeable part of the population (25%) has no such facilities at all (AAWSA, 2003). Although constructed wetlands have such a proven effectiveness for treatment of a variety of wastewaters (Kyambadde, 2005), no work has been done in Ethiopia. But all of the treatment options were conventional methods (both centralized and decentralized) would require high initial and operational costs, as well as skilled manpower for operation and maintenance (Simi and Mitchell, 1999). For developing countries like Ethiopia that have limited resources for the construction and operation of conventional treatment plants, there should be an option which is economical, but produce an effluent with same, even better quality from the conventional treatment system. This necessities the provision of energy and cost effective secondary wastewater treatment facilities for small communities such as schools, hospitals, Military camps, colleges, farms, industries, and universities where on-site wastewater disposal technology is predominant. The necessity of constructing wetland is a good option for the treatment of wastewater.

2.4. Waste Stabilization Ponds

Waste water stabilization pond technology is one of the most important natural methods for wastewater treatment. Waste stabilization ponds are mainly shallow man-made basins comprising a single or several series of anaerobic, facultative or maturation ponds the primary treatment takes place in the anaerobic pond, which is mainly designed for removing suspended solids, and some of the soluble element of organic matter (BOD_5). During the secondary stage in the facultative pond most of the remaining BOD_5 is removed through the coordinated activity of algae and heterotrophic bacteria. The main function of the tertiary treatment in the maturation pond is the removal of pathogens and nutrients (especially nitrogen). Waste stabilization pond technology is the most cost-effective wastewater treatment technology for the removal of pathogenic micro-organisms. The treatment is achieved through natural disinfection mechanisms. It is particularly well suited for tropical and subtropical countries because the intensity of the sunlight and temperature are key factors for the efficiency of the removal processes (Mara et al. ,1992).

2.4.1. Waste Stabilization Ponds Types

WSP can be classified in respect to the type(s) of biological activity occurring in a pond. Three types are distinguished: anaerobic, facultative and maturation ponds. Usually a WWSP system comprises a single series of the aforementioned three ponds types or several such series in parallel. In essence, anaerobic and facultative ponds are designed for

Biological Oxidation Demand (BOD) removal and maturation ponds for pathogen removal, although some BOD removal occurs in maturation ponds and some pathogen removal in anaerobic and facultative ponds. Generally, in WSP systems, effluent flows from the anaerobic pond to the facultative pond and finally, if necessary, to the maturation pond. However, for better results wastewater flowing into an anaerobic pond shall be preliminary treated in order to remove coarse solids and other large materials often found in raw wastewater. Preliminary treatment operations typically include coarse screening, grit removal and, in some cases, combination of large objects (Hamzeh and M.Ponce, 2012)

2.4.1.1 Anaerobic ponds

These units are the smallest of the series. Commonly they are 2-5 m deep and receive high organic loads equivalent to100 g BOD_5/m^3 d. These high organic loads produce strict anaerobic conditions (no dissolved oxygen) throughout the pond. In general terms, anaerobic ponds function much like open septic tank and work extremely well in warm climates. A properly designed anaerobic pond can achieve around 60% BOD5 removal at 20° C. One-day hydraulic retention time is sufficient for wastewater with a BOD5 of up to 300 mg/l and temperatures higher than 20° C. Designers have always been preoccupied by the possible odour they might cause. However, odour problems can be minimized in well designed ponds, if the SO_4^{2-} concentration in wastewater is less than 500 mg/l. The removal of organic matter in anaerobic ponds follows the same mechanisms that take place in any anaerobic reactor (Mara et al. ,1992 ;Pena,20002)

2.4.1.2 Facultative ponds

These ponds (1-2 m deep) are of two types: primary facultative ponds receive raw wastewater, and secondary facultative ponds receive the settled wastewater from the first stage (usually the effluent from anaerobic ponds). Facultative ponds are designed for BOD_5 removal on the basis of a low organic surface load to permit the development of an active algal population. This way, algae generate the oxygen needed to remove soluble BOD_5. Healthy algae populations give water a dark green colour but occasionally they can turn red or pink due to the presence of purple sulphide-oxidising photosynthetic activity (Mara and Pearson, 1986). This ecological change occurs due to a slight overload. Thus, the change of colouring in facultative ponds is a qualitative indicator of an optimally performing removal process. The concentration of algae in an optimally performing facultative pond depends on organic load and temperature. The photosynthetic activity of the algae results in a diurnal variation in the concentration of dissolved oxygen and pH values. Variables such as wind velocity have an important effect on the behaviour of facultative ponds, as they generate the mixing of the pond liquid. As Mara et al. (1992) indicate, a good degree of mixing ensures a uniform distribution of BOD_5, dissolved oxygen, bacteria and algae, and hence better efficiency of wastewater stabilization. The ponds usually have an aerobic upper layer and anaerobic lower layer. This facultative condition occurs because high oxygen levels cannot be maintained to the total depth of aerobic ponds. So a fully aerobic surface layer develops, along with an aerobic/anaerobic intermediate layer, and a fully anaerobic layer on the pond bottom. More technical details on the efficiency of the process and removal mechanisms have been reported (Mara et al., 1992; Curtis, 1994).

2.4.1.3 Maturation ponds

These ponds receive the effluent from a facultative pond and its size and number depend on the required bacteriological quality of the final effluent. Maturation ponds are shallow (1.0-1.5 m) and show less vertical stratification, and their entire volume is well oxygenated throughout the day. Their algal population is much more diverse than that of facultative ponds. Thus, the algal diversity increases from pond to pond along the series. The main removal mechanisms especially of pathogens and faecal coliforms are ruled by algal activity in synergy with photo-oxidation. More details on these removal mechanisms in maturation ponds can be found in (Curtis, 1994).On the other hand, maturation ponds only achieve a small removal of BOD_5, but their contribution to nitrogen and phosphorus removal is more significant. Mara et al. (1992) report a total nitrogen removal of 80% in all waste stabilization pond systems, which in this figure corresponds to 95% ammonia removal. It should be emphasized that most ammonia and nitrogen is removed in maturation ponds. However, the total phosphorus removal in WSP systems is low, usually less than 50% (Mara et al., 1992; Mara and Pearson, 1986).

CHAPTER III

3. MATERIAL AND METHODS

3.1. Description of the Study Area

3.1.1 Hawassa City

The study was conducted at Awasa city the capital city of Southern Nations, Nationalities, and Peoples Region. Awasa (also spelled Awassa or Hawassa) is a city in Ethiopia, on the shores of Lake Awasa in the Great Rift Valley. Located in the Sidama Zone 270 km south of Addis Ababa via Debre Zeit, 130 km east of Sodo, 75 km north of Dilla and 1125 km north of Nairobi. The city lies on the Trans-African Highway 4 Cairo-Cape Town, with a latitude and longitude of 7°3′N 38°28′E and an elevation of 1708 meters. It is a rapidly expanding city. Shops, small industries and residences are generally present in all part of the city. It is characterized as sub- humid climate and has extended period of wet season from March to October, in addition to the main rainy season taking place from July to September .The maximum amount of mean annual rainfall goes up to 1150 mm. The study area has mean annual temperature of 19.5^0C with March and April having the highest and November and December having the lowest Temperature (Birenesh Abay,2007).

A rapid growth of population along with development activity per individuals and low awareness are some of the common reasons for high rate of waste generation. The streams, rivers and lakes into which waste is dumped are used for various purposes such as drinking, washing and other domestic activities by downstream inhabitants. The water body in the city such as Lake Awassa, it lying 268 km (167 miles) south of Addis Ababa, in the Main Ethiopian Rift, surface elevation: 1,686 m (5,531 feet) above sea level, it is one of the extremely rare freshwater lakes with no visible outlet. The most persuasive explanation about the mysterious nature of the lake calls attention to the possible existence of underground water outflow for maintaining freshwater with low level of salinity. Tikur Wuha, the only perennial river feeding the lake drains the vast swamps of Wendo Genet area, which in itself drains the highlands on the east. The surface area of the lake is about 95.84 km^2 (37 mi^2), 16km (10miles) long, up to 8km (5 miles) wide, and it has estimated volume of 1.3 billion m^3 (45.9 billion ft^3). While the maximum depth of the lake is about 21.6 m (70.9 feet), its mean depth however is 10.7m (35 feet). About half a dozen species of fish thrive in the lake, attracting various birds for feeding. Pelicans, storks, herons, hammerkops, sea eagles, kingfishers...etc. can be watched from the site of small scale fish market, on the shore at Amora Gedel. From large mammals, hippos are at home in the Lake, and can be viewed from small local boats that can be hired in the area. Lake Awassa has several ecological and economical functions such as domestic water supply, recreation, fisheries, and ecotourism.

