# BIOLOGICAL AND PHYSICOCHEMICAL WATER QUALITY PROFILE OF LAKE ADDELE, EASTERN HARARGHE DISTRICT OROMIYA, ETHIOPIA

**MSc THESIS**

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**MASTER OF SCIENCE IN BIOTECHNOLOGY**

**Genawork Molla Godebo**

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## HARAMAYA UNIVERSITY

## POSTGRADUATE PROGRAM DIRECTORATE

I hereby certify that we have read and evaluated this thesis prepared, under our guidance, by **Genawork Molla**, titled ***"Biological and physicochemical water quality profile of lake Addele, Eastern Hararghe Oromiya, Ethiopia."*.** We recommend that it be submitted as fulfilling all the thesis requirements.

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I dedicate this thesis to my family for helping me during the study with love and hospitality, and for their dedicated partnership in the success of my life.

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By my signature below, I declare and affirm that this Thesis is my own work.I have followed all ethical and technical principles of scholarship in the preparation, data collection, data analysis and compilation of this Thesis. Any scholarly matter that is included in the Thesis has been given recognition through citation.

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## ABBRIVATION AND ACRYNOMS

| | |
|---|---|
| BOD | Biochemical Oxygen Demand |
| COD | Chemical Oxygen Demand |
| DO | Dissolved Oxygen |
| DIW | Deionozed water |
| EC | Electrical Conductivity |
| EPA | Environmental Protection Authority |
| FAAS | Flame Atomic Absorption Spectrometer |
| FAO | Food and Agricultural Organization |
| E | Evennes |
| H | Shannon weaver diversity index |
| Hmax | Richness of taxa |
| IDL | Instrumental Detection Limit |
| MDL | Method of Detection Limit |
| SPSS | Statistical Package for Social Sciences |
| TDS | Total Dissolved Solids |
| TSS | Total Suspended Solids |
| UNEP | United Nations Environmental Program |
| USFDA | United States Food and Drug Adminstration |
| USEPA | United States Environmental Protection Agency |
| SD | Standard Deviation |
| WHO | World Health Organization |
| WQI | Water Quality Index |

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**BIOLOGICAL AND PHYSICO CHEMICAL WATER QUALITY PROFILE OF LAKE ADDELE, EASTERN HARAREGHE DISTRICT OROMIYA, ETHIOPIA**

***ABSTRACT***

*Freshwater ecosystems harbour a considerable proportion of Earth's biodiversity, even though they cover < 2 % of the land surface. Lakes are one of humanity's most important resources,where they are viewed as highly productive biological systems.The availability of good quality water is the major factor for preventing diseases and improving quality of life. In the present study the physicochemical parameters and the occurrence of three heavy metals in the tissues of fish specimens, Catfish (Clarias garpiens) and Tilapia (Oreochromis niloticus) and in the water samples as well as benthic macro-invertbrates were investigated. The water, fishes and Benthic macro invertbrateMIs samples were collected from Lake Addele at three selected sampling sites namely, in the road side, middle part and slant part (the hilly side) of the lake. The concentrations of selected heavy metals such as zinc (Zn), cadmium (Cd) and lead (Pb) in water samples and their accumulations in the edible tissues of fish samples were determined using Flame Atomic Absorption Spectrophotometery.The phosphate and nitrate were determined using UV specrophoto meter.The BMIs were identified by referring the standard species identification key for invertebrates. The results revealed that the dissolved heavy metals concentration in water samples were in the range of 4.10 to 5.62 mg/L for zinc (Zn), 0.096 mg/L 0.17 to for cadmium (Cd), 1.43 to 2.84 mg/L for lead (Pb) in both dry and wet seasons.The highest concentration of zinc, cadmium and lead in water samples were recorded during the dry season. The concentration of the same heavy metals in fish samples ranged between 0.03 to 0.082 mg/L for cadmium (Cd), 0.20 to 2.2 mg/L for lead (Pb) and 0.024 to 3.43 mg/L for zinc (Zn) in both fish species. Among the detected metals, zinc (Zn) showed the maximum bioaccumulation in fish samples.The measured values of physicochemical parameters of water samples ranged with respect to temperature from 19-22.8$^{o}$C, pH 8.16-8.72, biological oxgen demand (BOD) 15- 24 mg/L, the chemical oxgen demand (COD) 130- 190 mg/L, dissolved oxgen (DO) 2.26 - 5.76 mgL, electrical conductivity (EC) 279 - 639µs/cm, nitrate 2.86 - 5.09 mg/L and phosphate 0.211 - 1.35 mg/L. The results of diversity of BMIs, the Shannon Weaver index (H) values ranged from 0.469 - 0.491, the taxa richness (E) values ranged* from *0.1262 - 0.1322,and the taxa evenness Hmax values ranged 3.71 - 3.91 during the dry and wet seasons. The concentrations of the studied heavy metals in water and fish samples were above the recommended limit by WHO and FAO. Thus, regular monitoring of the lake is needed by using essential biological and physico-chemical parameters.*

***Key words*****:** Benthic macroinvertbrate, Fish, Heavy metals, Lake Addele,Physicochemical.

# 1. INTRODUCTION

Freshwater environments are subjected to increasing degradation. In addition to the extensive range of natural stresses encountered by organisms in their habitats, human activities can generate other environmental stresses. Such harmful alteration, disruption, or destruction of freshwater environments could become irreversible (Christian and Fernando, 2014). Improving our understanding of freshwater ecology is therefore very important not only because of its biological implications, but also because the proper management of freshwater is of practical interest to mankind.

Among the fresh waters, only about 5% of them or 0.15% of the total world waters are readily available for beneficial use (Sandeep *et al*., 2011 ; Chidambaram *et al.*, 2010) and from these lakes hold 100 000 $km^3$ of fresh water (90%) of earth's liquid surface total water. Ethiopia has 199.3 billion cubic meters (BCM) potential of surface water and 185.6 BCM of groundwater as a reserve (Tamiru, 2006). Due to increasing population growth, human water demand for domestic, industrial and agricultural purposes to supply adequate food for the nation is increasing (UNDP, 2006) and water becoming a scarce commodity in most part of the world. In the world, peoples living under water-stressed condition are ranges from 1.4 billion to 2.1 billion (Arnell *et al.*, 2004).

The availability of good quality water is a necessary feature for preventing diseases and improving quality of life (Oluduro and Aderiye, 2007).Water is a necessary element for endurance of living on earth, which contains minerals, essential for humans as well as for earth and aquatic life (Versari *et al.,* 2002). Lakes have long been at the centre of human attention. Several cities, industrial infrastructures and agriculture complexes have been built up in the vicinity of rivers and other water bodies.

Development of human communities and increase in irresponsible use of water resources has deteriorated river and lake water qualities (Sanchez, E ; Manuiel, F. 2007). Population growth and pollution caused by toxic waste water, surface water runoffs from municipal, industrial and agricultural sources have increased pollution load and further limited healthy water resources (Siemonov, 2003) and surface water quality management. Bearing the idea in mind it is inevitable to understand quality of surface water for various purposes such as use for drinking, industries and agriculture.

Water is the most important natural resource and is essential for survival and the development of modern technology (Wong *et al*., 2001; Ashraf, 2005 and Gad, 2009). Due to population growth water pollution is a serious environmental problem in the world. Pollution describes the introduction of foreign substances into biosphere. Some of these pollutants find their way into the human system through the food chain (Saleh *et al.,* 2010). Pollution of the aquatic environment has been considered a major threat to the aquatic organisms. The agricultural water containing pesticides, fertilizers and runoffs in addition to sewage. Effluents supply the water bodies and sediments with huge quantities of heavy metals (ECDG, 2002). The pollution caused by heavy metals might have dreadful effects on the ecological equilibrium and a variety of aquatic entities (Akinmoladun *et al.,* 2007, and 2006)

Freshwater environments can be monitored by physical, chemical, and biological parameters. Biological parameters integrate information over longer periods of time and better represent the responses of aquatic habitats making biotic monitoring indices excellent tools for the sustainable management of water resources. Literature reviews of running water assessments based on biological indicators identify at least 100 indices developed over the past ten years, of which about 60% are based on macro invertebrates, more than any other group of freshwater organisms. Despite a wide range of adaptations, certain macro invertebrate taxa can serve as indicators of environmental conditions. Several groups of aquatic insects are among the organisms that are extensively used for monitoring aquatic ecosystems (Christian and Fernando, 2014).

Heavy metal pollution of aquatic environment have become a great concern and they are very harmful as a result of their non-biodegradable nature and their potential to accumulate in different body parts of organisms. They can also be concentrated along the food chain, producing their toxic effect at points after removed from the source of pollution. Thus compared to other types of aquatic pollution, heavy metal pollution is less visible but its effects on the ecosystem and humans can be intensive and very extensive (Edem *et al*., 2008).

Physicochemical and biological water quality indicators will be affected by various ways. The main causes for water quality deterioration are anthropogenic and natural agents (Chaterjee and Raziuddin, 2002). Some of the natural and human induced factors which affect the quality of water for various purposes are geology, hydrology, natural hazards, sedimentation/erosion, agricultural activities, industrial, mining, fishing, sewage discharging/disposal, deforestation, and other commercial activities. These activities aggravate the pollution of water body and greatly influence the quality of water (Zinabu, 2002; Tamiru, 2006)

Monitoring and control of surface water is critical to guaranty high quality water for various applications (Bollinger *et al*., 1999). Lakes and surface water reservoirs are the planet's most important freshwater resources and provide numerous benefits and used for domestic and irrigation purposes, and provide ecosystems for aquatic life especially fish, in that way functioning as a source of essential protein, and for significant elements of the world's biological diversity. They have important social and economic benefits as a result of tourism and recreation, and are culturally and aesthetically important for people throughout the world. They also play an equally important role in flood control (An *et al*., 2002).

However, the remarkable increase in population resulted in a considerable consumption of the water reserves worldwide (Ho *et al*., 2003). The quality of surface water is mainly affected by natural processes (weathering and soil erosion) as well as anthropogenic inputs (municipal and industrial wastewater discharge). United State National Sanitation Foundation (UNNSF) has proposed nine factors including dissolved oxygen (DO), Fecal Coliforms, Biological Oxygen Demand (BOD), pH, water temperature ($^0$C), Phosphate, Nitrate, total Suspended Solids (TSS) and turbidity which are suitable for use in temperate regions for WQI assessment (Princy *et al*, 1999). The index uses water properties as measurable quality values to calculate total water quality index (Qram, 2010, Brown *et al.,*1970).

According to Galadima *et al*. (2011) the common sources of water that are available to local communities in Nigeria are fast being severed by a number of anthropogenic factors, of which Pollution remains the most dominant problem. Agriculture, as a major cause of degradation of surface and groundwater resources through erosion and chemical runoff, has caused a serious concern the global implications of water quality.

Several researchers have worked in the study area both at regional and local levels in the past. Most of previous works focused on the hydrogeology, lake level and land use changes. The other works in relation to groundwater system analysis were done by

Wakgari Furi (2005), Geletu Belay (2006) . These studies demonstrated the groundwater flow system and model based groundwater flow system analysis which is believed to be important for the groundwater management. Abdulaziz Mohamed (2006) tried to estimate the groundwater recharge based on conventional water balance approach. Characterization of aquifers based on the various hydraulic parameters and the suitability of groundwater both in quality and productivity have been described by Nata *et al.* (2010).

The previous works had their own limitations and didn't provide any comprehensible ideas with respect to the biological profile of water quality. Most of the previous studies were not detailed and did not focus on the chemical profile. Therefore, this study was intiated to obtain some clear ideas with regards to the afore-mentioned problems and other related aspects of the lake.

**General Objective**

To assess the biological and the physico-chemical quality of water samples of Lake Addele,eastern Ethiopia.

**Specific Objectives**

- To describe the physical properties of Lake Addele water.
- To determine the chemical profile of the water samples of Lake Addele.
- To determine the selected heavy metals ( Cd, Zn and Pb) concentrations in the water and Fish samples of Lake Addele.
- To asses the benthic macro-invertebrate species diversity and distribution in Lake Addele.

# 2. LITERATURE REVIEW

## 2.1. Environmental Pollution

The worst industrial accident in the world occurred in 1984 in a pesticide plant in Bhopal, India, where 200,000 people were exposed to methyl isocyanate. The gas leak and explosion at the plant caused more than 6,000 deaths, and another 50,000 people suffered long-term health effects (Dhara *et al*. 2002). Exposures to ambient air pollution, toxic chemicals, and pesticides generally have been problems that cause disease in high-income countries (HICs). Was the Bhopal disaster an anomaly? Or was it an early indicator of an emerging global pattern in which environmental pollution and toxic chemicals are becoming a greater source of health risk in low- and middle-income countries (LMICs).

In the past decade, with the globalization of trade, the spread of the Western life style and the increasing globalization of the chemical manufacturing industry, toxic chemicals, highly hazardous pesticides, and chemical wastes, which previously were found only in developed countries, have been infiltrating LMICs with increasing rapidity (Spitz, 2003). The manufacture and use of chemicals are shifting to LMICs, where labour costs are low and environmental and public health protections are few (Cole and Eliott 2005; Cole, *et al*. 2010; Cole, 2004; Kearsley and Riddel, 2010). Chemical and pesticide pollution are increasing in LMICs, and hazardous wastes, including electronic waste, are accumulating (Grant 2014; Heacock *et al*., 2015; Luzardo *et al.* 2014 and Perkins *et al*. 2014). At the same time, pollution-related chronic diseases such as asthma, heart disease, stroke, and cancer are becoming epidemic in countries where they were previously seldom seen (De Maio, 2011; Kelly *et al*., 2012; Landrigan and Fuller, 2014; Lim *et al*., 2012 and Murray *et al.,* 2015). The once separate patterns of disease in LMICs and HICs are converging (Dhara *et al*. 2002).Water pollution is a major global problem which requires ongoing evaluation and revision of water resource policy at all levels (international down to individual aquifers and wells). It has been suggested that it is the leading worldwide cause of deaths and diseases and that it accounts for the deaths of more than 14,000 people daily (West, 2006 and Pink, 2006).

Freshwater environments are subjected to increasing degradation. In addition to the extensive range of natural stresses encountered by organisms in their habitats, human activities can generate other environmental stresses. Such harmful alteration, disruption, or destruction of freshwater environments could become irreversible (Christian and Fernando, 2014). Among the fresh waters, only about 5% of them or 0.15% of the total world waters are readily available for beneficial use (Sandeep *et al.*, 2011 and Chidambaram *et al.*, 2010) and from these lakes hold 100 000 $km^3$ of fresh water (90%) of earth's liquid surface total water. Ethiopia has 199.3 potential surface water and 185.6 (billion cubic meters) groundwater as a reserve (Tamiru, 2006) Due to increasing population growth, human water demand for domestic, industrial and agricultural purposes to supply adequate food for the nation is increasing (UNDP, 2006) and water becoming a scarce commodity in most part of the world.

### 2.1.1. Toxic Chemicals and Pesticides

Toxic chemicals and pesticides have long been important environmental pollutants in HICs, and thousands of these substances have been disseminated widely into the environment over the past century (Fischetti, 2010). This long-standing concentration of toxic synthetic chemicals in the environment in HICs reflects the geographic origins of the chemical manufacturing industry, which began in Western Europe in the late 19th and early 20th centuries and then spread in the $20^{th}$ century to North America, Japan, and Australia (Aftalion, 2001). Many of the synthetic chemicals in widest use in these countries have never undergone any safety testing, and their potential toxicity is not known (Landrigan and Goldman 2011). Only about 20% have been screened for developmental toxicity (Goldman, 1998).

Scientists know even less about the possible synergistic effects of simultaneous exposures to multiple untested synthetic chemicals. National bio monitoring surveys conducted in the United States have documented several hundred synthetic chemicals in detectable quantities in the bodies of virtually all Americans of all ages (CDC 2009). Toxic chemicals have been linked to numerous diseases through toxicological and epidemiological studies, and the list is growing as research into environmental causes of non-communicable disease continues.

The likelihood is high that there are additional diseases and disabilities caused by widely used synthetic chemicals where the etiologic associations have not yet been recognized (Grandjean and Landrigan 2014). Chemicals of particular concern include organic chemicals that persist in the environment long after their production and use have been stopped, such as polychlorinated biphenyls, and non-persistent chemicals to which individuals are constantly exposed, such as the plastic components and plasticizers bisphenol A, other bisphenols, and phthalates.

Exposures to these organic chemicals have been associated with increased risk of diabetes (Lee *et al*., 2007, 2012, 2014), hypertension (Goncharov *et al*. 2011), cardiovascular disease (Lang *et al*.,2008; Lind *et al*., 2012), obesity (Newbold 2010; Trasande *et al.,* 2012), and cancer (Lauby-Secretan *et al.* 2013).Pesticides are frequently applied in agricultural, forestry, and urban settings. There are tens of thousands of pesticides in use, many of which are synthetically produced. Pesticides will break down in the environment forming by-products, some of which are toxic whereas others are relatively non-toxic (Baldock *et al*., 2000 and Schulz, 2004).

Acute immediate toxic effects can influence the survival or reproduction of aquatic species leading to the disruption of predator-prey relationships and a loss of biodiversity. If aquatic organisms are not harmed immediately, they may concentrate chemicals from their environment into their tissues. This bio concentration can lead to biomagnifications a process in which the concentrations of pesticide and other chemical are increasingly magnified in tissues and other organs as they are transferred up the food chain. The chronic effects of these substances on aquatic organisms include health repercussions such as cancers, tumours lesions, reproductive inhibition or failure suppressed immune systems, disruption of the endocrine (hormone) system, cellular and DNA damage, and deformities (Ongley, 1996). Terrestrial predators that feed on aquatic species may also be affected (Baldock *et al.*, 2000 Mineau *et al.*, 2005).

Many pesticides have been linked to health problems in humans and animals. Direct exposure can occur during the preparation and application of pesticides to crops. More frequently, exposure occurs when ingesting these agrochemicals while consuming contaminated foods. People are exposed to pesticides through aquatic systems either by ingesting fish or shellfish that have stored these compounds in their tissues or directly by drinking contaminated water. Pesticide exposure has been linked to cancer neurological damage, immune system deficiencies, and problems with the endocrine system (Mineau *et al.*, 2005; Luebke, 2002; Alavanja *et al.*, 2004 and Safe, 2000).

