ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDY

DEPARTEMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

ASSESSMENT OF IMPACTS OF URBANIZATION ON SURFACE WATER QUALITY, THE CASE OF KEHA RIVER, GONDAR TOWN, ETHIOPIA

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OCTOBER, 2018

ADDIS ABAB, ETHIOPIA

Certificate

This is to certify that the thesis prepared by Amsalu Alemu, entitled: **Assessment of Impacts of urbanization on surface water quality, the case of Keha River, Gondar town,** and submitted in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering (major in Water Supply and Environmental Engineering).

As a member of the board of examiners of the MSc, Thesis open defense examination, we certify that we have read, evaluated the thesis prepared by Amsalu Alemu and examined the candidate.

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DECLARATION

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

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Date and place of Submission School of Civil and Environmental Engineering, Addis Ababa University.

December, 2018.

Abstract

This study assessed the impacts of urbanization on surface water quality and identify the sources of pollution on Keha River in Gondar town. Urbanization and anthropogenic activities are the key factor causing water quality degradation as we go downstream along Keha River. Based on Keha watershed land use land cover in1999,2004,2006 and 2017, it is shown that there is significant land use change of the bare land, grassland and agricultural land converted into urban land use and Keha River water quality has deteriorate in the past 15 years. The critical source of pollutions are industries like Moha soft drink industry, Gondar hospital, Kedame Gebeya Commercial market, a lot of hotels and restaurants among others. To analyze the river water quality fourteen (14) different strategic sampling sites were selected. The analysis consisted of in situ and laboratory analysis of samples using standard methods. The result indicated that the range of PH (5.9-8.97mg/l), Conductivity (142-1231 us/cm), Turbidity (8-1072 NTU), Dissolved Oxygen (7.4-2.1mg/l), BOD (4.1-217mg/l), TDS (102-1298mg/l), Alkalinity (89-508mg/l), Total Hardness(103-283mg/l), Iron(0.15-0.76), Chromium(0.02-0.42), Manganese(0.02-3.9), Phosphate(1.37-32.7mg/l), Nitrate(35.4-178mg/l), Total coliform counts(2.9-495) and E.Coli counts (2-273.8) for rainy and dry seasons. At all sampling sites except upstream of Keha River the Physico- chemical and bacteriological results of water samples were above the Ethiopian and WHO standard limit indicated that Keha River was polluted. Except upstream of Keha River, at all sites the Dissolved Oxygen (DO) is less than 5 mg/l that is below the WHO and Ethiopian minimum standard limit. High nitrate and phosphate cause of eutrophication, high total coliform and high E.coli lead to water borne disease and the death of the communities especially children because some people like the daily laborers and street children were used for drinking this polluted River within the study area. It is therefore concluded that the river in the study area is polluted and not fit for domestic use. It is recommended that the water of Keha River should not be used directly for domestic purposes. It is also recommended that an IWRM approach be used in order to solve the pollution problem. Keha River health restorative work is require for multiple importance such as ecosystem regeneration, water quality improvements, reduce any negative impacts on the water resources and aquatic life of Keha River.

Key Words: *Gondar City. Impacts of Urbanization, Keha River, Surface water quality*

Acknowledgment

My sincere gratitude goes to my advisor Dr.Ing.Geremew Sahilu for his valuable advice, encouragement and endless support throughout my work.

Great thanks go to Addis Ababa Institute of technology, school of Civil and Environmental Engineering and school of graduate study encourage, support and for financial assistance they made to me.

I would like to thank University of Gondar, institute of Technology encourage, support and for financial assistance they made to me. I would like also to thank water quality laboratory technician and Environmental health quality laboratory technician, Mr. Eskezia and Mr.Tsegaye.

I would like to specially recognize my family for their constructive assistance they made to me.

Great thanks to my Colleagues, Hydraulic and water resource Engineering Department Instructors at University of Gondar Mr. Wendosen, Mr. Beuketu, Mr. Asnakew Mulualem, Mr. Semagn Yalew and Mr. Eunetu Tarekegne for your support and encouragement to the achievement of this goal.

The last but not the least I would like to thank Gondar town communities, Gondar town Municipality, central Gondar Zone water irrigation and Energy department, Gondar city water supply sanitation office, Gondar city environmental protection, urban sanitation, beauty and green development office for your great support by giving essential data for this research.

Abbreviations

AAU	Addis Ababa University
ANRS	Amhara National Regional State
APHA	American Public Health Association
BOD5	Biochemical Oxygen Demand 5-day
CSA	Central Statistical Authority of Ethiopia
DO	Dissolved Oxygen
EC	Electrical Conductivity
EEPA	Ethiopian Environmental Protection Authority
EPA	Environmental Protection Authority
GCWSSS	Gondar City Water Supply and Sanitation Service
GPS	Global positioning system
HSSE	Health, Safety, Security and Environment
IWRM	Integrated Water Resource Management
mg/l	milligram per litter
MoWIE	Ministry of water, Irrigation and Energy
TDS	Total Dissolved Solids
UN	United Nation
UNESCO	United Nation Education Since and Culture Organization
WHO	World Health Organization

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Chapter One: Introduction

1.0. Background

Water is an essential and life-sustaining resource for humans and all life on the Earth. As far as human existence and development is concerned, water plays a crucial role in agricultural, domestic, industrial, recreational, religious activities among others. Humans have used rivers since the beginning of civilization. Due to the enormous importance of water for human development, early civilizations thrived along Rivers such as the Nile, Tigris and Euphrates in ancient Mesopotamia, Indus in India, and Huang He in China(Isaac Monney *et al.*, 2013). The understanding of the ability to work with water resources and its natural cycles was one of the major factors which determined the success and failure of most civilization.

Urbanization is one of the most detrimental forces affecting surface water quality in the world today. The movement of people to the periphery of the urban centers will mean marginal clearing of the already limited agricultural land for building homes and other infrastructure constructions, i.e., roads, parking lots and other infrastructure developments. The influence of urbanization on river systems was the most significant, and 60% of river systems were changed greatly because of urbanization in the world(Deng et al., 2015). More than half of the world's rivers are seriously polluted, degrading and threatening the health of the people who depend on rivers (Deng et al., 2015). The combination of rapid urbanization, industrialization, population growth, and low environmental awareness poses a major threat to worldwide valuable freshwater resources. Eighty percent of Indians drink polluted water and there is water supply shortage (Kirch, 2002).

Surface water is one of the most influenced ecosystems on earth, and its alterations have led to extensive ecological degradation such as a decline in water quality and availability. Anthropogenic activities, such as land use, and sewage discharge, have caused degradation of surface water quality all-around the world. These reasons cause the deterioration of surface water quality, and damage its use for agriculture, drinking, industry, recreation and other purposes as a result impacts of urbanization on water quality deteriorates. Many countries have difficulties protecting their surface and groundwater resources and in many locations around the world discharges of untreated domestic and industrial wastes threatening ecosystems and human health (Abdel-Magid and Ahmed, 2015).

African Water problems includes water scarcity driven by increasing population pressure, pollution of rivers, streams and lakes. This is due to lack of water resources management, unsustainable policies, inadequate capacity resulting from inadequate education. Increasing water pollution causes not only the deterioration of water quality but also threatens human health and the balance of aquatic ecosystems, economic development and social prosperity. The environmental challenges in the developing world has been fuelled by the great waves of urbanization and inadequate urban infrastructure. According to Isaac Monney *et al. (*2013), the African continent has the highest rate of urbanization with an annual growth rate of 3.5% while Sub-Saharan Africa tops the global urbanization chart on the measure of rate of growth of urban populations. Human civilization has led to dynamic shifts in the patterns of water use, resulting in inevitable discharge of liquid and solid wastes into water bodies resulting in adverse effects upon the receiving water bodies. Urbanization growth coupled with industrialization during past few years has resulted into depleting water ecosystems of major cities in worldwide (Wakuma, 2015). There is currently a lack of studies that quantify water quality variation (deterioration or otherwise) due to both socio-economic and infrastructure development in a catchment.