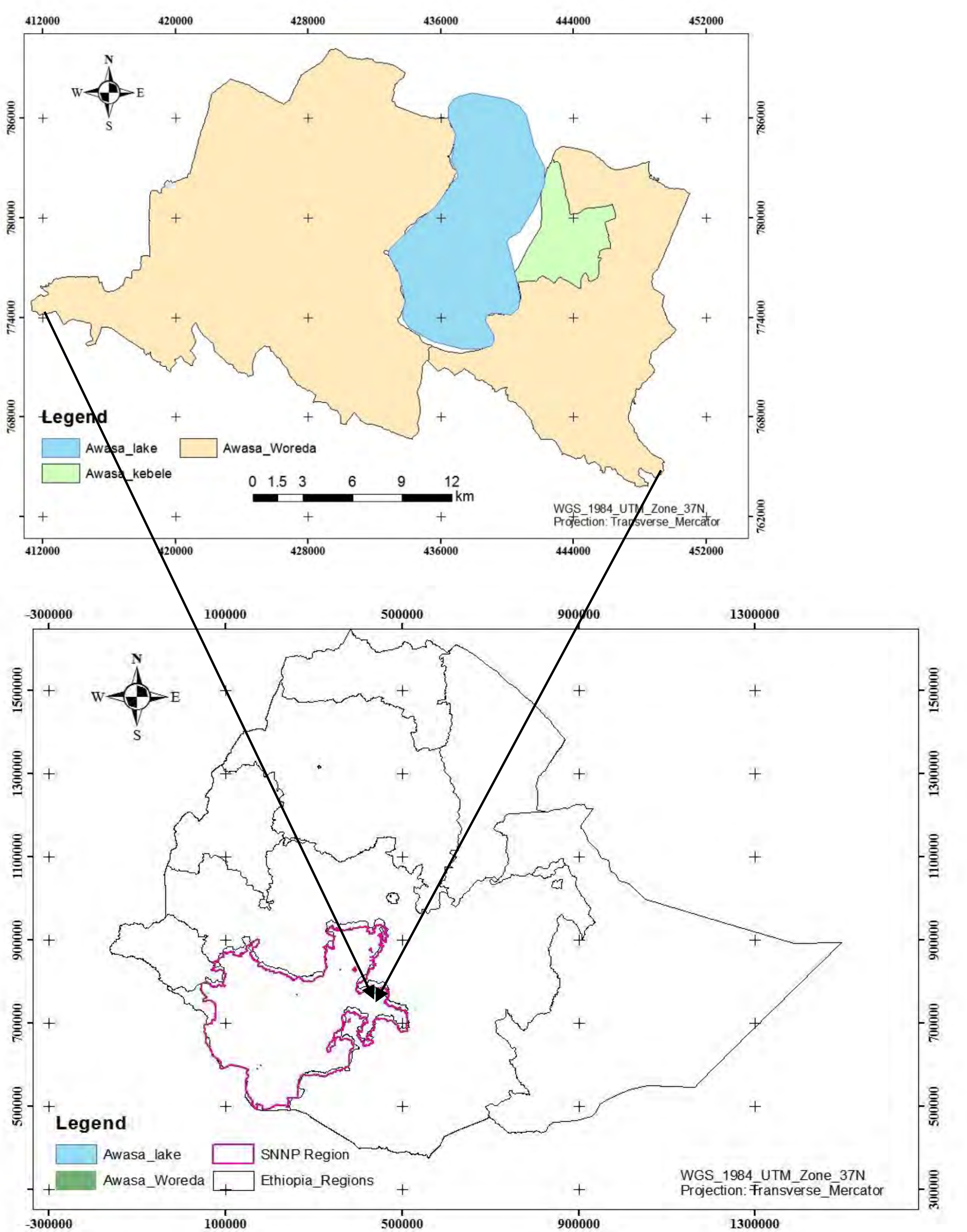

Fig. 1: Map study area (Source: SNNPRS Finance and Economic Development Bureau)

3.2. Sampling

Five sites were selected from both wastewater channel and on the lake. Municipal wastewater of Awassa was selected as the focus for this study where attempts were made to determine impact of the effluents from the municipality on Lake Awssa. The study area starts from Welde Amanuale Adebabay which situated at eastern part of the city and ends at western part by joining to the Lake. The sampling sites were designated as S1 to S5 located on the map as shown in (Fig. 2).According to the field studies and surveys conducted along a municipal waste water channel in the study area, the potentially polluted with high number of effluent (their exposure to municipal discharges) were selected as study sites. The storm channel of the town starts from a point called′Welde Amanuale Adebabay′at upper stream and at the downsteam the Lake which is a receiving water body and the total distance of the study area is about 3km along storm canal 0.5km along the Lake totally 3.5km. The samples were collected directly from different sampling locations along Wastewater channel and on the Lake two times per month using clean 1-L polyethylene bottles for physiochemical analysis. Samples were transported to the Addis Ababa University Centre for Environmental Science laboratory in ice box within 24hr this was recommended time (APHA, 1995). The samples kept in refrigerator at 4 ^{O}C until analyze for parameters. From these study sites, physiochemical samples collected for four times May 27/ 2013 to July 2013 at fifteen days gap. In general, sample collection and handling procedure were performed according to the standard procedures recommended by American Public Health Associations (APHA, 1999).

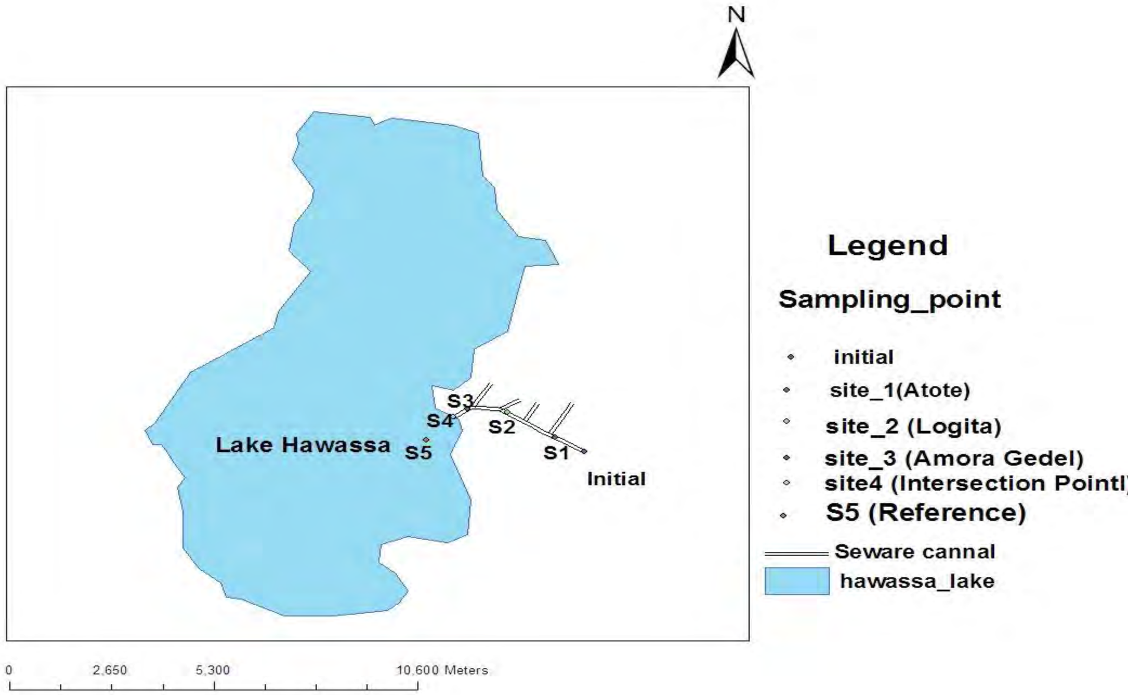

Fig. 2: Wastewater channel that collects waste from Awassa city and discharges to Lake Awassa (GIS information source:- SNNPR Land Administration/Use and Environmental Protection Authority)

Table 2 Summary of the sampling sites along storm channel and on the Lake

S.№	Samplings	Site area	Description
1	Site 1 (S1)	Right side of Cherenet A/Mariam Building on the way of storm channel	The point where the municipal wastes from Welde Amanuale Adebabay up to Atote is collected and join the storm channel.
2	Site 2 (S2)	1.2 km downstream of storm canal (in front of Logeta Hotel)	An additional municipal wastewater joining points at the downstream, where at this point a volume of wastewater is bigger than site 1.
3	Site 3 (S3)	Amora Gedel	A point at downstream on the storm channel about 1 km from the above site(S2)
4	Site 4 (S4)	Mouth of the channel on the Lake	The end point of storm channel at about 0.8km from the S3 at the mouth of the channel on the Lake.
5	Site 5 (S5)	On the Lake Awassa about 0.5 km from point of Municipal waste water joining the Lake	The need of this site is to estimate physiochemical parameters of Lake Awassa .

3.3. Physiochemical Measurements

The physiochemical parameters were assessed are temperature(^{0}C), turbidity(NTU), pH, electrical conductivity (CD)(μScm-1), water smell ,total dissolved solids (TDS)(mg/L),suspended solids(SS), phosphate,PO_4^{3-}(mg/L), total nitrogen (TN),nitrate nitrogen (NO_3^--N), ammonia nitrogen (NH_3-N), nitrite nitrogen(NO_2^--N), Chloride, biological oxygen demand BOD_5(mg/l) and chemical oxygen demand(COD).The parameters such as conductivity (EC), temperature, pH and water smell of the municipal wastewater and lake were measured in situ using portable water quality measuring equipment. It was done using a conductivity meter (Wagtech International N374, +M207/03IM, USA) to measure conductivity (EC), Temperature was measured using thermometer in ^{0}C ,a portable pH meter (Wagtech International N374, M128/03IM, USA) was used to determine pH, and water smell was tested through observation on its smell, weather the wastewater had an objection to nose or note. These equipments were calibrated one day before each sampling period. The Chemical oxygen demand (COD), Total nitrogen (TN), nitrate nitrogen (NO_3^--N), ammonia nitrogen (NH_3-N), nitrite nitrogen (NO_2^--N), and Orthophosphate (PO_4^{-3}), were measured by colorimetrically using spectrophotometer (HACH model DR/2400 portable spectrophotometer, Loveland, USA) according to HACH (2002) instructions/procedures. Argentometric Method was used to determine Chloride (Cl^-). Five-day biochemical oxygen demand (BOD_5), Total dissolved solids (TDS), total suspended solids (TSS), were determined using the standard methods of American Public Health Association (APHA, 1999). Finally turbidity was measured by nephlometr.The parameters analyses were done in the Centre for Environmental Science Laboratory, College of Natural Science, and Addis Ababa University.

