

**LEVEL OF SOME SELECTED HEAVY METAL CONCENTRATIONS IN
WATER, SEDIMENT AND FISH SAMPLES OF LAKE TINIKE,
EASTERN HARARGHE ZONE, EASTERN ETHIOPIA**

MSc THESIS

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**Level of Some Selected Heavy Metal Concentrations in Water, Sediment and
Fish Samples of Lake Tinike, Eastern Hararghe Zone, Eastern Ethiopia**

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MASTER OF SCIENCE IN BIOTECHNOLOGY**

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I dedicate this thesis to my family members for their love and care in the success of my life and memorable and valuable encouragements in my academic career while I was doing this study.

STATEMENT OF THE AUTHORS

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ACRONYMS AND ABBREVIATION

AAS	Atomic Absorption Spectrophotometer
FAAS	Flame Atomic Absorption Spectrophotometer
ATSDR	Agency for Toxic Substances and Disease Registry
ASM	American Society for Microbiology
CMP	Central Maine Power
CSA	Central Statistics Agency
EAT	Environmental and Analytical Toxicology
FAO	Food and Agricultural Organization
GF	Graphite Furnace
HICs	High Income Countries
IRJES	International Research Journal of Environmental Science
IDL	Instrument Detection Limit
LMICs	Low and Middle Income Countries
LOQ	Limit of Quantification
MDL	Method Detection Limit
QC	Quality Control
RCB	Recycling Council of British
RSD	Relative Standard Deviation
USGS	United State Geological Survey

TABLE OF CONTENTS

[STATEMENT OF THE AUTHORS](#)

v

<u>BIOGRAPHICAL SKETCH OF THE AUTHOR</u>	vi
<u>ACKNOWLEDGEMENTS</u>	vii
<u>ACRONYMS AND ABBREVIATION</u>	viii
<u>LIST OF TABLES</u>	xii
<u>LIST OF FIGURES</u>	xiii
<u>LIST OF TABLES IN APPENDIX</u>	xiv
<u>LIST OF FIGURES IN THE APPENDIX</u>	xv
<u>1. INTRODUCTION</u>	1
<u>1.1. Objectives of the Study</u>	5
<u>2. LITERATURE REVIEW</u>	6
<u>2.1. Importance of Water</u>	6
<u>2.1.1. Fresh Water</u>	6
<u>2.1.2. Lake and Reservoirs</u>	7
<u>2.1.3. Water Quality</u>	7
<u>2.2. Physico-chemical Parameters</u>	9
<u>2.2.1. Temperature</u>	9
<u>2.2.2. pH</u>	10
<u>2.2.3. Conductivity</u>	10
<u>2.2.4. Total Dissolved Solids (TDS)</u>	11
<u>2.3. Environmental Pollution</u>	11
<u>2.4. Sources of Water Pollution</u>	12
<u>2.4.1 Toxic Chemicals and Pesticides</u>	13
<u>2.4.2. Thermal Pollution</u>	14

<u>2.4.3. Agricultural Pollution</u>	
14	
<u>2.4.4. Anthropogenic Activity</u>	
15	
<u>2.4.5. Heavy Metal Pollution</u>	
16	
<u>2.5. Risk of Heavy Metals to Human Health</u>	16
<u>2.5.1. Copper (Cu)</u>	
17	
<u>2.5.2. Cadmium (Cd)</u>	
18	
<u>2.5.3. Lead (Pb)</u>	
18	
<u>2.5.4. Manganese (Mn)</u>	
19	
<u>3. MATERIALS AND METHODS</u>	20
<u>3.1. Description of Study Area</u>	20
<u>3.2. Topography of the Study Site</u>	21
<u>3.3. Sampling Sites and Sample Collection</u>	22
<u>3.3.1. Sampling sites</u>	
22	
<u>3.3.2. Water Sample Collection</u>	
22	
<u>3.3.3. Sediment Sample Collection</u>	
23	
<u>3.3.4. Fish Sample Collection</u>	
23	
<u>3.4. Design of the Study</u>	23
<u>3.5. Physico-chemical Parameters</u>	24
<u>3.5.1. Determination of pH, Conductivity, Total dissolved Solids (TDS) and Temperature of Water Samples</u>	
24	
<u>3.5.2. Determination of conductivity and pH of sediment samples</u>	25
<u>3.6. Water Sample Preparation and Determination of Heavy Metal Concentrations</u>	25
<u>3.7. Sediment Sample Preparation and Determination of Heavy Metal Concentrations</u>	26

<u>3.8. Fish Sample Preparation and Determination of Heavy Metal Concentrations</u>	26
<u>3.9. Equipments and Chemicals</u>	26
<u>3.10. Quality Control (QC) and Assurance</u>	27
<u>3.11. Statistical Data Analysis</u>	27
<u>4. RESULTS AND DISCUSSION</u>	29
<u>4.1. Physico-chemical Parameters of Water Samples</u>	29
<u>4.2. Chemical Parameters of Sediment Samples</u>	33
<u>4.3. Level of Heavy Metal Concentration in Water Samples</u>	36
<u>4.3.1. Level of Copper Concentration in Water Samples</u>	36
<u>4.3.2. Level of Cadmium Concentration in Water Samples</u>	37
<u>4.3.3. Level of Lead Concentration in Water Samples</u>	39
<u>4.3.4. Level of Manganese Concentration in Water Samples</u>	39
<u>4.4. Level of Heavy Metal Concentration in Sediment Samples</u>	40
<u>4.4.1. Level of Copper Concentration in Sediment Samples</u>	40
<u>4.4.2. Level of Cadmium Concentration in Sediment Samples</u>	41
<u>4.4.3. Level of Lead Concentration in Sediment Samples</u>	43
<u>4.4.4. Level of Manganese Concentration in Sediment Samples</u>	45
<u>4.5. Level of Heavy Metal Concentration in Cat Fish Samples</u>	46
<u>4.5.1. Level of Copper Concentration in Cat Fish Samples</u>	46
<u>4.5.2. Level of Cadmium Concentration in Cat Fish Samples</u>	47
<u>4.5.3. Level of Lead Concentration in Cat Fish Samples</u>	48
<u>4.5.4. Level of Manganese Concentration in Cat Fish Samples</u>	50
<u>5. SUMMARY, CONCLUSION AND RECOMMENDATION</u>	52
<u>5.1. Summary</u>	52
<u>5.2. Conclusions</u>	53
<u>5.3. Recommendations</u>	54
<u>6. REFERENCES</u>	55

LIST OF TABLES

Table

Page

1	Physico-chemical properties of water samples collected from Lake Tinike at dry and wet seasons Means \pm SD.	30
2	Chemical parameters of sediment samples collected from Lake Tinike during dry and wet seasons Means \pm SD	34
3	Heavy metal concentration of water samples collected from Lake Tinike during dry and wet seasons Mean \pm SD	38
4	Heavy metal concentration of sediment samples collected from Lake Tinike during dry and wet seasons Means \pm SD	44
5	Heavy metal concentration of fish samples collected from Lake Tinike during dry and wet seasons Means \pm SD	49

LIST OF FIGURES

Figure

Page

[1. Map of Haramaya Woreda in Eastern Hararghe Zone, Oromia Region, Ethiopia](#)

21

LIST OF TABLES IN APPENDIX

T a b l e

Page

1	Mean comparisons among heavy metals in water samples	66
2	Mean comparisons among heavy metals on sediment samples	66
3	Mean comparisons among heavy metals on fish samples	67
4	The WHO/FAO standard values for water, sediment and fishes	67

LIST OF FIGURES IN THE APPENDIX

Figures

Page

1	Calibration Curve of Copper	68
2	Calibration Curve of Cadmium	68
3	Calibration Curve of Lead	69
4	Calibration Curve of Manganese	69
5	During Sediment Preparation	70
6	Water Samples Preparation	70
7	Fish Samples	71
8	During water, sediment and fish samples digestion	72
9	During water, sediment and fish samples filtration	73
10	Filtered water, sediment and fish samples	74

Level of Some Selected Heavy Metal Concentrations in Water, Sediment and Fish Samples of Lake Tinike, Eastern Hararghe Zone, Eastern Ethiopia

ABSTRACT

A study was done to assess the level of some selected heavy metal concentrations in water, sediment and fish samples as well as to determine the physico-chemical parameters of water and sediment samples collected from Lake Tinike, during dry and wet seasons. To achieve those objectives, a laboratory based cross sectional study was conducted from January to June, 2017. Water, sediment and fish samples were collected from purposefully selected sites in three sampling sites during the dry and wet seasons. Analyses for heavy metals in fish, sediment and water samples were done using an Atomic Absorption Spectrophotometer (AAS). The physicochemical parameters like temperature, pH, total dissolved solids (TDS) and conductivity were also determined in the present study. The results revealed that the overall mean values of copper (Cu), cadmium (Cd), lead (Pb) and manganese (Mn) in water samples of all sampling sites in dry and wet seasons were 0.96 ± 0.02 , 0.05 ± 0.003 , 0.13 ± 0.07 and 1 ± 0.01 mg/L, respectively. The overall mean values of Cu, Cd, Pb and Mn levels observed in sediment samples of all sampling sites and both seasons were 2 ± 0.041 , 0.8 ± 0.008 , 1.7 ± 0.1 and 1.22 ± 0.1 mg/kg, respectively. Similarly, the overall mean values of Cu, Cd, Pb and Mn detected in fish samples of all sites and both dry and wet seasons were 2.78 ± 0.034 , 0.07 ± 0.001 , 1.72 ± 0.02 and 3.46 ± 0.08 mg/kg, respectively. This results showed that, the fish samples had highest mean value of Cu, Pb and Mn as compared with the mean value of water and sediment samples. But the lowest and medium mean values were recorded in water and sediment samples, respectively. From the selected heavy metals, Cd, Pb and Mn in water samples exceeded the maximum permissible limits of drinking water. In sediment samples, Cu, Cd and Mn concentrations were above the permissible limit except Pb. Unlike the Cd and Mn, the concentrations of Cu and Pb in fish samples were recorded above the permissible limit. These indicated that the most of analyzed heavy metal results in water, sediments and fish samples were from Lake Tinike had recorded levels above the international permissible limits. The findings of this study would have important information on the implications of public health with regard to heavy metal concentration in water and fish consumers of Tuji, Kura, Tinike and the surroundings.

Keywords: Ethiopia, fish, heavy metals, Lake Tinike, sediment, water.

1. INTRODUCTION

Water is one of the most valuable natural resources. The quality of water is of vital concern for the mankind since it is directly linked with human welfare. 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. 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 (Christian *et al.*, 2014).

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, essential for humans as well as for earth and aquatic life. Lakes have long been at the centre of human attention. Several cities, industrial infrastructures and agriculture complexes have been built up in 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, 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 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 (Siemonov, 2003)

Pollution of the aquatic environment has been considered a major threat to the aquatic organisms. Such pollutants are mostly caused by different sources among others are agricultural practices where fresh water bodies are contaminated by pesticide. An agricultural water containing pesticides, fertilizers and runoffs in addition to sewage, effluents supply the water bodies and sediments with huge quantities of heavy metals. The pollution caused by heavy metals might have dreadful effects on the ecological equilibrium and a variety of aquatic entities (Akinmoladun *et al.*, 2007).

Among the fresh water, only about 5% of them or 0.15% of the total world water is readily available for beneficial use and from these lakes hold 100,000 km³ of fresh water, 90% of earth's liquid surface total water. Ethiopia has 199.3 billion cubic meters (BCM) potential surface water and 185.6 BCM groundwater as a reserve (Tamiru, 2006). Due to increasing population growth, human demands water for domestic, industrial and agricultural purposes and to supply adequate food for the nation is increasing 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 per year or based on the long-term average annual runoff above 0.4 (Amundsen, 2002).

Heavy metal pollution of aquatic environment has 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 organism. 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 metals pollution is less visible but its effects on the ecosystem and humans can be intensive and very extensive (Duran, 2006).

The main causes for the water quality deteriorations are anthropogenic and natural agents. Some of the nature and human induced factors which affect the quality of water are natural hazards, sedimentation or erosion. These activities aggravate the pollution of water body and greatly influence the quality of water. Knowledge on point sources of pollution and pollutants in the region are prerequisite for appropriate use of water (Chaterjee *et al.*, 2002).

Increased metal loads in fish, water and sediments are also a human health concern due to biomagnifications of metals along the aquatic and terrestrial food chains and food webs (Zhao, 2014). Overall, human health risks are primarily due to the elevated concentrations of mercury, lead, cadmium, argon and selenium in water and aquatic animals including fish that are part of the local people's diet (Arnell *et al.*, 2004). Consumption of arsenic-laden water and food crops rice in Southeast Asia including Bangladesh, India and the Bengal region in general has also been linked to several health conditions such as cancer of the skin, kidneys, bladder and lungs

(Damodharan, 2013). Cadmium has been linked to kidney and liver damage as well as osteoporosis and pulmonary emphysema as reported in Japan where people consumed rice cultivated using cadmium-contaminated irrigation water (Lukin *et al.*, 2002). Osteoporosis, brittle nails and hair loss have been attributed to consumption of selenium-contaminated foods as was the case in China. Water and foods containing elevated copper and nickel have been linked to liver and kidney failure (Duruibe *et al.*, 2007).