In developing countries high population growth rates like Ethiopia leads to a rapid expansion of urban growth, causing changes in land use land cover in many metropolitan areas. These uncontrollable urban changes around the Ethiopian towns can increasing adverse effects such as pollution, environmental, social and cultural disturbances (Ambaye, 2012). Ethiopia, situated in the horn of Africa, is confronted with poor sanitation and drinking water infrastructure. In most of the towns of Ethiopia there are rivers that pass-through or on outskirts of the towns and serve as the main source of water for home consumption as well as for any other activities though they are serving as dumping areas of wastes. The main source of water pollution in Ethiopia is sewage of domestic and rural waste water, industrial and agricultural activities (Lisa, 2009). People who live near the area use the water for domestic consumption as well as for another activities like irrigation. Some pollutants released dangerous chemical products and others deserted different waste materials.

At the sides of Akaki River that runs through the center of Addis Ababa there are many industrial establishments among which most of them are discharging their effluents directly to this river without any prior treatment (Eshetu, 2012). Surface waters have for a long time been considered as a convenient receiver of wastes, such is the case with Keha River, Gondar town. The entry of waste into water bodies disrupts the quality of the ecosystem and this use of surface waters conflicts with all other intended uses of that water such as domestic use. Currently, Addis Ababa is one of the fast growing cities and at the same time the rivers in the city are vulnerable to pollution. Walgamo River which is located closer to Kotebe Metropolitan University is polluted and unsafe for domestic use (Berihun *et al*., 2017).

Decrease in water quality can lead to increased treatment costs of potable and industrial process water. The use of water with poor quality for agricultural activities can affect crop yield and cause food insecurity. Generally, much attention has not been devoted to adequately protect this all-important resource. This is the fact that huge amount of wastes are disposed of within receiving waters daily.

In urban center of the developing world, surface water resources have become dump yards for waste. There is an urgent need to monitor and assess these resources, as this information is crucial for sustainable decision-making and management. It is significant to have information about water quality and pollution sources in order to implement sustainable water-use management strategies. Information on the quality of any aquatic environment ensures knowing the physical, chemical, biological and ecological characteristics, and useful for intended uses of the environment. Therefore, investigating the impacts of urbanization on river systems is crucial to the sustainable management and conservation of rivers.

The land use within a watershed has a great impact on the water quality of rivers (Chu *et al*., 2013). The water quality of rivers may degrade due to changes in the land cover patterns within the watershed as human activities increase. Point sources that affect the quality of water include wastewater treatment facilities while non- point sources include runoff from urban areas and farming activities. Polluting substances that lead to deterioration of water quality affect most freshwater.

1.1. Statement of the problems

Keha River in Gondar town has been for a long time considered as a convenient receiver of wastes. The entry of waste into water bodies disrupts the quality of the ecosystem. Keha River is the most threatened river from urban domestic waste, industrial waste and agricultural waste in Gondar. Much of the wastes, both domestic and industrial produced in Gondar town reaches the Keha River seriously polluting. All of these issues can be accounted either directly or indirectly to urbanization pressure and human activities in the study area.

Due to the climate and the environment degradation the catchments in the rivers are not possible in Gondar for a sustainable water supply all along the year (Gondar City Water Supply and Sanitation Service, 2012). The shortage of water supply in the town has caused various burdens on the community related to economic and health matters. Sixty five percent of less than five years mortality in the study area is due to diarrhea in which water related diseases occupy a high proportion (Admassu, 2002). The quality of water is vital concern to humans as water quality is directly linked with human welfare. Women are the one to carry the entire burden of water problem. They travel to different places where they can get water, carry and bring water home to accomplish the day-to-day domestic activities, waste much of their time and energy. All this in general affects their engagement in other activities within and outside home.

The issue of impacts of urbanization on surface water quality has been weakly addressed in Gondar town. The presence of a number of various point and non-point sources of pollution around the Keha River may have a harmful effect on the water quality of the river. Most of the communities lack of appropriate sanitary infrastructure for liquid waste disposal, major portions of grey water and black water generated are disposed into Keha River which is the heart of Gondar town. The increasing vulnerability of Keha River is one of the grand challenges in Gondar town today and the entry of waste into Keha River may disrupts the quality of the ecosystem. Assessing the impacts of urbanization on surface water quality is necessary for effective water resources management. In order to prevent Keha River from pollution it is critical that the assessment of impact of urbanization on Keha River quality should be perform.

1.2. Objectives

1.2.1. General objective

The main objective of the research was to assess the impacts of urbanization on surface water quality and to identify the sources of pollution on Keha River in Gondar city, Ethiopia.

1.2.2. The specific objectives

1. To analyze the selected physical, chemical and biological parameters of Keha River and compare with the WHO and Ethiopian water quality standards for domestic uses.

2. To assess the spatial and temporal variation in water quality of the keha River

3. To identify the sources of pollution affecting water quality the case of Keha River in Gondar town

1.3. Research questions

1. What is the status of Keha River water quality with respect to WHO and Ethiopian water quality standards?

2. Is there the spatial and seasonal water quality variation from upstream to downstream and from dry season and wet season in Keha River?

3. What are the sources of pollution affecting Keha River water quality in Gondar town?

4. What are the effects of land use change and urbanization on water quality in Keha River?

1.4. Significance of the study

Ethiopia's water resources are under increasing threat of pollution from various anthropogenic sources and activities. Understanding the impacts of urbanization on surface water quality is critical, as it helps in the formulation of sound strategies and policies aimed at reducing the negative impacts of urbanization on water quality. Efforts to reduce water pollution have been hampered by lack of adequate water quality data. This study therefore described the physical, chemical and biological properties of the surface water in the Keha River and how these vary spatially and temporally according to different anthropogenic activities as a step towards strategic water policy development.

Insights gained from the study will be useful for the protection of the Keha River. The river provides water to Gondar town communities for domestic and agriculture water use. Keha River experienced industrial, commercial and domestic activities in its catchment area, making it prone to pollution. Also, poor quality water used for communities may lead to health problem. Since this research focuses on assessment of the impacts of urbanization on surface water quality provide greater importance to the research community, water resources engineers, urban planners, environmental agencies, stake holders as well as decision making groups in terms of understanding the impacts of urbanization on surface water resources in Gondar area. It is expected to increase the knowledge and up to date information on urban water resources vulnerability to pollution and the possible protection strategies. This helps in the achievement of Sustainable Development Goal 6 (SDG 6), which states the need to reduce pollution, by eliminating dumping and minimizing release of chemicals into surface waters (UN Water, 2009).

The results of this study could provide better information and understanding about the trends of River water quality changes in Gondar area as a result of driving urbanization activities. Moreover, the findings of this study will be an initial input for future research direction for interested groups in the study area and serve as baseline data for any further investigation, as a useful material for academic purposes. Therefore, protection of the water resource will help in improvement the economy of the country.

1.5. Scope of the study

Keha River in this research was studied of its water physical, chemical and biological parameters such as Electrical Conductivity, Turbidity, pH, Temperature, TDS, Dissolved Oxygen, BOD, Nitrates, Phosphates, Total Hardness, Total Alkalinity, Iron, Manganese, Chromium, Bacteriological parameters like total coliform and E-Coli. Parameters that had been analyzed were selected considering critical anthropogenic activities taking place in the Keha River

1.6. Limitation of the study

Like any other research work, this study has also faced a number of limitations in the process of convening the work. The main obstacles were: The absence of historical data, gauged data, previous river water quality data that could showed successive trends of Keha River pollution. The sampling time for dry season March was selected based on the minimum flow of the river and for wet season August was selected due to peak flow of the river and additional moths were not include due to time and financial limitation. The study was concluded only water quality selected parameters both dry season and wet season due to historical data and gauged data constraints. Iron, Manganese and Chromium were analyzed but heavy metals like Lead, Cadmium, Mercury and others were not include due to lack of reagents and financial constraints.