3.4 Data Analysis

The data analysis for all parameters was made by using SPSS version 16.0 and origin version 8.0 Software and excel program. SPSS was used to determine the Mean, Standard deviation and range of the parameters. The coefficient of correlation between some physicochemical parameters was calculated by Pearson correlation test at 0.05 and 0.01 significant levels and results were presented in terms of Tables, graphs and charts performed using origin version 8.0 Software and Microsoft office excel 2007 program.

Statistical analysis of data was carried out using SPSS 16.0 statistical package program. One way ANOVA (Analysis of Variance) was performed for statistically significant difference in the physico-chemical parameters between the five sampling sites. Difference in mean values were accepted as being statistically significant if $P < 0.05$.

3.5. Limitations of the Study

The Samples taken from Lake Hawassa may not be representative for determining the overall water quality of the Lake.

CHAPTER IV

4. RESULTS AND DISCUSSION

4.1 Physico-chemical Parameters

4.2 Municipal Wastewater of Hawassa City

The mean concentrations of the pollutants along the receiving water body are given in Table 3. At subsequent sampling sites (S1, S2 and S3) downstream Municipal Wastewater of Hawassa city the concentrations of most pollutants showed increasing trend until sampling point (S4) near Lake Awassa.

Table 3. Physicochemical Characteristics of Municipal Wastewater of Hawassa city (Concentrations are in mg/l except for pH, temperature and conductivity) Mean value (n=4)

Variable	Site 1	Site 2	Site 3	Site 4	Site 5	P - value
PO_4^{-3}	2.05±1.34	3.03±0.33	4.20±0.14	2.02±0.33	0.34±0. 06	0.000
EC	1099.25±210.36	1271.25±413.52	1287.75±297.23	1091.00±134.81	865.00±66.73	0.182
T^0	21.50±2.69	21.93±2.20	22.00±2.16	22.50±1.85	23.00±2.71	0.921
pH	7.54±0.22	7.36±0.52	7.94±0.41	8.21±0.35	8.31±0.28	0.010
TDS	531.75±24.88	635.00±27.74	755.25±162.70	643.75±72.23	513.00±45.77	0.007
TSS	138.75±51.42	199.75±84.74	276.75±109.76	60.50±27.23	21.75±23.89	0.001
Turbidity	148.50±49.48	166.00±51.82	226.00±35.56	63.21±45.53	23.28±21.10	0.000
BOD_5	14.95±4.20	24.14±2.79	26.97±3.56	13.69±2.07	6.03±1.74	0.000
COD	33.18±3.84	62.50±4.12	75.48±3.48	30.50±4.60	13.28±2.00	0.000
NO_3^--N	1.80±0.43	2.53±0.76	3.77±0.34	0.89±0.20	0.41±0.25	0.000
NO_2^--N	0.27±0.17	0.18±0.16	0.14±0.11	0.20±0.15	0.11±0.15	0.668
NH_3-N	1.50±0.52	2.47±0.39	4.39±0.99	1.25±0.28	0.52±0.25	0.000
TN	16.00±1.63	18.25±0.96	32.75±2.75	22.50±2.65	10.00±1.63	0.000
Cl	12.98±5.47	14.32±4.80	18.58±14.88	12.44±4.14	18.50±3.16	0.676
Total hardness	49.50±14.46	157.75±181.55	292.75±438.21	76.00±44.21	61.75±47.05	0.488

The mean characteristics of raw wastewaters from Awassa city are presented in Table 3.The significant pollution parameters for these effluents include a COD mean concentration ranged from (13.28±2.00mg/l -75.48±3.48), BOD_5 concentration of (6.03±1.74 mg/l -26.97±3.56mg/l). Chloride and total hardness concentrations with mean values ranged from (12.44±4.14-18.58±14.88) and (292.75±438.21mg/l- 49.50±14.46) respectively. Ammonia and total nitrogen concentrations were with mean values of ranged (0.52±0.25mg/l -4.39±0.99 mg/l) and (10.00±1.63-32.75±2.75mg/l) respectively. The mean phosphorus, nitrate and nitrite content of the effluent were also found to be 0.34±0.06mg/l -4.20±0.14, 0.41±0.25mg/l-3.77±0.34 and 0.11±0.15mg/l- 0.27±0.17 mg/l respectively. The concentration of nitrite was negligible when the value compared with other parameters investigated. The pH values were 7.36±0.52-8.31±0.28 indicating alkalinity of the wastewater. Total Dissolved solids, electrical conductivity and Total Suspended Solids of the effluent wastewaters were (513.00±45.77-755.25±162.70) mg/l, (865.00±66.73-1287.75±297.23) (µS/cm) and (21.75±23.89 - 276.75±109.76) mg/l, respectively. The investigation of temperature demonstrated that the average temperature was measured to be ranged from 21.50±2.69 - 23.00 ±2.7 ^{O}C. The average concentration of turbidity was 23.28±21.10NTU -226.00±35.56 NTU.

4.2.1. pH

The mean pH concentration along wastewater channel of Awassa city downstream ranged from (7.36±0.52-8.31±0.28) (Table 3) (Fig: 3). The highest mean pH measurement was recorded at S5 (8.31±0.28)(on the Lake Awassa) whereas the lowest measurements was from S2 (7.36±0.52) at downstream of storm channel (in front of Logeta Hotel) and a high neutrality in pH was seen at this site too. The range is safe according to the standard sated by WHO for drinking water or irrigation (6.5 - 8.5) or World Bank Group for liquid effluent (6.5 – 9) Table1. Statistical analysis (ANOVA) showed that in the present study pH value was significantly different among sites (P= 0.010, F=4.924).Among fifteen day interval pH (P=0.142) was not statistically different. TUKY-HSD tests demonstrated that there was not statistically significantly difference for all fifteen day interval, so the variation was significant at the site than fifteen day gap.

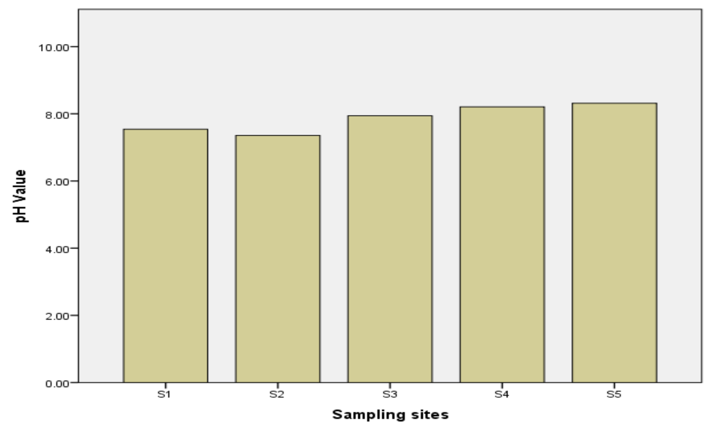

Fig-3 Mean Concentration of pH downstream municipal wastewater of Hawassa city

pH is an indicator of the acidity or alkalinity of water. The pH of all the water samples were in agreement with pH assigned by EPA as the standard pH of water which ranges from 6.5 – 8.5 (EPA, 2002). The pH of water affects the solubility if many toxic and nutritive chemicals, which affects the availability of these substances to aquatic organisms. As acidity increases, most metals become more water soluble and more toxic. Toxicity of cyanides and sulfides also increases with a decrease in pH (increase in acidity) except few such as ammonia which becomes more toxic with only a slight increase in pH. Run off, sewage, geology (limestone is associated with more alkaline conditions); high nutrient levels are some of the causes to acidity or alkalinity. High nutrient levels cause excessive growth of algae and plants that will lift pH values. Outside what is considered the normal pH range there may be a loss of sensitive species. If extremely high or extremely low pH, values occur, it would result in the death of all aquatic life (EPA, 2012). Alkaline conditions can also increase the toxicity of other pollutants such as ammonia. High pH value could alter the toxicity of other pollutants in the water bodies. For example, ammonia is much more toxic in alkaline water than acid because free ammonia (NH_3) at high values (pH>8.5) is more toxic to aquatic biota than when it is in the oxidized form (NH_4 +) (Källqvist and Svenson, 2002). In addition, pH levels outside of 6.5-9.5 can damage and corrode pipes and other systems, further increasing heavy metal toxicity. Even minor pH changes can have long-term effects. A slight change in the pH of water can increase the solubility of phosphorus and other nutrients – making them more accessible for plant growth (Washington State Department of Ecology, 1991). These chemicals can come from agricultural runoff, wastewater discharge or industrial runoff. Mining operations (particularly coal) produce acid runoff and acidic groundwater seepage if the surrounding soil is poorly buffered. Wastewater discharge that contains detergents and soap-based products can cause a water source to become too basic (Osmond et al., 1995).