### 2.1.2. Thermal Pollution

Thermal pollution is the rise or fall in the temperature of a water natural body of water caused by human influence. Thermal pollution, unlike chemical pollution, results in a change in the physical properties of water. A common cause of thermal pollution is the use of water as a coolant by power plants and industrial manufacturers. Elevated water temperatures decreases oxygen levels, which can kill fish, and can alter food chain composition, reduce invasion by new Thermopolis species (Goel, 2009). Urban runoff may also elevate temperature in surface waters (Kannish and Michael, 2008). Thermal pollution can also be caused by the release of very cold water from the bused of reservoirs into warmer rivers onto warmer roars (Edward, 2012).

### 2.1.3. Agricultural Pollution

According to Galadima *et al.* (2011) agriculture, as the single largest user of freshwater on a global basis and as a major cause of degradation of surface and groundwater resources through erosion and chemical runoff, has cause to be concerned about the global implications of water quality. The associated agro food-processing industry is also a significant source of organic pollution in most countries. The primary agricultural pollutants are nutrients (particularly nitrogen and phosphorus), sediment, animal wastes, pesticides, and salts. Agricultural sources enter surface water through direct surface runoff or through seepage to ground water that discharges to a surface water outlet.

The most common sources of excess nutrients in surface water are chemical fertilizers and manure from animal facilities. Such nutrients cause eutrophication in surface water. Eutrophication is thus depriving the river of oxygen (called oxygen debt). As algae dominates and turn the water green, the growth of other water plants is suppressed; these die first disrupting the food chain. Pesticides used for pest control in agricultural operations can also contaminate surface as well as ground-water resources. Some of these pesticides contain endocrine disrupting chemicals that can mimic or antagonize the effects of endogenous hormones could potentially have serious effects not only on the development and well-being of an individual organism, but perhaps more importantly on the ability of that organism to reproduce, and its offspring to survive and eventually reproduce. Nitrates also soak into the ground and end up in drinking water Health problems can occur as a result of this and they contribute to methemeglopbinemia or blue baby syndrome which causes death in infants.

### 2.1.4. Anthropogenic Activity

Anthropogenic activities continuously increase the amount of heavy metals in the environment, especially in aquatic ecosystem. Pollution of heavy metals in aquatic ecosystem is growing at an alarming rate and has become an important worldwide problem (Malik *et al.,* 2010). Increase in population, urbanization, industrialization and agriculture practices have further aggravated the situation (Gupta *et al.,* 2009). As heavy metals cannot be degraded, they are deposited, assimilated or incorporated in water, sediment and aquatic animals (Linnik and Zubenko, 2000) and thus, causing heavy metal pollution in water bodies (Malik *et al.,* 2010).Therefore heavy metals can be bio accumulated and biomagnified via the food chain and finally assimilated by human consumers resulting in health risk (Agah *et al*., 2009). Fishes are often used as indicators of heavy metals contamination in the aquatic ecosystem because they occupy high trophic levels and are important food source.

### 2.1.5. Heavy Metal Pollution

Metals are natural elements of the environment that are found in varying levels in ground and Surface waters, and are classified into two types; essential and non-essential elements. Essential elements such as copper (Cu), iron (Fe), manganese (Mn), nickel (Ni) and zinc (Zn) are required for various biochemical and physiological functions, while other metals including cadmium (Cd),chromium (Cr), mercury (Hg), lead (Pb), arsenic (As), and antimony (Sb) are non-essential and play no significant biological role. Living organisms require trace amounts of essential heavy metals, but these can become toxic at high doses Frieden, 1974, and Flores, and Perez,1999 copper Gabbianelli, *et al*., 2003, zinc Roney, *et al.,* 2006) iron Park, *et al* 2007 Tchounwou, .*et al*., 2012;), , and are highly toxic and can exert their toxicity at low doses, and consequently these five elements rank among the priority metals that are of great public health significance.

These metals may accumulate in the food chain and pose carcinogenic and other adverse risks to human health due to bioaccumulation over time. Research has indicated that environmental exposure to heavy metals increases the risk for developing cancers, diabetes, kidney failure and damage to the nervous system Zhao, *et al* 2014, Baatrup, 1991 and Khan, 2014). However, connections must be established between the external levels of exposure of these elements, internal levels of tissue contamination and their adverse effects kidney failure and damage to the nervous system (Zhao, *et al* 2014, Baatrup, 1991 and Khan, 2014). However, connections must be established between the external levels of exposure of these elements, internal levels of tissue contamination and their adverse effects. The metal which has a relatively high density and toxic at low quantity is referred as heavy metal, e.g., arsenic (As), lead (Pb), mercury (Hg), cadmium (Cd), chromium (Cr) etc. Heavy metals are metallic elements which have a relatively high density, and they are poisonous at low quantity.

The excess quantities of heavy metals are detrimental as these destabilize the ecosystems because of their bioaccumulation in organisms and elicit toxic effects on biota and even death in most living organisms. Most of the heavy metals are poisonous, while some metals are less toxic. All heavy metals, in spite some of them are essential micronutrients, have their toxic effects on living organisms via metabolic interference and mutagenesis. Such toxic effects of heavy metals include reduction in fitness, interference in reproduction leading to carcinoma and finally death (Pandey and Madhuri, 2014).

Organic matter is the major pollutant in wastewater. Traditionally organic matter has been measured as BOD and COD. The COD analysis is 'quick and dirty' (if mercury is used). BOD is slow and cumbersome due to the need for dilution series (Henze.M and Comeau.Y 2008). The availability of water and its physical, chemical, and biological composition affect the ability of aquatic environments to sustain healthy ecosystems: as water quality and quantity are eroded, organisms suffer and ecosystem services may be lost.Typically, water quality is determined by comparing the physical and chemical characteristics of water sample with water quality guidelines or standards (Carr, and Neary, 2006). Pollution has become a serious threat, and has brought hazards to the growing population as well as the environment. The speedy urbanization and industrialization has led to increased disposal of pollutants like heavy metals, radio nuclides, and various types of organic and inorganic substances into the environment ( Praveena *et al*., 2013).Heavy metals from motor vehicles (via urban storm water runoff (Schlueler and Thomas, 2010) and acid rain drainage.

#### 2.1.5.1. Lead

The exposure of Pb can cause many effects depending on level and duration of Pb.The developing foetus and infant are more sensitive than the adult. Mostly the bulk of Pb is received from food; however, other sources may be more important like water in areas with Pb piping and pump solvent water, air near point of source emission, soil, dust and paint flakes in old houses or contaminated land. In air, the Pb levels are brought in food through deposition of dust and rain containing metal on crops and soil. In environment the Pb comes from both natural and anthropogenic sources. The Pb exposure can be through drinking water, food, air soil and dust from old paint. The Pb is among the most recycled non-ferrous metals, so its secondary production has grown steadily. The high levels of Pb may result in toxic effects in human which in turn cause problems in the synthesis of haemoglobin (Hb), effects on kidneys, gastrointestinal tract (GIT), joints and reproductive system, and acute or chronic damage to nervous system (Lenntech, 2012).

#### 2.1.5.2. Cadmium

The Cd derives its toxicological properties from its chemical similarity to Zn. The Cd once absorbed by an organism, present for many years, though it is eventually excreted. It is produced as an inevitable by-product of Zn refining. The Cd is mostly used in Ni/Cd batteries, rechargeable or secondary power sources exhibiting high output, long life, low maintenance and high tolerance to physical and electrical stress. The coating of Cd provides good corrosion resistance, particularly in high stress environments like marine and aerospace applications where high safety or reliability is required; the coating is preferentially corroded if damaged. As an impurity, it is present in several products, including phosphate fertilizers, detergents and refined petroleum products. Average daily intake of Cd for humans is 0.15µg from air and 1µg from water. The Cd if exposed for long time may cause kidney dysfunction. Its high exposure may cause obstructive pulmonary disease and lung cancer. Bone defects have also been reported in humans and animals. Besides, it can also cause increased blood pressure and myocardial disease in animals (Lenntech, 2012).

#### 2.1.5.3. Zinc

Zinc is an essential element for the life of animal and human beings. It is found in virtually all food and potable water in the form of salts or organic complexes (WHO, 2011).

According to Momtaz (2002), the most common minerals of Zn are zinc sulphide (ZnS), zincite (ZnO), and smithsonite ($ZnCO_3$). Zinc is used in many industries for example, in the manufacture of dry cell batteries and production of alloys such as brass or bronze (Momtaz, 2002). The main sources of Zn pollution in the environment are zinc fertilizers, sewage sludges, and mining (Bradi, 2005). Urban runoff, mine drainage, and municipal sewages are the more concentrated sources of zinc in water (Damodharan, 2013).

Zinc plays a vital role in the physiological and metabolic process of many organisms (Rajappa *et al.,* 2010). It is an essential element in animal diet but it is regarded as potential hazard for both animal and human health (Amundsen *et al.,* 1997). It plays an important role in protein synthesis. Zinc shows fairly low concentration in surface water due to its restricted mobility from the place of rock weathering or from the natural sources (BIS, 1998). Zinc may be toxic to aquatic organisms but the degree of toxicity varies greatly, depending on water quality characteristics as well as species being considered (Datar and Vashishtha, 1990). The permissible limit of zinc in water is 3 mg/l (WHO, 2008). Drinking water containing high levels of zinc can lead to stomach cramps, nausea and vomiting (Damodharan, 2013). Other clinical signs of Zn toxicity have been reported as diarrhea, bloody urine, liver failure, kidney failure and anemia (Duruibe *et al.,* 2007).

## 2.2. Importance of Water

Water is the most natural resource and is essential for survival and the development of modern technology (Wong *et al*., 2001; Ashraf, 2005 and Gad, 2009). Due to population growth water pollution is a serious environmental problem in the world. Pollution describes the introduction of foreign substances into bio sphere; some of these pollutants find their way into the human system through the food chain (Saleh *et al.,* 2010). Pollution of the aquatic environment has been considered a major threat to the aquatic organisms. The agricultural water containing pesticides, fertilizers and runoffs in addition to sewage effluents supply the water bodies and sediments with huge quantities of heavy metals (ECDG, 2002). The pollution caused by heavy metals might have dreadful effects on the ecological equilibrium and a variety of aquatic entities (Akinmoladun *et al.,* 2007, Vosylien and Jankait, 2006). Water is the elixir of life, a valuable gift of nature to mankind and millions of other species living on the earth (Chidambaram *et al.,* 2010). It is available in the world in huge quantity in the order of $1400 \times 10^6$ $km^3$,but only 41 000 $km^3$circulates through the hydrological cycle, the remaining being stored for long periods in the oceans, ice caps and aquifers and only 3% of the water in the world are fresh water (Acreman, 1998).

## 2.3. Fresh Water

Clean fresh water is a basic human need as well as an important natural resource. Protecting or improving water quality is a great concern to governments around the world. Yet, in the United States (U.S.), recent surveys determined that 44% of sampled stream miles were polluted (United States Environmental Protection Agency, USEPA, 2009), and that 42% of U.S. wadeable streams and rivers were in poor condition while only 25% were in fair condition when compared to eco region-specific reference conditions (Paulsen *et al.,* 2008).

Among the fresh waters, only about 5% of them or 0.15% of the total world waters are readily available for beneficial use (Sandeep *et al.,* 2011; Chidambaram *et al.*, 2010) and from these lakes hold 100 000 $km^3$ of fresh water(90%) of earth's liquid surface total water. Ethiopia has199.3 BCM potential surface water and 185.6 BCM (billion cubic meters) ground water as a reserve (Tamiru, 2006). Due to increasing population growth, human water demand for domestic, industrial and agricultural purposes to supply adequate food for the nation is increasing (UNDP, 2006) and water becoming a scarce commodity in most part of the world.In the world peoples living under water-stressed condition ranges are from 1.4 billion to 2.1 billion (Arnell *et al.*, 2004).Water-stressed condition refers to per capita water availability below 1,000$m^3$ per year or based on the long-term average annual runoff above 0.4 (WorldBank, 1992).

Freshwater environments are subjected to increasing degradation. In addition to the extensive range of natural stresses encountered by organisms in their habitats, human activities can generate other environmental stresses. Such harmful alteration, disruption, or destruction of freshwater environments could become irreversible (Christian and Fernando, 2014). Improving our understanding of freshwater ecology is therefore very important not only because of its biological implications, but also because the proper management of fresh water is of practical interest to mankind. Around the world the demand of freshwater is increasing due to population growth and industrial development. According to the Food and Agriculture Organization (FAO) of the United Nations, agriculture is the largest user of water resources around the world, accounting for 70 percent of all freshwater withdrawals followed by industry 20 percent, and domestic use 10 percent (FAO, 2006). The importance of freshwater in the evolution of fishes is also evidenced by the fact that over 41 % of all fish species are found in fresh water, even though freshwater habitat represents only a small percentage (0.01 % by volume) of the earth's water resource (Miller and Harley, 2002).

Aquatic ecosystems are threatened on a world-wide scale by a variety of pollutants as well as destructive land-use or water management practices. The extent of human activities that influence the environment has increased dramatically during the past few decades. Among several factors that contribute to the decline of water quality: exponential growth of human population, industry and agriculture are at the heart of many aspects of pollution on aquatic ecosystem especially fresh water. Until recently, environmental degradation and deterioration of water quality by pollution was not a serious problem. But nowadays, the quantities of wastes are beyond dilution and self purification capacity of water body (Baye Setotaw, 2006).

## 2.4. Fresh Water Monitoring

Freshwater environments can be monitored by physical, chemical, and biological parameters. Biological parameters integrate information over longer periods of time and better represent the responses of aquatic habitats making biotic monitoring indices excellent tools for the sustainable management of water resources. Literature reviews of running water assessments based on biological indicators identify at least 100 indices developed over the past ten years, of which about 60% are based on macro invertebrates, more than for any other group of freshwater organisms. Despite a wide range of adaptations, certain macro invertebrate taxa can serve as indicators of environmental conditions. Several groups of aquatic insects are among the organisms that are extensively used for monitoring aquatic ecosystems (Christian and Fernando, 2014).

## 2.5. Water Quality

The quality of any body of surface or ground water is a function of either or both natural influences and human activities. Without human influences, water quality would be determined by the weathering of bedrock minerals, by the atmospheric processes of evapo transpiration and the deposition of dust and salt by wind, by the natural leaching of organic matter and nutrients from soil, by hydrological factors that lead to runoff, and by biological processes within the aquatic environment that can alter the physical and chemical composition of water. As a result water in the natural environment contains many dissolved substances and non-dissolved particulate matter. Dissolved salts and minerals are necessary components of good quality water as they help maintain the health and vitality of the organisms that rely on this ecosystem service (Stark *et al.*, 2000).

Water can also contain substances that are water can also contain substances that are harmful to life. These include metals such as mercury, lead and cadmium, pesticides, organic toxins and radioactive contaminants Water from natural sources almost always Water from natural sources almost always contains living organisms that are integral components of the biogeochemical cycles in aquatic ecosystems. However, some of these, particularly bacteria, protists, parasitic worms, fungi, and viruses, can be harmful to humans if present in water used for drinking. The availability of water and its physical, chemical and biological composition affect the ability of aquatic environments to sustain healthy ecosystems: as water quality and quantity are eroded, organisms suffer and ecosystem services may be lost. Moreover, an abundant supply of clean, usable water is abasic requirement for many of the fundamental uses of water on which humans depend. These include, but are not limited to:

-water used for human consumption and public water supply;
-water used in agriculture and aquaculture;
-water used in industry;
-water used for recreation; and
-Water used for electrical power generation.

The quality of water necessary for each human use varies, as do the criteria used to assess water quality. For example, the highest standards of purity are required for drinking water, whereas it is acceptable for water used in some industrial processes to be of less quality. The quality of water required to maintain ecosystem health is largely a function of natural background conditions. Some aquatic ecosystems are able to resist large changes in water quality without any detectable effects on ecosystem composition and function, whereas other ecosystems are sensitive to small changes in the physical and chemical makeup of a body of water and this can lead make up of a body of water and this can lead of biological diversity.

The degradation of physical and chemical water quality due to human influences is often gradual, and subtle adaptations of aquatic ecosystems to these changes may not always be readily detected until a dramatic shift in ecosystem condition occurs. For example, in many shallow European lakes, the gradual enrichment of the surface water with plant nutrients has resulted in shifts from systems that once were dominated by rooted aquatic plants to systems that are now dominated by algae suspended in the water column (Scheffer *et al*., 2001). Regular monitoring of the biological, physical and chemical components of aquatic ecosystems can serve to detect extreme situations in which the ability of an ecosystem to return to its normal state is stretched beyond its limit.

Typically, water quality is determined by comparing the physical and chemical characteristics of a water sample with water quality guidelines or standards. Drinking water quality guidelines and standards are designed to enable the provision of clean and safe water for human consumption, thereby protecting human health. These are usually based on scientifically assessed acceptable levels of toxicity to either humans or aquatic organisms. Guidelines for the protection of aquatic life are more difficult to set, largely because aquatic ecosystems vary enormously in their composition both spatially and temporally, and because ecosystem boundaries rarely coincide with territorial ones.

Therefore, there is a movement among the scientific and regulatory research community to identify natural background conditions for chemicals that are not toxic to humans or animals and to use these as guidelines for the protection of aquatic life (Dodds and Oakes, 2004; Wickham *et al*., 2005;Robertson *et al.,* 2006. Other guidelines, such as those designed to ensure adequate quality for recreational, agricultural or industrial activities, set out limits for the physical, chemical, and biological composition of water needed to safely undertake different activities.(Robertson *et al*., 2006; Dodds and Oakes, 2004; Wickham *et al*., 2005).

Water which is a simple chemical compound with the chemical formula $H_2O$, containing one oxygen and two hydrogen atoms in a molecule connected by covalent bonds (Henniker, 2011) and existing as a liquid at temperature above $0^0$C (273.15K, $32^0$F) at sea level, often co-exists on earth with its solid state, ice and gaseous state (water vapour or steam) also existing in a liquid crystal state near hydrophilic surfaces (Gerardi and Zimmerman, 2012) is very important in the sustenance of life on earth. This is because water is one of the most important and abundant compounds of the ecosystem. All living organisms on the earth need water for their survival and growth. As of now only earth is the planet having about 70% of water.(Basavaraja *et al.,* 2011).