1.7. Structure of the thesis

The thesis is divided into five chapters. Each chapter contains sections and subsections. Chapter one highlights the rational of the research with details of the research objectives and problem statements of the study area. The scope, significance and limitations of the study was also summarized in this chapter

Chapter Two explains the state-of-the-art urban river quality and the impacts of land use change in urban settlements.

Chapter Three explains Research design and methodology, presents the study areas, describes sampling points and method to evaluate water quality.

Chapter Four elaborates result and discussion on physical, chemical and biological parameters in detail. It also explain impacts of urbanization on surface water quality the case of Keha River and the linkages between urbanization and water pollution.

Chapter Five ends up with conclusion and possible recommendations from the study.

Chapter Two: Literature review

2.1. Impacts of urbanization on surface water quality

Rapid urbanization has led to dynamic shifts in the patterns of water use, cause unavoidable discharge of liquid and solid wastes into water bodies resulting in adverse effects upon the receiving water bodies (Dladla, 2009). Anthropogenic activities are human activities that negatively affect the water quality making it polluted and hence unsuitable for normal uses(Amah-Jerry *et al*., 2017). Overpopulation in urban areas has caused many problems considering enormous need of water, food and infrastructure, and tremendous pollution amounts to the water. The problems are more evident in developing countries, which have made the situation even more difficult due to absence of finance and proper policies. Urbanization is one of the most detrimental forces affecting river health and one of the biggest challenges facing watershed managers (Riley, 2008).Anthropogenic activities result in significantly decrease of surface water quality of aquatic systems in watersheds (Amah-Jerry *et al*., 2017).

Land use and land cover changes have significant impact on the water quality in a watershed. Since the landscape contains the natural resources on which humans depend, i.e. water, biomass, energy sources and other basic materials (author), any use or exploitation of these resources can cause changes in the land cover, which consequently modifies the local ecosystem.

The rapid rate of urban growth and its subsequent urban expansion leads to increasing impact on water quality due to increased water pollution. The increased disposal of sewage, industrial effluents and agricultural and urban runoffs raising the chemical, physical and the microbiological contents of the water bodies. It is the fact that as urbanization expands the land with its natural vegetative and forest covers are cleared to give way for residential and industrial purposes. There is a general saying that urbanization has converted the green space into black space, referring to the asphalt and other hard concrete surfaces.

In the African setting the most striking environmental problems and subsequent impacts of urbanization, aside water resources are unsustainable land use changes, land degradation, deforestation and loss of biological diversity. According to (Mohammed, 2004) inadequate and unsound management of natural resources are one of the underlying causes of this situation. Point sources that affect the quality of water include wastewater treatment facilities while non- point sources include runoff from urban areas and farming activities. Rivers are particularly vulnerable to land use change and ubiquitous exploitation. Anthropogenic activities are directly reflected in land use characteristics. During the urban development process, urbanization and urban activities had a significant negative impact on the river water quality (Ouyang *et a*l., 2006).

Understanding the relationship between land use and water quality is helpful for identifying primary threats to water quality, and the relationships are meaningful for effective water quality management because they can be used to target critical land use areas to minimize pollutant loadings Deforestation, agricultural activities and urbanization generally modify land surface characteristics, alter runoff volume, change water temperature, generate pollution, and increase algal production and decrease concentrations of dissolved oxygen in water bodies (Ding *et a*l., 2015).

2.1.1 Impacts of urbanization on water demand

Increasing urbanization means more consumption and need of different products. The production of these needs water and creates more pollutants. In developing countries where the urbanization is occurring most rapidly the technology is not high enough to take responsibility of water treatment and clean production. Humanity today experiencing a dramatic shift to urban living. Local urban environmental stressors and global ones are combining to accelerate the rate of degradation freshwater ecosystems worldwide (Lugo, 2015). Humans must use water for many purposes, and water quality deteriorates as a result. According to (United Nations World Water Development Report, 2014),Global population is projected to reach 9.3 billion in 2050 and Population growth leads to increased water demand, reflecting growing needs for drinking water, health and sanitation, as well as for energy, food and other goods and services that require water for their production and delivery. Communities living along rivers are most affected by these negative trends. Pollution of rivers and lakes are two top environmental concerns. During the process of urbanization, reflectivity of land surface is considerably changed when large areas of natural or agricultural lands are converted to built-up areas (Xiao *et al*., 2007).The lack of sanitation and sewage treatment is the biggest factor regarding water pollution.

2.1.2. Impacts of Land use change on water quality

The land use within a watershed has a great impact on the water quality of rivers and deterioration water quality has become a global issue of concern as human populations grow, urbanization, industrial and agricultural activities expand (UN Water, 2009).The water quality of rivers may degrade due to changes in the land cover patterns within the watershed as human activities increase. Point sources that affect the quality of water include wastewater treatment facilities while non- point sources include runoff from urban areas and farming activities. Polluting substances that lead to deterioration of water quality affect most freshwater.

Increase in urban population can affect water quality in several ways. The migrations of from rural into urban areas requires the municipalities to accommodate and provide for both a higher demand for safe and clean freshwaters and an increase in the volumes of generated wastewater, which will need to be treated. The movement of people to the periphery of the urban centers will mean marginal clearing of the already limited agricultural land for building homes and other infrastructure constructions, i.e., roads, parking lots etc. These processes impact negatively on the availability as well as quality of water resources as lakes, streams, rivers, and in some cases ponds in an area (Mohammed, 2004).

Water quality analysis is one of the most important aspects in surface water studies and it is a critical factor for assessing the pollution level. The quality of surface water is a very sensitive issue. The degradation of water may occur due to change in quality caused by contamination or pollution so that it becomes unsuitable to users. This degradation is more on rivers which flows through potential sources of pollution. In Africa Freshwater quality is declining, as a result of: pollution from industrial and sewage outflows, agricultural run-off; and saltwater intrusion. About 70% of industrial wastes in developing countries especially in Africa are disposed of untreated into surface waters where they contaminate existing water supplies which pose health risks to nearby communities (UN Water, 2009). In Ethiopia Direct discharge of domestic and municipal sewage is not limited to Akaki River. However, the same problem is also deteriorating the quality of Huluka River, west Showa zone of Ethiopia. The direct discharge of the pollutants to downstream of Huluka River could entail negative effect on the quality of the river, as well as serious harm to the aquatic life and downstream users (Eshetu, 2012).Lack of water management is both an environmental and a social problem, faced in many communities, all over the world. Surface water quality deterioration is a serious problem in many rapidly urbanizing in developing countries. There is currently a lack of studies that quantify water quality variation (deterioration or otherwise) due to both socio-economic and infrastructure development in a catchment. It is well known that population growth and industrial activities are drivers of water quality change and water quality deterioration in rivers.

The increased effects of deteriorated water quality on the health of living beings in general and on the humans in particular could be disturbing, given the significant role of water in human activities.