The problems of metal pollution are currently increasing in many Ethiopian Rift Valley Lakes. It is mainly associated with expansion of industrial activities and intensification of agricultural activities. Due to fast growing industries in and around Hawassa city, Lake Hawassa is one of the most exposing lakes to different sources of pollutant (Tigist and Girma, 2014). Under some environmental conditions, those pollutants including metals could accumulate and get biomagnified through food chain to toxic levels and eventually results in ecological damage (Kassaye *et al.*, 2014).

Information pertaining the state of metals in contaminated aquatic systems and their potential risk to aquatic organisms and other terrestrial organisms including human is of paramount importance to formulate and implement sound environment system in metal affected aquatic systems (EAT, 2014). Heavy metals are potentially toxic to organisms causing lethal and sub lethal effects. Above threshold levels, these metals have been shown to adversely affect both aquatic and terrestrial organisms. Human health may also be impacted negatively through consumption of metal-contaminated foods and water (Grandjean *et al.*, 2014).

Several researchers have worked in Tinike Lake 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 and the contribution of small scale irrigation to households farm income and food security were done by Jemal and Gadisa (2016). 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 (2006) estimated 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. The most important works in relation to physico-chemical parameter were done by (Gupta, 2009).

The previous works have their own limitations (work done on lake level and ground water system) and don't provide any comprehensible ideas with respect to the heavy metal concentrations in water, sediment and fishes. To save human lives and other organisms from disasters due to toxic effects of heavy metals, preventive measures need to be enforced. Several non-government agencies are also busy educating people about the harmful effects of metals and other pollution and the ways to prevent it.

Therefore, the main objective of this study was to assess the concentration level of selected metals in the water, sediment and fish samples of Lake Tinike, Haramaya Woreda, Eastern Ethiopia. The results obtained from this study would provide base line information regarding the levels of heavy metals in the water, sediment and fish samples of the lake, contributing to the effective monitoring of both environmental quality and the health of the organisms inhabiting the Lake ecosystem.

1.1. Objectives of the Study

General Objective was

To assess the level of some selected heavy metal concentrations (copper, cadmium, lead and manganese) in water, sediment and in fish samples of Lake Tinike, Hararghe Zone, Eastern Ethiopia.

Specific Objectives were

1. To analyze the physico-chemical (Temp, pH, EC and TDS) properties of water and sediment samples.
2. To determine the levels of selected heavy metals (Copper, Cadmium, Lead and Manganese) in water samples.
3. To determine the levels of selected heavy metals (Copper, Lead, Cadmium and Manganese) in sediment samples.
4. To determine the levels of selected heavy metals (Copper, Lead, Manganese and Cadmium) in fish samples.

2. LITERATURE REVIEW

2.1. Importance of Water

Water is the most natural resource and is essential for survival and the development of modern technology. 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 (Gupta *et al.*, 2000).

2.1.1. 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 (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 (Premlata *et al.*, 2009).

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. 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% of all freshwater withdrawals followed by industry 20% and domestic use 10% (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, 2006).

2.1.2. Lake and Reservoirs

Lake and surface reservoirs are nature's most critical freshwater resources and have various uses. They are used for domestic and irrigation purposes and provide habitats for aquatic life as a source of essential protein and for significant element of the world's biological diversity. The quality of freshwater 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 (Simeonov, 2003).

2.1.3. Water Quality

The quality of any body of surface or ground water is a function of either or both natural influences and human activities (Chaterjee *et al.*, 2002). Without human influences, water quality would be determined by the weathering of bedrock minerals, by the atmospheric processes of evapotranspiration 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 (Metcalfs, 1989). 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 harmful to life. These include metals such as mercury, lead and cadmium, pesticides, organic toxins and radioactive contaminants (Kiflom and Tarekegn, 2015). 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 a basic requirement for many of the fundamental uses of water on which humans depend. These include: for human consumption and public water supply, in agriculture and aquaculture, in industry, for recreation and 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 to a loss of biological diversity (Kataria *et al.*, 1998).

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 (Chow *et al.*, 2003). 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 (Sanchez *et al.*, 2007).

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 (Begum *et al.*, 2005). 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 (WHO, 2011). 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 (Wickham *et al.*, 2005).

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 (Malik *et al.*, 2010).

2.2. Physico-chemical Parameters

Understanding a lake's physical and chemical 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 are:

- Physical measurements like temperature, salinity, color etc.
- Chemical measurements such as total dissolved solids (TDS), pH, and conductivity. These parameters were important to study water quality at the moment of study, because its result fluctuates with seasonal variation of the weather condition and based on level of input of pollutants at a certain time (Gupta *et al.*, 2009).

2.2.1. 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 (Navneet *et al.*, 2010). 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 (Sanchez *et al.*, 2007). Water temperature influences aquatic weeds, algal blooms and surrounding air temperature (Gupta *et al.*, 2009). The metabolic and physiological activity and life process such as feeding, reproduction, movements and distribution of aquatic organisms are greatly influenced by water temperature.

2.2.2. pH

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 (Metcalfs *et al.*, 1998). Natural acidity in rainwater is caused by the dissolution of atmospheric carbon dioxide (CO₂). The hydrogen ions entering a drainage basin in rainwater are neutralized by carbonate and silicate minerals as water percolates through soils (Navneet, 2010).

2.2.3. 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 centimeter apart, conductivity is generally reported as microsiemens per centimeter ($\mu\text{s}/\text{cm}$) or millisiemens (ms). 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 (Navneet *et al.*).

2.2.4. Total Dissolved Solids (TDS)

Total dissolved solids (TDS) denote mainly the various kinds of mineral present in water samples. They can be measured as the residue left after evaporation of the filtered sample. The principal constituents are usually the cations calcium, magnesium, sodium and potassium and the anions carbonate, bicarbonate, chloride, sulphate and particularly in groundwater, nitrate (from agricultural use) (Viessman, 2001).

2.3. Environmental Pollution

Environmental pollution is the contamination of the physical and biological components of the earth or atmosphere system to such an extent that normal environmental processes are adversely affected. Exposures to ambient air pollution, toxic chemicals and pesticides generally have been problems that cause disease in high-income countries (HIC). It was 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 (LMIC) (Dhara *et al.*, 2002). 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).

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. The manufacture and use of chemicals are

shifting to LMICs, where labor costs are low and environmental and public health protections are few (Roney, 2006). Chemical and pesticide pollution are increasing in LMICs and hazardous wastes including electronic waste, are accumulating (Alavanja *et al.*, 2004).

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. 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 (Sanchez, 2007).

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 (Christiane *et al.*, 2014). Among the fresh water, only about 5% of them or 0.15% of the total world waters are readily available for beneficial use (Chidambaram *et al.*, 2010) and from these lakes hold 100, 000 km³ of fresh water (90%) of earth's liquid surface total water. Ethiopia has 199.3 BCM potential surface water and 185.6 BCM (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.

Sediment, soil particles carried to a streambed, Lake or Ocean, can also be pollutant if it is present in large enough amounts. Soil erosion produced by the removal of soil-trapping trees near water ways or carried by rain water and flood water from croplands, strip mines and roads can damage a stream or lake by introducing too much nutrient matter, this leads to eutrophication. Sedimentation can also cover streambed gravel in which many fish, such as salmon and trout, lay their eggs. Excessive sediment load as the result of adverse human activities in the water shed, the riparian side and head water is a major factor for decline of benthic communities in rivers and streams (USEPA, 2012). Sediments affect the in stream biotic community by reducing habitat, altering water movement, food quality and interstitial spacing (Minshall, 1984). Fine sediments

decreases the diversity of in stream biotic communities since the suspended solids absorb heat from sunlight, causing to increase and ultimately reduction in dissolved oxygen (Morrisette, 2001).

2.4. Sources of Water Pollution

Water pollution may be defined as any impairment in its native characteristics by addition of anthropogenic contaminants to the extent that it either cannot serve to humans for drinking purposes and/or to support the biotic communities (Christiane *et al.*, 2014). The main sources of pollution that enter surface water bodies are industries, municipal solid waste and oily wastes from garages and fuel stations (Fischetti *et al.*, 2010). Organic and inorganic substances which are released into the environment as a result of domestic, agricultural and industrial water activities lead to organic and inorganic pollution (Lim *et al.*, 2010).

Water courses receive pollution from many different sources, which vary both in strength and volume. The composition of wastewater is a reflection of the life styles and technologies practiced in the producing society. It is a complex mixture of natural organic and inorganic materials as well as man-made compounds. The inorganic constituents include large concentrations of sodium, calcium, potassium, magnesium, chlorine, sulphur, phosphate, bicarbonate, ammonium salts and heavy metals (Lim *et al.*, 2010). Rapid urbanization and industrialization with improper environmental planning often lead to discharge of industrial and sewage effluents into rivers (Praveena *et al.*, 2013).

2.4.1 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 20th century to North America, Japan and Australia. Many of the synthetic chemicals in widest use in these countries have never undergone any safety testing and their potential toxicity is not known. Only about 20% have been screened for developmental toxicity (Goldman, 2011).

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 (Malik *et al.*, 2010).

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). 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 (Baye, 2006). 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 chemicals are increasingly magnified in tissues and other organs as they are transferred up the food chain (Malik *et al.*, 2010). The chronic effects of these substances on aquatic organisms include health repercussions such as cancers, tumors lesions, reproductive inhibition or failure suppressed immune systems, disruption of the endocrine (hormone) system, cellular and DNA damage and deformities. Terrestrial predators that feed on aquatic species may also be affected (Baldock *et al.*, 2000).

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 (Alavanja *et al.*, 2004). 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 (Agah *et al.*, 2009).

2.4.2. Thermal Pollution

Thermal pollution is the rise or fall in the temperature of a water natural body 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 (Galadima *et al.*, 2011).

2.4.3. 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 (Baldock *et al.*, 2000). 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 (Khan *et al.*, 2014). 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 methemeglobinemia or blue baby syndrome which causes death in infants (Khan, 2014).

2.4.4. Anthropogenic Activity

Anthropogenic activities continuously increase the amount of heavy metals in the environment, especially in aquatic ecosystem. 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 bioaccumulate and biomagnified via the food chain and finally assimilated by human consumers resulting in health risk. 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 (Agah *et al.*, 2009).

2.4.5. Heavy Metal Pollution

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 (Zhao *et al.*, 2014). 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 (Momtaz, 2002).

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 (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 (Luzardo, 2014).

2.5. Risk of Heavy Metals to Human Health

Toxic heavy metals entering the ecosystem may lead to bioaccumulation, particularly through the consumption of fruits and vegetables, causing an excessive build-up of heavy metals in the body. Some heavy metals that are most often found to be responsible for harmful damage to humans are lead, cadmium, cobalt and nickel. Some heavy metals such as copper, chromium, iron, zinc and manganese are necessary for the body but in case of over exposure, they can lead to heavy metal toxicity symptoms. When in trace quantities, some of these heavy metals, like copper and zinc, are micronutrients (Dhara *et al.*, 2002).

However, they can pose a significant health risk to humans, leading to various chronic diseases, particularly in elevated concentrations or in prolonged dietary intakes. Heavy metals are not biodegradable, have long biological half-lives and have the potential for accumulation in the different body organs leading to unwanted health effects (Murray *et al.*, 2015). Most heavy metals are extremely toxic and because of their solubility in water, contamination may readily reach toxic levels. Food chain contamination is one of the most important pathways for the entry of these toxic pollutants in to the human body (ATSDR, 2005).

Heavy metal containing pollutants accumulate into water column, sediment and organisms like plant and animals. Metal concentration in the aquatic environment favors the entry into biogeochemical cycle and leading to toxicity in the aquatic biota. Generally, fishes and humans are accumulated these metals, because they are top consumers in aquatic ecosystem and food chain respectively (Galadima *et al.*, 2011). Accumulation in the aquatic bodies show direct consequence to the living beings and aquatic ecosystem. Heavy metals also may adversely affect the plant growth, animal and people's health, when they used the contaminated water for irrigation and drinking purposes in that area (Varsha *et al.*, 2017).

The people of those areas where staple food includes fish and river water for drinking are mostly a pollution. There are several reports on metal toxicity that the metal contaminated food, water and fish affect the human health. In humans, heavy metals may cause genotoxicity, joints and muscles pain, gastrointestinal disorders, vision problem, cancer and increase susceptibility to microbial infections (Kelly, 2012).

2.5.1. Copper (Cu)

Metal ions can be incorporated into food chains and concentrated in aquatic organisms to a level that affects their physiological state. Of the effective pollutants are the heavy metals which have drastic environmental impact on all organisms (Mason, 2002). Trace metals like Cu and others play a biochemical role in the life processes of all aquatic plants and animals; therefore, they are essential in the aquatic environment in trace amounts. Cu occurs in the compounds with no known functions as well as enzymes having vital function in plant metabolism (Itanna, 2002). It is found as component of food eaten by humans and animals. It is widely distributed in foods with organ meat and seafood having the highest concentrations (10-100 mg/kg) and dairy products having relatively low levels. High levels of Cu have been also identified in wheat bran, beans and seeds. Although humans are exposed to Cu from many sources including drinking water, soil and dust 75-99% of Cu intake is from food (Frieden *et al.*, 2000).