Rivers and streams are the most important freshwater resource for man, unfortunately, stream waters are being polluted by indiscriminate disposal of sewage, industrial waste and plethora of human activities, which affects their physico-chemical characteristics and microbiological quality (Koshy and Nayer, 2013). Generally a pollutant refers to the degradation of water quality. From a public health of ecological views, a pollutant is only biological, physical and chemical substance that in identifiable excess is known to be harmful to other desirable living organisms (Nnorom, 2010). Water pollution is a major global problem which requires ongoing evaluation and revision of water resource policy at all levels (international down to individual aquifers and wells). It has been suggested that it is the leading worldwide cause of death and diseases that it accounts for the deaths of more than 14,000 people daily (Pink and Daniel, 2006).

Pollution of the aquatic environment is a serious and growing problem. Increasing numbers and amounts of industrial, agricultural and commercial chemicals discharged into the aquatic environment have led to various deleterious effects on aquatic organisms. Aquatic organisms, including fish, accumulate pollutants directly from contaminated water and indirectly from contaminated water and indirectly via the food chain (Hammer, 2014).

### 2.5.1. Wastewater Quality

Wastewater quality can be well-defined by physical, chemical, and biological characteristics. Physical parameters include color, odor, temperature, solids, turbidity, oil, and fat. Chemical parameters associated with the organic components of waste water contain the biological and chemical oxygen demand (BOD), chemical oxygen demand (COD), entire organic carbon (TOC), and overall oxygen demand (TOD). Inorganic chemical parameters include pH, acidity, nutrients and the like (Manahan, 2001 cited in Asrat Gebremariam, 2014). the biological oxygen demand (BOD) Value is reduced before let into natural waterways and chemical oxygen demand (COD) make up more.

### 2.5.2. The Availability of Good Quality Water

The availability of good quality water is a necessary feature for preventing diseases and improving quality of life (Oluduro and Aderiye, 2007). Safe, clean, accessible and affordable water is considered to be a fundamental human right (UN, 2010).

Lakes have long been at the core of human attention and development of human communities. Irresponsible use of water resources has worsened river and lake water qualities (Sanchez, 2007). Upsurge in population and pollution caused by toxic wastes, surface runoffs from domestic and agricultural sources have increased pollution load and further limited healthy water resources (Siemonov, 2003). Bearing in mind that it is inevitable to understand surface water quality for various purposes such as drinking, recreation and irrigation, knowledge of point sources of pollution and pollutant in the region are prerequisite for appropriate use of water (Siemonov, 2003).

## 2.6. Lake and Reservoirs

Lake and surface reservoirs are nature's most critical fresh water resources and have various uses. They are used for domestic and irrigation purposes and provide ecosystems for aquatic life as a source of essential protein and for significant element of the world's biological diversity. The quality of fresh water is mainly affected by natural processes such as weathering and soil erosion as well as anthropogenic activities. The anthropogenic activity represents a constant polluting source while surface runoff is a seasonal phenomenon, mainly affected by climatic conditions (Singh *et al*., 2004). Water quality monitoring has a high priority for the determination of current conditions and long term trends for effective management.

Lakes are more sensitive to pollution inputs because they flush out their contents relatively slowly. Even under natural conditions, Lakes undergo eutrophication, an aging process that slowly fills in the Lake with sediment and organic matter. The eutrophication process alters basic Lake Characteristics such as depth, biological productivity, oxygen levels, and water clarity.

## 2.7. Biological Components of the Aquatic Ecosystem.

Organisms, populations, and communities composed of different species make up the biological diversity of aquatic ecosystems. From acelular microbes such as viruses, bacteria, protists, and fungi, to multi-cellular organisms such as vascular plants, aquatic invertebrates, fish and wildfowl, the community of organisms that resides within and near aquatic ecosystems simultaneously plays a vital role in regulating biogeochemical fluxes in their surrounding environment and is influenced by these same biogeochemical fluxes. Aquatic organisms, often considered engineers of aquatic ecosystems, not only such changes and have important roles in cleansing and detoxifying their environment (Ostroumov, 2005).

The bacteriological examination of water has a special significance in pollution studies, as it is a direct measurement of deleterious effects of pollution in human health (APHA, 2014). Water pollution is of various kinds ;Surface water and groundwater have often been studied and managed as separate resources, although they are interrelated. Surface water seeps through the soil and becomes groundwater. Conversely, groundwater can also feed surface water sources. Sources of surface water pollution are generally grouped into two categories based on their origin (Agarwal and Manish, 2011).

### 2.7.1 Accumulation of Heavy Metals in Fish

Fish are used as bio-indicators of aquatic ecosystems for estimation of heavy metal pollution and potential risk for human consumption **(**Agarwal *et al*., 2007). Bioaccumulation of metals in fish takes place directly, from the water by gills and indirectly from food. The metals such as Cu, Zn, Fe and Co are essential and have important biochemical function in the organism as opposed to non essential metals like Pb, Cd, and Hg and As. According to Bryan and Hummerstone (1973) essential metals are used either an electron donor system or function as ligands in complex enzymatic compounds. The essential trace metals are only used in trace amount by the organism and usually they are found in small concentration in the environment. The amount of heavy metals in the organism does not exceed the level which allows the enzyme system to function without interference. The excess amount of heavy metal in the organism can be regulated by homeostasis But, if the heavy metal concentration at the source of supply such as water and food is too high, the homeostasis mechanism finishes functioning and the essential heavy metals act in either in acutely or chronically toxic manner. The function of uptake and excretion in fish is determined the accumulation of metal in fish. The gills are likely sites of metal uptake from water due to their large surface area and the close proximity of the internal constituent of the body and external environment (Wepener, 1997). Within the body, the degree of accumulation in different tissues is dependent on the binding of the metal to specific ligands (Dallinger *et al*., 1987) stated that as far as fish is concerned, there are three possible ways by which metals may enter the body through the body surface, the gill, muscle and the alimentary tract. But little is known about the uptake of heavy metals through the skin. It can be assumed that the body surface of fish is more or less impervious to harmful substance in the surrounding water.

Heavy metals have an effect on different aquatic organisms but its effect is often complex and difficult to interpret. Dissolved oxygen, pH, salinity, temperature and hardness of water have been shown to be factors that influence the physiology of an organism and the rate of uptake of heavy metals. The main factors concerned in determining the seasonal variation of heavy metal levels in aquatic biota are the extent of pollutant delivery into the aquatic environment, the weight change occurring in the organisms and the direct effects of salinity,temperature and other water qualities which vary seasonally (Chaudhari *et al.,*1996).

**2.7.2. Macro-Invertebrates and Water Quality Assessment**

The major reason for using benthos in toxicity test is that information of the effects of toxicants on macro-invertebrates is essential in the protection of aquatic ecosystems. Toxicity tests help in evaluating the nature and degree of harmful effects produced on aquatic organisms by toxicants since toxicants alter the distribution, density and behaviour of aquatic invertebrates by direct lethal or sub lethal action on a particular species, or indirectly by affecting a species" food, competitors, predators, or habitat (Maciorowski and Clarke, 1977).

According to Maciorowski and Clarke (1977); Metcalfs (1989) and Bode *et al*., (1996) the criteria and/or advantages why benthos should be used in water quality assessment include Sampling procedures are relatively well developed Can be operated by someone working alone There are identification keys for most groups of macro-invertebrates. Are reasonably sedentary with comparatively long lives, so that they can be used to assess water quality at a single site over a long period of time.The size of benthos is almost ideal for water quality testing, since many are macroscopic and can even be recognized with the naked eye.The diversity of aquatic invertebrates provides several attributes that can be utilized as responses in laboratory toxicity test.

Reproduction and life-cycle may be completed with 2 to 4 weeks with genera such as *Daphnia* and *Chironomus* whereas life-cycle studies with rapidly reproducing fish may require 3 months to 2 years. The group is heterogeneous and so a single sampling technique may catch a considerable number of species from a range of phyla. Since taxa (family, genus or species) differ in their tolerance to pollutants, particular taxa make useful „"indicators"" of conditions. As benthic invertebrates respond sensitively not only to pollution, but also to a number of other human impacts (physical modification, recreational and others) so, they potentially be used for a holistic indication system for Lake Ecosystem health. Their ubiquitous presence and their relative longevity may be seen as strong points recommending them for use in an indication system.There are some disadvantages of using benthic macro-invertebrates for bio assessment as described according to Metcalfs (1989) and Bode *et al.* (1996):

Their aggregated (patchy) distribution means that, to obtain a representative sample of a site, many samples must be taken. The muddy, depositing substrata of the lowland areas of rivers, or of lakes, are often dominated by chironomids and tubifid worms, which are groups difficult to identify to species level. The insect members of the community may be absent for part of the year, so that seasonal variation may prevent comparison of samples and will make interpretation difficult.

**2.7.3. The Role of Benthic Macro-Invertebrates for Bio Assessment**

Several biological communities including microphyto benthos, macrophytes and fishes have been considered in assessments of water quality. However, the use of benthic invertebrate communities as indicators of environmental degradation or restoration has become widespread and reliable for bio-assessment since the benthos broadly reflect environmental conditions (Jackson, 1993; Rosenberg and Resh, 1993).Freshwater benthic macro-invertebrates, or „"benthos", are animals that inhabit the bottom of substrates (for example, sediments, debris, macrophytes and filamentous algae) of their habitats for at least part of their life cycle and are larger than 500µm. They are retained by mesh sizes from 200-500 micrometers. Benthic macro-invertebrates include insect larvae, annelids (leeches), oligochaetes (worms), crustaceans (crayfish and shrimp), mollusks, (clams and mussels), and gastropods (snails).

Insect larvae tend to be the most abundant benthic macro-invertebrates in freshwater aquatic ecosystems (Rosenberg and Resh, 1993). Because of their abundance and position as "middlemen" in the aquatic food chain, benthos plays a critical role in natural flow of energy and nutrient (Bode and Novak, 1995; Barbour *et al.*, 1996). Aquatic invertebrates are morphologically, physiologically and ecologically diverse and therefore exhibit a wide range of responses to toxicants (Maciorowski and Clarke, 1977). As benthic macro-invertebrates tend to remain in their original habitat, they are affected by local changes in water quality.

Some are capable of tolerating higher loads of pollution than others. If the pollution is severe, the whole community structure may simply in favour of tolerant species. Although the abundance of certain species may increase, the diversity and species richness decreases. By assessing indicator species, diversity, and functional groups of the benthic macro-invertebrate community, it is possible to determine water quality (Lange, 1994). Recently, benthic macro-invertebrates have been found as the most common faunal assemblages for bio assessment and provide more reliable assessment of long term ecological changes in the quality of an aquatic system compared to its rapidly changing physico-chemical characteristics.

Well developed water quality monitoring programs involve measurements of physical, chemical and biological parameters and provide valuable information on the impact of water quality. The benthic macro-invertebrates respond differentially to biotic and abiotic factors in their environment. Consequently, the structure of macro-invertebrate has long been used as bio-indicators to assess the water quality of a water body (Reynoldson *et al*., 1989; Duran, 2006). As fish are constantly to exposed pollutants in contaminated water, they could be used as excellent biological markers of heavy metals in aquatic ecosystem (Mance, 1987). In addition, the liver can be regarded as the body's detoxification organ and hence a target organ of various xenobiotic substances.

## 2.8. Physico-Chemical Parameters

Understanding a lake's physical, chemical and biological properties is essential to determining the lake's condition and in making informed lake management decisions. The most commonly used physico-chemical parameters for water quality measurement of lakes were

Physical measurements like temperature

Chemical measurements such as nutrients (nitrates and phosphate), total dissolved solids (TDS), pH, and conductivity. These parameters are important to study water quality at the moment of study only because the valueits result fluctuate with the diurnal and seasonal variation of the weather condition and based on level of input of pollutants at a certain time

### 2.8.1. pH and Alkalinity

In water, a small number of water ($H_2O$) molecules dissociate and form hydrogen ($H^+$) and hydroxyl ($OH^-$) ions. The alkalinity composed primarly of carbonate and bicarbonate so very acidic water can cause heavy metals,such as copper and aluminium to be released in to the water.If the relative proportion of the hydrogen ions is greater than the hydroxyl ions, then the water is defined as being acidic. If the hydroxyl ions dominate,then the water is defined as being alkaline .The relative proportion of hydrogen and hydroxyl ions is measured on a negative logarithmic scale from 1 (acidic) to 14 (alkaline): 7 being neutral (USEPA, 1997; Friedl *et al.,* 2004)

The pH of an aquatic ecosystem is important because it is closely linked to biological productivity. Although the tolerance of individual species varies, pH values between 6.5 and 8.5 usually indicate good water quality and this range is typical of most major drainage basins of the world,Natural acidity in rainwater is caused by the dissolution of atmospheric carbon dioxide ($CO_2$). The hydrogen ions entering a drainage basin in rainwater are neutralized by carbonate and silicate minerals as water percolates through soils. This neutralization capacity in soils determines whether or not acid precipitation will cause water quality impacts in receiving water bodies. The ability of rocks and soils in any given drainage basin to buffer the acidity of rain water is related to the residence time of water in the soil as well as the levels of calcium carbonate, bicarbonate, and silicate minerals (Friedl *et al.,* 2004; Wetzel and Likens, 2000).

Lakes and ponds show regional differences in pH due to differences in geology and hydrology of the catchment area, input of acidifying substance, and productivity of the system, but the pH in the majority of lakes on earth is between 6 and 9 (Bronmark and Hansson, 1998).The change in the pH value of water is important to many organisms. Aquatic insects are extremely sensitive to pH value below 5.The Gastropods, mayflies, stoneflies and caddis flies are some of macro-invertebrate groups that prefer pH level from 7-9.5. One of the most significant environmental impacts of pH is involvement on synergistic effects. For example, very acidic water can cause heavy metals, such as copper and aluminum to be released into the water. These heavy metals may accumulate on the gills of fish or cause deformities in young fish, reducing their chance of survival. The pH value of a lake mainly depends on the relative quantities of calcium, carbonate and bicarbonate ions in the water (Sivakumar and Karuppasamy, 2008). pH is most important in determining the corrosive nature of water. Lower the pH value higher is the corrosive nature of water.PH was positively correlated with electrical conductance and total alkalinity (Guptaa, 2009).

### 2.8.2. Temperature

Most aquatic organisms have adapted to survive within a range of water temperature. Organisms like stoneflies and mayflies prefer cooler water, while others like dragonflies need warmer condition. As the temperature of water increases, cool water species will be replaced by warm water organisms. Temperature also affects aquatic life sensitivity to toxic wastes and disease, either due to rising water temperature or the resulting decrease in dissolved oxygen. Water temperature influences aquatic weeds, algal blooms and surrounding air temperature (Gupta *et al.,* 1993). The metabolic and physiological activity and life process such as feeding, reproduction, movements and distribution of aquatic organisms are greatly influenced by water temperature.

### 2.8.3. Conductivity

Conductivity is a measure of the water's ability to conduct an electric current. It is also useful for estimating the concentration of total dissolved solids (TDS) in the water. Because the measurement is made using two electrodes placed one centimetre apart, conductivity is generally reported as microsiemen‟s per centimetre (µS/cm). The lakes with high alkalinity often have high conductivity (Bronmark and Hansson, 1998). Conductivity shows significant correlation with ten parameters such as temperature, pH value, alkalinity, total hardness, calcium, total solids, total dissolved solids, chemical oxygen demand, chloride and iron concentration of water. Navneet Kumar *et al* (2010) suggested that the underground drinking water quality of study area can be checked effectively by controlling conductivity of water and this may also be applied to water quality management of other study areas. It is measured with the help of EC meter which measures the resistance offered by the water between two platinized electrodes. The instrument is standardized with known values of conductance observed with standard KCl solution.

### 2.8.4. Phosphate ($PO4^{-3}$ )

Phosphorus comes from several sources like human and animal wastes, industrial wastes, agricultural runoff, and exposed soil erosion. The total phosphorus concentration above

0.03mg/l stimulates the algal growth which result eutrophication, causing a shift in aquatic life to a fewer number of pollution tolerant species such as midge larvae and worms. Eutrophication threatens to limit organisms diversity and recreational opportunities. The phosphate which is found in the lake that includes organic and inorganic, phosphate are apart of living and dead plants and animals. Most natural lakes (not affected by man) have phosphorus concentrations between 1 and 100 µg/l (Bronmark and Hansson, 1998). Fertilizers containing nutrients- nitrates and phosphates which are found in storm water runoff from agriculture, as well as commercial and residential use (Allen and Robert, 2013)

**2.8.5 Nitrates ($NO_3^-$)**

A septic tank system containing household wastewater from toilet, bathtubs and washing machines which are the major sources of nitrate in lakes. The two other important source of nitrate are fertilizers and the runoff from cattle feedlots and dairies. Nitrate concentration indicates organic pollution in an area. Nitrates concentrations in lakes vary widely from about 100µg/l to over 6000µg/l. In most lakes the concentration is usually from 4-1500µg/l but in polluted lakes, the level extends to more than 5000µg/l (Bronmark and Hansson, 1998).

**2.8.6. Dissolved Oxygen**

DO is one of the most important parameter. Its correlation with water body gives direct and indirect information e.g. bacterial activity, photosynthesis, availability of nutrients, stratification etc. (Premlata Vikal, 2009). DO indicate physical, chemical and biological activities in lake water and it is an important indicator of water quality. DO affect the solubility and availability of many nutrients and the productivity of many aquatic ecosystems. In the progress of summer, dissolved oxygen decreased due to increase in temperature and also due to increased microbial activity (Moss 1972, Morrissette 1978, Sangu 1987, Kataria, 1996). The high DO in summer is due to increase in temperature and duration of bright sunlight has influence on the % of soluble gases ($O^2$ & $CO^2$). During summer the long days and intense sunlight seem to accelerate photosynthesis by phytoplankton, utilizing $CO_2$ and giving off oxygen. This possibly accounts for the greater qualities of $O_2$ recorded during summer (Krishnamurthy R, 1990). DO in sample is measured titrimetrically by Winkler's method after 5 days incubation at 293 K. The difference in initial and final DO gives the amount of oxygen consumed by the bacteria during this period. This procedure needs special BOD bottles which seal the inside environment from atmospheric oxygen.