2.2. Standards for water quality

In order to understand the different nature of pollutants, the values of certain parameters have been evaluated with respect to the acceptable permissible limits of WHO and Ethiopian standard for drinking water. This helps to indicate the pollution levels of Keha River. Water Quality standards or guidelines originate from different countries such as European Union participant countries, individual countries, or international organizations such as the US Environmental Management Agency (Environmental Protection Agency, 2001). Developing countries face the challenge of lack of sufficient water quality data for decision making (WHO, 2011). Water quality data is required in the assessment of the suitability of water for intended uses such as drinking, industrial use, agricultural use and use in mines. The main aim of the imposition of water quality standards is the protection of the end uses of water, be it humans, the environment or industries (Environmental Protection Agency, 2001). The establishment of water quality regulations and monitoring programs is critical for water resources planning and management. Establishing appropriate standards requires information on the degree of tolerance of each of the specific use on the amount of contamination and possible effects (Environmental Protection Agency, 2001).Water quality standards ensure that the water quality is maintained to a desirable level that will suit both human needs and the environment. However different countries and organizations have their own specific water quality standards and guidelines for that particular region depending on the geographic location, nature of contaminants in receiving waters, health hazards and intended uses.

2.3. Water quality in rivers

Water quality is a term used to describe the physical, chemical and biological characteristics of water in respect to its suitability for a particular purpose and any characteristic of the water that affects its water quality parameter (Oyhakilome *et al*., 2012). The selection of water quality assessment parameters depend on the needs and objectives of the assessment (Bartram and Balance, 1996). Primary parameters such as temperature, pH and dissolved oxygen are essential as they influence reactions in water and the later important for sustaining aquatic life, (Chapman, 1996).Other parameters are selected based on the needs of the water quality assessment.

2.4. Physio- chemical and biological water quality parameters

Physical, chemical and biological parameters which include, turbidity, electrical conductivity (EC), Total Dissolved Solids (TDS), pH, nitrate, phosphate, total alkalinity, Iren, chromium, total hardness, Biological Oxygen Demand (BOD) dissolved oxygen(DO),Total coliform and E-coli are going to be discussed in detail. The physical, chemical and biological composition of surface water and its properties is basically governed by natural processes and human activities which can either be point or non-point sources. Human activities are major factors determining the quality of surface water through effluent discharges, use of agricultural chemicals and eroded soils. Anthropogenic activities result significantly decrease of surface water quality of aquatic systems in watersheds. Rivers in a watershed play a major role in assimilating or carrying off municipal and industrial wastewater and runoff from agricultural land. Therefore, a river is a reflection of its watershed. River inflows contribute main pollutants to most lakes in a watershed, thereby tending to induce serious ecological and sanitary problems (Amah-Jerry *et al.*, 2017). Pollution of surface water bodies, resulting from anthropogenic activities, is a growing concern worldwide. The selection for the river water quality assessment method vary according to the needs and objectives. Selection of parameters for testing of water is solely depends upon for what purpose going to use that water and what extent need of its quality and purity.

i. Temperature

Temperature is a critical water quality parameter, since it directly influences the amount of dissolved Oxygen, heavy metal ions and PH. In an established system the water temperature controls the rate of all chemical reactions, also it affects growth, reproduction and other characteristics of aquatic life. Drastic temperature changes can be harmful and sometimes lead to fatal of aquatic life (Devangee P. Shukla et al., 2017).Higher water temperatures than 25^0C for prolonged period of time causes aquatic organisms to get stressed and die (Environmental Protection Agency, 2001). Factors that can cause changes in water temperature for water bodies include weather changes, industrial effluent discharge on the water body.

ii. PH

PH, or the "potential of hydrogen", is a measure of the concentration of hydrogen ions in the water. This measurement indicates the acidity or alkalinity of the water. On the pH scale (0-14), a reading of seven is considered to be "neutral". Readings below seven indicate acidic conditions, while readings above seven indicate the water is alkaline, or basic. Naturally occurring fresh waters have a pH range between six and eight. The pH of the water is important because it affects the solubility and availability of nutrients, and how they can be utilized by aquatic organisms. The pH is an important variable in water quality assessment as it influences many biological and chemical processes within a water body and all processes associated with water supply and treatment (Chapman, 1996). PH can be used to sensitively indicate differences in water quality, thereby indicating the suitability of the water for intended uses. Low pH increases solubility of heavy metal compounds which in turn results in higher concentrations of heavy metals in water. Extremes in pH can also affect the palatability of the water.

iii. Turbidity

The American Public Health Association (APHA) defines turbidity as "the optical property of water sample that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample. "Turbidity may be caused when light is blocked by large amounts of silt, microorganisms, plant fibres, wood ashes, chemicals and coal dust. The most frequent causes of turbidity in lakes and rivers are plankton and soil erosion from logging, mining, and dredging operations. The units of measure for turbidity are Nephelometric Turbidity Units or NTUs (Lutz D, 2004).Turbidity affects fish and aquatic life by interfering with sunlight penetration. Water plants need light for photosynthesis. If suspended particles block out light, photosynthesis and the production of oxygen for fish and aquatic life will be reduced. If light levels get too low, photosynthesis may stop altogether and algae will die. It is important to realize that reduced photosynthesis in plants result in lower oxygen concentrations and large carbon dioxide concentrations in a water body. Turbidity will also affect the fish negatively in terms of food identification (Cunningham *et al.*, 2003).

iv. Total dissolved solids (TDS)

Total dissolved solids (TDS) are a measure of the amount of particulate solids that are in solution. This is an indicator of non-point source pollution problems associated with various land use practices though point sources also contribute. The TDS measurement should be obtained with conductivity meter and is expressed in mg/l (Chapman, 1996).

v. Total Alkalinity

Total Alkalinity (TA) is the ability of water to neutralize acids added to the water and is expressed in mg/l (Environmental Protection Agency, 2001). TA is composed mainly of bicarbonate (HCO_3), carbonate (CO_3) and hydroxyl (OH^-) ions and is expressed as mg/l of $CaCO_3$. There is a direct relationship between TA and pH, an increase in TA causes an increase in water PH. Normal alkalinity in river water is in the range 120 mg/l - 170 mg/l for unpolluted rivers (Ding et al., 2015). Total alkalinity, therefore, can be used as a measure of the river waters buffering capacity.

vi. Nitrate

Nitrate is most commonly found from organic and inorganic sources such as fertilizers and waste discharges (Environmental Protection Agency, 2001). Nitrate becomes more toxic to humans after converting to nitrite which can cause anemia as it combines with hemoglobin in red blood cells of humans (Elshorbagy A. and Ormsbee L., 2006). Domestic wastewater contains high levels of nitrogen which can be converted to nitrate in water resources, thereby causing eutrophication (Mishra *et al.*, 2009). In streams or rivers, elevated nitrates concentrations are usually due to runoff from agricultural land and this causes significant increase in the nitrate content in receiving waters. The recommended nitrate level for surface water is less than 50 mg/l (Environmental Protection Agency, 2001). The presence of nitrates in river water is a sign of agricultural runoff, storm drains and poorly functioning septic systems, thus suggesting the need for immediate action to be taken before the situation worsens.

vii. Phosphate

Phosphates enter waterways from human and animal wastes, phosphate-rich rocks, and wastes from laundries, cleaning and industrial processes, and farm fertilizers. Phosphates stimulate the growth of plankton and water plants that provide food for fish. This may increase the fish population and improve the waterway's quality of life. However if too much phosphate is present, algae and water weeds grow wildly, choke the waterway, and use up large amounts of oxygen. This is called eutrophication and may cause the death of fish and aquatic organisms. The aesthetic values of the river will decline; hence, the need to control the amount of phosphates available to a water body.

viii. Dissolved Oxygen (DO)

Dissolved Oxygen (DO) is vital because it supports the lives of aquatic organisms which also help break down organic compounds in water. DO concentration effects biodegradation speed in water bodies (Ding *et al.*, 2015). DO is affected by entry of organic matter in to rivers especially from runoff during and after a rainfall event. DO in surface water should be greater than 5 mg/l in order to support a variety of aquatic life