Copper is an essential element and adverse health effects are related to its deficiency as well as excess. The places where copper accumulates are the liver first, then the brain and the reproductive organs. Long term exposure to Cu can cause irritation of the nose, mouth and eyes and causes headaches, stomachaches, dizziness, vomiting and diarrhea (Lenntech, 2012).

2.5.2. Cadmium (Cd)

Taking appropriate measures to prevent Cd accumulation in the environment seems vital, because Cd may be easily absorbed by some plants used for human consumption and accumulates in agricultural products in concentrations that can even be considered toxic for some plant species (Jullius *et al.*, 2015). Health risk due to heavy metal contamination of soil has been widely reported. Cd is becoming an increasing health concern in wastewater irrigated agriculture, especially due to its association with damage to kidneys and bones and its potential carcinogenic nature (Praveena *et al.*, 2013).

Unfortunately, the consumption of this potentially dangerous metal is increasing in developing countries; because people often discharge this pollutant into the wastewater stream carelessly. Contaminated food can deplete some essential nutrients in the body. The consumption of vegetables containing accumulated Cd is a known pathway for the entry of toxic metals into

humans. This could result in reduced immunological defense and some disabilities associated with malnutrition (Alavanja *et al.*, 2004).

2.5.3. Lead (Pb)

Lead is a toxic element that can be harmful to plants, although plants usually show ability to accumulate large amounts of lead without visible changes in their appearance or yield. Lead is a well-known neurotoxin. Exposure in uterus, during breastfeeding and in early childhood may all be responsible for the effects. Lead accumulates in the skeleton and its mobilization from bones during pregnancy and lactation causes exposure to fetuses and breastfed infants (Momtaz, 2002). Because of lead's persistence and potential for global atmospheric transport, atmospheric emissions affect even the most remote regions of the world (WHO, 2007). Pb toxicity causes reduction in the haemoglobin synthesis, disturbance in the functioning of kidney, joints, reproductive and cardiovascular systems and chronic damage to the central and peripheral nervous systems (Momtaz, 2002). It has been suggested that lead on a cellular and molecular level may permit or enhance carcinogenic events involved in DNA damage, DNA repair, and regulation of tumors suppressor and promoter genes. It can also reduce cognitive development and intellectual performance in children and damage kidneys and reproductive system

2.5.4. Manganese (Mn)

Manganese is naturally occurring in many surface and ground water sources and in soils that erode into these water bodies. Human activities are also responsible for much of this manganese contamination in water in some areas (EPA, 2004). Sources of manganese due to human activities in the environment include, combustion of coal, residential combustion of wood, iron and steel production plants and power plants. The primary sources of manganese for surface and ground water releases are industrial facility effluent discharge, landfill and soil leaching and underground injection (EPA, 2004).

3. MATERIALS AND METHODS

3.1. Description of Study Area

The study was conducted at Lake Tinike, Haramaya Woreda, East Hararghe Zone, in Oromia National Regional State. The Woreda is located at 30°E latitude and longitude 26°N and has 33 rural kebeles. It is one of the 19 woredas of the East Hararghe zone located at the distance of 508 kms from Addis Ababa to the east and 18 kms west of city. According to CSA (2011), Haramaya woreda has a total population of 271, 394, of which 138,376 were males and 133, 018 were females. The total area of the woreda is about 55 km² (55,100 ha), the total cultivated land is 38,497 ha. The predominant soil types of the district are Rigo soil (60%) and a heavy black clay soil (vertisols) (40%). The rainfall of the district is bimodal, erratic and uneven in distribution, the short rain season occurring between the months of February to May and the long rain occurring between the months of June to September. The mean annual rainfall is 492 mm ranging from 118-866 mm (HWA0, 2012).

The major crops grown in the area include sorghum, maize, haricot bean, wheat, barley, ground nut, potato, onion, khat and vegetables. The most common cash crops in the district are vegetables and khat. Livestock are important components of the farming system. The livestock rearing is mostly not greater than four animals per household because of shortage of grazing land, the animal feeding method is most commonly the cut and carry system. The woreda has 2,424 improved ground water/wells, 24,827 traditional wells and 2,948 ponds. About 21,400 farm households use the above irrigation systems in order to secure their food self sufficient and improve their livelihood (HWA0, 2012).

Out of the total cultivated land of the woreda 38,497 ha-is under irrigation where the irrigable land is estimated to be 12,586 ha in two growing seasons. First round season (September to December) covers 12,586 ha. and second round season (January to April) covers 4,169 ha. In the first growing season, the crops being irrigated are vegetables 3,462 ha. and Khat 4,562 ha (total 8,024 ha) (Gadisa, 2016).

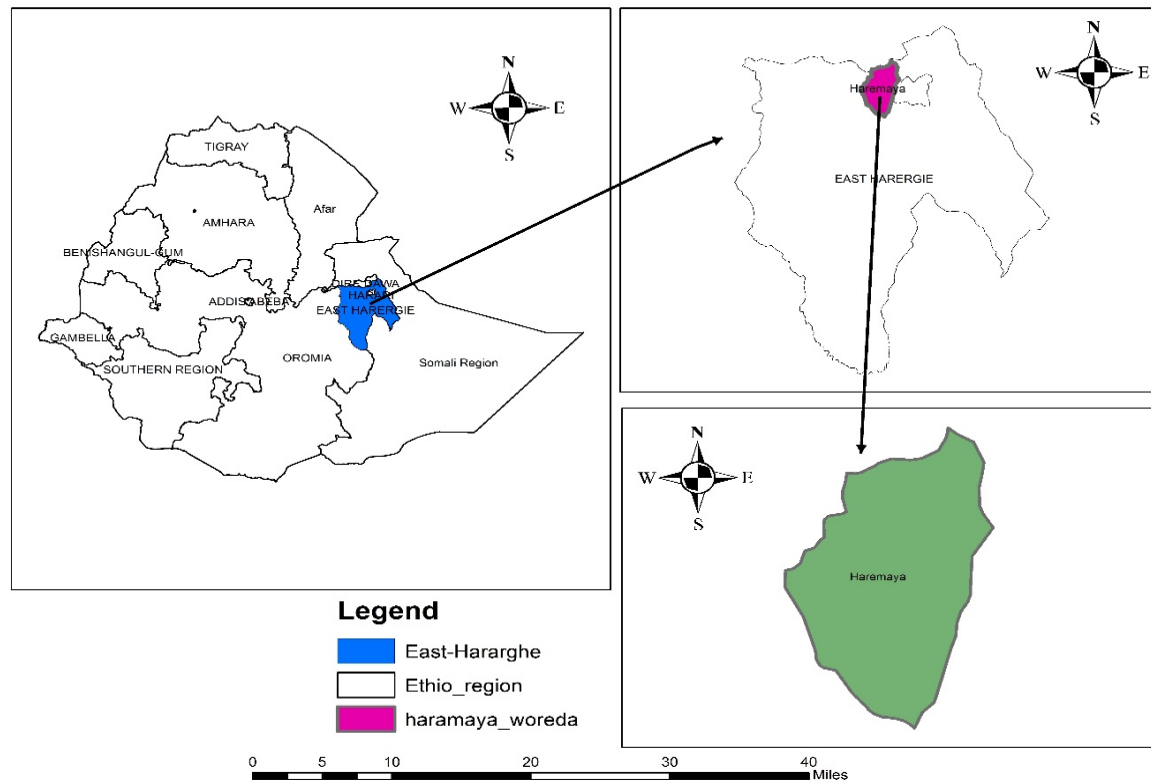


Figure 1. The map of Haramaya Woreda in Eastern Hararghe Zone, Oromia Region, Ethiopia

3.2. Topography of the Study Site

The area is intensively cultivated and virtually no arable land is left for fallow and private grazing. About 71% of Lake Tinike watershed is characterized by undulating and rolling topography. The hilly and steep land in the east and northeast of the catchment covers only 8%. The remaining part is a flat land in the middle and close to the catchment. The altitude of the catchment ranges between 1480 and 2343 m. As cultivation is practiced on slopy lands, soil erosion is a serious problem in the watershed. According to the slope map of the watershed, the undulating and rolling features covering 74% of the catchment dominate the land form. The hilly and steep land accounts for 8% and the flat land about 17%. The land slope with the shape of convex and

concave has almost equal proportion each being 47% of the total area. Land with uniform slope is only 6% of the total area (Solomon, 2002).

As annual reports of the Haramaya woreda Agricultural Development Office indicate, Lake Tinike is located at the adjacent of five kebeles namely, Amuma, Kuro jalala, Finkile, Tinike and Tuji Gabisa farmers' associations. In the water shade the area surrounded by water coverage of Lake Tinike is about 47 ha. It has 1790 ha of land identified as potential priority development area for irrigation. Out of this 880 ha is mostly being irrigated with traditional method (flooding or furrow irrigation). At the same time shallow ground water/well irrigation schemes irrigate about 580 ha of potential farm land. It shows that out of the total of 4,636 households having access to the irrigation schemes, only 2720 households are directly benefiting from the 1460 hectares of irrigable land (HWAO, 2012).

3.3. Sampling Sites and Sample Collection

3.3.1. Sampling sites

Sampling sites were purposefully selected based on the research objectives. For this study, three sample collection sites were selected based on the major discharge entrance points site1 (Tuji), site2 (Kuro) and site3 (Tinike). The sampling occasions were intended to capture the hydrologic variations experienced in the study area and enabled to capture the spatial and temporal variations in heavy metal concentrations in water, sediment and fish samples. As such three sites receiving discharges from the watershed, farm discharge points, road discharge (which is from Kuro, Tuji and Tinike washed down) and rural water discharge point were chosen to study the level of heavy metal concentrations in water, sediment and fish samples at Lake Tinike.

3.3.2. Water Sample Collection

Water samples were collected 2 times (from January to March) for dry season, from May to June for wet season from three selected sites of the Lake. The sampling bottles (polyethylene bottles) were pre-conditioned with 5% nitric acid and later rinsed thoroughly with distilled de-ionized water and were labeled as water sample site one (Wss1) Tuji catchment, water sample site two (Wss2) Kura catchment and water sample site three (Wss3) Tinike catchment point. About 1L of the water samples were taken from 1m offshore selected sites in polyethylene bottles and placed in ice box and brought to HU laboratory.

3.3.3. Sediment Sample Collection

Sediment samples were collected from three selected sites of the bank of the Lake by grab into plastic bags. The catchment was labeled as sediment sample site one (Sss1) Tuji catchment, sediment sample site two (Sss2) Kura catchment and sediment sample site three (Sss3) Tinike catchment point. From each site 1kg of sediment samples were collected and weighed by spring balance, labeled and put into ice box and brought to the HU laboratory.

3.3.4. Fish Sample Collection

Fish traps were used to capture fish for this study. Fish traps were deployed at the selected sampling sites with the help of local fishermen. Sites were randomly labeled as fish sample site one (Fss1), fish sample site two (Fss2) and fish sample site three (Fss3). Three samples of fishes were collected by fisher man from the selected sites of the lake. The mass and length of the fishes were measured immediately by measuring instruments (spring balance and meter). Then fishes were stored under ice box and transported to the laboratory. Generally, during both dry and wet seasons, the sample collection was started from fishes.

3.4. Design of the Study

The design of the research involved a cross sectional survey based method, which was based on the determination of the concentration of selected heavy metals in water, sediment and fish samples from three different parts of Lake Tinike during dry and wet seasons. Accordingly, the first samples were collected during the dry season from Jan 10-Mar 25, 2017 and the second samples were collected during the wet season from Apr 3-Jun 28, 2017. This was because the heavy metals discharge from different sources by different agents during dry and wet seasons differ. This could have an influence on the concentration of metals in water, sediment and fish samples in the lake. The samples were collected from different parts of selected sites of the lake by local fisher man and sample collectors, then measured, weighed, dried and digested the sediment and fish samples in Haramaya University Central Laboratory, before the samples were analyzed for the chosen elements using flame atomic absorption spectrophotometer.

3.5. Physico-chemical Parameters

Water and sediment samples were tested for different physico-chemical parameters. The following different physico-chemical parameters were tested to assess the quality of water and sediment.

3.5.1. Determination of pH, Conductivity, Total dissolved Solids (TDS) and Temperature of Water Samples

The pH of each water sample was measured by pH meter (JENWAY, 3310) in Haramaya University, Chemistry Department, Post Graduate Laboratory. The conductivity was measured by conductivity meter (JENWAY, 4310) with Electrode/ATC probe. A voltage was applied between the two electrodes in the probe immersed in 50 mL beaker which contain water sample. The drop in voltage cause by the resistance of the water was used to calculate the conductivity per centimeter. Temperature was measured by thermometer. Total dissolved solids (TDS) was measured as the residue left after evaporation of the filtered samples. For this, an evaporating beaker (50 mL) was dried till constant weight and the weight of the evaporating beaker was recorded. The water samples were filtered through whatman filter paper to remove turbidity. i.e. the filtrate should be as much clear as possible. The 50mL clear filtrate was evaporated in the heat at 105⁰C for 1:30 hour in an oven. After this, the evaporating beaker was placed in decicator for cooling for one hour. Finally, the weight of evaporating beaker was taken and the total dissolved solids as calculated by the following formula (Zeynab, 2012).