4.2.2. Temperature

The average temperature measures of Hawassa city of municipal wastewater had no big gap (Table 3).It was ranged from its highest (23.00) at S3 to its lowest (21.05) at S1.There was no (T) (P=0.921) significant difference recorded among sites. Among the two weeks based interval there was significant deference recorded (T) ;(P=0.00). Water temperature plays an important factor which influences the chemical, biochemical and biological characteristics of water body. In an established system the water temperature controls the rate of all chemical reactions, and affects fish growth, reproduction and immunity. Drastic temperature changes can be fatal to fish (Patil et al., 2012*)*.Temperature is the most important factor which influences the chemical and biological characteristics of the aquatic system. These values were found within the range of surface waters temperature, 0° C to 30° C .The little variation in each sampling points could be influenced by air circulation, flow and depth of the water body (Chapman, 1996).

4.2.3. Conductivity (EC)

The value of electrical conductivity fluctuates from 865.00µS/cm to 1287.75µS/cm. The maximum value (1287.75µS/cm) was recorded in S3 and minimum value (1287.75µS/cm) in S5. Among sites and the fifteen day sampling interval the average EC recorded was not significantly different EC (P>0.05) (Table 3 and 9).Electrical conductivity is defined as the measure of waters ability to conduct an electrical current through dissolved ions. These ions include sodium, calcium, potassium, magnesium, iron, aluminum, chloride, sulphide, carbonate and bicarbonate. So the conductivity increases not only with the increase total dissolved solids but also water temperature (Davis, W.S.1995). Again a solubility of ions depends on pH value. A high value is preferable for some ions to be dissolved. The value was higher than the acceptable ranges of the provisional discharge limits set by the Environmental Protection Authority (EPA, 2003) (Table 1). Those values indicate municipal wastewater of Hawassa city contained substantial dissolved (mobile) ions such as sulfate, nitrate, Iron ion and other ions. Similar studies on Lake Awassa Zenebe Yirgu (2011) reported that the value of electrical conductivity concentrations was in the range of 3783±171.5-7343±146.3 mg/l. High mean value of TDS and EC scored at upper stream in this study which could be due to the sediment deposits including materials such as eroded soils, leaves and twigs as reported by (Admusu Tassewu, 2007).

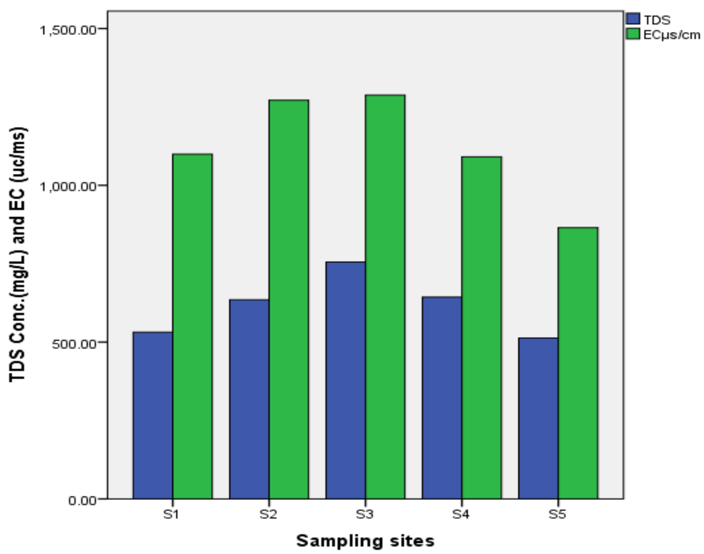

Fig-4 Mean values of TDS and EC downstream municipal wastewater of Hawassa city

4.2.4. Turbidity

The mean turbidity value at each five sampling sites of a storm channel of Hawassa city downstream and at the Lake ranged from 23.28±21.10 up to 226.00±35.56 NTU. The maximum turbidity was recorded at S3 where the wastewater loses its transparency than the other sites. Among the sites there was significant deference was recorded but turbidity was not significant different among the two weeks based interval (Table3 and 9). In this study, the mean value of turbidity was above the standard levels of 5 mg/L for drinking water (Table 4). Total dissolved solid (TDS) and suspended solid (SS) are indicators for general water quality as they directly affect the aesthetic value of water by increasing turbidity. Turbidity is a measure of light transmission and indicates the presence of suspended material such as clay, silt, finely divided organic material, plankton, inorganic material and other microorganisms. It may impart a brown or other colour to water bodies and may interfere with light penetration and photosynthetic reaction in stream and lake.

Turbidity is an indication of the clarity of a water; is as an optical property; presence of colloidal particles. The colloidal material which exert turbidity they may be harmful or cause undesirable testes and odour. Disinfection of turbid water is difficult because of adsorptive characteristic some colloid and the solids may partially shield organism from disinfectant. Turbidity can indicate that water may be contaminated with pathogens presenting human health concerns (Olson, 2004).

4.2.5. Total dissolved solids (TDS)

The mean concentration of total dissolved solids (TDS) ranged 513.00±45.77 up to 755.25±162.70 (Table 3). The highest mean concentration (755.25±162.70 mg/l) was recorded at site 3(S3) and the lowest (513.00±45.77 mg/l) at site 5 (S5).Among sites the average TDS recorded was significantly different at S3 (TDS) ;(P=0.007) than the rest of study sites. However among two weeks based interval there was no significant deference recorded (TDS); (P=0.756) (Table 9). Except for S3 in all the sites downward streams along the channel the concentration of TDS was in declining. The mean concentration of total dissolved solid (TDS), (513.00±45.77 - 755.25±162.70 mg/l) was higher than the provisional discharge limits set by the World Band Group (WBG, 2006), World Health Organization (WHO, 2003) and Environmental Protection Authority (EPA, 2003) (Table 1). Total dissolved solids refer to the filterable residue that pass through a standard filter disk and remain after evaporation and drying to constant weight at 103-1050 ^{0}C. Total Dissolved solid (TDS) includes those materials dissolved in the water, such as, bicarbonate, sulphate, phosphate, nitrate, calcium, magnesium, sodium, organic ions, and other ions. These ions are important in sustaining aquatic life. However, high concentrations can result in damage to organism's cell (Mitchell and Stapp, 1992). TDS can be naturally present in water or the result of mining, oil and gas drilling, or some industrial or municipal treatment of water (Pennsylvania State, 2010) Some dissolved solids come from organic source such as leaves, silt, plankton, and industrial waste and sewage (APHA, 1996). Dissolved solids in freshwater samples include soluble salts that yield ions such as calcium, chloride, bicarbonate, nitrates, phosphates, and iron. The correct balance of dissolved solids in the water is essential to the health of aquatic organisms for several reasons. One reason is that many of these dissolved materials are essential nutrients for the general health of aquatic organisms. Another reason is that the transport of ions through cellular membranes is dependent on the total ionic strength of the water. Too many dissolved salts in the water can dehydrate aquatic organisms. Too few dissolved salts, however, can limit the growth of aquatic organisms that depend on them as nutrients www.epa.gov/OW/resources. High concentrations of dissolved solids can lead to unpleasant taste and laxative effects in drinking water (other effects may be: reduced water clarity, decrease in photosynthesis, binding with toxic compounds and heavy metals, and increased water temperature through greater absorption of sunlight) (Flint River,2011).

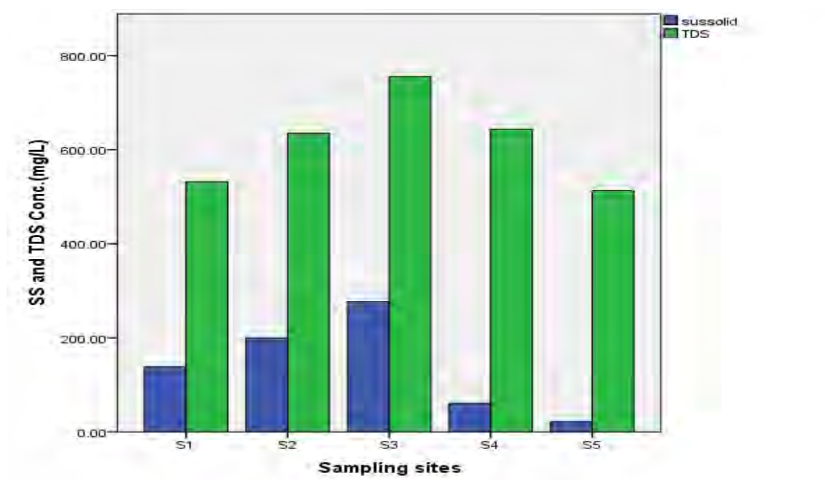

Fig- 5 Mean Concentration of TSS and TDS downstream municipal wastewater of Hawassa city

4.2.6. Total suspended solids (TSS)

The maximum TSS concentration mean value was within ranges (21.75±23.89mg/l up to 276.75±109.76) (Table 3) (Fig: 6).The highest mean value was at S3 while the lowest mean concentration was at S5 (on lake Hawassa).The mean TSS measures were significant different among the sample sites (TSS) ;(P=0.001) .Among two weeks based interval (TSS) was not significant difference (P= 0.829) (Table 9). The mean concentration of total sespended solid (TSS), was higher than the provisional discharge limits set by the World Band Group (2006), World Health Organization (WHO 2003).Suspended solids are the term used to describe particles in the water column. Practically, they are defined as particles large enough to not pass through the filter used to separate them from the water. An increase in water flow or a decrease in stream-bank vegetation can speed up the process of soil erosion and contribute to the levels of suspended particles such as clay and silt.