(Environmental Protection Agency, 2001). DO plays a very significant part in the breakdown of organic waste in the water. Lower concentration of dissolved oxygen means more accumulation of biological substances in the water. Oxygen levels can be reduced through over fertilization of water plants by run-off from farm fields containing phosphates and nitrates (the ingredients in fertilizers). Under these conditions, the numbers and size of water plants increase a great deal. Then, if the weather becomes cloudy for several days, respiring plants will use much of the available DO. When these plants die, they become food for bacteria, which in turn multiply and use large amounts of oxygen (Canter W., 1985).

ix. Biological Oxygen Demand (BOD)

Biological Oxygen Demand (BOD) is the quantity of oxygen needed to breakdown organic waste in water and measurement is obtained after 5 days. BOD reduces the amount of DO available for aquatic organisms and the levels of BOD in receiving waters is directly increased by the discharge of waste that is high in organic matter (Kgabi N., 2015). These organic wastes emanate from municipal sewage, industrial wastewater and runoff from catchments. The recommended BOD level for surface water is less than 5 mg/l (Environmental Protection Agency, 2001).

x. Chloride

Chloride is found in all water resources in the world with levels varying and reaching the highest in sea water (35000 mg/l) (Kgabi N., 2015). The water containing chloride concentration above 250 mg/l has a salty taste and people can object to drink it or use it (Ding et al., 2015). In rivers, the chloride concentration is in the range 15 -35 mg/l which is way lower than the drinking water quality standard value of 250 mg/l (Environmental Protection Agency, 2001)). Chloride poses no health risks to humans, however high concentration can give the water a salty taste.

xi. Electrical conductivity (EC)

EC in water is a measure of the capability of water to pass electrical flow. Increase in temperature results to increase in EC in water. The recommended EC level for surface water is less than 1000 µS/cm (Environmental Protection Agency, 2001). Electrical conductivity is essential as it can be used as an indicator of total dissolved organics, bases, acids and salts in water. Measuring EC helps water resources managers assess water quality in terms of the presence of metal ions, salts and other pollutants that may render the water unsuitable for intended uses.

xii. Colour

People in certain parts of the world have even altered to other types of water supply due to the colour of water that they have been receiving from their existing supplies even though the water may have been safer (Elshorbagy A. and Ormsbee L., 2006). Because of the variability, it is important that numerous measurements are complete to find the correct variety of colour in river water (Environmental Protection Agency, 2001).

x**iii. Total Hardness (TH)**

Total Hardness (TH) is the capacity of water to destroy the lather of detergents or soaps. Recent studies have shown that in developing countries the number of people dying due to heart diseases was lower in places where the water people use was hard (Environmental Protection Agency, 2001). Total Hardness consists of Calcium and Magnesium or Calcium Carbonate(Kgabi N., 2015). Total Hardness at higher concentrations (>200 mg/l) can cause blockages in pipes, affect boilers in industries and neutralize the lathering properties of water (Kgabi N., 2015).

xiv. Total coliform

Total Coliforms (TC) comprise of faecal and non faecal bacteria which may originate from soil or plant material. In water quality, Total Coliform is a sign for the presence of pathogens in the water (Environmental Protection Agency, 2001). Sources of bacteria can be the digestive system intestines for humans or warm blooded animals (Ding et al., 2015). In surface waters, Total Coliform concentration less than 1000 CFU/100 ml is recommended. But for drinking water and health reasons, it is recommended that only water without any coliform should be used to minimize the risk of contracting infections (Environmental Protection Agency, 2001). Total coliform in river water can be used as an indicator of the total bacteria or pathogenic organisms that can be found in the water. High total coliform count in river water is due to runoff from catchment, sewage discharge and poor sanitation.

xv. E.coli

E.coli is an affiliate of the faecal coliform microbes and originates in the human intestines (Environmental Protection Agency, 2001). E.coli bacteria serves as an excellent sign for faecal pollution in water as they can live longer than other bacteria or disease causing organisms (Olorode *et al.,* 2015). Failing septic tanks, leaking sewer pipes, broken wastewater treatment plants, open defecation and storm water runoff are possible E.coli sources in river water. For the safety of drinking water, the E.coli count should be 0

(Environmental Protection Agency, 2001). Analysis of water for E.coli is important for assessing microbial pollution in the water. Occurrence of E.coli in water at high concentration means that the water is not safe for drinking and there is high possibility for waterborne infections such as diarrhea, cholera, and many more.

2.5. Temporal and spatial variation

For effective water-quality assessment and management a reflection of the temporal variation characteristics is very important. Temporal variation is the assessment of the effect of time on pollution such as the seasonal pattern and its effect on the constituent's relationship. Variation in water quality is caused by natural process and anthropogenic sources (Li R *et al*., 2007).The spatial extent of pollution is critical as the mixing of pollutants occurs over a given distance. From a water quality management perspective accurate assessment of spatial and temporal variation of pollutant loadings in streams within a watershed is essential (Elshorbagy A. and Ormsbee L., 2006). The risk associated with pollution depends on both the extent of the temporal and spatial variation of the pollutant.

Chapter Three: Material and methods

3.1. Description of the study area

The study area is found in the city of Gondar in the North Western part of Ethiopia about 737km from Addis Ababa. The main highway connects Addis Ababa with Gondar via Bahir Dar. The city is situated in the foothills of Simien Mountains at an average elevation of 1950 m.a.s.l. The City of Gondar, founded by Emperor Fasiledes in 1636 A.D, is also the current capital of the North Gondar Administrative Zone. It was once the Capital of Ethiopia for more than 200 years. The city is endowed with historical sites registered by UNESCO at international level and it provides a big stimulus to the economy by attracting tourists to the area (Gondar City Water Supply and Sanitation Service, 2012).

Gondar initially developed between Angereb River on the east and Keha River on the west which meet in the south eastern part of the city and then expanded towards the south, south east and south west and finally adjoining the earlier settlement of Azezo. Keha River which is a tributary to Megech River that drains into Lake Tana. Keha River is located near Gondar university teaching hospital in the western part of Gondar and it is highly affected by agricultural and domestic wastes.

3.1.1. Population and migration

The national census conducted by the Central Statistical Authority of Ethiopia, the population number has grown to 207,044 (CSA, 2007). The city is the first in terms of population size in the region, Amhara regional state. Most of the migrations happen from less developed regions to more developed areas (CSA, 2007). According to CSA report, the proportion of migrant in Gondar town was known to be 42% in 2007 which was higher than the regional figure (8.3%) in the same year (CSA, 2007).

3.1.2. Climatic condition

The rainfall pattern of Gondar is unimodal and characterized by a single maximum rainfall pattern with peaks in July and August. The agro-ecological climatic zone is "wine Dega" with a mean annual temperature ranging from 12.9^0C to 26.4^0C and an average of 20^0c.

3.1.3. Soil

Soil in Gondar can be classified as silty clay, silty clay loam or silty sand derived from deeply weathered basalt. The soils have brown color on the hills and sloppy areas and dark to gray color in parts of the city. Generally, the clays and or silts occupy the top most part of the soil, while sands, gravel and boulders are at the bottom.