Where

A = Initial weight of the evaporating beaker(g)

B = Final weight of the evaporating beaker(g)

TDS = Total dissolved solids

V = Volume of the sample (50 mL)

3.5.2. Determination of conductivity and pH of sediment samples

The physico-chemical properties of the sediment samples were determined by suspending the dried and sieved sample in distilled water (1:4 w/v) ratio. After continuous shaking of the mixture for 30 min, then the mixture was allowed to settle. The pH of the suspension was determined

using pH meter (JENWAY, 3310). Similarly, the electrical conductivity of the sediment was determined in the filtrate of the water extract using conductivity meter.

3.6. Water Sample Preparation and Determination of Heavy Metal

Concentrations

The digestion flasks (100 mL) were prepared and labeled as (Wss1) for water sample site one, (Wss2) for water sample site two and (Wss3) for water sample site three in triplicate. Exactly 50 mL of the water sample was taken in each labeled digestion flask. Then 1mL of concentrated HNO₃ and 2.5 mL of concentrated HCl were added and covered by watch glass. The flasks were placed at 110⁰C over a hot plate for four hours under hood. The digested samples were cooled at room temperature and filtered using filter paper. The filtrate was filled up to 50 mL by de-ionized water in measuring flask (100 mL). Then reagent blank solution was prepared and stored under 4⁰C in refrigerator until analyses.

Calibration curve was constructed in order to determine the concentration of the experimental water samples for copper, cadmium, lead and manganese. Series of standard solutions were prepared using the stock solutions and diluted with distilled water to obtain four working standards for each metal ion of interest. A total of four metals were analyzed using flame atomic absorption spectrophotometer (FAAS). All the four metals (Cu, Cd, Pb and Mn) were analyzed by the absorption mode of the instrument. The concentrations and measured absorbance data for each set of standard metal ion solutions were used to construct the calibration curve then the unknown concentration of the samples were calculated using the equation from the standard calibration curve (Kiflom and Tarekegn, 2015).

3.7. Sediment Sample Preparation and Determination of Heavy Metal

Concentrations

The Sediment samples were dried for moisture determination in petridishes under oven at 50°C for 48 hours and the samples were grinded and powdered (Zhang, 2016). The sieved samples were packed into polyethylene bags as labeled during sample collection time like (Sss1,Sss2 and

Sss3). All the sediments were digested separately using aqua-regia. In this procedure, 1g of sediment sample from each samples were weighed and soaked in aqua-regia solution that contains 7.5 mL of 37% HCl and 2.5 mL of 68% HNO₃ with a ratio of 3:1. The samples were digested for two hours at 150°C and were cooled and filtered using filter paper. The same calibration curve and standard solutions were used as water samples.

3.8. Fish Sample Preparation and Determination of Heavy Metal

Concentrations

By removing the skin part, the flesh (tissue part) of the fishes were taken and washed by distilled water. Then 20 g of the edible part of the fishes were placed on a petridishes and dried in an oven at 120⁰C for ten hours. The oven dried samples were then powdered using ceramic grinding machine. Three digestion flasks (25 mL) were prepared as labeled (Fss1, Fss2 and Fss3) in triplicate. Then from each of the three powdered sample 1g was taken and placed into the prepared digestion flasks. Then 6 mL of the 68%HNO₃ and 2 mL of 30%H₂O₂ were added, covered by watch glass and placed on hot plate inside a fume hood at 140⁰C for three hours. Following this the mixture was cooled at room temperature, filtered by filter paper and diluted with doubled distilled water to make it ready for analysis using FAAS.

3.9. Equipments and Chemicals

Ceramic pestle and mortar were used for grinding and homogenizing dried sediment and fish samples according to its type; digital analytical balance and dry heat oven were used for weighing and drying the samples, respectively. Flame atomic absorption spectrometry (210VGP, BUCK SCIENTIFIC, USA) equipped with deuterium background and hallow cathode lamp of each of metals was used to detect the absorbance of the metals (Cu, Cd, Pb and Mn) using air acetylene flame. Borosilicate volumetric flasks were used during dilution of samples and preparation of metal standard solutions. Hotplates and hood were used to digest selected samples. A refrigerator was used to store the samples which were digested till analysis.

All the chemicals that were used were, of analytical grade. Distilled water was used for sample preparation, dilution and rinsing apparatus prior to analysis. Copper nitrate, cadmium nitrate, lead

nitrate and manganese nitrate were used to prepare standards; 68% HNO₃, 30% H₂O₂ and 37% HCl were used for digestion of samples.

3.10. Quality Control (QC) and Assurance

During sampling and laboratory analysis of heavy metal contaminated samples care was taken to prevent sample contamination and to ensure the reliability and quality of the analytical results. First of all, the use of metallic tools was avoided whenever possible. Sediment and water samples should be collected using tools made of stainless steel and stored in non-metallic containers, such as polyethylene bottles or bags, at 4°C prior to laboratory treatment. All glass and plastic ware was soaked in weak inorganic acid, e.g. 10% (v/v) nitric acid and rinsed thoroughly with distilled and deionized water before use to ensure that there is no contamination of the laboratory accessories. In order to provide valid and reliable data in a timely manner, a quality control system must be implemented throughout the analytical process (Tarek, 2011).

3.11. Statistical Data Analysis

The data was tested for normality and homogeneity of variance using Kolmogorov Smirnov Normality Test $p \leq 0.05$ and Levene's Test for equal variances $p \leq 0.05$, respectively using (SPSS software version 20). Using data that satisfied the assumptions of normality was compared the heavy metal concentrations in water, sediment and fish samples from the selected study sites using analysis of variance (ANOVA) to test and compare the concentration level differences amongst sites and sampling seasons ($\alpha = 0.05$). Nonparametric tests were applied to data that do not meet assumptions of normality and homogeneity of variance (Aelion, 2008).

Various descriptive statistical procedures (mean, standard deviation, linear regression and correlation analysis) were utilized in this study. All the descriptive statistical procedures were conducted using Excel software (Microsoft office Excel 2007). The levels of selected heavy metals (Cu, Mn, Cd, Pb) determined in samples of the sediment, fish and water were reported as the mean with corresponding standard deviation. Linear regression and correlation analysis were performed for the calculation of slope (m) and correlation coefficient (R) of the regression line of each sample by T-Test method (Maina, 2014). In statistical analyses, confidence level was held at

95% and $P < 0.05$ (at 5% level of significance) for heavy metal determination was considered as significant.

4. RESULTS AND DISCUSSION

4.1. Physico-chemical Parameters of Water Samples

Data related to physico-chemical characteristics of water samples are summarized and presented in Table 1. The mean temperature ($^{\circ}\text{C}$) of water samples taken from site1, site2 and site3 during dry season was 22 ± 0.3 , 21 ± 0.00 and 22 ± 0.00 , respectively. Similarly, the mean temperature ($^{\circ}\text{C}$) of water samples taken from site1, site2 and site3 during wet season was 23 ± 0.3 , 22 ± 0.3 and 23 ± 0.00 , respectively. The mean temperature recorded in site1 during the dry season was greater than site2. Similarly, the mean value of temperature in site1 during the wet season was greater than site2. 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 21 to 22.3 and 22 to 23.3 $^{\circ}\text{C}$, respectively. These results showed the temperature was significantly ($p < 0.05$) different among seasons.

As shown in Table 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 Canadian Council of Minister of Environment (CCME) (2000) guidelines for community water use.

Similar to this study the temperature in Huluka and Alaltu Rivers of Ambo, Ethiopia, was analysed ranged from 23.0 to 16.2 $^{\circ}\text{C}$ and 23.1 to 17.5 $^{\circ}\text{C}$, respectively, were found to be above the maximum permissible limit of the CCME (Wondimu, 2011). Gupta *et al.* (2003) temperature greatly affect the ecosystem and life either directly or indirectly depends on the temperature of water. The rise in temperature of water accelerates chemical reactions, reduces solubility of gases, amplifies taste and odour and elevates metabolic activity of organisms (IJEB, 2012).

Table 1. Physico-chemical properties in water samples collected from Lake Tinike at dry and wet seasons Means \pm SD.

Seasons	Sites	Temp	pH	EC	TDS
Dry	Site1	22 \pm 0.3 ^a	7.14 \pm 0.00 ^c	0.9 \pm 0.03 ^a	569 \pm 0.3 ^{ba}
	Site2	21 \pm 0.00 ^{bc}	7.12 \pm 0.003 ^{ac}	0.63 \pm 0.03 ^{bc}	541 \pm 0.6 ^c
	Site3	22 \pm 0.00 ^c	7.15 \pm 0.003 ^b	0.7 \pm 0.00 ^c	559 \pm 0.3 ^a
	MVDS	22 \pm 0.2	7.14 \pm 0.006	0.74 \pm 0.03	556 \pm 4.2
Wet	Site1	23 \pm 0.3 ^{ca}	7.13 \pm 0.003 ^a	0.87 \pm 0.03 ^{ab}	570 \pm 0.6 ^{cb}
	Site2	22 \pm 0.3 ^a	7.11 \pm 0.003 ^{bc}	0.7 \pm 0.03 ^b	543 \pm 1.2 ^a
	Site3	23 \pm 0.00 ^b	7.13 \pm 0.003 ^{ca}	0.73 \pm 0.03 ^{ca}	562 \pm 0.3 ^{ca}
	MVWS	23 \pm 0.24	7.13 \pm 0.003	0.8 \pm 0.03	558 \pm 4.06
OMVDWS		22.5 \pm 0.002	7.13 \pm 0.003	0.8 \pm 0.02	557 \pm 2.83
Maximum Permissible Limit		15 ^{***}	6.5–8.5 ^{***}	1 ^{***}	1000 ^{***}

SD = Standard Deviation of the mean, Temp = Temperature(⁰C), EC = Electrical Conductivity (ms/cm), TDS = Total Dissolved Solids (mg/L), MVDS = Mean Value of Dry Season, MVWS = Mean Value of Wet Season, OMVDWS = Overall Mean Value of Dry and Wet Seasons, a-b-c Means with different superscript letters down the column for the same parameter in different Sites do significantly differ (P<0.05).

****Source: WHO (2011)/CCME guideline value for drinking water*

The mean pH value of water samples taken from site1, site2 and site3 during dry season was 7.14 ± 0.00 , 7.12 ± 0.003 and 7.15 ± 0.003 , respectively (Table 1). Similarly, the mean pH value of water samples taken from site1, site2 and site3 during wet season was 7.13 ± 0.003 , 7.11 ± 0.003 and 7.13 ± 0.003 , respectively. The pH of water samples recorded in dry and wet seasons were found to be slightly alkaline. As shown in Table 1 there was slight differences in pH values of water samples taken in dry and wet seasons ($p < 0.05$). The pH values of water samples in dry and wet seasons ranged from 7.12 to 7.15 and 7.11 to 7.13, respectively (Table 1).

This result indicated that the mean differences of the pH recorded at different sampling sites of the lake water was significantly ($P < 0.05$) different among most sites and between seasons. During the wet season the pH was at its minimum value and dry season it was at the maximum values. The slight increase in alkalinity in dry season could possibly be from calcium bedrock weathering or may reflect the importance of dissolution of limestone and dolomites in the watershed and it is in agreement with earlier study by Melaku *et al.* (2007) on Tinishu Akaki River.

The pH was low at the entry point of both seasons to the Kura catchment point (site2) and high in the Tuji catchment point (site1) of the lake. The increase might be due to the addition of sewage wastewater, and a pH value greater than 7.15 at the Tuji sampling point (site1) may possibly be due to the presence of free ammonia, which is likely to pose problems when the water is used by Tuji inhabitants and other users for drinking, irrigation and fishing. 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). However, all the values of pH were within the limit of the WHO (2011) guidelines for livestock watering and for irrigation.

In contrast to this study, Duran *et al.* (2006) reported that the pH was in the ranges from 7.2 to 9.9 during the study period (dry and wet months) which was above the standard detection limit for water set by WHO (2011). 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 show near neutral or slightly alkaline pH (Rajasegar, 2003). Hence, in this study, the lake water do not have any health threats on human and aquatic organisms if they are consumed for different purposes in the study area (Table 1).

The mean EC (ms/cm) values of water samples taken from site1, site2 and site3 during dry season was 0.9 ± 0.03 , 0.63 ± 0.03 and 0.7 ± 0.00 ms/cm, respectively (Table 1). Similarly, the mean values EC (ms/cm) of water samples taken from site1, site2 and site3 during wet season was 0.87 ± 0.03 , 0.7 ± 0.03 and 0.73 ± 0.03 ms/cm, respectively. The mean EC values recorded in water samples shows variation among the three sampling sites in both seasons. Similarly, the results showed that there was a significantly difference ($P < 0.05$) of most EC values at different sampling sites of the lake.