### 2.8.7. Chemical Oxygen Demand (COD)

COD is another measure of organic material contamination in water specified in mg/L. COD is the amount of dissolved oxygen required to cause chemical oxidation of the organic material in water. Both BOD and COD are key indicators of the environmental health of a surface water supply. They are commonly used in waste water treatment but rarely in general water treatment. Milacron Marketing Co.). 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).

### 2.8.8. Biochemical Oxygen Demand (BOD)

Biochemical oxygen demand (BOD) forms the key indicator of organic load in any wastewater system. The property is expressed as the amount of dissolved oxygen required by aerobic biological organisms for degrading organic materials present in a given water sample at certain temperature over a specific time period (Sawyer CN and McCarty PL, 1978). When any kind of organic matter is present in water, the microorganisms start breaking down this organic load. During this process, the dissolved oxygen present in the water is consumed through the respiration of aerobic microorganisms, the amount of consumption being dependent on the organic load in the water. Thus a low BOD is an indicator of good quality while high BOD indicates polluted water (Lee ,1951) and Robson,2002).

The BOD is most commonly expressed in milligrams of oxygen consumed per liter of sample during 5 days of incubation at 20°C and is often used as a surrogate of the degree of organic pollution of water. This five-day incubation period has been commonly accepted as a compromise between a short test-period and the detection of a practically complete biological breakdown of organic materials in effluents because while it takes 20 days to achieve a complete degradation, about 70% of the biologically convertible substances are broken down after only 5 days of incubation at 20°C Hütter LA, 1992 and Heukelekian H, Gelman I 1951) Studies of biochemical oxidation by direct methods.

Therefore, the changes in BOD for the first five days of incubation at the temperature of 20°C can fairly indicate how effectively the processes of self-purification of any water will take place and the course and also the effectiveness of wastewater treatment of sewages in the oxygen reactors in the sewage treatment plants Gajkowska-Stefanska *et al*., 1994). Since BOD is directly connected with the oxygen status of any water body which is essential for sustaining the biological lives in any aquatic system Chen *et al*., 2000), an understanding of the BOD values of different waste waters and the corresponding organic loads which are ultimately released to various aquatic bodies with or without any treatment, appears to be essential (Nemerow 1974; Tchobanoglous and Schroeder, 1987).

# 3. MATERIALS AND METHODS

## 3.1. Description of the Study Area

The study area is located in East Harargehe Zone of Oromia Regional State, Eastern Ethiopia. It is found 515 km south east of Addis Ababa .Lake Addele (300 ha) is located in Haramaya Wereda, East Harerghe Zone. Lake Addele is 26 km west of the city of Harar, and is to the north of the main Harar road with latitude of 9° 25' 33" N and longitude 41° 57' 03" E (Fishpool and Evans 2001). The lake is surrounded by small hills and derives its water directly from rainfall and from several small streams that drain catchments to the west and north; floods from adjacent watersheds also occur (Fishpool and Evans 2001) (Fig.1). The climate of the study area is sub humid with relatively high rain fall. According to the Ethiopian traditional way of climate zoning, it can be grouped as Weina Dega (Subtropical) with an altitude ranging from 1967 m to 2429 m above sea level, and monthly mean temperature is between 14.47 °C and 19.13°C (Fishpool and Evans 2001).

The major land form of the area is composed of local ridges, hills and relatively flat topography. The flat topography of the area is mainly localized to the Haramaya and Addele seasonal lakes with an altitude ranging from 2010 m to 2024 m while the hilly landscape bounded the study area in the north west and north east part close to Damota village with an altitude ranging from 2270 m to 2400 m above sea level.The major portions of the agricultural soils in the catchment are shallow in depth. Most of the steeper slope soils of the catchment are unproductive and exposed on the surface through erosion and weathering processes. The five major soil types in the catchment are lithosols, regosols, cambisols, fluvisols and vertisols (Tamirie, 1981 cited in Shimelis *et al*., 2011).

The principal land use within the study area is agricultural activity, where crops and vegetables such as sorghum, maize, chat, etc, are cultivated. Almost all vegetables are generally cultivated in the low land topography of the study area while chat (*Catha edulis*), sorghum and maize are highly cultivated in the hilly landscapes. Most marginal and grazing lands are brought under cultivation. As per the national population and housing census of 2007, the total population of the Addele-Haramaya dry lake catchment is about 297,904. Out of this, 91% of the belongs to Haramaya woreda while about 6% and 3% are that of Haramaya University and Aweday town respectively. The livelihood of the community in the catchment is mainly based on mixed farming by growing crops and livestock production.

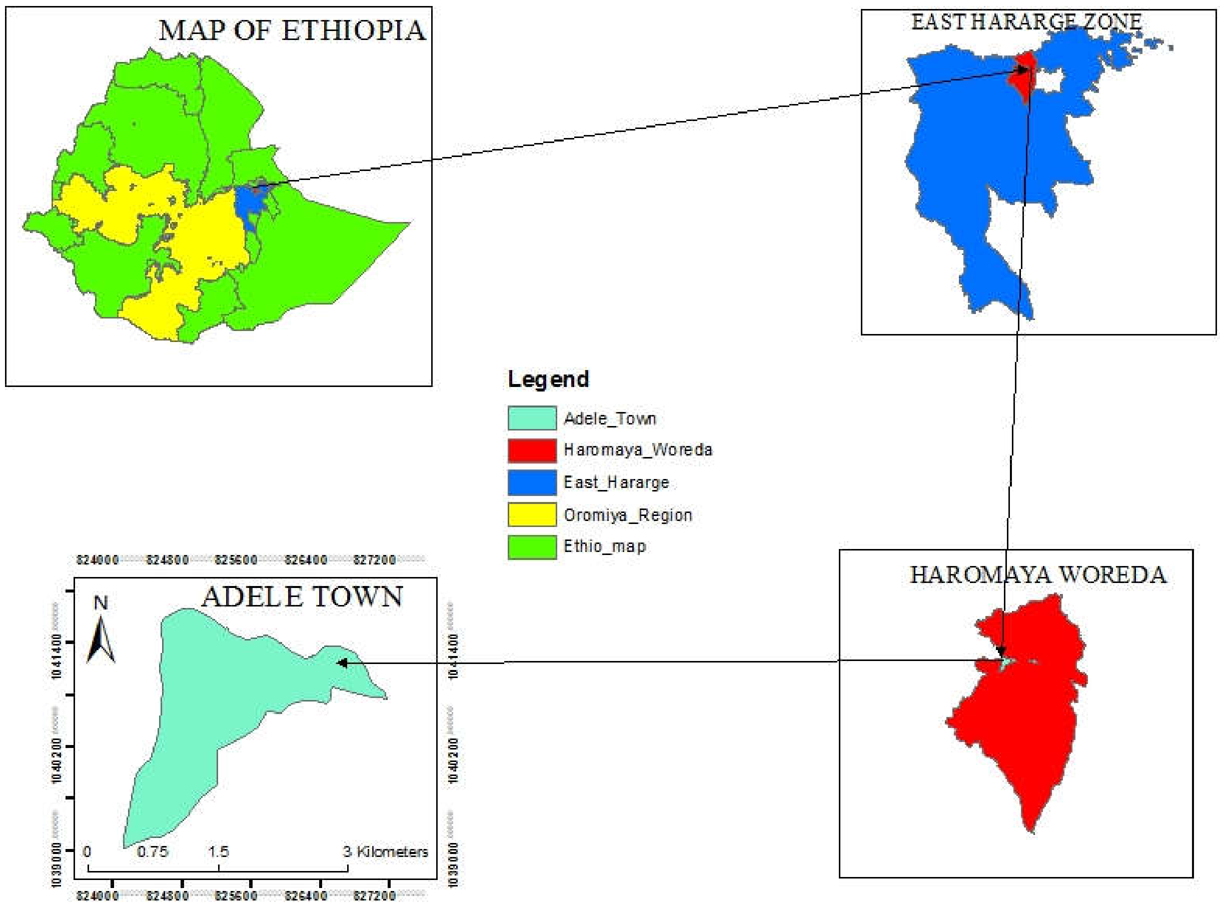



Figure 1. Location of the study area

## 3.2. Research Design and Sampling Method

The design of the research involves a cross sectional survey based study. Samples of water were collected from the lake during the two seasons, wet and dry season. The samples were taken from three directions of Lake Addele, site-1 from the road side, site-2 at the middle of lake and site -3 at slant (the inclined part of the lake or small hill side of the lake).The number of samples taken for laboratory investigation were 9 samples of water and 9 samples of fish species. This was performed by a distance of 50m in order to get representative sample and 50 cm depth were freshly collected in order to exclude the dust materials as well as oily liquids suspended at the top of the lake. Finally, the freshly collected water samples were mixed together and taken as composite sample for digestion process and transferred to ice box. Fish samples were collected by 0.5 mm mesh size nets and three fishes were sampled from each site, two type of fishs Catfish (*Clarias gariepinu*) and Tilapia fishes (*Oreochromis nilotica*) were collected transferred to ice box and then taken to the laboratory.The samples for macro invertebrates were collected by using D- net and Ekman grab (for deeper Benthic macro- invertebrates were sampled from the Lake water using net sampler (frame shape rectangular, area 625 $cm^2$, net mesh size 500µm from multi-habitat units) following standard methods developed for Rapid Bio assessment Protocol (Barbour *et al*., 1996).

## 3.3. Laboratory Investigation

The laboratory investigations were done at Haramaya University and Harar Beer Factory**.**

### 3.3.1. Digestion Procedure for Water Samples

For Cd and Pb, 100 mL of water sample was placed to in a beaker and 0.5 mL Nitric acid ($HNO_3$) and 5 mL hydrochloric acid (HCl) were added. And Subsequently the mixture placed on a hot plate for digestion for 2 hour. After digestion, it was made up to 100 ml and for Zinc: 100ml of water sample was placed to in a beaker and 0.5 ml Nitric acid ($HNO_3$) and 5 ml hydrochloric acid (HCl) were added. And Subsequently the mixture placed on a hot plate for digestion for 2 hour. After digestion, it was made up to 100ml. Heavy metal concentrations were determined by Atomic Absorption Spectrophotometer (AAS) **(**Thomas and Mohaideen, 2015).

### 3.3.2. Digestion Procedure for Fish Samples.

Fish muscle parts were dried in an electric oven at 100-105$^0$C until constant weight was obtained. The samples were crushed using a clean mortar and pestle to produce powdered forms. A homogenized 0.5 g of each ground fish powder sample was weighed using analytical balance. Each of 0.5 g of powder sample was then transferred into a digestion flask to which 12 mL of a mixture of Nitric acid (70%, Spectrosol) and hydrogen peroxide (35%,Riedel-de Haen) prepared in a 1:1 (v/v) ratio was added. The suspended mixture was digested for one hour, until a clear solution was obtained (Larissa *et al*., 2011). After that, it was allowed to cool and then filtered through Whatman no 42 filter paper. Finally, the filterate so obtained was diluted to 50 mL in a volumetric flask with deionized water and properly stored for later analysis of the heavy metal content using Flame Atomic Absorption Spectrophotometer.

### 3.3.3. Processing and Digestion of Fish Tissues for Metal Analysis

The deep frozen fish samples for the two fish species (*Oreochromis nilotica* and *Clarias gariepinus*) were thawed at ambient laboratory temperature overnight. The skin of each fish sample was removed using plastic knives to avoid metal contamination and this was followed by extraction of fish muscles. Fish muscles were put in a pre-acid washed and oven-dried crucibles. The samples were then dried to a constant weight in an oven at 50$^0$C (Plate3.4).The dried fish samples were allowed to cool in a desiccator at room temperature. After cooling, 82 gm of fish muscle was accurately weighed using a Shimadzu electronic weighing balance (Model ATX224) and transferred into a clean a beaker. Dried fish samples for each fish species were digested in triplicates according to the methods described in APHA (2005). To each weighed fish muscle samples 18ml of concentrated nitric acid was added and heated at 100 $^0$C on a hot plate in a fume hood chamber. A few drops of hydrogen peroxide (analytical grade) were added until there were no brown fumes. The digested fish sample solution was then filtered using Whatman 0.42μm filter paper in a 25 ml volumetric flask and topped to the mark with distilled water. The metal analysis done using a computerized Varian Atomic Absorption Spectro photometer (model Spectra AA-10).

### 3.3.4. Preparation of Stock Standard Solution for Calibration

Calibration curves were plotted for each metal by running a range of concentration of freshly prepared standard solution. For the linear dynamic range, the calibration standard was prepared using an appropriate dilution of the stock solution of each of cadmium, zinc and lead (stock solutions of 1000 ppm for each metal) solutions with distilled water. For Cd serial dilution was prepared as follows: 0.01, 0.10, 0.20 and 0.3 ppm from 10 ppm intermediate standard stock solutions in order to obtain the corresponding absorbance. Similarly, for Pb and Zn serial dilution were prepared as follow: 0.05, 0.10, 0.20, and 0.30 and 0.5, 1.0, 2.0 and 4.0 ppm respectively from 10 ppm of intermediate concentration (Kiflom and Tarekegn, 2015).

## 3.3.5 Instrument Detection limit For Heavy Metals.

Instrument detection limit is defined as the minimum concentration of analyte that can be measured. In other words ,it is the lowest analyte concentration that can be distinguished from statistically fluctuations in a blank, which usually correspond to the signal of blank three times the standard deviation of the blank,(3 standard deviation blank (David and Terry,2008). As shown in Table 2, the method detection limit values of the investigated element by FAAS along with their instrument detection limit are presented, respectively.

Table 1.Heavy metal detection lmit for water and fish samples

| Elements | IDL (mg/l) | Wave Length (nm) | IDL of Water sample(mg/L) | IDL of Fish Sample (mg/L) |
|---|---|---|---|---|
| Zn | 0.001 | 213.9 | 0.003 | 0.004 |
| Cd | 0.002 | 228.8 | 0.004 | 0.004 |
| Pb | 0.010 | 220.4 | 0.017 | 0.014 |

## Calibration Curve

Calibration curve for Cd, Zn and Pb was obtained by using suitable standard solution prepared from stock solution. Calibration standard for the element analyzed was prepared in concentration ranges expected for the analyte in the sample being analyted. In addition the calibration was prepared by taking to in consideration the optimum working range of the elements. The determination coefficient of ($R^2$) value that are closer to the absolute value of 1 indicate that there is a strong relationship between the variable being determined where as value closer to zero(0) indicate that there is no linear relationship between (Mwangi, 2013).The determination coefficient of the element were determined using prepared standard concentration versus their corresponding absorbance. The determination coefficient based on the calibration curve their corresponding metal are presented in Table 3.These curves were obtained by plotting absorbance reading against corresponding concentration of the metals investigated with optimized instrument condition. The calibration curve of all the metals is listed consecutively in the appendix figures.

Table 2 Heavy Metal Cofficient of Determimnation

| Heavy metal | Concentration in mg/L | Coefficient of determination ($R^2$) |
|---|---|---|
| Zn | 0,0.5,1,2,4 and 8 | 0.992 |
| Cd | 0.01,0.1,0.2 and 0.3 | 1 |
| Pb | 0.05,0.1,0.2 and 0.3 | 0.9991 |

#### 3.3.6 Determination of physico- chemical parameters of water samples

#### 3.3.6.1. Determination of Chemical Oxygen Demand (COD)

The chemical oxygen demand of water is the quantity of oxygen, in milligrams, required to oxidize or stabilize the oxidizable chemicals present in one litre of water under specific conditions. 2.5 mL of the sample was taken in a tube and 1.5 mL of 0.25 N $K_2Cr_2O_7$ (potassium dichromate), spatula of mercuric sulphate $HgSO_4$ and 3.5 ml of COD acid were added and kept in COD reactor for 2 hrs at150$^0$C. After cooling the sample was titrated against FAS (standard ferrous ammonium sulphate 0.1N) with ferroin used as indicator. The end point is reddish brown colour. In the blank tube 2.5 ml of distilled water was taken and then was follow the same procedure was followed for the blank water sample (Clesceri*, et al., 1989).*

**COD** was then calculated with the following formula**;**

COD (mg/l) = (blank value-titrated value) ×N of FAS×8000/ volume of sample

8000 = mill equivalent wt of $O_2$×1000ml

### 3.3.6.2 Determination of Biochemical Oxygen Demand (BOD)

Biochemical oxygen demand (BOD) of a sample is the milligram of oxygen required to biologically stabilize 1L of the sample water (by bio-degradation of organic compounds with the help of micro-organisms) in 5 days at $20^{0}$C.If the BOD value of a sample is high, then that sample contains too much of bio-degradable organic compounds and so will pollute the receiving water highly.

**Procedure**

Measure of BOD = Initial oxygen- Final Oxygen after (5 days at 20 $^{0}$C) or Two standard 300 mL BOD bottles were filled completely with sample water. The bottles were sealed. Oxygen content (DO) of one bottle was determined immediately. The other bottle was incubated at 20 $^{0}$C for 5 days or (or at 27 $^{0}$C for 3 days) in total darkness to prevent algal growth.After which its oxygen content was again measured. The difference between the two DO values is the amount of oxygen consumed by micro-organisms during 5 days and is reported as $BOD_5$.Since the saturated value of DO for water at 20 $^{o}$C is 9.1 mg/L only and that the oxygen demand for sample of water may be of the order of several hundred mg/L, therefore, samples water are generally diluted so that the final DO in BOD test is always ≥ 2 mg/L.

Precaution was also taken so as to obtain at least 2 mg/L change in DO between initial and finalvalues

$$BOD_5 = \frac{DO_i - DO_f}{P}$$ .

Where, $DO_i$ and $DO_f$ are initial and final DO concentrations of the diluted sample, respectively. P is called as dilution factor and it is the ratio of sample volume (volume of sample water) to the total volume (lake water plus diluent water). In the above formula, it was assumed that the diluted lake water had no oxygen demand of itself and that the dilution lake water used was pure.( Russell, 2006).

### 3.3.6.3 pH

pH of the water samples was determined using a Win Lab pH meter. Alkalinity was determined by the titrimetric method according to (API-RP45) as shown in ALPHA 2320-B Method of 2012 and total hardness by EDTA titrimetric Method as described in ALPHA 2340-C Method (2012)

#### 3.3.6.4 Dissolved Oxygen

Dissolved oxygen was measured on site using oxygen meter (Model: DO -5510 M.R.C). The DO probe was immersed into the reservoir water at a depth of 0.3 m. While gently stirring the water with the DO probe, the readings were allowed to stabilize and DO was read in mg $L^{-1}$(.JulIus, 2015)

#### 3.3.6.5 Electrical Conductivity

A multi-range conductivity meter (Model: HI 9033 HANNA instruments, Romania) was used to measure electrical conductivity of surface water in all sampling sites. The meter was lowered into the sample water to a depth of 0.3 m and then allowed to stabilize before taking the conductivity readings in µS $cm^{-1}$ (JulIus, 2015).