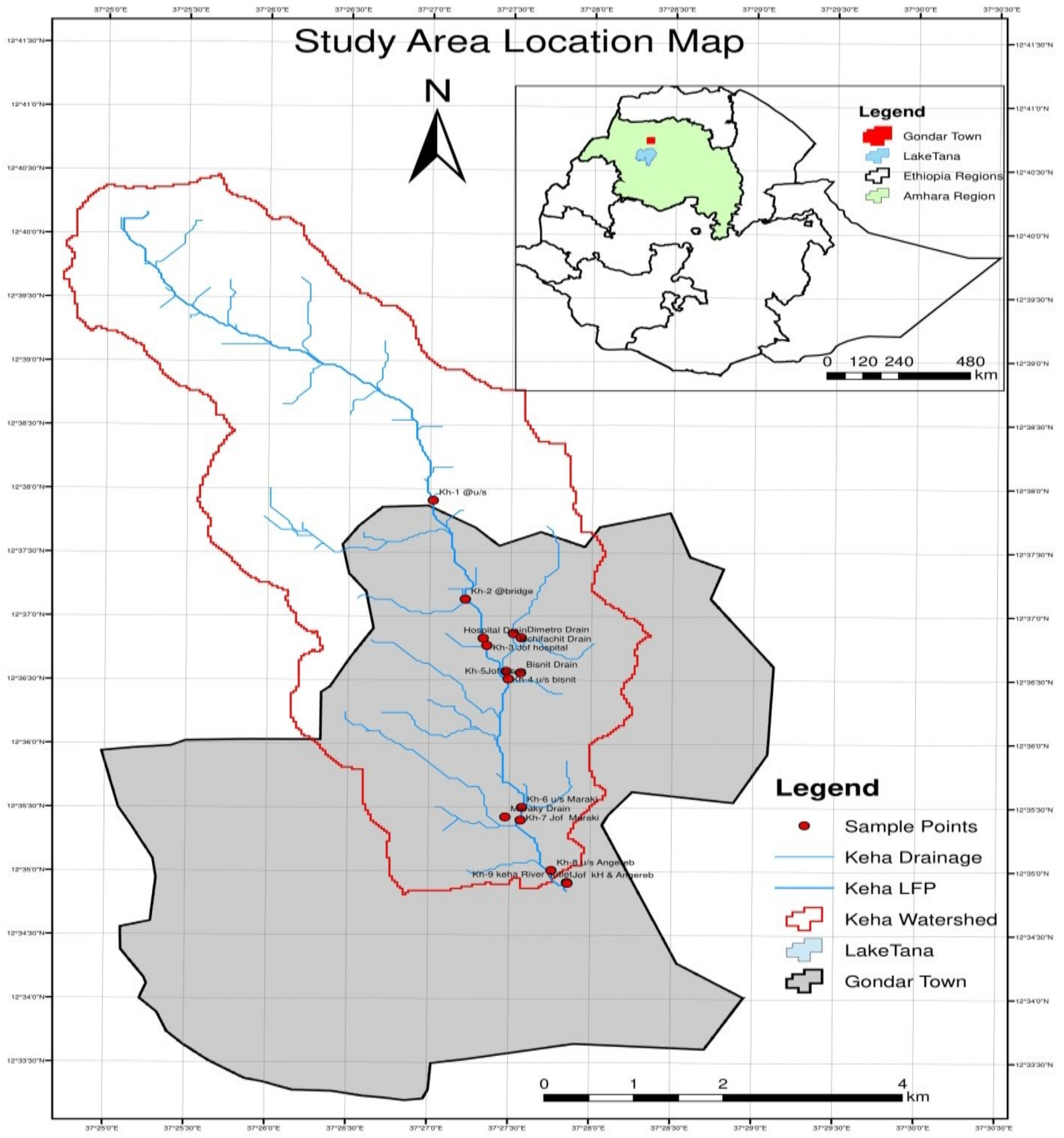


Figure-1. Location Map of The study area, Gondar city

3.1.4. Topography

Gondar town is situated on a mountainous terrain at an average elevation of 1950 masl. The city is characterized with rounded hills and gentle slopes. There are two rivers running across the boundaries of the town: Angereb River and Keha River, and the main parts of the city are located on the ridge between the two rivers. Angereb is steeper than the slope facing Keha River and as result most of the population of the town is concentrated on the slope facing the Keha River. The topography of the majority of the town including the airport and Azezo is gentle slope. The areas surrounding Lake Tana including Fogara plain and Kola Diba area are flat (Gondar City Water Supply and Sanitation Service, 2012).

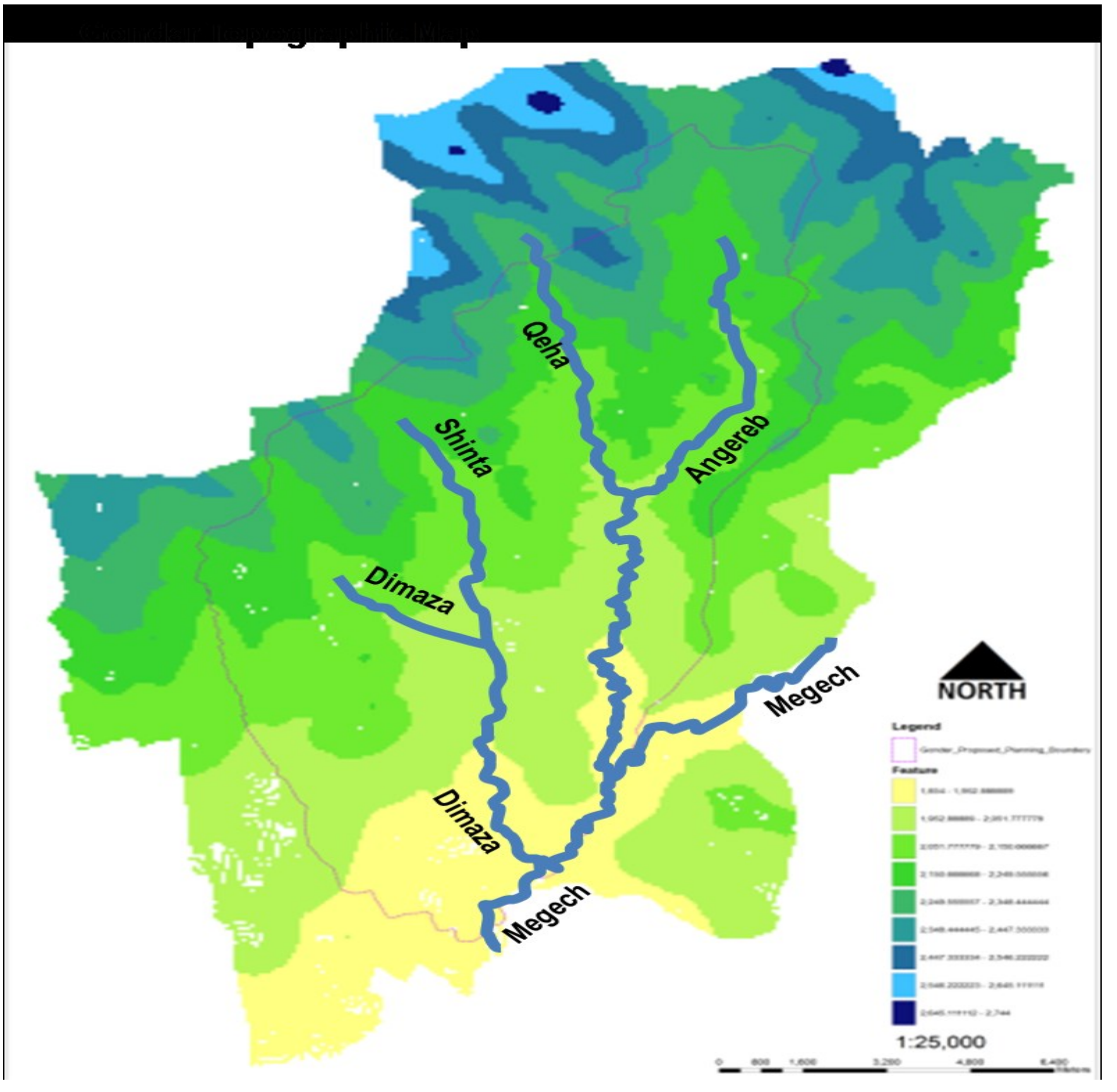


Figure-2. Topographic map of Gondar
(Source: ANRS Regional urban planning institute, 2015)