Electrical conductivity (EC) of the water samples ranged from 0.63 to 0.9 ms/cm and 0.7 to 0.87 ms/cm in dry and wet season, respectively (Table 1). In dry season, the maximum and minimum conductivity was detected in site 1 and site 3, respectively. Similarly, in wet season the maximum and minimum value was detected in site 1 and 3, respectively. In both dry and wet seasons, the mean value of EC were 0.74 ± 0.03 and 0.8 ± 0.03 ms/cm, respectively (Table 1).

These indicated that, the mean result of EC in wet season was higher than the EC mean values in dry season. This is well below the WHO guideline value prescribed for the EC in water for drinking purposes. Similar to this study, Bass *et al.* (2008) reported electrical conductivity of the water samples which was below the maximum permissible limit set by WHO (2011).

The mean TDS (mg/L) value in water samples taken from site1, site2 and site3 during dry season was 569 ± 0.03 , 541 ± 0.6 and 559 ± 0.3 mg/L, respectively. Similarly, the mean TDS (mg/L) value recorded in water samples taken from site1, site2 and site3 during wet season was 570 ± 0.6 , 543 ± 1.2 and 562 ± 0.3 mg/L, respectively. The Total Dissolved Solids (TDS) is an important parameter in evaluating the suitability of water for irrigation since the solids might clog different pores and components of water distribution system. The TDS present in the water affects its aesthetic value as well as its physico-chemical properties (Malairajan *et al.*, 2008).

The TDS values ranged between 541 to 570.6 mg/L (Table 1). The mean value of TDS was 556 ± 4.2 in dry and 558 ± 4.06 mg/L wet season. This showed that, there was a significantly lower TDS concentrations in water samples in all sampling sites. The mean TDS value recorded in the present study area was below the drinking water standard (1000 mg/L) set by WHO (2011). A

similar result was also reported for Huluka River in Ambo, the TDS values ranged from 113.8 during dry and from 351.5 mg/L during wet seasons.

In contrast to this current study, Preston and Dutton (2005), reported that the TDS levels exceeded the standard limit of WHO (2011) and it could be due to cut off the river bank for agricultural practices, cultivation in the river bed and along the bank area as well as use of fertilizers and pesticides, and river bank erosion. Generally, the analyzed physico-chemical parameters (, pH, TDS and EC) in all water samples, were below their maximum tolerable limits and hence they are in safe base line levels for human and aquatic organisms consumption except temperature.

4.2. Chemical Parameters of Sediment Samples

Table 2 showed the results for pH and electrical conductivity of sediment samples collected from three different sites during the dry and wet seasons. In this study only chemical parameters such as electrical conductivity and pH values were measured. The mean pH value in sediment samples taken from site1(7.6 ± 0.03), site2(7.17 ± 0.03) and site3(7.16 ± 0.004) during dry season. Similarly, the mean pH value in sediment samples taken from site1(7.16 ± 0.00), site2(7.18 ± 0.00) and site3 (7.16 ± 0.003) during wet season. In both dry and wet seasons, the pH value in sediment samples were ranged from 7.16 to 7.6 in all sampling sites of the lake. The pH values of sediment samples were slightly basic with the highest and lowest values recorded at site1 (7.8) and site3 (7.16), respectively in both wet and dry season.

Table 2. Mean \pm SD of chemical parameters in sediment samples collected from Lake Tinike during dry and wet seasons

Seasons	Sites	PH	EC
Dry	Site1	7.6 \pm 0.03 ^{ac}	1.00 \pm 0.06 ^{cb}
	Site2	7.17 \pm 0.03 ^{ab}	0.65 \pm 0.003 ^{bc}
	Site3	7.16 \pm 0.004 ^{cb}	0.71 \pm 0.003 ^b
	MVDS	7.31 \pm 0.14	0.8 \pm 0.06
Wet	Site1	7.16 \pm 0.00 ^a	1.15 \pm 0.01 ^a
	Site2	7.18 \pm 0.00 ^{bc}	0.67 \pm 0.003 ^{bc}
	Site3	7.16 \pm 0.003 ^b	0.76 \pm 0.003 ^{ac}
	MVWS	7.4 \pm 0.09 ^{cb}	0.86 \pm 0.1 ^a
OMVDW		7.35 \pm 0.064	0.83 \pm 0.05

SD = Standard Deviation of the mean, EC = Electric Conductivity (ms/cm), MVDS = Mean Value of dry Season, MVWS = Mean Value of Wet Season, OMVDW = Overall Mean Value of Dry and Wet Season.

The results of the study indicated that the mean pH values recorded in sediment samples showed variations among the sampling sites and significantly different ($p < 0.05$). In reference to the detection limit of pH indicated in Appendix Table 4, the pH of the current sediment samples were recorded within the normal range of WHO (2011). Conversely, Walker *et al.* (2006) reported that the pH value was above the detection limit of WHO in sediment ecosystem of Vasai Creek, London, New York.

As a result showed in Table 1 and 2, the overall mean value of pH in water and sediment samples were 7.13 ± 0.003 and 7.35 ± 0.064 , respectively. The result of the current study indicated that the overall mean values of pH on sediment samples were higher compared with the overall mean value of pH on water samples Table 1 and 2. However, the variations in pH might also be attributed to redox changes in sediments and water column apart from the influence of fresh water (Chatterjee *et al.*, 2002). Therefore, the sediment samples in the present study suggests that it has no any health risks on humans and aquatic fishes and even it can be used for agricultural activities, it is safe.

The mean value of EC (ms/cm) in sediment samples taken from site1, site2 and site3 during dry season was 1.00 ± 0.06 , 0.65 ± 0.003 and 0.71 ± 0.003 ms/cm, respectively. Similarly, the mean value of EC (ms/cm) in sediment samples taken from site1, site2 and site3 during wet season was 1.15 ± 0.01 , 0.67 ± 0.003 and 0.76 ± 0.003 ms/cm, respectively. The conductivity study on sediment shows variation in conductivity values between 0.65 ms/cm to 1 ms/cm at site 2 and 1 respectively during dry season. Whereas, in wet season, it ranged from 0.67 to 1.15 ms/cm at site 2 and 1, respectively (Table 2). The highest value was detected in site1 at wet season and the lowest was recorded in site2 during dry season. Statistical analysis showed that the mean differences of the EC recorded at different sampling sites of the lake water was significantly ($P < 0.05$) different among sites. This value suggested that, most of the collected sediment samples values of electrical conductivity were recorded with in the normal range of WHO as showed in (Appendix Table 4) in all sampling sites except site1 of dry and wet seasons. Because, it is above the maximum permissible limit of WHO.

In the present investigation, the overall mean values of EC on water and sediment samples were 0.8 ± 0.02 and 0.83 ± 0.05 ms/cm, respectively. This result indicated that, the overall mean value of EC on sediment samples were greater than the overall mean value of EC on water samples.

Generally, the increase in EC was recorded in site1 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).

4.3. Level of Heavy Metal Concentration in Water Samples

4.3.1. Level of Copper Concentration in Water Samples

The mean concentrations of copper (Cu) detected in water samples collected from site1, site2, and site3 during the dry season was 1.54, 0.5 and 0.6 mg/L, respectively (Table 3). Similarly, the mean concentrations of Cu detected in water samples that were collected in site1(1.9), site2(0.64) and site3(0.62) mg/L during the wet season. The concentrations recorded during dry and wet season ranges between 0.5 to 1.54 mg/L and 0.62 to 1.9 mg/L, respectively. As a result indicated in Table 3, the mean concentration of Cu ranged from 0.5 to 1.9 mg/L on water samples. In this study, the maximum and minimum concentrations were detected in site 1 and 2 in both dry and wet seasons. Comparatively, the mean concentration of Cu in wet season was greater than the mean concentration of dry season. This is may be because of the fact that, these toxic metals which are directly or indirectly channeled or receiving discharges from the watershed, farm discharge, road discharge, and rural water discharge points to the water.

The mean concentrations of Cu recorded in all sampling sites at dry and wet seasons were below the recommended maximum value of drinking water set by WHO (2011). Relatively similar to this finding, Adie *et al.* (2009) reported that the Cu concentrations ranged from 0.022 to 0.042 mg/L in Ikpoba river, Nigeria, which was below the detection limit of Cu in drinking water set by WHO (2011). In addition, the study conducted by Asma Iqbal *et al.* (2013) reported that the concentrations of Cu ranged from 0.258 to 0.659 mg/L in water samples of Sosiani River, Kenya, which was below the detection limit for drinking water.

A study done in United Kingdom (ATSDR, 2005), the mean Cu concentration on water samples of River Stour ranged from 0.003 to 0.019 mg/L was similarly below from the standard of the WHO (2011) as the results of Cu in the present study. The study show that copper levels are generally within normal range almost in all sampling sites of the lake and may be safe according to the given standard value of drinking water set by WHO (2011).

4.3.2. Level of Cadmium Concentration in Water Samples

The mean concentrations of cadmium (Cd) detected in water samples of site1, site2, and site3 during dry season was 0.04, 0.02 and 0.03 mg/L, respectively (Table 3). Similarly, the level of Cd concentrations detected in water samples of site1, site2, and site3 during wet season were 0.17 mg/L, 0.03 mg/L and 0.05 mg/L, respectively (Table 3). The range of Cd concentrations detected during the dry and wet seasons were from 0.02 to 0.04 mg/L and from 0.03 to 0.17 mg/L, respectively (Table 3). Based on the result, the maximum value of Cd was obtained in wet season as compared to that of dry season. The mean concentration of Cd detected in water samples showed variation among sampling sites and between seasons. Similarly, the mean concentrations of the Cd recorded at different sampling sites of the lake water were significantly ($P < 0.05$) different among sites and between seasons.

However, all of the water samples which were analyzed for Cd metal was above the recommended maximum limits of WHO (2011) as showed in (Appendix Table 4). This is may be because leachate from garbage and solid wastes often find their way into the river through underground drainage and surface flood run-off during the rainy season (IJCS, 2011). Relatively, similar results, according to the report of Judith *et al.* (2014) in Lake Naivasha, Kenya, the concentration level of Cd in water ranged between 0.004 mg/L to 0.129 mg/L, which was above the detection limit of drinking water set by WHO.

The study revealed that, the heavy metal Cd content in the Tinike Lake is beyond the normal range and is extremely dangerous for human consumption and another purposes in the study area. Therefore, the exceeded concentration of Cd in all water samples might be attributed to the use of water from contaminated source for cultivation. Because, according to Shahu *et al.* (2017) reported that, cadmium has been carcinogenic, embryotoxic, teratogenic and mutagenic and may cause hyperglycemia, reduced immunopotency and anemia, as it interferences with iron metabolism. Furthermore, Cd in the body has been shown to result in kidney and liver damages and deformation of bone structures (Alloway, 2017).

Table 3. Heavy metal concentration in Mean \pm SD in water samples collected from Lake Tinike during dry and wet seasons

Seasons	Selected Sites	Detected Heavy Metals			
		Copper(Cu)	Cadmium(Cd)	Lead(Pb)	Manganese(Mn)
Dry	Site1	1.54±0.305 ^a	0.04±0.003 ^{ac}	0.16±0.011 ^{cb}	1.5±0.01 ^a
	Site2	0.5±0.003 ^{cb}	0.02±0.00 ^{ba}	0.06±0.011 ^a	0.7±0.01 ^{bc}
	Site3	0.6±0.074 ^{bc}	0.03±0.12 ^b	0.07±0.001 ^b	0.71±0.013 ^{ca}
	MVDS	0.88±0.3	0.03±0.008	0.09±0.03	0.97±0.24
Wet	Site1	1.9±0.004 ^c	0.17±0.004 ^{bc}	0.26±0.011 ^{bc}	1.6±0.02 ^c
	Site2	0.64±0.005 ^{ac}	0.03±0.003 ^c	0.08±0.02 ^{ac}	0.7±0.018 ^{bc}
	Site3	0.62±0.0003 ^b	0.05±0.004 ^a	0.2±0.00 ^c	0.8±0.01 ^{ab}
	MVWS	1.05±0.4 ^b	0.08±0.006	0.18±0.05	1.03±0.24
OMVDWS		0.96±0.02	0.05±0.003	0.13±0.07	1±0.01
Maximum Permissible Limit		2.0 ^{***}	0.01 ^{***}	0.05 ^{***}	0.5 ^{***}

SD = Standard Deviation of the Mean, MVDS = Mean Value of Dry Season, MVWS = Mean Value of Wet Season, OMVDWS = Overall Mean Value of Dry and Wet Seasons

a-b-c Means with different superscript letters down the column for the same parameter in different sites do significantly differ ($P < 0.05$), Cu = Copper, Cd = Cadmium, Pb = Lead, Mn = Manganese

****Source: WHO (2011)*

4.3.3. Level of Lead Concentration in Water Samples

The data related to the concentrations of lead (Pb) detected in water samples during the dry and wet seasons were summarized and presented in (Table 3). The mean value of Pb concentration detected in water samples of site1(0.16), site2(0.06) and site3(0.07) during dry season. The mean concentrations of Pb in water samples of site1(0.26), site2(0.08) and site3(0.2) mg/L during wet season. The mean value and range of Pb concentrations observed during the dry season were 0.09 ± 0.03 mg/L and 0.06 ± 0.011 to 0.16 ± 0.011 mg/L, respectively (Table 3). Similarly, the mean value and range of Pb concentrations detected in water samples taken during the wet season were 0.13 ± 0.07 mg/L and 0.08 to 0.26 mg/L, respectively (Table 3). The higher concentration level of Pb was detected in wet season as compared to dry season sampling. Its mean concentration was ranged from 0.06 to 0.26 mg/L and significantly ($p < 0.05$) difference in most sampling sites of lake.