#### 3.3.6.6 Determination of Nitrate

Prepare 100 mL of nitrate calibration standards for 2, 4, 6, 8 and 10mg/L by serially diluting appropriate amounts of the 100mg/L stock solution, and making them up to the mark with HCl (1mL) and modulabwater.Obtain an unknown nitrate sample and analyse this in parallel with afreshly obtained creek water sample.Filter a portion of the sample through 0.45µm Millipore paper, then take a 25mL aliquot and transfer to a 50mL volumetric flask, add HCl (1mL) and make up to the mark with modu lab water. Read the absorbance of the samples and standards at both 220nm and 275nm.Use modulab water containing HCl as a blank. Prepare a calibration graph and determine the concentration of nitrate ion in the unknown and the creek sample (Rand, *et al*., 1992)

#### 3.3.6.7 Determination of phosphate

A stock solution of phosphate (1000 mg/L) in water was used to prepare a 40.00 mg/L phosphate solution in a 100 ml volumetric flask by dilution with deionized water water. Following preparation of solutions; the sample cup was filled with the 40.00 mg/L phosphate solution up to the 25 mL mark. The tip of the Vacu-vial ampule was placed in the sample cup, snapped, and the ampule then inverted several times to promote mixing. The ampule was dried and left to stand for five minutes and the absorbance measured in the spectrophotometer. This technique was also carried out for the reference sample supplied in the test kit.Using the UV Lab software, the LAMBDA 265 instrument parameters were to measure the absorbance at 420 nm. Following measurement of the blank, the absorbance of the known phosphate solution in the Vacu-vial was recorded.

## 3.4. Collection and Identification of Benthic Macro-Invertbrates

Benthic macro- invertebrates were sampled from the Lake water using net sampler (frame shape rectangular, area 625 $cm^2$, net mesh size 500µm from multi-habitat units) following standard methods developed for Rapid Bio assessment Protocol (Barbour *et al*., 1996). All the animals collected were immediately fixed in 10% formaldehyde in the field and then transferred to 70% ethanol alcohol. The debris and other confusing detroit was removed. After that the benthic macro-invertbrate were pick out by forceps. The macro-invertebrates were sorted, identified to the family level using keys given by Bouchard (2004) and counted under stereo microscope the Gerritsen *et al* (1998), the Shannon-Wiener Diversity index (H) is commonly used to calculate aquatic and terrestrial biodiversity.

$$H= -\sum_{i=1}^{s}(Pi)\ (\log_2 Pi)$$

This index was calculated as: where "pi" is the proportion of individuals in the "$i^{th}$" taxon of the community and "s" is the total number of taxa in the community. As the number and distribution of taxa (biotic diversity) within the community increases, so does the value of "H" (Gerritsen *et al.,* 1998). Hmax = Maximum diversity possible

(N) is number of the species

Hmax=ln (N)

E= Eveness=H/Hmax

Based on the calculation of diversity index, the classification of species diversity of Wilhemı is characterized as follows:

a. If diversity index (H') < 1 = low species diversity, low distribution of individual species, and low ecosystem stability;

b. If 1 < diversity index (H') < 3 = medium species diversity, and medium ecosystem stability;

c. If diversity index (H') > 3 = high species diversity, high distribution of individual species, and high ecosystem stability Khan, *et al*.,2007 : Verissimo, *et al.,*2012 and Dhembare, 2011

## 3.5. Data Analyses

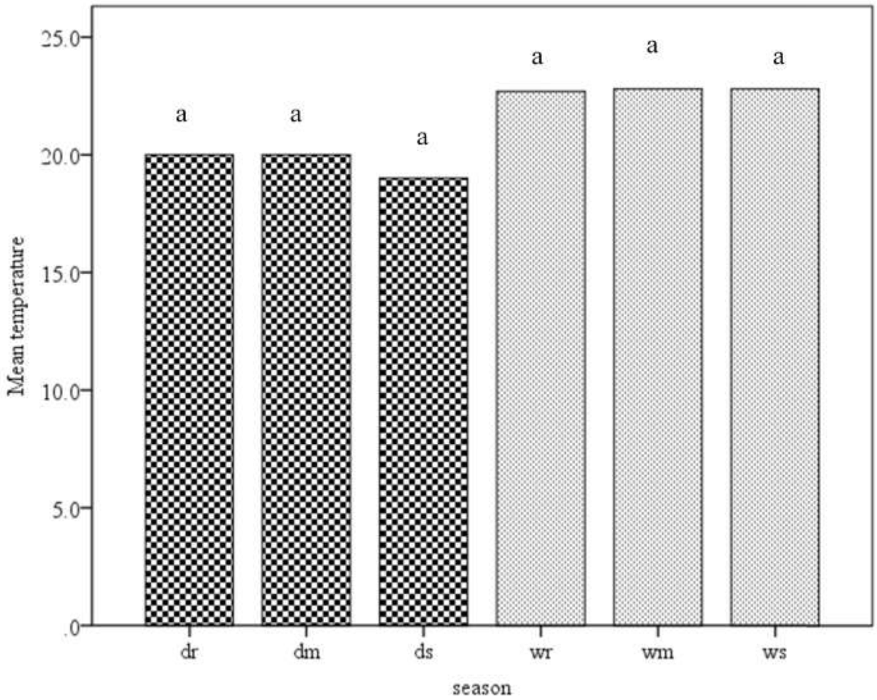
The results were analyzed by oneway ANOVA. The data was analyzed by using statistically model like as one way ANOVA to test significant difference between physical, chemical and macro invertebrates among the site. For site comparisons, the physico-chemical variables and benthic macro invertebrate community structures were analyzed for all of the three sampling sites with descriptive statistic mean and standard deviation and the inferential were one way anova and mean difference. For all statistical tests, a probability of $P<0.05$ was considered statistical significant. SPSS and Microsoft Excel sheet on computer were used to analyze data obtained from physico-chemical and biological parameters.

# 4. RESULTS AND DISCUSSION

## 4.1. Physical Properties of The Addele Lake Water Samples

The data related to physical (temeperature) parameter of water samples are summarized and presented in Figure 2. As the result showed in Figure 1 the mean temperature ($^0$C) of water samples taken from the road side, middle part and slant side during the dry season was ranged from 19 to 20 $^0$C, respectively. Similarly, the mean temperature ($^0$C) of water samples taken from road, middle and slant parts of the Lake during the wet season ranged from 22.7 –22.8 $^0$C. The mean temperature recorded in road side during the wet season was greater than that of dry season. Similarly, the mean value of temperature in middle side during the wet season was greater than dry season. The mean temperature recorded in slant side during the wet season was greater than that of dry season and the mean temperature values recorded in water samples showed variations among the three sampling sites in both seasons. The temperature of water samples taken in dry and wet seasons ranged from 19 to 20 and 22.7 to 22.8$^0$C, respectively.These results showed the temperature was significantly ($p<0.05$) difference among seasons.

As the result showed in Figure 1 the mean value of temperature in wet season was higher when compared with the mean value of dry season. This result indicated that the temperature was found to be above the maximum permissible limit of the CCME (2000) guidelines for community water use. Similar to this study (Zelalem Desalegne, 2007) reported as it was measured at the central part, the temperature of Lake Addele ranged from 22°C to 26°C. The maximum surface water temperature of Lake Addele is closer to those of Ethiopian Rift Valley Lakes including Lakes Ziway (18.5-27.5°C); by Tilahun (1988), Abijata and Langano (18-27°C) by Kebede *et al. (*1994) respectively, were found to be above the maximum permissible limit of the CCME, 2000. An average temperature of 22.15 $^o$C for the surface and 22.12 $^o$C for the bottom of the Lake was recorded. The temperature varies between a minimum and maximum value of 20.97 $^o$C and 23.47 $^o$C for the surface and 21 $^o$C and 23.27 $^o$C for the bottom respectively (Berhanu Rabo 2008).




*Note:- Different letters a,b and c for the same season and different site are significantly different (P = 0.05)*
*WR =wet road, WM=wet middle, WS=wet slant; DR=dry road, DM=dry middle, DS=dry slant*

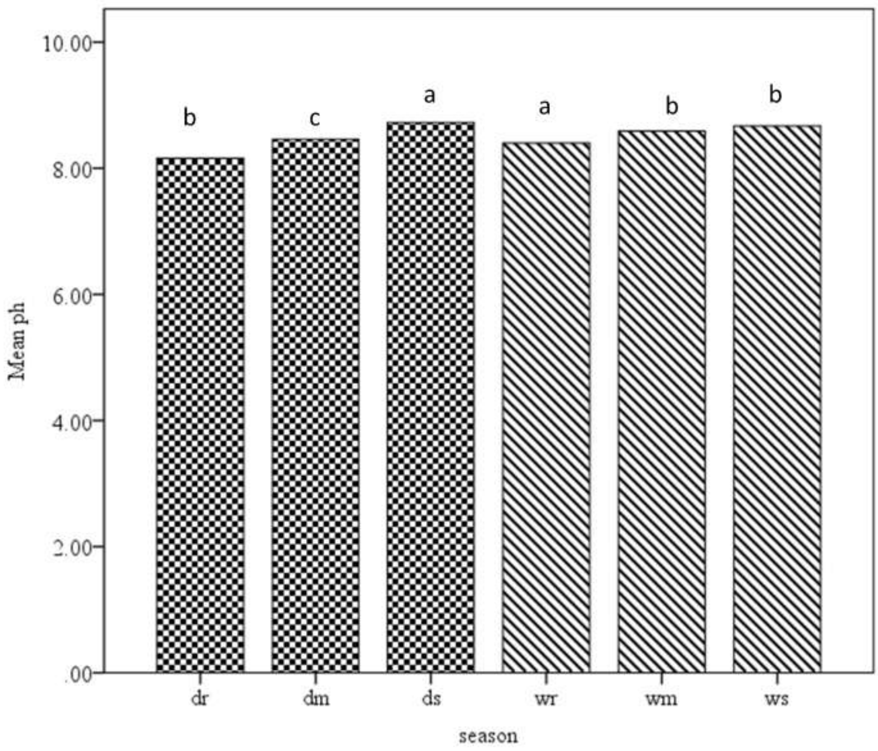
**Figure 2.** Mean ±**SD** of temperature measurements of Addele Lake water sampled during the wet and dry seasons 2017/2018.

## 4.2 Chemical Profile of Water Samples From Lake Addele

### 4.2.1. pH.

As the result shown in Figure 2 the mean value pH of water samples taken from road, middle and slant during dry season were 8.46±0.026, 8.16±0.03 and 8.72±0.010, respectively. And, the mean value pH of water samples taken from road, middle and slant during wet season were 8.59±0.00, 8.4±0.100 and 8.4±0.02, respectively. The pH (hydrogen ion concentration) of water samples recorded in dry and wet seasons were found to be slightly alkaline. As the result showed in Figure 2 there were slight differences in pH values of water samples taken during dry and wet seasons. The pH values of water samples in dry and wet seasons ranged from 8.16 to 8.72 and 8.4 to 8.59 respectively (Figure 2). The pH of Lake Addele in dry season varied from 8.16 to 8.72 which indicate that the Lake is a basic one. The recorded value is more or less similar to Lake Kuriftu with a minimum of 8.2 in August, 2005 to a maximum of 8.8 in November, 2005 (Desalegn, 2007), these tend to remain at high levels owing to the high buffering capacity of the Lake waters (Talling and Lemoalle, 1998).This result indicated that the mean differences of the pH recorded at different sampling sites of the Lake water were significantly ($P<0.05$) different among sites and between seasons. During the wet season the pH was at its minimum and dry season it was at the maximum values. The pH in water samples ranged from 8.16 to 8.72 in both seaons and scholars stated that the pH of water is important for the biotic communities as most of the plant and animal species can survive in narrow range of pH from slightly acidic to slightly alkaline condition (Naryan, 2008). In the study period i.e. February 2017 to Septembers 2017 pH value ranged from 8.16 and 8.72 to. The maximum pH reported during wet was very low due to the water levels and concentration of nutrients in water (Naryan, 2008) and maximum was during dry due to the dilution of water by addition of rain water (Reddy Vk, 2009).

The pH was low at the middle part of both seasons and high in slant side of the Lake. The increasement might be due to the addition of sewage wastewater, and may possibly be due to the presence of free ammonia, which is likely to pose problems. Ammonia is much more toxic in alkaline waters than in acidic ones because free ammonia at high pH values is more toxic to aquatic biota than when it is in the oxidized form (Heukelekian *et al*., 2001). But all the values of pH were within the limit of the WHO (2011) guidelines for livestock watering and for irrigation but only the slant side are above the WHO guideline. These conditions may be due to relatively higher temperature in the slant side or due to same ions dissociated from domestic wastes and agricultural runoff. The higher pH values observed suggests that carbon dioxide, carbonate-bicarbonate equilibrium is affected more due to change in physicochemical condition (Karanth 1987).The pH of the aquatic systems is an important indicator of water quality and the extent of pollution in the studied areas. Unpolluted water normally shows near neutral or slightly alkaline pH (Rajasegar, 2003). Hence, in this study, the Lake water do have any health treats on human and aquatic organisms when they consumed for different purposes in the study area (see in Appendix)



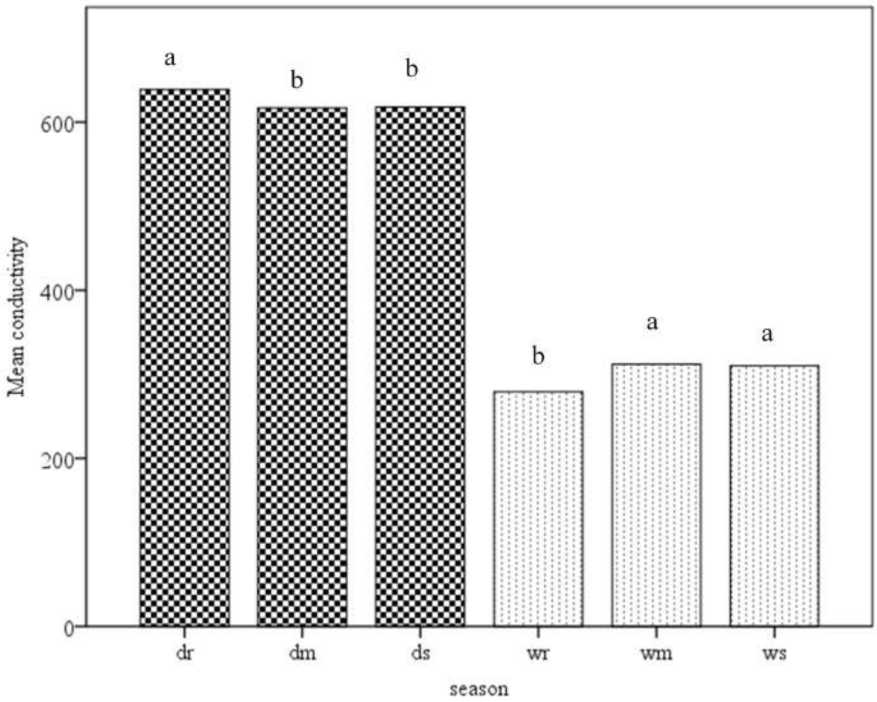

*Note:- Different letters a,b and c for the same season and different site are significantly different (P = 0.05).*
*WR =wet road, WM=wet middle, WS=wet slant, DR=dry road, DM=dry middle, DS=dry slant.*

Figure.3. Mean ± SD of pH measurements of Addele Lake water sampled during the wet and dry seasons

### 4.2.2 The Conductivity

Electrical conductivity varies among sites and seasons ranging from (310 to 639 µS/cm) where the highest value recorded was from road side during dry season.The mean values of EC on water samples from road,middle and slant side during dry and wet season were 639±1.00,617 ± 1.00 and 618±0.00 µS /cm and 279 ± 0.00,312 ±3.46 and 310 ±1.001 µS/cm respectively. This result indicated that, the overall mean value of EC of water samples in dry season were greater than the overall mean value of EC of water samples in wet season. The highest electrical conductivity was reported during dry 639 µS /cm due to the addition of domestic wastage into the lake (Verma PU, 2012 and lowest in wet 301 µS /cm because of water dilution by rainy water (Solanki, 2012).

Generally, the increase in EC was recorded on road side in both the dry and wet seasons due to the discharge of domestic and sewage wastewater and also due to enrichment of electrolytes, possibly due to the phenomenon of mineralization or weathering of sediments. These results were supported by (Preston *et al*., 2000). This result indicated that the mean differences of the conductivity recorded at different sampling sites of the Lake water were significantly ($P<0.05$) different among sites and between seasons. Using electrical conductivity as water quality index (Moore, 1989), the Lake has good water quality. Its range 80.40–178.80 µS/cm will protect diverse species of organisms. All these values are by far above the WHO (2008) guidelines value recommended for drinking purpoe (1500 µS/cm).




*Note:- Different letters a,b and c for the same season and different site are significantly different (P = 0.05)*
*WR = wet road, WM = wet middle, WS = wet slant DR=dry road, DM = dry middle, DS = dry slant*

Figure 4**.** Mean ± SD of conductivity measurements of Addele Lake water sampled during the wet and dry seasons**.**

**4.2.3 Biochemical Oxygen Demand**

BOD is an important parameter of water quality which measures the quantity of oxygen consumption by microorganisms during decomposition of organic matter. The BOD results of Lake Addele various among site and seasons ranging from (15 to 24 mg/L) where highest value recorded was from road side during wet seasons. The mean values of BOD on water samples from road,middle and slant side during wet and dry seasons were 24±1.0, 20 ± 1.0 and 20±2.0 mg/L and 17 ± 0.0, 19 ±0.0 and 15 ±1.0 mg/L respectively. The overall mean values of BOD of water samples in wet season were greater than that of the dry seasons. The highest demand of oxygen in the water was recorded during wet season was 24 mg/L due to the possible addition of high amount of waste along with rain water from the surrounding and addition of organic waste in Lake by certain human activities which also be responsible for the increase in BOD (Solanki (2001,2007). The high BOD values observed during wet season may be due to increase urban runoff which carries pet wastes from streets and sidewalks; nutrients from lawn fertilizers; leaves, grass clippings, and paper from residential areas into the river.