Suspended solid (SS) can come from silt, decaying plant and animals, industrial wastes, sewage, etc. They have particular relevance for aquatic organisms that are dependent on solar radiation and those whose life forms are sensitive to deposition. High concentrations have several negative effects, such as decreasing the amount of light that can penetrate the water, thereby slowing photosynthetic processes which in turn can lower the production of dissolved oxygen; high absorption of heat from sunlight, thus increasing the temperature which can result to lower oxygen level; low visibility which will affect the fish' ability to hunt for food; clog fish' gills; prevent development of egg and larva; decrease the effectiveness of drinking water disinfection agents by allowing microorganisms to "hide" from disinfectants within solid aggregates. Natural movements and migrations of aquatic populations may be disrupted. It can also be an indicator of higher concentration of bacteria, nutrients and pollutants in the water (Tarazona and Munoz, 1995).

4.2.7. Biological oxygen Demand (BOD_5)

The maximum concentration of BOD5 was recorded at S3 (26.97±3.56 mg/l) and the minimum value was recorded at S5 on Lake Hawassa (6.03±1.74mg/l) (Table 3) (Fig: 6).There was BOD5; P=0.00 significant deference recorded among sites. Among the two weeks based interval there was no significant deference recorded (BOD5); (P=0.892). In this study, the concentration of BOD_5 was above the standard levels of 10 mg/l of the effluent quality discharged in to the lake (Table 8). The high levels of BOD are indications of the pollution strength of the wastewaters. They also indicate that there could be low oxygen available for living organisms in the wastewater when utilizing the organic matter present. Biological Oxygen Demand (BOD) is a measure of the oxygen used by microorganisms to decompose organic compounds in a liter of wastewater (U.S. EPA, 2002). Natural sources of BOD in surface water include organic material from decaying plants and animal waste. Human sources of BOD include faeces, urine, detergents, fat, oils and grease. The discharge of waste with high level of BOD can cause water quality problems such as sever dissolved oxygen depilation and fish kill in receiving water bodies (Micheal et al., 2001). If excess biodegradable C finds its way to surface or groundwater it can result in low dissolved oxygen concentrations in water and create taste and odor problems (U.S. EPA, 2002). Direct discharge of untreated domestic waste into the water bodies was responsible for the high organic pollution, and led to very high BOD and COD values in the upstream sites, which were gradually reduced in the downstream sites (Usharani et al., 2010). So that discharging of those effluents to lake would be harmful for sustaining aquatic life.

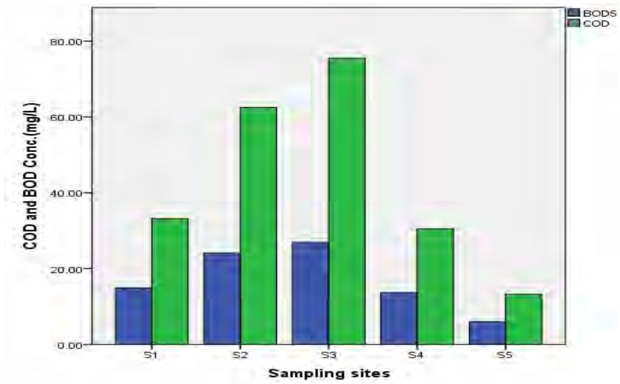

Fig- 6 Mean Concentration of COD and BOD_5 downstream municipal wastewater of Hawassa city.

4.2.8. Chemical oxygen Demand (COD)

The pollution profiles for COD along wastewater channel downstream ranged from (13.28±2.00–75.48±3.48mg/l) (Table 3) (Fig: 6).The maximum concentration of COD was recorded at S3 (75.48±3.48mg/l) and the minimum value was recorded at S5 on Lake Hawassa (13.28±2.00 mg/l).There was BOD5; P=0.00 significant deference recorded among sites. Among fifteen day interval there was no significant deference recorded (BOD5) ;(P=0.988). The concentration of BOD_5 was lower than standard levels of 100 mg/L of wastewater acceptable for discharging in to Lake Water (Table 8). High COD levels imply toxic condition and the presence of biologically resistant organic substances (Sawyer and McCarty, 1978). COD is the measure of the amount of oxygen in water or wastewater consumed for chemical oxidation of pollutants. Chemical oxygen demand (COD) does not differentiate between biologically available and inert organic matter, and it is a measure of the total quantity of oxygen required to oxidize all organic material into carbon dioxide and water. COD values are always greater than BOD values, but COD measurements can be made in a few hours while BOD measurements take five days (Barnes et al., 1998).Basically, municipal wastewater contains high level of Chemical Oxygen Demand (COD) and Total Suspended Solid (TSS). This high level of Chemical

Oxygen Demand (COD) results low Dissolve Oxygen (DO) in water and this can lead to mortality of aquatic live. In addition, suspended solid such as organic and inorganic material can cause dirt and odor to the water (Muhammad, 2009). According to Rehm *et al*., (1999), the COD-BOD ratio is an important value in determining the biodegradability of the pollutants in wastewater. Accordingly, if the ratio is <2, the load is considered easily biodegradable (Rehm *et al.,* 1999). Since the ratio of COD-BOD at the highest concentration (75/26) (Table 6) was >2.5, the pollutant load was not easily biodegradable which results in higher COD than BOD values.

4.2.9. Phosphate (PO_4^{-3})

The maximum phosphate concentration was recorded at S3 (4.20±0.14 mg/l), where as the minimum concentration was from S5 (0.34±0. 06 mg/l) (Table 3) (Fig 7). The records of Statistical analysis (ANOVA) showed that in present study phosphate concentration at S3 was significantly higher than the phosphate concentration recorded from other study sites of Hawassa city municipal waste water (PO_4^{-3})(P=0.000). Among the two weeks interval pH (P=0.893) was not statistically different. TUKY-HSD tests demonstrated that there was not statistically significantly difference for all the four rounds, so the variation was significant at the site than the two weeks based interval.

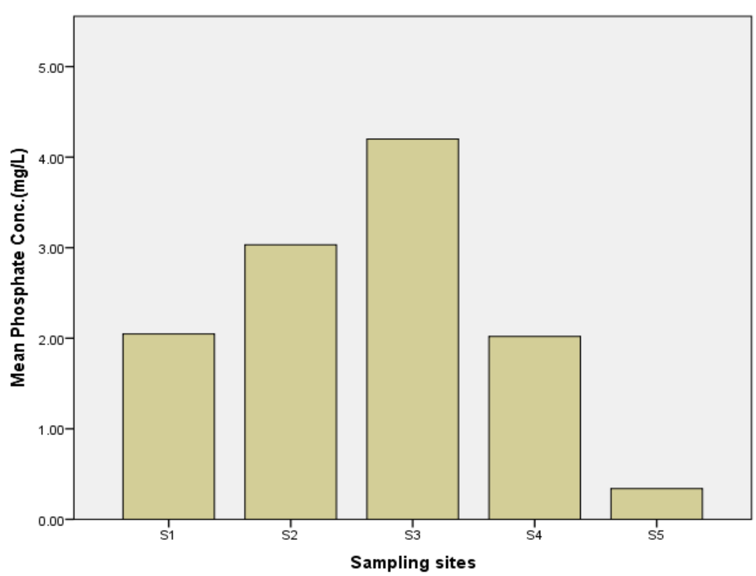

Fig-7 Mean PO_4^{-3} Concentration of municipal wastewater of Hawassa city

Both WHO and World Bank Group suggested that the limit value of PO_4^{-3}should be less than 1mg/l to keep drinking water and other water body from eutrophication. But in the present study at S1, S2, S3 and S4 the value were by far higher than the recommended value (Table 1).This indicates that the level of phosphate concentration due to its concentration at municipal wastewater of Hawassa city relatively significant indicating that disposal of phosphate from domestic and industrial sewage as washing powder, intensive rearing of livestock and the use of phosphate containing particles is very high. This therefore means that the effluent, basing on results of phosphorus content which is the limiting factor to eutrophication has significant adverse effects on the receiving lake. Eutrophication is one of fresh water impairment caused by high $PO_4^{-3}$and NO_3-N. Thus, they can have significant environmental impacts such as algal blooms and can restricting the use of water bodies for purposes such as recreation or drinking water for human and animal use. Deterioration of water quality and eutrophication are due to human activities include bethinks, washing of clothes, vehicles and household utensils. Rain, surface water runoff, agriculture run off; washer man activity could have also contributed to the inorganic phosphate content. Sources of phosphorus include certain soils and bedrocks, wastewater and domestic phosphate based detergents, human and animal wastes, decomposing plants, and runoff from fertilized lawns and cropland (Morrison *et al*., 2001).

4.2.10. Ammonia (NH_3-N)

The maximum average concentration of total nitrogen (32.75±2.75mg/l) was recorded at site 3 and the lowest TN was recorded at S5 (10.00±1.63mg/l) which was higher than the WHO (2003) standards set emission limit value 10 mg/l,(Table 1). The mean TN measures of S3 were significantly higher than the TN measures of the rest of sample sites (Fig: 8). (TN); (P=0.000) (Table 4).Among the two weeks based interval the average TN recorded was not significantly different (TN);(P=0.993) (Table 7). High concentration of total nitrogen could indicate pollution of a water body that is rapidly converted to ammonia. Ammonia and total nitrogen in wastewater results from the breakdown of proteins and amino acids in organic waste (Pressley et al., 1972). Ammonia exerts an oxygen demand in receiving waters, which can depress or deplete dissolved oxygen, impacting the aquatic ecosystem. Ammonia can also contribute to eutrophication and can be toxic to sensitive aquatic biota (Constantine, 2006; Ramisetty, 1999).The levels of ammonia N in municipal wastewater of Hawassa city was in the range of (0.52±0.25–4.39±0.99 mg/l) (Table 1) (Fig: 8) and was below the standard discharge limit (EPA, 2003), 20 mg/l (Table 1). Due to its toxicity to aquatic biota including fisheries, the European Union has set a safe limit of 0.005–0.025 mg NH_3-N mg/l (Chapman, 1996). Ammonia, formed only at high pH values (pH>8.5), is extremely toxic to fish and other aquatic life at high concentration (>2mg/l) (Berenzen *et al*., 2001; Källqvist and Svenson, 2002).Ammonia is much more toxic in alkaline water than acidic. One of the reasons for the bad odour that can be sensed along the lake courses during the field sampling could be due to presence of ammonium.