In this study, the concentration level of lead was above the permissible limit in all samples of the water. Similar study carried out by Koech *et al.* (2014) reported that, the Pb concentration level in Lake Naivasha, Kenya, ranged from 0.11 mg/L to 0.496 mg/L. This result indicated that, the Pb concentration level was above the maximum detection limit set by WHO. Current study showed that, water samples were collected and analyzed for heavy metal Pb, it was found that the concentrations levels were above the maximum permissible limits set by WHO like to Cd concentration levels as showed in (Table 3). The variation in lead metal content is probably due to anthropogenic factors, seasons of the year (dry and wet season), rain fall and so on. This revealed that, the level of Pb in the Lake Tinike have a health risks when consuming by aquatic organisms and humans and even if use for agricultural activities and another purposes in the study area.

4.3.4. Level of Manganese Concentration in Water Samples

In this study the mean concentrations of Mn was (1.5) in site 1, (0.7) in site2 and (0.71 mg/L) in site3 during dry season and (1.6) in site1, (0.7) and (0.8 mg/L) in site3 in wet season (Table 3). Likewise, the mean concentrations of Mn ranged from 0.7 to 1.5 mg/L to 0.7 to 1.6 mg/L, respectively in both dry and wet seasons. In dry season the maximum and minimum concentrations of Mn were recorded in site1 and 2 as well as in wet season its maximum and minimum concentrations were also detected in site1 and 2. As the result indicated that the detected concentrations of Mn in wet season were greater than the concentrations of Mn in dry

season. The overall mean concentration of Mn on water samples ranged from 0.7 to 1.6 mg/L for all sampling sites.

Based on the guideline values of WHO Mn was found to be above the detection limit. Similar studies done by Boran *et al.*, (2010) reported that Mn concentration ranged from 0.07 to 1.58 mg/L in Delta Lake, Egypt, which was above the recommended maximum limit value for drinking water. In contrast to this study, ATSDR (2000) reported that in river water in the USA found dissolved Mn level ranging from 0.011 to 0.051 mg/L, which was below the recommended maximum value for drinking water. This study showed that, the Mn content in the Lake Tinike is beyond the normal range and is dangerous for human consumption.

Therefore, when water concentrations exceed the WHO guideline standards of the drinking water, the contribution from water becomes significant and put you at an increased health risk. Some heavy metals, including manganese are necessary for the body but in case of overexposure they can lead to heavy metal toxicity symptoms. However, the elevated concentration can pose a significant health risk to humans, leading to various chronic diseases, particularly in elevated concentrations or in prolonged dietary intakes (Sharma *et al.*, 2009).

4.4. Level of Heavy Metal Concentration in Sediment Samples

4.4.1. Level of Copper Concentration in Sediment Samples

The mean concentration of copper (Cu) in site1(2.19), site2(1.8) and site3(1.9) mg/kg during dry season. In second season (wet season) the concentration of Cu in site1(2.3), site2(1.9) and site3 (1.95) mg/kg was detected (Table 4). The study showed that the mean concentrations of Cu ranged from 1.8 to 2.19 mg/kg to 1.9 to 2.3 mg/kg, respectively in both dry and wet seasons on sediment samples. Like water samples, the maximum concentration of Cu in sediment samples were also recorded in site1 and its minimum was recorded in site2 during dry and wet seasons. However, the mean concentration of Cu in wet season was higher than the one in the dry season at all sampling sites. As it can be seen from the results in Table 4, the mean concentrations of copper ranged from 1.8 to 2.3 mg/kg in both dry and seasons of this study. Similarly, the results showed that the mean difference of Cu concentration in sediment samples in most study sites were significantly different ($P < 0.05$).

From the analysis it can be seen that, the concentration of Cu in water and sediment samples in different sampling site during dry and wet period of Tinike Lake have the maximum value

recorded in site1. This could be drawn from the fact that site1 been an area of activities that could lead to the production of these toxic metals which are directly or indirectly channeled or receiving discharges from the watershed, farm discharge, road discharge, and urban water discharge points to the Lake Tinike. Agrochemical substances that runoff to those sites can cause variation in metal concentration (CMP, 2003).

Unlike water samples, the concentrations of Cu in sediment samples exceeded the recommended maximum value of WHO (2011) in both dry and wet seasons at all sampling sites of the Lake. Based on the results in Table 3 and 4, the mean concentration of Cu was higher on sediment samples than the concentration level of Cu on water samples of this study. Probably, the high level of copper in the sediment is attributed to the sink of heavy metals that enters the water body from runoffs during the raining season. This runoff is known to contain heavy metals (Doelman *et al.*, 2016).

Similar reported that conducted by Ratemo *et al.* (2014) the sediments from Sher Karuturi, Flamingo and Malewa River mouth, the level of Cu was exceeded the WHO recommended guidelines for such sediments in Kenya. Doelman *et al.* (2016) demonstrated that the higher concentration of Cu in the sediment suggests that the sediment is the ultimate recipient of heavy metals in the aquatic ecosystem. This result suggests that, the accumulation of elevated concentration of Cu in all sampling sites might be attributed to the use of sediment from contaminated source for agricultural irrigation purpose through drainage system. This is may be a risk for consuming aquatic and terrestrial organisms including fishes, plants and humans.

4.4.2. Level of Cadmium Concentration in Sediment Samples

The mean concentration of Cd in site1(0.83), site2(0.76) and site3(0.8) mg/kg, during dry season in sediment samples. In second season, the concentration in site1(0.84), site2(0.76) and site3 (0.83) mg/kg during wet season (Table 4). In this study, the relatively highest and lowest concentrations recorded in site1 and site2 during dry season. Similarly, during wet season the highest and lowest concentrations were detected in site1 and site2, respectively. The higher mean concentration level of Cd was recorded in wet season when compared with the value obtained in dry season. This result implied that site1 during wet season was the most contaminant sites among all sampling sites in this investigation. The Cd in sediment samples showed relative variations

among sampling sites and ranged from 0.76 to 0.83 mg/kg to 0.76 to 0.84 mg/kg, respectively in dry and wet seasons. The mean concentration of Cd ranged from 0.76 to 0.84 mg/kg on sediment samples at all sampling sites (Table 4).

As the guideline values of WHO (2011) the concentration level of Cd in all sampling sites were above the recommended maximum value as similar to Cd detected on water samples. As it can be seen the results in Table 3 and 4, the mean values of Cd were 0.05 ± 0.003 and 0.8 ± 0.008 mg/kg, respectively in both water and sediment samples. These results indicate that, even if Cd exceeded similarly from the standard value of WHO, but the individual concentration level in each samples were quite different i.e. on sediment samples the concentration level of Cd were greater than the concentration level of water sample in both dry and wet seasons. Similar to this study, from Malewa River, Flamingo and Sher Karuturi sampling sites cadmium concentrations level were exceeded the WHO limits for sediment and significantly lower than those measured by Ozturk *et al.* (2009).

The highest cadmium levels found in sediment samples suggest that cadmium occurred in washed down wastes, vegetables and irrigation water as a consequence of human activities involving unmanaged utilization of herbicides, chemical fertilizers and manures in the catchment area of the irrigation water source (McBride, 2003). Therefore, the exceeded level of Cd in sediment may be a risk factor for Cd associated health problems. It may be also a risk to use this sediment for agricultural irrigation and other purposes, because, cadmium is becoming an increasing health concern in wastewater irrigated agriculture, especially due to its association with damage to kidneys and bones and its potential carcinogenic nature (Chaney *et al.*, 2011).

4.4.3. Level of Lead Concentration in Sediment Samples

In this study the concentration of lead (Pb) was (1.7) at site1, (1.2) at site2 and (1.8 mg/kg) at site3 during dry season. Whereas, the concentration level of Pb during wet season was (2.2) at site1, (1.2) at site2 and (1.9 mg/kg) at site3 (Table 4). In this study, the highest concentration was observed in site1 and the lowest was in site2 in dry season. The mean concentration of Pb in sediment sample as indicated in (Table 4) was relatively lower during dry season as compared wet season. The mean concentration of Pb was ranged from 1.2 to 1.8 mg/kg to 1.2 to 2.2 mg/kg,

respectively in dry and wet seasons. Moreover, the Pb mean concentration level ranged from 1.2 to 2.2mg/kg at all sediment sampling sites.

The Pb concentrations in sediment samples were significantly ($p < 0.05$) lower than those recommended by the WHO (2011). In this investigation, the mean values of Pb were 0.13 ± 0.07 mg/L and 1.7 ± 0.1 mg/kg, respectively in water and sediment samples. The result indicated that the detected concentration level of Pb in sediment samples were relatively higher as compared to the concentration level of Pb in water samples at all sampling sites. In contrast to this result, Ogendi *et al.* (2014) reported the exceeded level of lead concentration in the Malewa River mouth and Lake Naivasha, Kenya, on sediment samples.

Table 4. Heavy metal concentration in Mean \pm SD in sediment samples collected from Lake Tinike during dry and wet seasons

Seasons	Selected Sites	Detected Heavy Metals			
		Copper(Cu)	Cadmium(Cd)	Lead(Pb)	Manganese(Mn)
Dry	Site1	2.19 \pm 0.006 ^a	0.83 \pm 0.01 ^{ac}	1.7 \pm 0.2 ^a	1.66 \pm 0.1 ^{ab}
	Site2	1.8 \pm 0.014 ^c	0.76 \pm 0.003 ^b	1.2 \pm 0.11 ^c	0.8 \pm 0.01 ^c
	Site3	1.9 \pm 0.003 ^{bc}	0.8 \pm 0.01 ^c	1.8 \pm 0.1 ^{ab}	0.95 \pm 0.01 ^{bc}
	MVDS	1.96 \pm 0.1	0.8 \pm 0.02	1.6 \pm 0.2	1.14 \pm 0.23
Wet	Site1	2.3 \pm 0.003 ^a	0.84 \pm 0.003 ^a	2.2 \pm 0.11 ^a	1.94 \pm 0.014 ^a
	Site2	1.9 \pm 0.003 ^{cb}	0.76 \pm 0.003 ^c	1.2 \pm 0.11 ^c	0.86 \pm 0.01 ^{cb}
	Site3	1.95 \pm 0.015 ^b	0.83 \pm 0.01 ^{ab}	1.9 \pm 0.10 ^{bc}	1 \pm 0.01 ^b
	MVWS	2.05 \pm 0.104	0.81 \pm 0.02	1.8 \pm 0.3	1.3 \pm 0.3
OMVDWS		2.00 \pm 0.041	0.8 \pm 0.008	1.7 \pm 0.1	1.22 \pm 0.1
Maximum Permissible Limit		1.6 ^{***}	0.6 ^{***}	3.1 ^{***}	0.5 ^{***}

SD = Standard Deviation of the Mean, MVDS = Mean Value of Dry Season, MVWS = Mean Value of Wet Season, OMVDWS = Overall Mean Value of Dry and Wet Seasons

a-b-c Means with different superscript letters down the column for the same parameter in different sites do significantly differ (P<0.05)

Cu = Copper, Cd = Cadmium, Pb = Lead, Mn = Manganese

****Source: WHO (2011)*

In addition, as the study of IRJES (2017) reported the exceeded value of Pb in aquatic system which comes from industrial discharge, lead containing pesticides, through precipitation, street runoff, and municipal waste water.

4.4.4. Level of Manganese Concentration in Sediment Samples

The mean concentration of Mn in site1, site2 and site3 during dry season was 1.66 ± 0.1 , 0.8 ± 0.01 and 0.95 ± 0.01 mg/kg, respectively. In this season the maximum concentration was detected in site1 while the minimum was detected in site2. On the other hand, Mn concentration during dry season in site1, site2 and site3 was 1.94 ± 0.014 , 0.86 ± 0.01 and 1 ± 0.01 mg/kg, respectively (Table 4). Like dry season the maximum concentration was recorded in site1 and the minimum was recorded in site2. In overall, the mean concentration of Mn on sediment samples ranged from 0.8 to 1.66 mg/kg to 0.86 and 1.94 mg/kg, respectively in dry and wet seasons. Consequently, higher mean concentration of Mn was recorded during wet season than the during dry season.

Similar to water samples, the concentration level of Mn on sediment samples were above the recommended maximum limits set by WHO (2011). The overall mean values of Mn both in water and sediment samples were 1 ± 0.01 mg/L and 1.22 ± 0.1 mg/kg, respectively. This indicated that the concentration level of Mn was above the maximum permissible limits of WHO (2011) both in water and sediment samples. However, the mean concentration level of Mn in water samples were less than the detected mean concentration level of Mn in sediment samples. This may be due to the fact that, according to the report of the lake sediments are normally the final pathway of both natural and anthropogenic components produced or derived to the environment (Edku *et al.*, 2008).