3.1. 5. Natural rivers

There are four rivers namely Shinta, Keha, Angereb and Dimaza in Gondar city. Most of the developed part of the city is located between these rivers. There are several small streams originating from the mountains and hills surrounding the city. The major streams apparently maintain a small base flow through groundwater discharged from springs and from seepage into the beds of the streams(Gondar City Water Supply and Sanitation Service, 2012). The rivers and streams feed into Megech River. Gondar city falls within the Megech river sub basin. Angereb, Keha, Shinta and Dimaza which flow through the city are all tributaries to the Megech and then to Lake Tana. Angereb and Keha Rivers join to Megech River upstream of the new Megech dam. The new Megech dam is located below the joining point of these rivers. Water pollution is observed along Keha River. The river lack defined buffer area, due to which they are influenced by houses. Shinta and Dimaza Rivers also feed into Megech River but downstream of the Dam. The Megech Dam which is currently under construction will have economic benefits to the town. In addition to the main rivers, Gondar has many small streams and seasonal rivers.

Figure 3. Communities use Keha River for close washing and bathing

3.1.6. Socio-Economic activities along Keha River

Gondar city is one of the cities in the region in which the promotion of Micro and Small Enterprise has been undertaking through a variety of activities. Some of them are food processing, hotels, restaurants, tea rooms, urban agriculture, Service, trade, Textile and garment, Construction and engineering, wood and metal working and others. Many housing units are built just along the river banks and their outfalls are connected to the Keha River at various sections.

Figure4. Urban agriculture along Keha River Gondar town

Gondar has one central market locally known as "Kedame Gebeya". This central market is located at the center of Gondar town. However, with the growing population of the city, the Kedame Gebeya market has long become highly crowded, chaotic and unsuitable market place (Gondar city administration office, 2011). The market has different sections for selling clothes, grain and food items, wood and charcoal, manufactured products, and metal scraps and salavages materials. G+1 building was built at the middle of the market and the road dividing the market it into two.

Figure5. Different markets and erosion observe the edge of Keha River 10/5/2017

There are cattle barns and cattle market owned by private cattle traders in and along Keha River banks. Cattle are collected here and then exported to Sudan. They face shortage of space, and are polluting the river too. This situation needs immediate attention appropriate site with good access shall be selected by considering the major access of cattle and direction of export.

Figure.6 cattle barns and markets along keha river banks

3.1.7. Existing land use and urban expansion of Gondar

Early settlements are concentrated in the areas between Angereb and Keha River and at Azezo including historical buildings, churches and heritage. Various castles in Gondar buildings, churches, monuments and ordinary dwelling houses were built within the mid-17^{th}- mid 19^{th} c centuries by Emperor Fasiledes and his followers, respectively, following the establishment of Gondar as a permanent capital. These relics are known as "Gondar Style" architecture owing to their impressive architectural novelty and some scholars have been driven to call the city an African Camelot (Gondar city administration office, 2011).

Potential expansion areas of Gondar are found in the east, west and south (Gondar city administration office, 2011). Recent residential areas have been developed in expansion areas of the town where land is available following the detail plans prepared by the municipality Gondar faces shortage of access roads that connect the residential areas eastern and western parts of the town that are dissected by the rivers. This situation is one of the main reasons for the creation of isolated residential settlements. Area and percentage share of existing land use shows the total area of the town within the 10 years period planning boundary i.e. 2015-25 is 18363.41 ha. Out of this 7263.62 ha (40%) is built-up (Gondar city administration office, 2011).

3.1.8. Existing water supply condition in Gondar town

Gondar town is currently getting water once in three days for just a few hours, which is inadequate for everyday activities of the household and residents are forced to get water from unprotected sources which are far from their homes (Shameless, 2013). Besides, they also buy water frequently from illegal persons and incur additional cost.

3.1.9. Existing sanitation system of Gondar town

Currently liquid waste is managed through pit latrines and sucked by vacuum trucks of the city and dumped in drying beds which are located near to the landfill site (Gondar City Water Supply and Sanitation Service, 2012). Gondar University has its own drying bed located in Maraki sub-city near to the engineering campus. Liquid waste from households, institutions and businesses is collected using septic tanks. The existing sanitation system in Gondar City is very poor status. Most of the excreta disposal facilities comprise traditional pit latrines that are poorly constructed, the household's uses open field liquid waste disposal which is a high health risk.

3.1.10. Waste disposal

According to (Gondar city administration office, 2011), long term feasibility study for Gondar city water supply and sanitation final report Annex1, most of the communities disposing of their waste water in open areas around their houses. Not all households brought their solid waste to the common collection point but disposed of it everywhere. The report mentioned as overall sanitary situation in the town bad or very bad in the areas because of the unsanitary disposal of solid waste, waste from slaughtered animals and waste water in the streets, smells from drains when solid and liquid waste were thrown led there and the lack of toilets with people urinating in the streets and / or using the areas around public toilets or construction sites to relieve themselves. 93% of households having access to a toilet, while the remaining households used the bush or open areas(Gondar City Water Supply and Sanitation Service, 2012). The solid waste disposal this site is also located close to potential expansion area of the town along a new asphalt road. Not only is this, there a large expansion area to the east of this site towards Angereb River. Therefore this issue needs serious consideration in the new structure plan.

Health condition of the community diarrhea is in many cases caused by poor sanitation and hygiene and poor / inadequate water supply while helminthiasis is often related to open defecation and / or use of poor latrines (Gondar City Water Supply and Sanitation Service, 2012). The incidence of diarrhea as registered by the health centers, is quite high in children below 5 years, i.e. nearly 66 cases per 1,000 children in this age group. The same situation applies to the officially registered cases of helminthiasis in children below 5 years and in persons of 5 years and above(Gondar City Water Supply and Sanitation Service, 2012).

Figure7. Waste damping along Keha River in Gondar town

Figure 8. Algae produced at downstream of Keha River due to nitrate and phosphate

3.2. Selection of the study area

Keha River was selected for the study because it is high receiver of wastes from various industries, households, commercial markets, institutions and agriculture. Anthropogenic activities take place in the river watershed, the prevailing serious problem in the town and the problem is aggravating from time to time. In addition, Keha River was selected for the study because there is limited information on the pollution which have an effect on water quality. The river supplies the communities for different purpose which contributes to the economy of the country. The river consists of different land uses that are indicated to progressively impact negatively on the quality of water. There is a need for an understanding of the effects of urbanization on surface water quality so as to enhance/strengthen monitoring water resource of the study area.

3.2.1. Description of Keha River

Keha River originates in the Simen Mountains at the northern part of Gondar town around Gondaroch Mariam. It flows through the center of Gondar town between Pisa and Gondar hospital runs to south direction then join to Megech River finally to Lake Tana. The length of Keha River from the source to the downstream end is 13.263 km and the catchment area of 32.965 km^2 from watershed delineation area shown (Figure 10).

Different anthropogenic activities are taking place along Keha River that negatively affect the water quality mainly affect the rivers making it polluted and hence unsuitable for normal uses. These activities had their wastes ending up in Keha River directly or through runoff during the rainy season. Different industries, institutions, hotels, hospital, commercial markets, groceries, constructions and others were discharged the waste to Keha River. But some people used the Keha River water for washing clothes, for bathing, for irrigation, some of the people also such as daily laborers, street children and the like used this Keha River for drinking purpose.