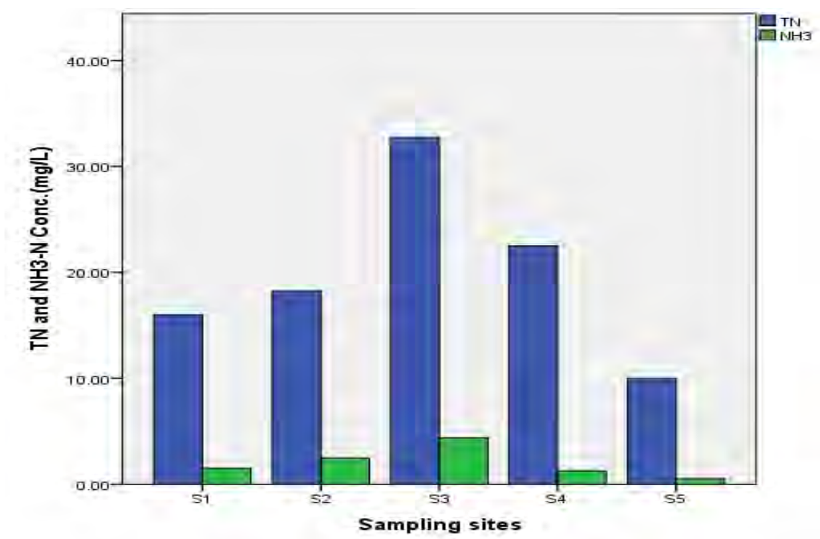

Fig- 8 Mean of TN and Ammonia downstream municipal wastewater of Hawassa city

4.2.11. Nitrate-Nitrogen (NO_3-N)

The maximum mean nitrate- nitrogen concentration (3.77±0.34mg/l) was recorded at S3.The minimum concentration was recorded at S5 (0.41±0.25mg/l).There was a significant difference between the mean nitrate nitrogen concentration of the study sites (NO_3^{-}N); (P=0.00). The pattern of NO_3^{-}N in the down steam sites a general decline from S3 to S5.There was no significant difference in nitrate nitrogen among the two weeks based sampling interval ;(P=0.814). In this study, the concentration of nitrate was lower than the standard levels of the effluent quality discharged in to surface water bodies (Table 1).

The mean nitrite nitrogen concentration ranged between 0.11±0.15mg/L to 0.27±0.17 mg/l. The highest concentration was measured at site 1while the lowest concentration was observed at site 5. The NO_2^- values were not significantly different (P=0.668) among the five sampling sites.

The amount of NO_3 - N is increased in the impaired sites S3 where human swage and fish carcass disposal were identified. Major contributors of nitrate are chemical fertilizers from cultivated land and drainage, from livestock feedlots, as well as domestic waste and some industrial waters in the course of leakage. www.realtechwater.com. Sources of nitrate contamination include fertilizers, animal wastes, septic tanks, municipal sewage treatment systems, and decaying plant debris (R. C. Jagessar & L. Sooknundun, 2011).

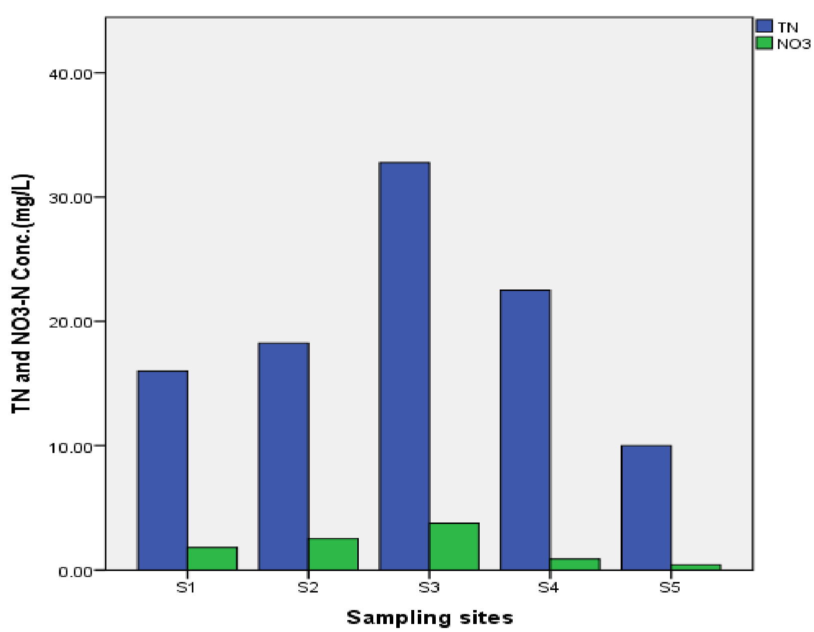

Fig- 9 Mean Concentration of Total Nitrogen and Nitrates downstream municipal wastewater of Hawassa city

Nitrogen is generally the limiting factor for algae growth in coastal waters. Thus, excess nitrogen, primarily in the form of nitrates, can cause the stimulation of plant growth, resulting in algal blooms or overgrowth of aquatic plants, which can have serious consequences for the receiving water such as odours, accumulation of unsightly biomass, dissolved oxygen depletion due to biomass decay, and loss of fish and shellfish.

(Washington State Department of Health, 2005).Nitrate N is an oxidized, inorganic form of nitrogen in water. Nitrogen is a necessary nutrient for plant growth. Too much phosphorus and nitrogen in surface waters contributes to nutrient enrichment, increasing aquatic plant growth and changing the types of plants and animals that live in a stream (Sisay Misganaw Tamiru, 2007). Nitrogen-containing compounds released into environment can create serious problems, such as eutrophication of rivers, deterioration of water quality and potential hazard to human health, because nitrate in the gastrointestinal tract can be reduced to nitrite ions. In addition, nitrate and nitrite have the potential to form N-nitrous compounds, which are potent carcinogens (Forman, 1991).

4.2.12. Chloride (Cl^-)

The values of chlorides range from 12.44±4.14 to 18.58±14.88mg/l. The maximum value (18.58±14.88mg/l) was recorded in the sites 3 and minimum value (12.44±4.14mg/l) in the S4. The mean concentration of Chloride (Cl^-), (21.75±23.89mg/l - 276.75±109.76) (Table 3) was lower than for drinking water set by the World Band Group (2008) and (QSAE, 2001) (Table 4). Umavathi et al (2007) showed that higher concentration of chloride is association with increased level of pollution. Chlorides are a salt compound resulting from the combination of Chlorine gases and metals which are found in the water bodies in varying amounts. However, their concentrations are significantly low. However, the industrial, domestic and agricultural wastewaters that are generated from the human society may contain large amount of chlorides, which can cause significant disruption in the ecological balance. The common chloride salts include Sodium Chloride (NaCl), and Magnesium Chloride ($MgCl_2$). The major impact that chlorides impart on the receiving waters is the permanent hardness. They are also known to increase the rate of sedimentation and thereby decreasing the water column depth (Apte et al., 2011). Chloride is an aesthetic contaminant as it imparts a salty taste to water. The concentration of chloride in water is variable and dependent on the chemical composition of water. Normally, ground water has a lower concentration of chloride than surface water. With regard to wastewater, the Cl_2 concentration can be quite elevated due to industrial processes and the high levels of sodium chloride in the diet, which pass unchanged through the digestive system (Raquel et al. 2002).

4.2.13. Total hardness

In the present study the value of total hardness ranges from 49.50±14.46 to 292.75±438.21mg/l sites (Table 3).The maximum value (292.75±438.21mg/l) was recorded in the Site 3(S3)and minimum value (49.50±14.46 mg/l) in the Site1(S1). Hard water has high concentrations of Ca^{2+} and Mg^{2+} ions. These high values may be due to the addition of calcium and magnesium salts. Among sites total hardness (P=0.488) was not statistically different. The mean value of total hardness was lower than for drinking water quality set by the QSAE (Table 4). Hardness in water is defined as concentration of multivalent cations such as Ca^{2+} and Mg^{2+} expressed as calcium carbonate (V.Sivasubramanian et al., 2012). Hard water is not suitable for domestic use such as washing, bathing, cooking as well as other purpose. Hard water is also not suitable for industrial and agricultural use. It damages the delicate machineries and affects the quality, stability and glossiness of the final product (Patil et al., 2012).