A large fraction of the Mn was found to originate from rock and soil dust (Lorena *et al.*, 2010). Therefore, the exceeded level of Mn in all sediment samples suggests that, this sediment is may be risk to Mn associated health problems in aquatic and terrestrial organisms including humans. In addition, it may be a harm to living resources, hazards to human health, hindrance to aquatic activities including fishing, impairment of sediment and water quality with respect to its use in agricultural, industrial, and often economic activities (Chouba, 2007).

4.5. Level of Heavy Metal Concentration in Cat Fish Samples

4.5.1. Level of Copper Concentration in Cat Fish Samples

As shown in Table 5, the mean concentration of copper (Cu) in fish samples taken from site1, site2 and site3 during dry season was 2.7 ± 0.003 , 2.76 ± 0.003 and 2.82 ± 0.003 mg/kg, respectively. Similarly, the mean concentration of Cu in fish samples taken from site1, site2 and site3 in the dry season was 2.8 ± 0.01 , 2.9 ± 0.1 and 2.71 ± 0.003 mg/kg, respectively (Table 5). The overall mean value of detected Cu in fish samples ranged from 2.78 ± 0.034 mg/kg to 2.9 mg/kg in all fish sampling sites of the study.

Unlike water and sediment samples, the maximum concentration of Cu was recorded in site3 and its minimum level was recorded in site1, during dry season. In second season the maximum and minimum concentration level of Cu was recorded in site2 and site3, respectively. Based on the results of the study, there was a mean concentration level variation of Cu in fish samples between dry and wet seasons i.e. the mean concentration level of Cu in fish samples during wet season was greater than the mean concentration result of Cu obtained in fish samples during dry season (Table 5).

The mean concentration levels in all sampling sites relatively exceeded the recommended maximum value of fishes except in site1 during dry season (WHO, 2011). Unlike water samples the concentration level of Cu in fish and sediment samples were above the maximum permissible limit set by WHO (2011). Based on this results, the overall mean concentration level of Cu in fish samples were detected a higher value when compared the overall mean value obtained on water and sediment samples (Table 3, 4, 5). This may be because the accumulation of Cu in the fishes generally via diet or direct exposure. Cu shows distinct affinity at low concentrations and accumulate in the fishes body and causes its morphological and histological changes (Saeed *et al.*, 2008). Moreover, Saleh (1982) reported that the amount of pollutants in the fish is directly proportional to the degree of pollution in the aquatic environment by heavy metals.

Similar findings have been reported in related studies such as that of WHO/FAO (2011) reported the relatively exceeded concentration level of Cu in two species of fish (Catfish and Tilapia) obtained samples from the Densu River in Weija District of Accra, Ghana. All of these studies and other similar researches indicate different concentrations of Cu metals presence in the fish body.

Another findings were in contrast with the results of a study carried out in the Malewa River, Cu concentrations in fishes were significantly lower than the WHO guideline values (Davies *et al.*, 2006).

Therefore, the fish samples currently analyzed have health threats on fishes and humans up on eating these fishes with regard to exceeded Cu concentration levels in the study area. Likewise, it can pose a significant health risk to humans, leading to various chronic diseases, particularly in elevated concentrations or in prolonged dietary intakes (Davies *et al.*, 2006).

4.5.2. Level of Cadmium Concentration in Cat Fish Samples

The data related to the concentration level of cadmium (Cd) detected in fish samples during the dry and wet seasons are summarized and presented in Table 5. As the result showed in table 5, the mean concentration level of Cd detected in fish samples of sit1, site2 and site3 during the dry season was 0.03 ± 0.01 , 0.08 ± 0.003 and 0.082 ± 0.007 mg/kg, respectively. Whereas, for the second season the mean concentration level of Cd was (0.11) at site1, (0.096) at site2 and (0.05 mg/kg) at site3. As it can be seen from the results in Table 5, the mean concentrations ranged from 0.03 to 0.082 mg/kg to 0.05 to 0.11 mg/kg, respectively in dry and wet season. The maximum concentration of Cd in dry season was detected in site3 and the minimum was recorded site1. Unlike dry season, the maximum and minimum concentration of Cd was recorded to site1 and site3, respectively during wet season. The mean values recorded in fish samples showed variation among the three sampling sites. In fish samples the mean values of concentration of Cd were significantly ($p < 0.05$) different between seasons.

In the study, as the results showed in Table 5 the detected mean value of Cd was 0.064 ± 0.01 and 0.085 ± 0.01 mg/kg. This result indicated that, the mean value of Cd is relatively higher in wet season compared with mean value of dry season. Unlike water and sediment samples, the concentration levels of Cadmium in fish samples were below the recommended maximum permissible limit of WHO/FAO (2011). The overall mean value of Cd in water, sediment and in fish samples were 0.05 ± 0.003 mg/L, 0.8 ± 0.008 mg/kg and 0.07 ± 0.001 mg/kg, respectively. As it can be seen from results in Table 3, 4 and 5, the concentration level of Cd in fish samples were less than the level detected on sediment samples as well as the detection limit of WHO/FAO. But

its concentration level was greater than the concentration level of water samples, This may be due to the fact that the accumulation of Cu in the fishes generally via diet or direct exposure.

Similar to this findings, Chaney *et al.* (2003) reported that Cd in catfish samples ranged from 0.015 to 0.196 mg/kg in Khorramabad City, west of Iran, which was below the recommended maximum permissible limit of WHO or FAO which was given for fishes. Some study conducted by Wongrat *et al.* (2006) reported that the Cd concentration in catfish body increased with increasing concentration in their food for long time significantly reduced fish growth. Therefore, this result indicates that, Cd may not pose any health problem in fishes and humans even if humans consuming fishes as a source of food and it is safety as the detection limit guideline of WHO/FAO (2011).

4.5.3. Level of Lead Concentration in Cat Fish Samples

The concentration of lead (Pb) in fish samples of site1, site2 and site3 during dry season was 1.63 ± 0.03 , 1.6 ± 0.00 and 1.73 ± 0.02 mg/kg, respectively (Table). Similarly, the mean concentration of Pb in fish samples of site1, site2 and site3 during wet season was 1.7 ± 0.06 , 1.92 ± 0.01 and 1.76 ± 0.01 mg/kg, respectively. Its concentration ranged from 1.6 to 1.73 mg/kg to 1.7 to 1.92 mg/kg, respectively during both dry and wet seasons. The results as showed in Table 5, the mean concentration of Pb was relatively higher in wet season than dry season. The highest concentration of Pb was recorded in site2 during wet season with the mean concentration of 1.92 ± 0.01 mg/kg and the lowest mean concentration was recorded in site2 of dry season with mean concentration of 1.6 mg/kg.

Like the mean concentration level of water and sediment samples, the mean concentration level of Pb exceeded the recommended maximum value. From the results in Table 3, 4 and 5, the overall mean concentration level of Pb on water, sediment and in fish samples were 0.13 ± 0.07 mg/L, 1.7 ± 0.1 mg/kg and 1.72 ± 0.02 mg/kg, respectively. As demonstrated in Table 3, 4 and 5, even if their concentration levels were similarly exceeded the standard of WHO/FAO (2011), but the individual concentration level of each samples were quite different at all sampling sites of this study.

Table 5. Heavy metal concentration in Mean \pm SD in fish samples collected from Lake Tinike during dry and wet seasons

Seasons	Selected Sites	Detected Heavy Metals			
		Copper(Cu)	Cadmium(Cd)	Lead(Pb)	Manganese(Mn)
Dry	Site1	2.7 \pm 0.003 ^a	0.03 \pm 0.01 ^a	1.63 \pm 0.03 ^a	2.3 \pm 0.1 ^a
	Site2	2.76 \pm 0.003 ^{ba}	0.08 \pm 0.003 ^c	1.6 \pm 0.00 ^{ab}	3.03 \pm 0.12 ^c
	Site3	2.82 \pm 0.003 ^c	0.082 \pm 0.007 ^b	1.73 \pm 0.02 ^c	3.9 \pm 0.1 ^{bc}
	MVDS	2.76 \pm 0.023	0.064 \pm 0.01 ^c	1.65 \pm 0.023	3.08 \pm 0.24
Wet	Site1	2.8 \pm 0.01 ^a	0.11 \pm 0.01 ^a	1.7 \pm 0.06 ^a	3.7 \pm 0.1 ^a
	Site2	2.9 \pm 0.1 ^{ab}	0.096 \pm 0.00 ^{bc}	1.92 \pm 0.01 ^b	4.51 \pm 0.11 ^b
	Site3	2.71 \pm 0.003 ^c	0.05 \pm 0.01 ^b	1.76 \pm 0.01 ^{ca}	3.3 \pm 0.12 ^{ca}
	MVWS	2.8 \pm 0.03	0.085 \pm 0.01	1.8 \pm 0.04	3.84 \pm 0.2
OMVDWS		2.78 \pm 0.034	0.07 \pm 0.001	1.72 \pm 0.02	3.46 \pm 0.08
Maximum Permissible Limit		2.7***	0.2***	1***	5.5***

SD = Standard Deviation of the Mean, MVDS = Mean Value of Dry Season, MVWS = Mean Value of Wet Season, OMVDW = Overall Mean Value of Dry and Wet Seasons,

a-b-c Means with different superscript letters down the column for the same parameter in different sites do significantly differ (P<0.05)

Cu = Copper, Cd = Cadmium, Pb = Lead, Mn = Manganese

*****Source: WHO (2011)**

The mean value of Pb in fish sample was higher compared with the concentration level of Pb in water and sediment samples. This may be because, some lead contaminants in the sediment and water are taken up by benthic organisms like fishes in a process called bioaccumulations, they build up the body, resulting in higher concentration detection (Abida *et al.*, 2005). Relatively contrast to this results Mortazavi *et al.* (2016) reported that the lead concentration ranged from 0.71 to 1 mg/kg in Khorramabad City, west of Iran. Therefore, exposure to high Pb levels in the aquatic system can cause generative damage and alteration in blood and nerves cells in fishes and other aquatic organisms.

4.5.4. Level of Manganese Concentration in Cat Fish Samples

As the result shown in Table 5, the mean concentration of manganese (Mn) detected in fish samples of site1, site2 and site3 during dry period was 2.3 ± 0.1 , 3.03 ± 0.12 and 3.9 ± 0.1 mg/kg, respectively. In second period, the mean concentration of Mn detected in fish samples of site1, site2 and site3 was 3.7 ± 0.1 , 4.51 ± 0.11 and 3.3 ± 0.12 mg/kg, respectively (Table 5). The mean concentration of Mn in fish samples ranged from 2.3 to 3.9 mg/kg to 3.3 to 4.51 mg/kg, respectively during dry and wet seasons. As the result indicated, the highest and lowest concentration level of Mn was recorded in site3 and site1, respectively during dry season. In second period, the highest concentration was recorded in site2 and the lowest was in site3.

The higher mean concentration of Mn was recorded in wet season as compared the result obtained in dry season of fish samples. There was a significance variation between dry and wet seasons in the concentration level of Mn. Manganese was present in fish samples from all sampling sites, but at levels below the WHO/FAO (2011) guidelines. The Mn concentration detected in fish was different from the one found in water and sediment samples i.e. Mn concentration levels were above the standard value of WHO/FAO (2011) in water and sediment samples. As indicated in (Table 3, 4 and 5) the mean concentration level of Mn in water, sediment and fish samples were 0.7 to 1.6 mg/L, 0.8 to 1.94 mg/kg and 2.3 to 4.51 mg/kg, respectively in all sampling sites of the study.

Based on these results, even if the concentration level of Mn in fish samples were below the maximum permissible limit of WHO/FAO, but the individual mean concentration levels were greater than the concentration levels of water and sediment samples (Table 5). Similar to this

findings, Praveena *et al.* (2013) reported that the concentrations of Mn metals in fish samples from the middle Black Sea were below the detection limit of WHO/FAO (2011). Therefore, the fish samples were currently analyzed for Mn, do not have any health threats on fishes and human even they use fishes as a source of food with regard to Mn concentration levels.

5. SUMMARY, CONCLUSION AND RECOMMENDATION

5.1. Summary

A study was designed to assess level of some selected heavy metal concentrations in water, sediment and fish samples and some physico-chemical parameters of water and sediment samples were collected from Lake Tinike, during dry and wet seasons. Samples were collected from purposefully selected sites in three sampling occasions during both the dry and wet seasons. Analyses for heavy metals in fish, sediment and water samples were done using an Atomic Absorption Spectrophotometer (AAS). The physico-chemical parameters of water and sediment samples of Tinike Lake were analyzed and most of the results were within and below the recommended value of WHO (2011) for survival, metabolism and physiology of aquatic organisms. However few parameters like electric conductivity and temperature were above the recommended standard values.