The conversion of ammonia to nitrate requires more than four times the amount of oxygen as the conversion of an equal amount of hydrocarbons to carbon dioxide and water. Though high BOD is always accompanied by low DO level, counter result is obtained in our study which is comparable to the study of ( Kankal, *et al.,* (2012) Gangasagark) Lake in India and this result is so near similar to the average concentration of biochemical oxygen demand in Futala Lake Nagpur water was 14.0mg/L to 20.0 mg/L in dry and 24.0 mg/L in wet season (Pur *et al.,* 2015). From the $BOD_5$ results in this study, it can be concluded that the ground water in the area studied is generally polluted due to high biochemical oxygen demand during dry season and wet season periods and is unfit for drinking since the range of $BOD_5$ values is above the maximum permissible level of 3.00 mg/L recommended by National Agency for Food and drugs Administration and Control (NAFDAC) 1922 and World Health Organisation WHO 2008). So according to WHO drinking water standard, BOD should not exceed 6 mg/L. The discharge of waste with high level of BOD can cause water quality problems such as sever dissolved oxygen deplation and fish kill in receiving water bodies (Micheal *et al.,* 2001). This result is similar with the study of Temesgen Tarekegne, 2015) at lake kurfito with the value of 24mg/l. This result indicated that the mean differences of the BOD recorded at different sampling sites of the Lake water were significantly ($P<0.05$) different among sites and between seasons.

The mean values of COD (Table 1) obtained from road, middle and slant during wet season were 190±, 300± and 210± (mg/L) respectively. The mean values of COD obtained

(Table 1) during dry season was 150±, 250± and 130± (mg/L). As shown in Table 1, the mean COD content were higher during wet season (300±20 mg/L) than at dry season (250±0.00 mg/L) with values ranging from 130± mg/L (lowest in slant) to 250± mg/L (highest in middle) at dry season and 190± mg/L (lowest in road) to 300± mg/L (highest in middle) at wet season. The higher mean COD content at dry season may be due to prolong accumulation of seeped organic leachates into the aquifers. High COD levels imply toxic condition and the presence of biologically resistant organic substances (Sawyer and McCarty, 1978). The COD ranges in this study show similarity with COD range of 98.7 - 316 mg/L obtained in impact assessment of human activities and seasonal variation on fresh water benue within makurdi metropolis in India. Statistical analysis showed significant difference among locations and between wet and dry seasons, at $p<0.05$. Chemical oxygen demand is the oxygen required for chemical oxidation of organic matter with the help of strong chemical oxidant. Seasonal analysis reveals that maximum values of COD are recorded during wet season and minimum in dry. The permissible limit is 10 mg/L (WHO, 2008).

### 4.2.4 Dissolved Oxygen

DO was found to be (Table.1) 5.76±0.02, 3.25±0.05 and 5.60±0.23 (mg/L) for road, middle and slant respectively during the dry season and 2.26±0.1, 3±0.0 and 4.26±0.1 (mg/L) were obtained as mean values for wet season (Table 1) for road, mid and slant respectively. There was high significant difference among locations and significant difference was observed in seasons was $p<0.05$. The lowest values of DO observed during wet season at road site could be due to phytoplankton bloom and decomposition of organic materials. The decrease in DO of water is due to its poor ability to hold oxygen at high temperature as a result of higher rate of microbial metabolism (Lewis, 2000).

Dissolved oxygen is very essential for all living organisms in any water bodies. The recorded level of dissolved oxygen in the water of Lake Addele ranged between 2.26- 5.76 mg/L (WHO range: 4.5-7.5 mg/L) for drinking purpose. Higher DO levels during the wet season than dry season may be attributed to seasonal stratification which occurs as a result of water's temperature dependent density. Implying that cold water can hold more dissolved oxygen than warm water. For instance, water at 20 $^{O}$C will be 100% saturated with 8 parts per million dissolved oxygen, while water at 8 $^{O}$C can hold up to 12 parts per million of oxygen before it is 100% saturated. Other factors for higher DO may be due to large population of plants, algae and cyan bacteria in Lake water. Also that DO levels can fluctuate significantly from day to night. This is referred to as the diurnal (daily) cycle, resulting from excess oxygen produce by rooted aquatic plants and algae during the daylight hours when they are photosynthesizing, this they must use for life processes during the dark hours (Manahan, (2005) and Zhao, (2006) Thus the higher DO levels observed in the wet season of this study also reflected more of the consequent massive aquatic plant growth observed during this period. Increased levels of BOD and COD decrease the dissolved oxygen content in the river water (Ubwa *et al*., 2013).

Table 3. Means values ± SD for various physico-chemical properties of water samples collected from Lake Addele at dry and wet seasons.

| | Wet season | | | Dry season | | |
|---|---|---|---|---|---|---|
| Parameter | A | B | C | A | B | C |
| BOD mg/L | 24±1.00$^{a}$ | 20±1.00$^{b}$ | 20±2.00$^{b}$ | 17±0.00$^{b}$ | 19±0.00$^{a}$ | 15±1.00$^{c}$ |
| COD mg/L | 190±2.00$^{b}$ | 300±20$^{c}$ | 210±00$^{a}$ | 150±10$^{b}$ | 250±00$^{a}$ | 130±00$^{c}$ |
| DO mg/L | 2.26±0.10$^{c}$ | 3±0.00$^{b}$ | 4.26±0.10$^{a}$ | 5.76±0.02$^{a}$ | 3.25±0.05$^{b}$ | 5.6±0.23$^{a}$ |
| Nitrate mg/L | 3.02±0.00$^{a}$ | 2.86±0.01$^{b}$ | 3.01±0.00$^{a}$ | 4.67±0.00$^{b}$ | 4.47±0.03$^{c}$ | 5.09±0.00$^{a}$ |
| Phosphate mg/L | 0.22±0.00$^{b}$ | 0.30±0.00$^{a}$ | 0.21+0.00$^{c}$ | 0.57±0.01$^{b}$ | 1.35±0.00$^{a}$ | 0.53±0.00$^{c}$ |

*Note: - Mean with the same superscript letters are not significantly different for each site.*

A= road, B= middle C = slant

### 4.2.5 Nitrates

The amount of nitrate recorded in the water of Addele Lake ranged from 2.86±0.010 to 5.09±0.00mg/L. The highest amount of nitrate was recorded during dry season was 5.09 mg/L because of high vegetation during dry which supported the growth of plankton (Pandit B.R and Solanki H.A (2004).The highest amount of nitrate concentration was known to support the formation of blooms Uduma, Au (2014).The lowest amount of nitrate in water was recorded during wet season was 2.86mg/L by the utilization by plankton and aquatic plants (Verma *et al*., 2010). Nitrate was found to be (Table1) 3.02±0.001, 2.86±0.010 and 3.012±0.001

(mg/L) for road, mid and slant respectively during the wet season and 4.67±0.001, 4.47±0.034 and 5.09±0.000 (mg/L) were obtained as mean values for dry season (Table 1) for road, mid and slant respectively. Nitrate are contributes to fresh water through discharge of sewage and industrial wastes and run off from agricultural fields Solanki HA (2012). The concentration of nitrate on the location of slant and road are nearly similar that is 3.02 and 3.012 (mg/L) respectively and at the site of middle was 2.86 mg/L which is different from slant and road during wet season. This is may be due to the sites are near to mixed immediately to the water that came's from erosion and through the canal. Similarly the concentration of nitrate in the site of road and middle are nearly similar but the slant site is different this is may be due to agricultural run of from the hill side .There was high significant difference among locations and significant difference was observed in seasons is $p<0.05$.The concentration of nitrate during wet and dry season was below the maximum permissible limit which is 5mg/L but only the slant side was above the permissible Limit of (WHO, 2008).

### 4.2.6 Phosphate

Phosphate comes from several sources like human and animal wastes, industrial wastes, agricultural runoff, and exposed soil erosion. Most natural Lakes (not affected by man) have phosphorus concentrations of between 1 and 100 µg/l (Bronmark and Hansson, 1998). The amount of phosphate recorded in the water of Addele Lake ranged from 0.2±0.000 to 1.35±0.005 mg/L during dry and wet season. The highest amount of phosphate was recorded during dry season was 1.35±0.0058 mg/L due to higher disposal of phosphate from domestic sewages and surface runoff from phosphate containing fertilizers (Korostynska *et al*., 2012) Phosphate was found to be (Table1) 0.216, 0.301 and 0.2110 (mg/L) for road, middle and slant respectively during the wet season and 0.572±0.01, 1.35±0.0058 and 0.5±0.0001 (mg/L) were obtained as mean values for dry season (Table 1) for road, middle and slant respectively. The concentration of phosphate on the location of slant and road are nearly similar that is 0.216 and 0.211 (mg/L) respectively and at the part of middle was 0.301 mg/L which is different from slant and road during wet season this is may be the distance of middle part from the slant and road .These site were suceptable to agricultural run of and erosion, wastes are easily mixed to this location. Similar fashion is holds true for the dry season.In the dry season concentration of phosphate were 0.572 and 0.5mg/L for site road and slant respectively, the concentration of phosphate for middle part were 1.35 mg/L.

The concentrations of phosphate during dry season were greater than wet season this could be due to dilution effect in the water of the Lake. The total phosphate concentration above 0.03mg/l stimulates the algal growth which result eutrophication, causing a shifting in aquatic life to a fewer number of pollution tolerant species such as midge larvae and worms. Eutrophication threatens to limit organisms diversity and recreational opportunities. According to Ayers and Westcot FAO (1985), the maximum allowable concentration of phosphate for irrigation water is 2mg/l**.** In this study**,** the entire site containing concentrations of $< 1.35$ mg/l.According to Illinois water quality standard for total phosphorus in Lakes is 0.05mg/L but concentrations above 0.03mg/L are enough to stimulate algae growth. The increase in phosphate content could be related to urban and /or agricultural activities (mainly from fertilizers), sewage and the use of phosphate additives in detergent formulations. The latter can be eroded into the river system during the disposal of wastewater generated domestically and municipally (Melakuetal, 2007). Eutrophication threatens to limit organisms diversity and recreational opportunities. Fertilizers containing nutrients nitrates and phosphates which are found in storm water runoff from agriculture, as well as commercial and residential use (Allen and Robert, 2013). The values obtained from the sites are significantly different ($p<0.05$ ) among each other for phosphate concentrations.

## 4.5 Measurements of Selected Heavy Metal Concentration in Addele Lake Water Samples.

Heavy metals uptake and accumulation occurs from water and food. The efficiency of assimilation in different organism might be affected by many factors such as salinity, temperature, season and interacting agents also have impact on this pattern. The concentration of metals in water samples of the Lake was one of the factors that affect the uptake and accumulation of heavy metals in the body of fishIt appears that seasonal variations in the concentration of trace elements in the Lake are strongly dependent on both the drainage water discharge from the various drains in the Lake as well as the velocity and direction of of winds. The presence of trace metal in Lake Addele is mainly of allochthonous origin due to either agricultural influx, waste of farms or sewage via surrounding cultivated lands (Belay and Eshete, 2014).

The dissolved metals concentration in Addele Lake water was measured in three sampling sites (road,middle and slant site during the dry and wet seasons of the area. The concentrations of dissolved heavy metals in Lake Addele were found to be above the the instrumental detection limit (FAAS) in all sampling sites**.**The average concentrations (mg/L) of heavy metals in water sample from the study site are shown in Table 4. Statical analysis revealed that the metal concentration in the water and samples differed significantly ($p<0.05$).

Table 1 .Heavy metals concentration of water mg/L in the study period

| Dry season | | | | Wet season | | |
|---|---|---|---|---|---|---|
| parameter | A | B | C | A | B | C |
| Cd (mg/l) | $0.05\pm0.03^{b}$ | $0.09\pm0.01^{a}$ | $0.09\pm0.01^{a}$ | $0.03\pm0.01^{c}$ | $0.05\pm0.01^{b}$ | $0.17\pm0.01^{a}$ |
| Zn (mg/l) | $5.51\pm0.00^{b}$ | $5.09\pm0.00^{c}$ | $5.62\pm0.001^{a}$ | $5.19\pm0.0001^{b}$ | $5.26\pm0.001^{a}$ | $4.10\pm00^{c}$ |
| Pb (mg/l) | $2.84\pm0.01^{a}$ | $1.9\pm0.02^{b}$ | $2.8\pm0.0010^{a}$ | $1.44\pm0.001^{c}$ | $1.87\pm0.002^{a}$ | $1.83\pm0.001^{b}$ |

*Note: - Mean with the same superscript letters are not significantly different for each site.*
A=road B=middle C=slant

### 4.5.1 Zinc

Zinc makes up about 75ppm of the earth's crust, making it the 24th most abundant element with a density of 7.14g/cm$^3$.Zinc is normally found in association with other bases metals such as Cu and Pb in ore and has a low affinity for oxygen and occurs as ore such as calamite $Zn(Co)_3$ and zincite ZnO).Other uses of Zn include making circuit board, photocopies, dry cell batteries and its compounds are used in chemical and pharmaceutical industries such as paints, medicines and nutritional supplement (Reilly,2002).The concentration (mg/L of zinc in the area of invstigation for Lake water were (5.512 mg/L, 5.09 mg/L and 5.62±0.001mg/L for the site road,middle and slant during the dry season respectively. And result of the wet season were (5.19±0.0001mg/L, 5.26±0.001mg/L and 4.10 mg/L for the site road, middle and slant side. The concentration (mg/L of zinc in the area of investigation for Lake water varies from 5.09 mg/L and 5.62±0.001mg/L.The highest concentration of zinc were recorded during dry season because during wet season the level of Lake water increased and the concentration of zinc becomes diluted. There is a significance difference between season at $p<0.05$). When this value compared with permissible level of USEPA (2011) and WHO (2008) which is 5mg/L they are slightly above this the maximum permissible limit.

### 4.5.2 Lead

Lead is the most significant of all the heavy metals because it is toxic, very common (Gregoriadou *et al*., 2001) and harmful even in small amounts. Pb enters the human body in many ways. It can be inhaled in dust from lead paints, or waste gases from lead gasoline. It is found in trace amounts in various foods, notable in fish, which are heavily subjected to industrial pollution. The distribution pattern of lead concentration in Lake Addele was ranged from 1.4360±0.001 to 2.84±0.0001mg/L at dry and wet season respectively. The result shows (Table 4) the concentration of lead is higher during dry season. Though the concentration of lead is lower during wet season due to the level of water increased the metals became diluted and less when we compared with the dry season. The recommended value lead by WHO and FAO (1998) is 0.5 mg/L. The concentration of lead in this study was above the permissible limit. This result shows that it does bring any health risk for aquatic life and agricultural purposes.

### 4.5.3 Cadmium

The data (Table 4) presented the mean concentration of cadmium in the Lake Addele were 0.05±0.03, 0.096±0.01mg/L and 0.096±0.01mg/L at the site of road, middle and slant respectively, for the dry season. And the mean concentration of cadmium in the wet season were (0.03±0.01mg/L, 0.05±0.01mg/L and 0.17±0.01mg/L for the site road, middle and slant, respectively. The maximum concentration of Cd (0.096±0.01mg/L) was detected in the samples taken from middle part and slant site during wet season. Although, the minimum concentration of Cd was detected (0.17±0.01mg/L) at the site of slant during wet season. The high level of Cd contamination may be due to soil composition, organic fertilizer and environment pollution in the study area. The ANOVA result shows that the Cd concentration in dry and wet seasons are significantly different ($p<0.05$) as seen individually.But the concentration of Cd in the middle part were ($p>0.05$). The maximum allowable limit recommended by (FAO, 1985; USEPA, 1986; WHO, 1998) for drinking, irrigation and aquatic life is 0.5mg/L. Cadmium occurs naturally in Zn, Pb and other ores which act as source to ground and surface water's can be released in drinking water from the corrosion of some galvanized drainage system and water main pipe material (Shahida *et al.,* 2009).This indicate that the concentration of cadmium assessed was below the permissible limit.

## 4.6. Measurments of Selected Heavy Metals Concentration in Tissue of Fish Samples in Catfish (*Clarias gariepinus )* and Tilapia (*Oreochromis nilotica* ) From Addele Lake.

The distribution and accumulation of metals in fish organs depend on the metal type, interaction with natural factor, ability to bind metals in the forms that are not biologically available, character of mechanisms determining bioaccumulation and excretion of metals, and also on the type of tissue, fish species, size and age (Kebede *et al*.,2010).The metal cadmium, chromium, cobalt, copper, lead, manganese, iron and zinc are of particular interest because they have anthropogenic sources that are likely to cause elevated levels in the aquatic environment and concentration for these metals have been reported for naturally occurring aquatic organism. In the present study the concentration of zinc, cadmium and lead in the tissue of edible parts of Catfish and Tilapia collected from Addele Lake were investigated.

Table 2 Heavy Metal Concentration in Catfish (clarias gariepinus) and tilapia (*oreochroms nilotica)* Fish

| **Dry season** | | | | **Wet season** | | |
|---|---|---|---|---|---|---|
| Parameter | A | B | C | A | B | C |
| Cd (mg/Kg) | 0.04±0.010[b] | 0.06±0.00[a] | 0.04±0.010[b] | 0.08±0.01[b] | 0.08 ± 0.000[a] | 0.03±0.010[c] |
| Pb (mg/Kg) | 1.56±0.005[b] | 0.9±0.003[c] | 2.2±0.000[a] | 0.08±0.00[c] | 0.20 ± 0.000[b] | 0.26±0.000[a] |
| Zn (mg/Kg) | 3.06±0.020[b] | 3.43±0.01[a] | 0.027±0.010[c] | 3 ± 0.000[b] | 3.2±001[a] | 0.02±0.001[c] |

*Note: - Mean with the same superscript letters are not significantly different for each site.*

### 4.6.1 Concentration of zinc (Zn) in Tilapia and Catfish

The concentration of zinc in the fish species for the dry season were 3.06±0.02 mg/L, 3.43±0.001mg/L and 0.027±0.01 mg/L for the site road, middle and slant respectively. And the concentration of zinc during the wet season were 3±0.00 mg/L, 3.2±001 mg/L and 0.0240±0.001mg/L for the site road, middle and slant respectively. The distribution pattern of zinc concentration in Lake Addele was ranged from 0.0240±0.001 mg/L to 3.43±0.001mg/L at wet and dry season respectively. The results shows (Table 5) the concentration of zinc is higher during dry season. The variations in heavy metal concentrations in freshwater fish is attributed to differences in metal concentrations in water, feeding patterns of fish and the season in which studies are done (Canli *et al.,* 1998). The concentration of Zn in all the fish samples were below the FAO maximum guideline limit of 30 mg/kg of Zn for safe human consumption (FAO, 1985). Zn toxicity is rare, but at concentration up to 40mg/kg, Zn may induce toxicity, characterized by symptoms of irritability, muscular stiffness and pain, loss of appetite, and nausea (WHO, 2011).