Table 4.Average concentration of different parameters from Lake Hawassa and the standards set by QSAE, WHO and USEPA

Parameters	Concentration in Lake Hawassa	Ethiopian (QSAE, 2001) for drinking water	WHO (2008)) for drinking water	Standard set by USEPA (2002), for Lake water
PO_4^{-3}	0.34	-	-	0.01
EC	865	-	-	-
T^0	23	-	-	-
pH	8.31	6.5-8.5	6.5-8	
TDS	513	1000	-	-
TSS	21.75	-	-	
Turbidity	23.28	5	5	-
BOD_5	6.03	-	-	5
COD	13.28	-	-	-
NO_3^--N	0.41	50	50	13
NO_2^--N	0.11	3	3	-
NH_3-N	0.52	1.5	-	0.02-0.4
TN	10	-	-	0.5
Cl	18.50	250	250	-
TH	61.75	300	-	-

4.3. Comparison of the Physico-chemical Parameters of Lake Hawassa with Drinking Water and for Lake Water Quality Standards

The average concentration of ammonium, nitrate, total nitrogen, and phosphate in Lake Hawassa was 0.52 mg/l, 0.41 mg/l, 10 mg/l and 0.34 mg/l, respectively. Nitrate was found at lower concentration of the standard level. In a similar study, nitrate was also found at a lower concentration in Lake Hawassa and Lake Ziway (Simachew Dires, 2008). However, ammonium, total nitrogen, total phosphorous and phosphate in Lake Hawassa were above the standard limits of 0.02-0.04 mg/l, 0.5 mg/l, 0.02 mg/l and 0.01 mg/l, respectively (USEPA,2002). These higher levels of nutrients can be important contributors to the eutrophication of the Lake. Thus, they can have significant environmental impacts such as algal blooms and can restricting the use of water bodies for purposes such as recreation or drinking water for human and animal use. The mean concentration of BOD_5 and COD of Lake Hawassa was 6.03 mg/ and 13.28mg/, respectively. BOD_5 particularly found at higher than for lake water standards (Tabl4). This matter so that may cause adverse effect on aquatic organisms by depleting the dissolved oxygen of the water in the receiving lake.

The average mean value of Total Dissolved solids, Chloride and Total hardness of Lake Hawassa were 513 mg/l, 18.50 mg/l and 61.75mg/l respectively. The mean pH concentration of Lake Hawassa was 8.31 .The average concentration of turbidity was 23.28 NTU. Total Dissolved solids, Chloride and Total hardness in Lake Hawassa were lower than standard limits of 1000 mg/L, 250 mg/L and 300 mg/L, respectively (QSAE, 2001 ;WHO , 2008). pH value was within standards limits. As it can be seen from Table 4 turbidity does not comply with the (QSAE and WHO) drinking water standards (Table 4). This indicates that discharging such effluents devastate the receiving environment.

Table 5. Comparison of the mean value of physicochemical parameters in Lake Hawassa water with reported (Concentrations are in mg/l except for pH, temperature and conductivity)

Parameters	LakeHawassa (Present study)	Lake Hawassa Zenebe Yirgu (2011)	Tikur-wuha downstream river Birenesh Abay(2007)	Lake Hawassa Simachew Dires(2008)
PO_4^{-3}	0.34	-	2.14	0.3
EC	865	832.33	1749.22	866
T^0	23	22.53	22.96	25.4
pH	8.31	8.73	9.02	8.5
TDS	513	499.00	985.85	-
TSS	21.75	14.67	642.16	-
Turbidity	23.28	-	-	21
BOD_5	6.03	-	315.90	26.6
COD	13.28	-	1105.34	71
NO_3^--N	0.41	-	9.24	0.4
NO_2^--N	0.11	-	-	0.04
NH_{3-}-N	0.52	-	2.69	0.5
TN	10	-	29.62	3.8
Cl	18.50	-	-	-
TH	61.75	-	-	-

4.4. Comparison of the Physicochemical Parameters Lake Hawassa with Discharge Point and Reported Literature

Samples were collected at Lake Hawassa around Amora Gedel site (about 1km from point of Municipal waste water joining the Lake) to determine different physicochemical parameters. The samples were taken randomly around certain distances from which the municipal wastewater discharged in to the Lake in order to know its effect on the receiving lake. Collection of the samples was based on APHA (1996) guidelines of water and wastewater sampling techniques. The relative concentrations of pollutants in the Mouth of the channel on the Lake (intersection point where the municipal wastewater join the Lake) were presented in Table 3. It was observed that concentration of most of pollutants were highest at the discharge points (Figures 4, 5, 6, 7,8,9) due to the increased discharges of municipal wastewater and fall at On the Lake Awassa about 1km from point of Municipal waste water joining the Lake due to the assimilation and dilution effects of the Lake. This clearly showed that the municipal wastewater plays substantial role in deterioration of water quality of the corresponding Lake Hawassa. The sources of pollution in Lake Hawassa were through Tikur Wuha, agricultural activities, the Referral Hospital and direct discharge of municipal wastewater from different direction of Hawass city contribute pollutants to the Lake.

The comparisons of the present study with the previous studies of the same lake were compiled in Table 5. Table 5 except BOD_5 and COD, all the physicochemical parameters of the Lake Hawassa almost similar with the study done by Zenebe Yirgu (2011) and Simachew Dires (2008) (Table 5). The possible explanation of the variation in the concentrations of BOD_5 and COD between the previous study and present study could be due to the different season of study period. The mean pH concentration of Lake Hawassa was 8.31 (Table 5). The Lake is an alkaline lake with a pH range of 8.3-9.1 mean value is 8.5 $\pm$0.3 (Simachew Dires, 2008). The mean pH concentration along Tikur-Wuha downstream ranged from (8.4±0.2 -10.32±0.04) (Birenesh Abay, 2007). Similar studies on Lake Awassa and its feeders reported a pH of 12 that it is highly alkaline (Zerihun Desta**,** 1997), and (Seyoum *et al*., 2003) reported a pH value which ranged from 7.9±0.1- 9.5±0.5 mg/l. According to this study scored pH range was (7.36±0.52-8.31±0.28). This can show no significant effect on the overall biodiversity.

4.5 Correlations Analysis

The correlations among physicochemical parameters of the Municipal Wastewater of Hawassa city are presented in Table 6. Correlation coefficient (r) between any two parameters, x & y is calculated for parameter such as water temperature, pH, turbidity, electrical conductivity, total suspended solid, total dissolved solids, total hardness, chloride, phosphate, total nitrogen, ammonia, nitrate, nitrite, biological oxygen demand and chemical oxygen demand of the Municipal Wastewater of Hawassa city. The degree of line association between any two of the water quality parameters as measured by the simple correlation coefficient (r) is presented in table-6.

Table 6 Correlation Coefficient (r) among physic-chemical parameters of the Municipal Wastewater of Hawassa city

parameters	PO^{-4}	EC	Temp	PH	TDS	SS	turbidity	BOD5	COD	NO^{-3}	NO^{-2}	NH_3	TN	TH	C
po4	1														
EC	.637**	1													
Temp	-.230	-504	1												
PH	-.257	-.022	.024	1											
TDS	.605**	.214	.162	.049	1										
TSS	.769**	.546*	-.422	-.406	.437	1									
turbidity	.806**	.527**	-.428	-401	.356	.881**	1								
BOD 5	.827**	.409	-.061	-419	-622**	.770**	.767**	1							
COD	.900**	.597**	-.194	-393	637**	.840**	.818**	.917	1						
NO3	.794**	.375	.078	-440*	641**	.705**	.743**	.884**	.894**	1					
NO2	-.112	-398	.740**	-455*	.129	-204	-190	.056	-0-.063	.222	1				
NH3	.797**	.492*	-095	-.304	.632**	.743**	.759**	.789**	.883**	.917**	0.009	1			
TN	-.839**	.417	-.054	-078	.647**	.624*	.644**	.699**	.766**	.713	-010	.800**	1		
TH	.316	-108	.527	.019	.552	-047	.091	.422	.343	.537**	.391	.335	.296	1	
Cl	.076	-070	.020	.407	.323	-128	.036	.012	.039	.006	-.273	.021	-.047	.566**	1

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

No mark: not significant correlation
Correlation rating: >0.81= strong
0.81- 0.31= moderate
<0.31=weak

The temperature has shown the significant positive correlation with nitrite, not significant positive correlation with pH, chloride, total hardness, nitrate while negative correlation shown with the turbidity, TDS, TSS, electrical conductivity, BOD, COD and phosphate. The pH had shown not significant positive correlation with chloride, total hardness and TDS. Negative correlation was observed with the rest all parameters. The electrical conductivity showed significant positive correlation phosphate, TSS, turbidity, COD, ammonia and not significant positive correlation TDS, BOD, total nitrogen and nitrate. Negative correlation is with total hardness, chloride and total hardness. This indicate that changing in amount of phosphate, TSS, turbidity, COD, ammonia have caused significant positive change in conductivity value of these wastewater. The total hardness had shown the significant positive correlation with chloride and nitrate while negative correlation with total suspended solid and EC. TSS has significant strong positive correlation with COD, BOD and EC phosphate, total nitrogen, nitrate, ammonia. It has also moderate positive correlation with TDS. However, weak negative correlation with water temperature, pH, nitrite, total hardness and chloride. This is pointed out that increase in TSS led to an increment COD, BOD and EC. The chloride had shown significant positive correlation with total hardness while negative correlation shown with hardness total, nitrogen, ammonia, nitrite, EC and TSS. The phosphate had shown significant positive correlation with EC, TDS, TSS, turbidity, BOD, COD, nitrate and ammonia while negative correlation temperature, pH, nitrite and total nitrogen. The BOD had shown positive significant correlation with the phosphate, TSS, turbidity ,nitrate, ammonia and positive correlation with COD while negative correlation with temperature, TDS and pH. The COD had shown the significant positive correlation with the phosphate nitrate, total nitrogen, ammonia, turbidity, TSS, TDS, EC and strong correlation with BOD.