The water quality of the lake is linked to human pressure associated with domestic, municipal sewage wastewater and agricultural activities. The overall mean values of Cu 0.96 ± 0.02 mg/L, 2 ± 0.041 mg/kg and 2.78 ± 0.034 mg/kg, and Cd 0.05 ± 0.003 mg/L, 0.8 ± 0.008 mg/kg and 0.07 ± 0.001 mg/kg, and Pb 0.13 ± 0.07 mg/L, 1.7 ± 0.1 mg/kg and 1.72 ± 0.02 mg/kg and Mn 1 ± 0.01 mg/L, 1.22 ± 0.1 mg/kg and 3.46 ± 0.08 mg/kg, respectively in water, sediment and fish samples at all sampling sites of the Lake. These results showed that the fish samples had higher mean value of Cu, Pb and Mn as compared with the mean value of water and sediment samples. But, the lowest and medium mean values were recorded in water and sediment samples, respectively.

From the selected heavy metals Cd, Pb and Mn in water samples exceeded the maximum permissible limits of drinking water except Cu, which was below the permissible limits of WHO/FAO (2011). In sediment samples Cu, Cd and Mn concentration levels were above the permissible limit of the sediment quality guidelines except Pb. The concentration levels of Cu and Pb in fish samples were above the recommended permissible limit of WHO, whereas Cd and Mn were within the limit. These indicated that the most analyzed results in Water, sediments and fish samples were from Lake Tinike had recorded levels above the international permissible limits set by WHO/FAO.

As most farmers irrigate for different agricultural products like vegetables and crops by using the lake water. The irrigation of water can also lead to accumulation of heavy metals in the soil 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 the environment when they used for agricultural irrigation. 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.

The study revealed that the water, sediment and fish samples in Tinike 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 Tinike. Data obtained from the heavy metal analysis suggested that, there were more risks from consumption of water and fishes. These were illustrated by high contamination of water, sediment and fishes by heavy metals in the 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 sediment 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 heavy metals bioaccumulation in water, sediment and fishes in the study area. Generally, the results of the present study revealed that that heavy metals contamination of water, sediment and fishes in varying magnitude among samples and between seasons in the study area which may lead to public health crisis.

5.2. Conclusions

Based on the result of the study, there is variation in concentration of selected heavy metals in water, sediment and fish samples and physico-chemical parameters of water and sediment among the sampling sites and between seasons compared. The physico-chemical parameters of water and sediment samples of Tinike Lake were analyzed and most results were within and below the recommended value of WHO (2011) set for survival, metabolism and physiology of aquatic

organisms. But few parameters like electric conductivity in sediment and temperature in water samples were above the recommended standard values.

Heavy metal concentrations that the most analyzed in water, sediments and fish samples were from Lake Tinike had recorded levels above the international permissible limits set by WHO/FAO (2011). The results presented demonstrate that there is a risk associated with the consumption of fish and water and vegetables grown on the Tuji, Kura and Tinike farm irrigated with the Tinike 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.

5.3. Recommendations

Based on the findings of this study, the following recommendations are forwarded:

- Further investigations are required to determine the heavy metal levels of the water, sediment and fishes to estimate the transfer factor.
- Conservation strategies should be in place as the lake provides a range of benefits such as source of water for agricultural irrigation, recreational interest and also as it is habitat for large number of wild life.
- Regular monitoring of the lake is needed by using essential biological and physico-chemical parameters.
- The scientific information obtained from studies should be placed in systematic and accessible database in an appropriate institution to follow the trend.

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7. APPENDICES

Appendix Table 1. Mean comparisons among heavy metals on water samples

Heavy Metals	Cadmium		Lead		Manganese	
	M e a n p-value		M e a n p-value		M e a n p-value	
	Difference		Difference		Difference	
Copper	0.919778*	0.000	0.825444*	0.003	0.031667*	0.002
	**		**		**	
Cadmium	-	-	0.094333*	0.005	0.951444*	0.021
			**		**	
Lead	-	-	-	-	0.857111*	0.004
					**	

Based on observed means, the mean difference was significant at the ($p < 0.05$) level.

Appendix Table 2. Mean comparisons among heavy metals on sediment samples

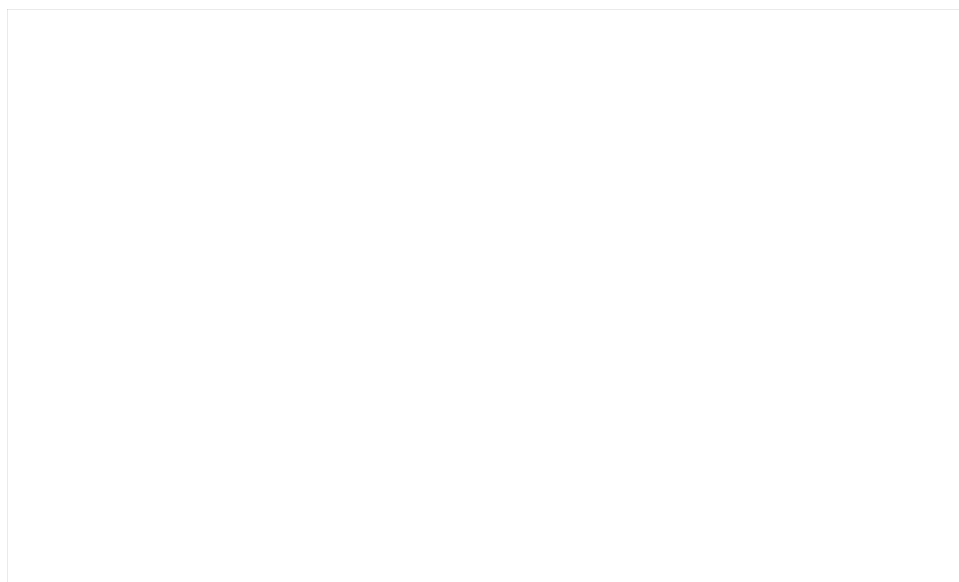
Heavy Metals	Cd		Pb		Mn	
	M e a n p-value		M e a n p-value		M e a n p-value	
	Difference		Difference		Difference	
Cu	1.1950***	0.002	0.3244***	0.004	0.7922***	0.001
Cd	-	-	0.8706***	0.001	0.4028***	0.000
Pb	-	-	-	-	0.4678***	0.002

Appendix Table 3. Mean comparisons among heavy metals on fish samples

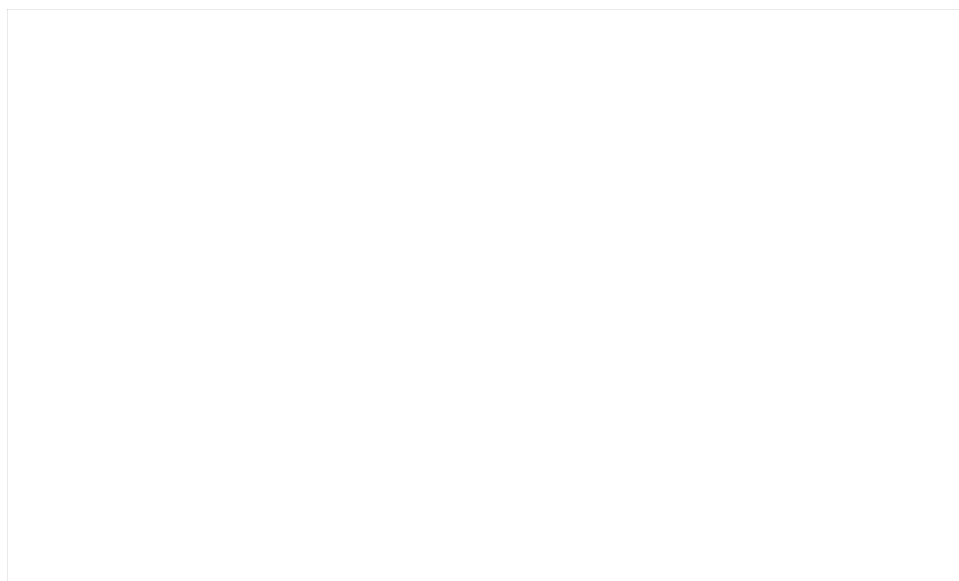
Heavy Metals	Cd		Pb		Mn	
	Mean	p-value	Mean	p-value	Mean	p-value
	Difference		Difference		Difference	
Cu	2.6826***	0.008	1.0317***	0.034	0.6956***	0.003
Cd	-	-	1.6509***	0.026	3.3781***	0.002
Pb	-	-	-	-	1.7272***	0.071

Appendix Table 4. The WHO/FAO standard values for physico-chemical parameters and heavy metals for water, sediment and fishes.

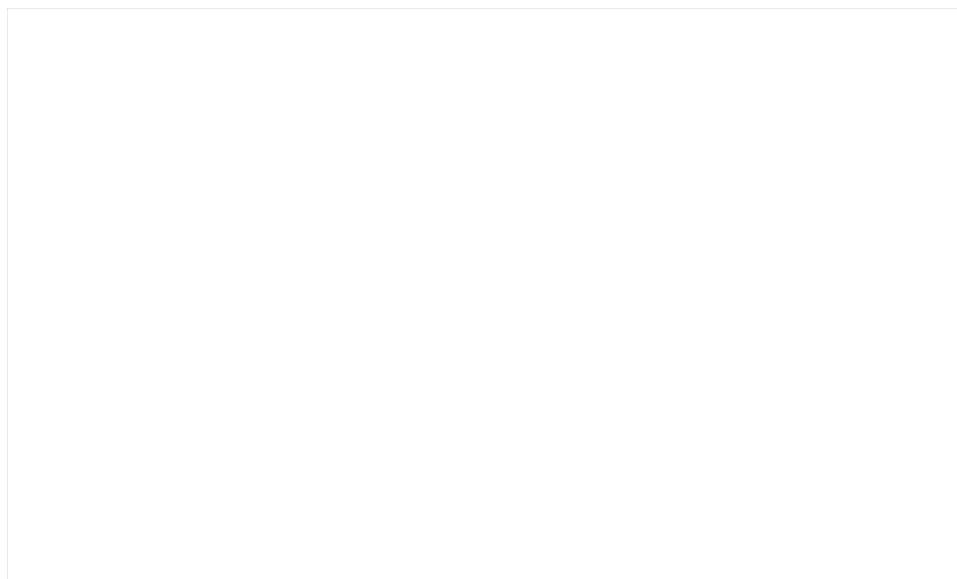
Types Samples	Types Parameters	Standard Values
Water	PH	6.5-8.5***
	Total Dissolved Solids	1000***
	Electric Conductivity	1***
	Temperature	15***
	Copper	2***
	Cadmium	0.01***
	Lead	0.05***
	Manganese	0.5***
Sediment	PH	-
	Electric Conductivity	-
	Copper	1.6***
	Cadmium	0.6***
	Lead	3.1***
	Manganese	0.5***
Fish	Copper	2.7***
	Cadmium	0.2***
	Lead	1***
	Manganese	5.5***



Appendix Figure 1. Calibration Curve of Copper



Appendix Figure 2. Calibration Curve of Cadmium



Appendix Figure 3. Calibration Curve of Lead



Appendix Figure 4. Calibration Curve of Manganese





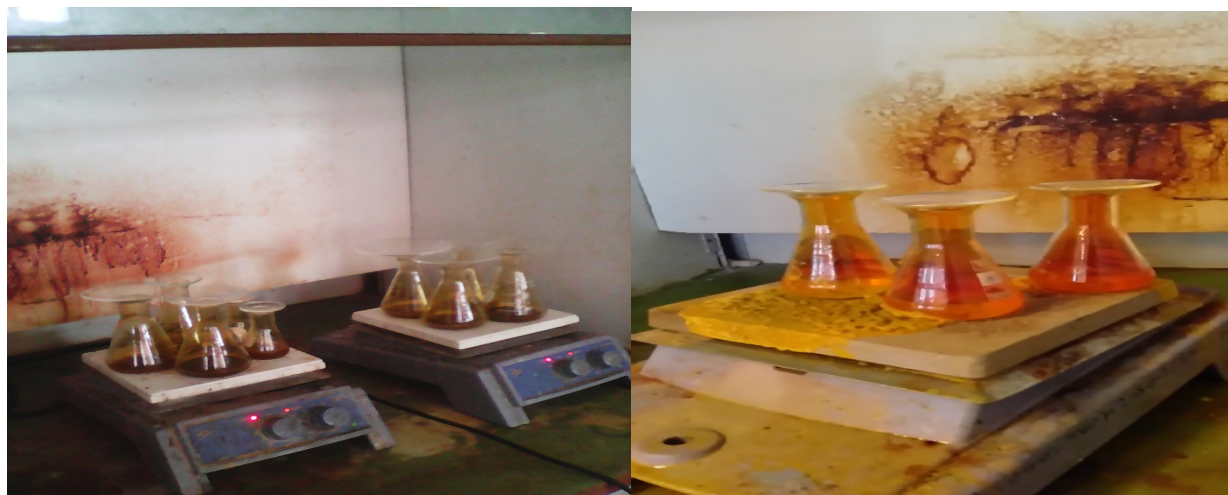
Appendix Figure 5. During Sediment Preparation



Appendix Figure 6. Water Samples Preparation



Appendix Figure 7. Fish Samples





Appendix Figure 8. During water, sediment and fish samples digestion





Appendix Figure 9. During water, sediment and fish samples filtration





Appendix Figure 10. Filtered water, sediment and fish samples