### 4.6.2 Concentration of Cadmium (Cd) in Tilapia and Catfish Samples

The amounts of cadmium concentration in fish samples obtained from Lake Addele were shown in Table 5. Cd is a non-essential element and is highly toxic to marine and fresh water aquatic life. The concentration of Cd in the fishes species for the dry season were 0.04±0.010mg/L, 0.06+0.00mg/L and 0.04+0.010 mg/L for the site road, middle and slant respectively. And the concentration of Cd during the wet season were 0.082±0.001mg/L, 0.08±0.00 mg/L and 0.03±0.01 mg/L for the site road, middle and slant respectively The highest Cd level recorded in fish were during dry season. The variations in heavy metal concentrations in freshwater fish is attributed to differences in metal concentrations in water, feeding patterns of fish and the season in which studies are done (Canli *et al.,* 1998).The mean concentration of Cd in the present study was above the maximum permissible limit recommended by WHO (2011) which is 0.2mg/kg.

### 4.6.3 Concentration of Lead (Pb) in Tilapia and Catfish Samples

Pb is both a toxic and non-essential metal having no nutritional value to living organisms. The mean value of lead concentration in the tissue of edible part of fish collected from the Lake Addele were 1.56±0.0005, 0.9±0.003 and 2.2±0.000 for the site road, middle and slant for dry season respectively. And during wet season were 0.08±0.01,0.20±0.000 and 0.260±0.00 for the site road,middle and slant respectively. The highest concentration of lead in fish recorded was during the dry season. This shows that high traffic density found near the study area played a significant role in the level of Pb in the Addele Lake water. From this it is possible to close that this Lake-water has relatively high concentration of Pb, and its effect on the aquatic systems is very high. Because of Pb is very toxic heavy metal even at low concentration. Thus, Lake Addele was not recommended for domestic use. From this, it could be observed that Pb level found in the study area was greater than the standard value given for Pb by WHO which is 0.01 mg/L. The pattern of metal distribution in the tissue has been suggested to reflect the route of metal uptake in fish, and this process is also strongly influenced by the water chemistry (Kebede *et al*., 2010).The concentration of Pb in the present study were low when compared with by (Kiflom and Tarekegn, 2015) were 3.85 mg/L from Hawassa and Ziway Lake (Kiflom and Tarekegne ).

## 4.7 Comparison of the Heavy Metal Concentration of the Current Study with Other Reported Concentration From Literature.

### 4.7.1 Water

The comparison of heavy metal concentration of the current study with reported literature is compiled in Table 6 below. It is important to compare the amount of heavy metals obtained from the analyses of water samples Lake Addele with amount sited in the literature from country side and other countries. This comparison helps to indicate the difference in composition and existence of deviation from certain guide lines. The possible explanation of the variation in the concentration of metals between the above all mentioned Lakes and Lake Addele could be due to the difference source of pollution, their exposure time for pollution, the water chemistry of the Lakes and the geological nature of the Lakes. There are some reports from different countries on the concentration of the selected heavy metals in water samples.The comparison of the value determined in this study with some other reported values were presented in Table 6 below. From the table, one can see that the concentration of the metals analysed in this study within the range of different reported value.

Table 3.Comparison of Heavy Metal in Lake Addele Water Sample mg/L with Reported Litrature**.**

| Heavy Metals | Concentration(mg/L) | Location | References |
|---|---|---|---|
| Zn | 5.09-5.62 | Ethiopia | **Present study** |
| | 0.069-0.18 | Egypt | Authman and Abbas,2007 |
| | 5.0 | - | USEPA,1993 |
| | 0.01-5.62 | Tanzania | Kisamo,2003 |
| Cd | 0.17-0.096 | Ethiopia | **Present study** |
| | 0.5 | - | FAO,1985;WHO,1993 |
| Pb | 1.44-2.84 | Ethiopia | **Present study** |
| | 6.5-7.59 | Sirlanka | Senarathne and Pathirathe,2007 |
| | 0.5 | - | FAO,1985 |

**4.7.2. Fish**

The comparisons of the present study with the previous studies with other Lakes were compiled in Table 7 below. The maximum mean accumulation of zinc found by Abayneh *et al*.(2003) in Tilapia and Cat species collected from Hawassa Lake were 0.027mg/L of zinc and from Abaya 0.014mg/L of Zn evaluated by Tariku *et al*.,(2015).

According to Kebede and Wondimu (2004) the mean accumulation of Cd and Pb in Tilapia and Catfish from Lake Hawassa were 1.04-1.43mg/L and 1.86-2.69mg/L respectively. Although the author was found the mean level of heavy metal accumulation of Cd and Pb in Tilapia from Lake Ziway were 0.44-0.89mg/L and 1.65-2.45mg/L,respectively. The accumulation of Cd in fish in the present study were lower than Lake Ziway and the accumulation of Pb in fish in the present study were nearly similar to Lake Ziway. The concentration of Cd in the two fish samples is still in a permissible value of Cd;0.5mg/kg that was proposed by the Food and Agricultural Organization (FAO,1985) to be safe for human consumption. Regarding to the other non essential trace element Pb, in most literature was above the permissible limit 0.5mg/L recommended by FAO (1985).

Table 4. Comparison of Heavy Metal Accumulation mg/Kg in Fish Sample from Lake Addele with Litrature Report

| Heavy metals | Concentration (mg/kg) | Location of Lake | References |
|---|---|---|---|
| Zn | 0.014 | Abaya | Tariku *et al.,*2015 |
| | **0.027-3.43** | **Addele** | **Present work** |
| | 0.027 | Awassa and Ziway | Abayneh *et al.,*2003 |
| Cd | 0.0037 | Abaya | Tariku *et al*.,2015 |
| | 1.04-1.43 | Hwassa and Ziway | Kebede and Wondimu,2004 |
| | 0.44-0.89 | Hwassa and Koka | Larissa *et al*.,2012 |
| | 0.34-0.58 | Tekeze River | Mulu *et al*.,2012 |
| | **0.03-0.082** | **Addele** | **Present work** |
| Pb | 1.86-2.69 | Awassa and Koka | Kebede and Wondimu,2004 |
| | 1.65-2.45 | Awassa and Koka | Larissa *et al.,*2012 |
| | 1.62-1.85 | Tekeze River | Mulu *et al.,*2012 |
| | **0.20-2.2** | **Addele** | **Present work** |

As mentioned above, the results obtained in this study were compared with the findings of other researchers were great difference about the contents of trace elements from this study. This difference in metals content may be due to highly irrigation activities around the Lake and anthropological activities near the ecosystem, and the presence of agents which either increase or decrease the metal content.Although distribution of pollutants among the various organs within an organism is not uniform but rather they accumulate in specific target organs. Liver, kidney and gills, are target organs for heavy metals accumulation in fish that can lead to pathological changes than the muscle tissue. According to (Akoto *et al*., 2014) the low levels of binding proteins in the fish muscle may account for their low concentrations of heavy metals.

## 4.8 The Benthic Macro-Invertebrate Species Diversity and Distribution in Lake Addele, Eastern Ethiopia.

The diversity and distribution of the benthic macro invertebrate species were estimated by calculating the benthic macro-invertebrate index such as Shannon Weaver diversity index, reachness and evenness of species, table 8. According to Shannon –wienner index the result obtained at site of road (0.491) indicates that diversity among species with even distribution relative to other sites where as there was low "H" value in road site (0.469) and slant site (0.486) which describes less diversity in which a community dominated by one family relative to other sites. The species diversity of the benthic macro-invertebrates in the three transect lines was computed and the results showed a species diversity of H=0.491. The species diversity was a bit low compared to the studies conducted by Penalosa (2010),Sambaan (2005), and Santiago (2002). This is may be due to the various anthropogenic activities in the study area like improper waste disposal of residential areas,hotel and a ship port, which are all near the study area.

According to Gerritsen *et al*. (1998) as the number and distribution of taxa (biotic diversity) within the community increases, so does the value of "H"). High values of "H" would be representing of more diversity community as well as even distribution. This provides valuable clues for water quality monitoring. In the same way taxa richness and diversity (H′=4.0775) characterize this site as well. The higher the index, the more diversity an organism has. The result obtained that indicates the water at the middle part has higher number of taxa than the other site. The higher taxa distribution implies the community was within stable life which indicates the water was in the higher quality. Similarly Richard (2003) stated that diversity values may vary directly with water quality and low diversity may indicate unstable community.The dominant taxa can survive with the stress the other taxa which was intolerant to the stress cannot survive and their number was decreased.

Table 8. Shanon Weaver Diversity Index, Evennes and Taxa Richness for BMI.

| ,Diversity index | Road | Middle | Slant |
|---|---|---|---|
| Shannon weaver diversity index $H=\Sigma^{s}_{i=1}(pi)(lnpi)$ | 0.469 | 0.4860 | 0.491 |
| E=H/Hmax | 0.1322 | 0.1262 | 0.1308 |
| Hmax=ln(N) | 3.7135 | 4.0775 | 3.9120 |

The richness of taxa also indicates water quality. According to Richard (2002) high taxa richness was generally associated with good water quality, low taxa richness does not necessarily indicate poor water quality. According to table 8 the species richness (Hmax) of the Lake Addele was 3.713, 4.07 and 3.912 road, middle and slant respectively. The Hmax of the middle part was greater than the other. Most values measured using the Shannon diversity index (Turkme and Kazanci. 2010). Ranged from 0.469 to 0.491. Values above 3.0 indicate that habitat structure is stable and balanced and values under 1.0 indicate the presence of pollution and degradation of habitat structure. Based on these criteria, none of the sites of Lake Addele exceeded the 1 level of the Shannon diversity index, for benthic macro invertebrates the studied area. (Table 8 ) This indicates the water quality at middle part was good according to Richard (2002). The presence or absence of certain taxa is also related to water quality rather than other ecological factors (Mason, 1996). According to Hilsenhoff (1988), the presence of pollution sensitive groups rather than pollution tolerant groups can indicate water quality because pollution tolerant groups can inhabit both habitats according to their niche preference. Benthic macro invertebrate species are differentially sensitive to many biotic and abiotic factors in their environment. Consequently, macro invertebrate community structure has commonly been used as an indicator of the condition of an aquatic system (Armitage *et al.*, 1983).

Increment in the total abundance does not show better environment because disturbance may favors some tolerant, opportunistic and less competent taxa with reduction in sensitive taxa (community dominated by few taxa). When streams become excessively acidic or alkaline, the change can adversely affect the biota. As those fish and macro invertebrates unable to tolerate the altered conditions decline, a tolerant organism increases in number due to lack of competition for food and habitat. This results in a healthy biological community dominated by few tolerant taxa (Kimmel, 1983).

The dominance of Chironomus spp. in areas enriched with high detritus matter and subsequently low dissolved oxygen was also reported by Callisto *et al.,* (2001). The physiological and morphological adaptation of the Chironomus through its ability to slow their metabolic rates was supposed to allow it to survive in harsh and hostile environments (Hamburger *et al.,* 1994). A larger body size which helps in ventilation of larval tubes also allows chironomids to tolerate low dissolved oxygen levels (Int Panis *et al.,* 1996). Therefore, the dominance of Chironomus can be an indicator of high organic pollution.

Table 9 Common BMI Identified From Lake Addele During The Study Period

| No | Identified Families of BMI | A | B | C |
|---|---|---|---|---|
| 1 | Chironomidae | 16 | 17 | 16 |
| 2 | Macromiidae | 2 | 6 | 4 |
| 3 | Physidae | 0 | 1 | 0 |
| 4 | Gyrinidae | 5 | 0 | 5 |
| 5 | Bactistidae | 1 | 6 | 1 |
| 6 | Gastropoda | 14 | 12 | 14 |
| 7 | Annelida | 12 | 17 | 10 |

A=Road B=Middle C=Slant

Water quality parameters such as DO, BOD and nutrients revealed a drastic increase and decrease in their concentrations for all water bodies sampled during the entire study period. This spatio-temporal change of water quality which could be attributed to different concentration of organic matter within a water body at a given point in time influenced the composition and distribution of macroinvertebrates. This observation is supported by Peeters *et al.* (2004) and Orwa *et al.* (2013) who stated that the distribution and composition of aquatic macroinvertebrate communities are influenced by a variety of environmental factors such as habitat characteristics, water quality, sediment quality, food quality and quantity along with biological factors such as competition and predation. As these environmental and biological factors change over time, the macroinvertebrate community also changes. In this study physico-chemical parameters such as temperature, pH, DO, BOD and directly influenced the composition and abundance of macrointervertebrates. High temperature,low DO and high BOD negatively influenced the species diversity, evenness and richness in lake Addele as they recorded low species diversity and richness and had low temperatures, high DO and low BOD resulting in high species richness. pH did not show any clear effects on macroinvertebrate diversity and richness. The changes of species diversity and richness were probably due to variation in the tolerance level of environmental degradation due to anthropogenic impacts observed in the Lake.

This could conform to the physical structure that could have provoked perturbations in aquatic invertebrate communities, but the response to such events varies according to species. This is also supported by Kari and Rauno (1993), Griffith *et al*. (2005) and Orwa *et al*. (2013) who concluded that the distribution of aquatic macroinvertebrate occurrence is set by physical and chemical tolerance of the individual macro invertebrates to an array of environmental factors. A lower value of the diversity index is generally interpreted as characteristic of polluted conditions over time, where a few tolerant genera dominate the community while higher values are recorded in unpolluted waters. Low species diversity was observed during high temperatures.

High competition for DO by macro invertebrates during respiration which only make the more tolerant species survive as the temperature conditions might also not be favourable to less tolerant species. This is in line with Seaman and Kok (1987) who reported that dissolved oxygen (DO) concentration in SWBs varied according to local conditions, mainly temperature, time of the day and season. In the present study, higher DO concentrations were recorded in water bodies at high temperatures. A possible explanation for this is that higher temperatures induce increased biological activity in the water column, with larger organisms requiring more DO for respiration and the smaller microorganisms increasing their demand for DO in order to carry out aerobic biodegradation of deposited organic matter in the water body.

# 5. SUMMARY, CONCLUSION AND RECOMMENDATION

## 5.1. Summary

This study was conducted to assess the biological and physicochemical indicator of water quality profile. Samples were collected from purposefully selected sites from three sampling occasions during both the dry and wet seasons. Analyses for heavy metals in fish and water samples were done using Atomic Absorption Spectrophotometer (AAS). Benthic macro invertebrate species were collected by using D-net; they were identified by using compound microscope and categorised at genus level. A total 159 of individual organisms were identified which belongs to ten different genus. The Physico-chemical parameters of water samples of Addele lake were analyzed and the most results were above value of WHO (2011) set for survival, metabolism and physiology of aquatic organisms.

Physico chemical properties used to measure the qualities of lake Addele were pH, temperature, Electrical conductivity, DO, BOD, COD, nitrate and phosphate.Higher values of the physicochemical property observed suggested that the Lake is highly polluted by sewage, domestic waste.The water quality of the Lake showed a pattern of behavior linked to human pressure associated with domestic, municipal sewage wastewater and agricultural activities. From the selected heavy metals studied concentration of Cd, Pb and Zn in water samples were exceeded the maximum permissible limits of drinking water set by WHO/FAO (2011). The concentration levels of Cd, Zn and Pb in fish samples were recorded above the permissible limit of WHO.

The irrigation of water can also lead to accumulation of heavy metals in the water,fish and consequently in to the vegetables, exposing the human population of the area and surrounding community to serious health risks, i.e. the water can easily spread toxic heavy metals from the contaminated source to different vegetables when they are cultivated using the environment when they used for agricultural irrigation

The diversity and distribution of the benthic macro invertebrate species were estimated by calculating the Benthic Macroinvertebrate index such as Shannon weaver diversity index, reachness and evenness of species.High values of “H” would be representing of more diversity community as well as even distribution. This provides valuable clues for water quality monitoring.

This study revealed that the water and fish samples in Addele lake were contaminated with some indicated heavy metals. This is because, the three selected sites, receiving discharges from the watershed, farm discharge points, road, rural and urban water discharge points channel to the Lake Addele. Data obtained from the heavy metal analysis suggests that, there were more risks from consumption of water and fishes.

## 5.2 Conclusion

Based on the result of this study, there is variation in values of physicochemical parameter concentration of selected heavy metals in water and fish samples and BMI distribution among the sampling sites and between seasons considered. The physico-chemical parameters of water samples of Addele lake were analyzed and the most results were above and within but few result below the recommended value of WHO (2011) set for survival, metabolism and physiology of aquatic organisms. In water samples, the concentration of Cd, Pb and Zn exceeded the maximum permissible limits of drinking water of WHO/FAO (2011). These indicated that the analyzed results in water and fish samples were from Lake Addele had recorded levels above the international permissible limits set by WHO/FAO (2011).Therefore, fish and water consumption by rural and urban population of Addele and neighbouring villages, means exposing the population to dangerous levels of heavy metals. The results presented demonstrate that there is a risk associated with the consumption of fish and water and vegetables grown in the Addele village and Addele farm irrigated with the Addele Lake, which has already contaminated by the waste discharged to it during the dry and wet season. Therefore, using this contaminated water for drinking or consumption of fishes from the study area might pose health hazard to human at the time of this study. It may be concluded that irrigation and other use of untreated sewage water and sediment are the main reasons for accumulation of heavy metals in lake. There is a need for controlling point sources that could be contributing to heavy metal pollution along the Lake and this could be done by encouraging farmers to use water and soil conservation measures like terracing, growing of cover crops and also use of organic fertilizer as it does not contain heavy metals. Continuous monitoring of the lake pollution should be carried out and appropriate monitoring protocol should be established. Suggestion is made for further research in monitoring of physicochemical, biological and heavy metals bioaccumulation in water and fishes in the study area. Generally, the results of the present study revealed tha heavy metals contamination of water, fish,BMI determination and physicochemical analysis in varying magnitude among samples and between seasons in the study area which may lead to public health risks.