CHAPTER V

5. CONCLUSIONS AND RECOMANDATIONS

5.1 Conclusions

From the findings of the study, the following points are concluded Physico-chemical results from this study showed that most of the parameters measured were all above the provisional standards value set out by EPA,WHO, USEPA,WBG and QASE. Significant pollution of the municipal wastewater was indicated for TSS, TDS, BOD_5, total nitrogen, Ortho-phosphate, TSS, TDS, electrical conductivity and turbidity. While lower concentration of chloride and total hardness was recorded. The levels of pH and water temperature studied in municipal wastewater were within permissible limit. The discharges of this wastewater in to the Lake mean that the effluent presents significant risks of pollution to the lake water and ecological damage. The high phosphate level would be harmful to the immediate environment and the receiving water bodies; since it stimulates eutrophication it also has poisoning potential for aquatic life.

The pH of this study showed that the lake water was slightly alkaline which might have an effect on the availability of dissolved metals. Ammonia becomes more toxic to aquatic biota with only a slight increase in pH.

Directly discharging municipal wastewater into the Lake impairs the sustainable utilization of the Lake for different purposes. These facts must regularly be brought to public awareness in developing countries like Ethiopia where local people discharge their wastes directly into the environment without considering the ecological consequences. This can lead towards a devastating environmental condition, unless municipal wastewater is managed properly. Proper disposal of municipal wastewater is primarily necessary to safeguard the environment from heavy loads of pollutants and toxic substance.

Results of physicochemical measurements indicated that water quality of Lake Hawassa has affected by the release of the wastewater from the city that is the main threat for not only the lake's aquatic diversity but also human health around the lake.

5.2 Recommendations

For sustainable management of municipal wastewater, environmental protection agencies at different level and other concerned administrative and/or non governmental bodies should take strict as well as technical measures. Enforcement of law and propagating environmental education to the community with special target to those contributors of the present degradation could be one solution. Providing different advantage such as taxation, cooperative and market value for those solid waste and liquid waste treatment and good environmental management could be another option. To achieve these goals the following points could be considered.

1. It should be an urgent pre requisite to require Wetland construction and its design based up on the original wastewater characteristics as alternative wastewater treatment facility and take necessary action to change wastewater to environmentally friendly form before discharging it into Lake Hawassa.
2. The local people ,Hawassa university community and some tourists coming to the city are complaining because of offensive smell around Amora Gedel .So independent investigation will be needed as this problem ultimately touches biodiversity and human being as well; to confirm whether that caused by pollution or not the pollution that comes from the municipal wastewater channel or not.
3. The disposal of municipal wastewater of Hawass city should include proper design and proper regulation and approval of effluent management options, because the direct discharge of waste to the surface water (nearby Lake) requires regulatory testing and monitoring to meet the stringent local standards on pollution discharge limits of effluent set by National Environmental Standards of Quality standards Ethiopia (EEPA).
4. As it was observed that some people use the lake water for drinking and domestic purpose, drinking for cattle and for irrigation so the local community should be aware of the pollutants to keep the lake from being susceptible for chemical and toxic substances gradually.
5. The issue of wastewater is for the entire nation; as long as its impact can spread from the serious damage of small locality up to a big alteration of weather and

climate. Thus each and every body should participate, plan and act over it to keep his or her environment clean, neat and free from untreated wastes.

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ANNEX I. Characteristics of municipal wastewater of Hawassa city and the Lake water

Table 7 Physico-chemical Characteristics of Lake Hawassa

Parameters	Units	Mean value (n=4)
PO_4^{-3}	mg/l	0.34±0. 06
EC	µScm-1	865.00±66.73
T^0	^0C	23.00±2.71
pH	pH units	8.31±0.28
TDS	mg/l	513.00±45.77
TSS	mg/l	21.75±23.89
Turbidity	NTU	23.28±21.10
BOD_5	mg/l	6.03±1.74
COD	mg/l	13.28±2.00
NO_3^--N	mg/l	0.41±0.25
NO_2^--N	mg/l	0.11±0.15
NH_{3-}-N	mg/l	0.52±0.25
TN	mg/l	10.00±1.63
Cl	mg/l	18.50±3.16
TH	mg/l	61.75±47.05

Table 8

Physico-chemical Characteristics of Municipal Wastewater of Hawassa city and Quality of Wastewater acceptable for discharging in to Lake Water (USEPA, 2001)

Parameters	**Units**	**Mean value (n=3)** of MWWHC	**Standards By USEPA (2001)**
PO_4^{-3}	mg/l	3.09	5
EC	µScm-1	1219.42	-
T	^0C	21.81	-
pH	pH units	7.61	6.5-8.5
TDS	mg/l	640.67	-
TSS	mg/l	205.08	-
Turbidity	NTU	180.17	-
BOD_5	mg/l	22.02	10
COD	mg/l	57.05	100
NO_3^--N	mg/l	2.7	5
NO_2^--N	mg/l	0.19	-
NH_{3-}-N	mg/l	2.79	10
TN	mg/l	22.33	-
Cl	mg/l	15.29	-
TH	mg/l	166.67	-

Table 9.Physicochemical characteristics of Municipal wastewater of Awassa in fifteen day interval (Concentrations are in mg/l except for pH, temperature and conductivity) Mean value (n=5)

variable	Round 1	Round 2	Round 3	Round 4	P-value
PO_4^{-3}	2.09±1.51	2.07±1.49	2.68±1.50	2.47±1.48	0.893
EC	924.80±105.54	1057.20±121.37	1262.80±308.23	1246.60±378.18	0.157
T	25.54±0.82	21.00±0.94	20.64±0.67	21.36±0.42	0.000
pH	7.76±0.56	7.51±0.44	8.00±0.50	8.21±0.34	0.142
TDS	661.60±141.67	601.60±66.16	580.00±38.65	619.80±184.97	0.756
SS	73.20±48.16	183.60±140.65	129.80±83.98	171.40±146.60	0.426
Turbidity	88.20±58.63	135.79±12175	149.00±76.54	128.60±81.21	0.723
BOD_5	17.78±10.09	17.80±8.26367	14.53±7.70128	17.86±8.37	0.892
COD	40.04±24.44	45.79±25.29	42.85±25.09	43.22±27.15	0.988
NO_3^-	2.38±1.58	1.82±1.11	1.67±1.37	1.64±1.35	0.814
NO_2^-	0.38±0.08	0.18±0.09	0.08±0.048	0.08±0.051	0.000
NH_3	2.08±1.40	2.04±1.13	2.16±2.11	1.83±1.52	0.989
TN	20.40±7.40	19.80±9.91	20.40±9.40	19.00±7.78	0.993
Cl	15.25±13.67	13.94±7.34	16.99±2.46	15.28±2.98	0.945
Total hardness	344.00±366.43	61.40±17.97	49.00±18.92	55.80±13.12	0.057

ANNEX II. ANOVA ANLYSES RESULTS

Table 10: One-Way ANOVA for multiple comparisons of municipal wastewater of Hawassa city among sites

		Sum of Squares	df	Mean Square	F	Sig.
PO^{-4}	Between Groups	32.506	4	8.126	26.698	.000
	Within Groups	4.566	15	.304		
	Total	37.071	19			
EC	Between Groups	469090.300	4	117272.575	1.797	.182
	Within Groups	978658.250	15	65243.883		
	Total	1447748.550	19			
Temp	Between Groups	4.908	4	1.227	.223	.921
	Within Groups	82.378	15			
	Total	87.286	19	5.492		
pH	Between Groups	2.748	4	.687	4.924	.010
	Within Groups	2.093	15	.140		
	Total	4.841	19			
pH	Between Groups	152913.500	4	38228.375	5.435	0.007
	Within Groups	105512.250	15	7034.150		
	Total	258425.750	19			
SS	Between Groups	170297.000	4	42574.250	9.182	.001
	Within Groups	69552.000	15	4636.800		
	Total	239849.000	19			
Turb	Between Groups	106396.170	4	26599.042	14.915	.000
	Within Groups	26750.165	15	1783.344		
	Total	133146.335	19			
BOD5	Between Groups	1142.754	4	285.689	31.416	.000
	Within Groups	136.404	15	9.094		
	Total	1279.158	19			

COD	Between Groups Within Groups Total	10288.816 207.041 10495.857	4 15 19	2572.204 13.803	186.355	.000
NO_3-N	Between Groups Within Groups Total	28.523 2.930 31.453	4 15 19	7.131 .195	36.512	.000
NO_2-N	Between Groups Within Groups Total	.054 .339 .394	4 15 19	.014 .023	.601	.668
NH_3-N	Between Groups Within Groups Total	35.605 4.652 40.257	4 15 19	8.901 .310	28.699	.000
TN	Between Groups Within Groups Total	1151.300 62.500 1213.800	4 15 19	287.825 4.167	69.078	.000

DECLARATION

I hereby declare that the work which is being presented in this thesis “**Assessment of Downstream Pollution Profile of Hawassa city and Its Influence on Lake Hawassa** ’’ is original work of my own ,has not been presented for degree of any other university an all the resource of materials used for this thesis have been duly acknowledge .

______________________ ______________________ ____________________

Temesgen Tarekegn Signature Date
(Candidate)

This thesis is presented under the supervision of advisors:

Prof. H.S.Patil , Signature: - --------------------- Date: - ----------------

PLACE AND DATE OF SUBMISSION:

Centre for the Environmental Science, Addis Ababa University

March, 2015