## 5.3. Recommendations.

The following suggestions are recommended in order to monitor and protect the aquatic environment; due to the anthropogenic emission increase through the time.Based on the findings of this study the following recommendations are forwarded:

- Regular monitoring of the lake is needed by using essential biological and physico-chemical parameters.
- Further studies are strongly recommended for monitoring and assessing human health risks in relation to environmental pollution through lake water quality in the study area.
- This study focused on only one fish body part. Hence, it is recommended to perform research works on the other fish organs that have the ability to accumulate trace elements such as gill, kidney and liver.
- The comparsion of heavy metals and the physico-chemical parameters of lake Addele water have to be checked before the water can be used for irrigation purpose by the local peoples surrounding the lake.
- Proper education should be given for the local farmers about the safe use of pesticides and fertilizers by the local administration.

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# 7. APPENDICES

## 7.1 List of Tables in the Appendix

Appndix Tabel 1 The WHO/FAO Standard Value for Physico-Chemcal Parameters and Heavy Metals for Water and Fish

| Types Samples | Types Parameters | Standard Values |
|---|---|---|
| Water | PH | 6.5-8.5 |
| | BOD | 20mg/l |
| | COD | 10mg/l |
| | DO | 5mg/l |
| | Electric Conductivity | 1500µS.cm$^{-1}$ |
| | Temperature | 15$^{o}$C |
| | Nitrate | 5mg/l |
| | Phosphate | 0.03 |
| | Cadmium | 0.5mg/l |
| | Lead | 0.5mg/l |
| | Zinc | 5mg/l |
| Fish | | |
| | Cadmium | 0.2 |
| | Lead | 0.01 |
| | Zinc | 30mg/Kg |

Appndix Tabel 2 t-test Analysis Result of The Two Season

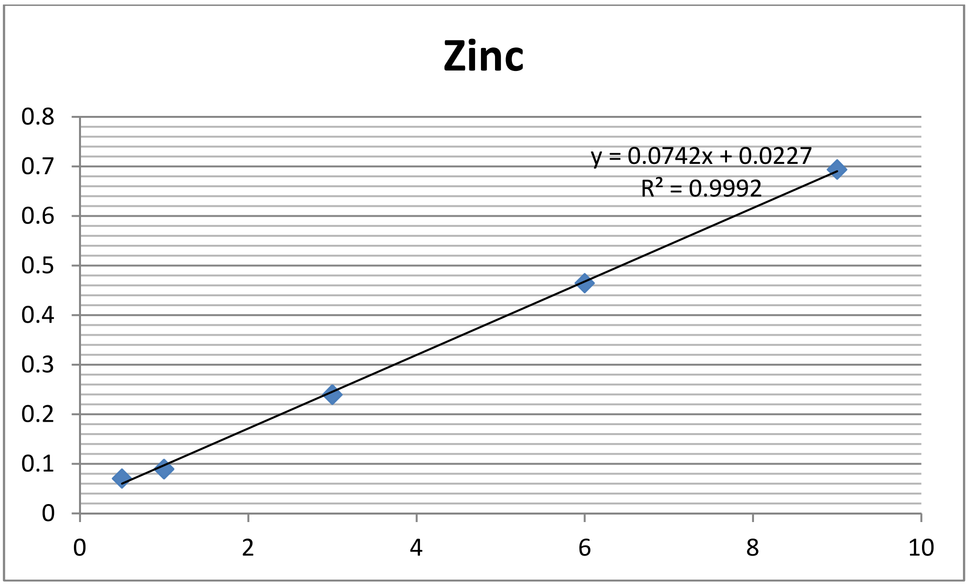
| Variables | Season | Df | t-critical | p-value |
|---|---|---|---|---|
| | Dry season<br>Wet season | 4 | 2.13 | <0.001 |
| BOD road | | 4 | 2.13 | >0.07 |
| BOD middle | | 4 | 2.13 | <0.000 |
| BOD slant | | 4 | 2.13 | >0.008 |
| COD road | | 4 | 2.13 | <0.001 |
| COD middle | | 4 | 2.13 | <0.001 |

| | | | | |
|---|---|---|---|---|
| COD slant | | 4 | 2.13 | Num |
| Conduc road | | 4 | 2.13 | <0.001 |
| Conduc middle | | 4 | 2.13 | <0.001 |
| Condu slant | | 4 | 2.13 | <0.001 |
| Turb road | | 4 | 2.13 | <0.001 |
| Turb middle | | 4 | 2.13 | <0.001 |
| Turb slant | | 4 | 2.13 | <0.001 |
| PH road | | 4 | 2.13 | >0.007 |
| PH middle | | 4 | 2.13 | >0.0005 |
| PH slant | | 4 | 2.13 | <0.008 |
| Temp road | | 4 | 2.13 | <0.004 |
| Temp middle | | 4 | 2.13 | <0.001 |
| Tempe slant | | 4 | 2.13 | <0.001 |
| DO road | | 4 | 2.13 | <0.0004 |
| DO middle | | 4 | 2.13 | <0.001 |
| DO slant | | 4 | 2.13 | <0.0004 |
| Phosphate road | | 4 | 2.13 | <0.001 |
| Phosphate middle | | 4 | 2.13 | <0.001 |
| Phosphate slant | | 4 | 2.13 | <0.001 |
| Nitrate road | | 4 | 2.13 | <0.001 |
| Nitrate middle | | 4 | 2.13 | <0.001 |
| Nitrate slant | | 4 | 2.13 | <0.001 |
| Cd road Fish | | 4 | 2.13 | >0.143 |
| Cd middle Fish | | 4 | 2.13 | >0.143 |
| Cd slant Fish | | 4 | 2.13 | <0.001 |
| Cd road water | | 4 | 2.13 | >0.001 |
| Cd middle water | | 4 | 2.13 | >0.069 |
| Cd slant water | | 4 | 2.13 | <0.0003 |
| Zn fish road | | 4 | 2.13 | <0.001 |
| Zn fish middle | | 4 | 2.13 | <0.001 |
| Zn fish slant | | 4 | 2.13 | <0.001 |
| Zn water road | | 4 | 2.13 | <0.001 |
| Zn water middle | | 4 | 2.13 | <0.001 |
| Zn water slant | | 4 | 2.13 | <0.001 |
| Pb fish road | | 4 | 2.13 | <0.001 |
| Pb fish middle | | 4 | 2.13 | <0.001 |
| Pb fish slant | | 4 | 2.13 | <0.001 |
| Pb water road | | 4 | 2.13 | <0.001 |
| Pb water middle | | 4 | 2.13 | <0.001 |
| Pb water slant | | 4 | 2.13 | <0.001 |

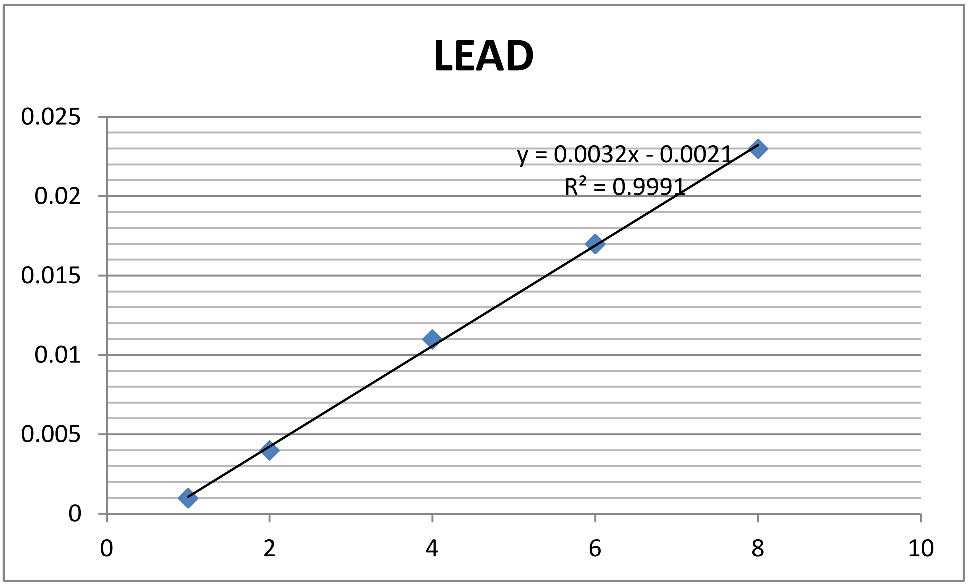
## 7.2 List of Figures in the Appendix

**Calibration curves for each selected heavy metal, phosphate and nitrate in water samples were listed as figure below.**

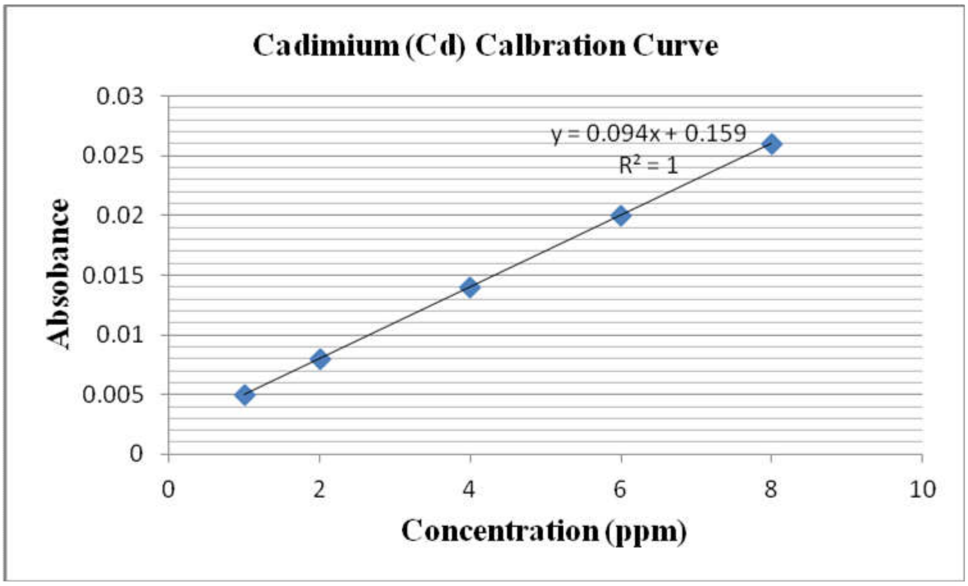
Appendix Figure 1.Calibration curve of Zinc and Lead for Water Sample**.**



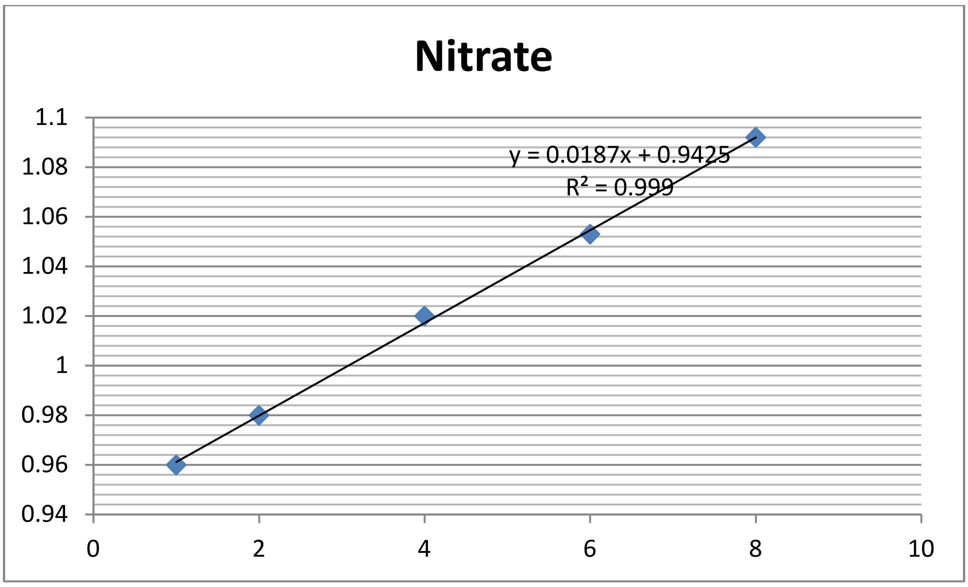

Appendix Figure 2.Calibration curve of Lead for Water Sample



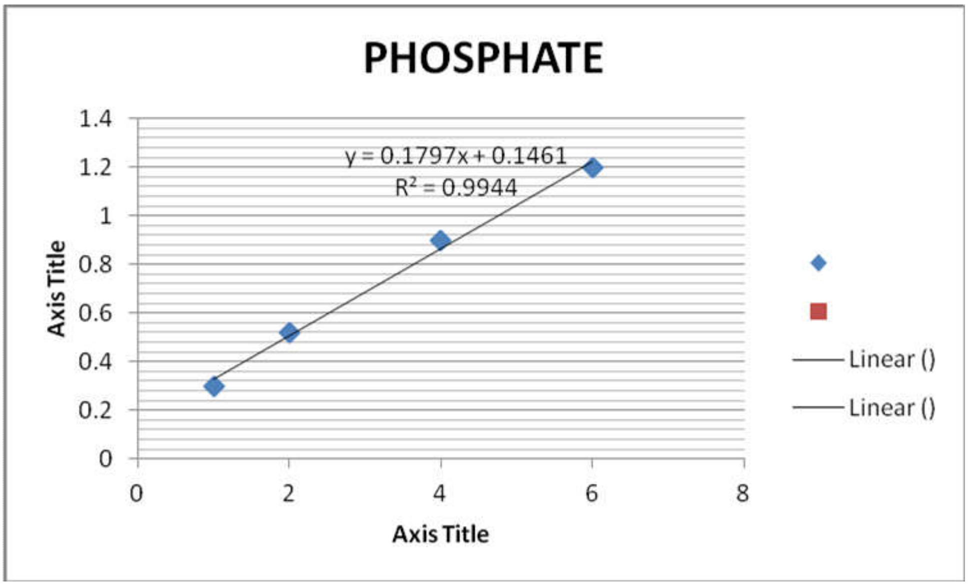
Appendix Figure 3.Calibration curve of Cadimium for water sample



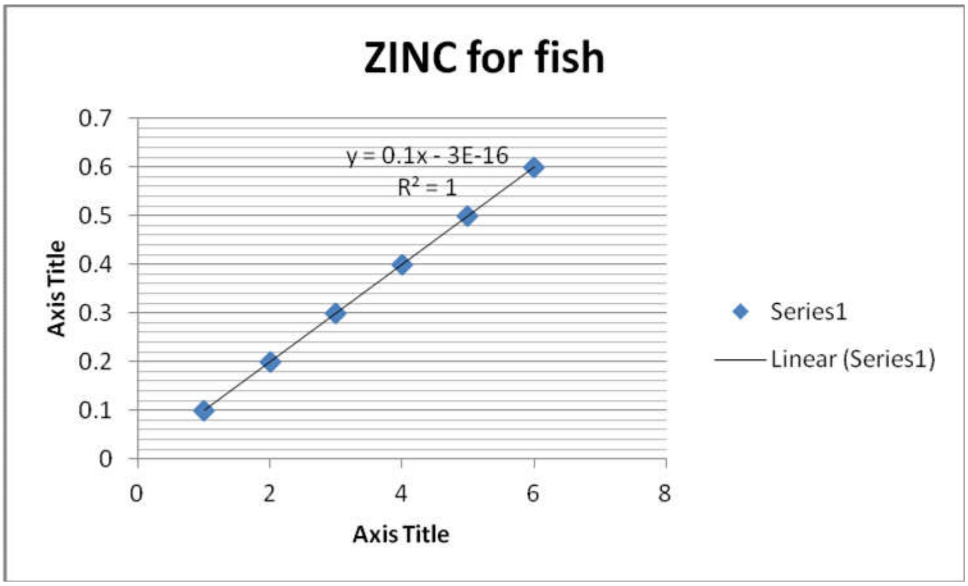

Appendix Figure 4. Calibration curve of Nitrate for water sample



Appendix Figure 5. Calibration curve of Phosphate for water sample.




Appendix Figure 6. Calibration curve of Zinc for water sample



Appendix Figure 7. Calibration curve of Cadmium for water sample

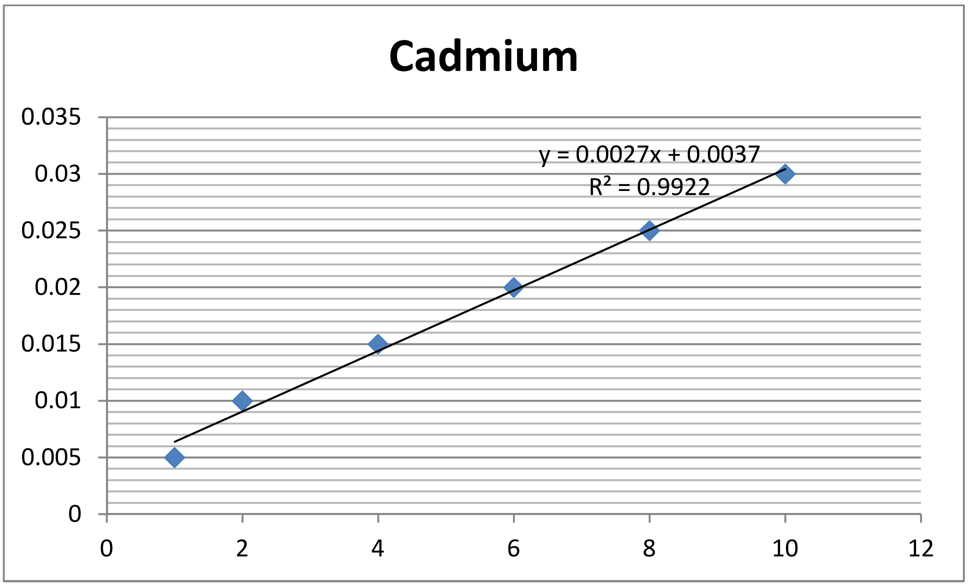


**Figure 8. Catfish ( *Clarias garpians*) and Tilapia (*Orochromis nilotica*)**