3.3. Research methodology

3.3.1. Desk study

This aspect of the study gathered as much as possible all relevant data on the research topic, published and unpublished reports were used. The study was started with literature review on impacts of urbanization on surface water quality and the effects of change in land use through time on the river water quality. All the necessary data required for the study were obtained from both primary and secondary sources. The major sources of secondary data were from government and non-government publications, annual and inventory reports, previous studies and books. Focus group discussion and key informant interview which were made with various stakeholders, community representatives, Gondar water supply and sanitation service office, City Administration and other concerned and affected bodies. In addition, personal observation, onsite measurement and laboratory analysis were also the other data sources which reinforced the required data from the study area and served as a check for data reliability.

3.3.2. Field observation and socio-economic survey

On-site observations formed an integral part of this research as it allowed the researcher to experience firsthand the various processes and activities that influence the water quality, health status and ecology of the Keha River. Rapid urbanization along the middle reaches of the Keha River has led to an increase in waste and storm water. In order to identify the anthropogenic sources (pollution sources) in the city, a socioeconomic survey was conducted. Written and oral interviews were both used to obtain data on anthropogenic activities. In some cases, mere site observation of the activities or of disposed wastes was used to obtain the information.

Location and referencing of sampling points, establishment of contacts with opinion leaders, brief interview with members of purposively selected households of the study area. Written and oral interviews were both used to obtain data on anthropogenic activities. During site observation of the activities of disposed wastes directly into Keha River was observed to obtain the information.

A questionnaire was used to get data on the types of wastes different institutions were producing in the study area (Appendix IV). The data collected could elucidate the types of wastes that were produced by each institution and whether the wastes ended up in Keha River or not. This questionnaire was not administered at random but rather targeted those institutions that were observed to be contributing to the pollution of the Keha River. The identification was done by inspecting the vicinity of the institution of whether there were open waste dumping or whether there was an emerging stream of effluents from the institution or company. There were quite a number of movements around the city within the Keha River catchment area, in order to capture real polluting institutions.

Figure9. Data was collected by site observation and interview

3.3.3. Interview and survey results within Gondar City communities

Written and oral interviews were both used to obtain data from the responsibility of Gondar city Communities on Keha River pollution concerns. The interview data was collected in Gondar city purposely selected 350 people in 10 Kebeles including collage condominium, Hospital area, municipality office, environmental protection and green development office, Water supply and sanitation office, water and irrigation office from December 13, 2017 to January 7, 2018. The information would be used by Amsalu Alemu for the MSc. thesis in Addis Ababa University, Addis Ababa institute of Technology). Based on the selected communities' response, an average of 33.7% disposing in the drainage system that some hotels and communities connect the septic tank to drainage systems, 31.8% disposing around Keha River, 25.2% disposing of their waste water in open areas around their houses and 13.5% in disposing pit. For further details, see the Table below.

Table1: Interview results of waste water disposal in 10 Kebeles

No	Name of Kebele	No of people	Drainage system	Disposal pit	Open area	In to Keha river	Other
1	Arada	35	37.1%	5.7%	14.7%	40.1%	2.8%
2	Arbegnoch	25	48%	12%	28%	8%	4%
3	Fasiledes	30	40%	6.7	16.7%	33.3%	3.3%
4	Maraki	35	31.5%	11.4%	17.1%	40%	-
5	Gabriel	25	32%	20%	36%	12%	-
6	Cherikos	30	46.7%	10%	13.3%	26.7%	3.3%
7	Lideta	25	32%	12%	20%	36%	-
7.1	Condominium	35	2.9%	14.3%	34.2%	48.6%	-
7.2	Hospital area	30	-	26.7%	30%	43.3%	-
8	Auto parko	35	25.8%	5.7%	20%	45.7%	2.8%
9	Adebabay Eysus	20	35%	25%	40%	-	-
10	Abejele	25	40%	12%	32%	16%	-
Total/average		350	33.7%	13.5%	25.2%	31.8%	3.2%

3.4. Sampling location and sampling time

Field surveys were carried out within the study area to identify sampling sites and attributes. These purposely selected sites shown the spatial variation from upstream to downstream and the tributaries were very critical causes that affect Keha River water. The sampling points were located by using a Garmin GPS 60 and are shown in table2.

3.4.1. Sampling location

The sampling points were selected based on the rate of human interference, field surveys, based on communities' interview response, and experience were carried out to identify the critical locations of sampling sites and attributes of Keha river pollution. Fourteen purposive sampling site of Keha River and its tributaries were selected to represent the water quality variations. The sampling was done at fourteen sampling points and the sampling location were the same for dry season and wet season (Table2). Nine sampling points were along the river, while the other five (5) sampling points were streams and drainage outlets that directly joins with Keha River in Gondar city.

The first point (keha1) was at the upstream portion of Keha River outside the city in rural area. At this point, the river is not exposed to the city's anthropogenic activities. This point was chosen to represent some sort of original conditions, where natural conditions slightly apply as compared to conditions within the city.

The second point (keha2) was above Gondar teaching hospital near the first bridge along the river in Gondar City. The third point (keha3) was below Gondar teaching hospital along the river in Gondar City. From point 2 up to point 7 all points were chosen to capture the different effects of the activities in the city. Keha5 was the middle stream of Keha River and keha7 was downstream of Keha River.

Bisnit stream One of the five streams that originates at Genet Mountain at Buluko (kebele 01), collects all types of wastes, Moha soft drink wastes, Pisa sub city wastes, Fasiledes preparatory school wastes, auto parko sub city residential and industrial wastes carry and directly enter to Keha River. Hospital drainage originates from Gondar university referral hospital that collects different wastes and directly enters in to Keha River. Kedame Gebeya sample point the wastes come from this huge commercial market activities and directly enter in to Keha River. Demetro and Fechfachit drainages originate from Fasiledes kebele that carry this kebele residential wastes, industrial wastes and commercial wastes then directly enters in to Keha River.

The last point keha9 was the outlet of Keha River to join with Angereb River. The coordinates of the locations of the sampling points were taken using a GPS. A total of 14 water samples, (9 from rivers and 5 from different streams that are join to Keha River) during dry and wet season were collected. The sample sites are indicated in Figure 10 below. Also see Table1for absolute locations and the elevations of these sites.

3.4.2. Sampling time

The sampling were done in both dry season and wet season. Temporal variation of the physical, chemical and biological quality of water body can be described by studying the relative concentration and biodegradation rate of the water. For dry season March was selected based on the minimum flow of the river and for wet season August was selected due to peak flow of the river. The temporal span of the field investigations was meant to cover both dry season (for consecutive four days from 09/03/18 to12/03/2018) and wet season (for consecutive four days from 7/08/18 to 10/08/18) due to time and financial limitation.

Table2: Description of Keha River sampling points

Points		**GPS Coordinates**	
No	Sample Location points and description	**Easting**	**Northing**
1	Keha-1 At the Upstream of keha river outside the city in rural area	0331945	1396637
2	Keha-2 near the bridge	0332174	1395512
3	Keha-3 (After keha & hospital drain joins)	0332428	1394808
4	Stream fechifachit outlet	0332433	1394860
5	Stream Hospital outlet	0332245	1394920
6	Stream Demetro outlet	0332543	1394628
7	Stream Bisnit outlet	0332531	1394386
8	Keha-4(Before Bisnit joins)	0332499	1394430
9	Keha-5(Middle stream of keha river	0332418	1394261
10	Kedame Gebeya	0332620	1392331
11	Keha-6 (Before keha & Maraki stream joins)	0332670	1392357
12	Keha-7 (After keha & Maraki stream joins)	0332684	1392287
13	Keha-8 (Before keha River& Angereb join)	0333215	1391534
14	Keha-9 (keha River outlet or end)	0333266	1391357

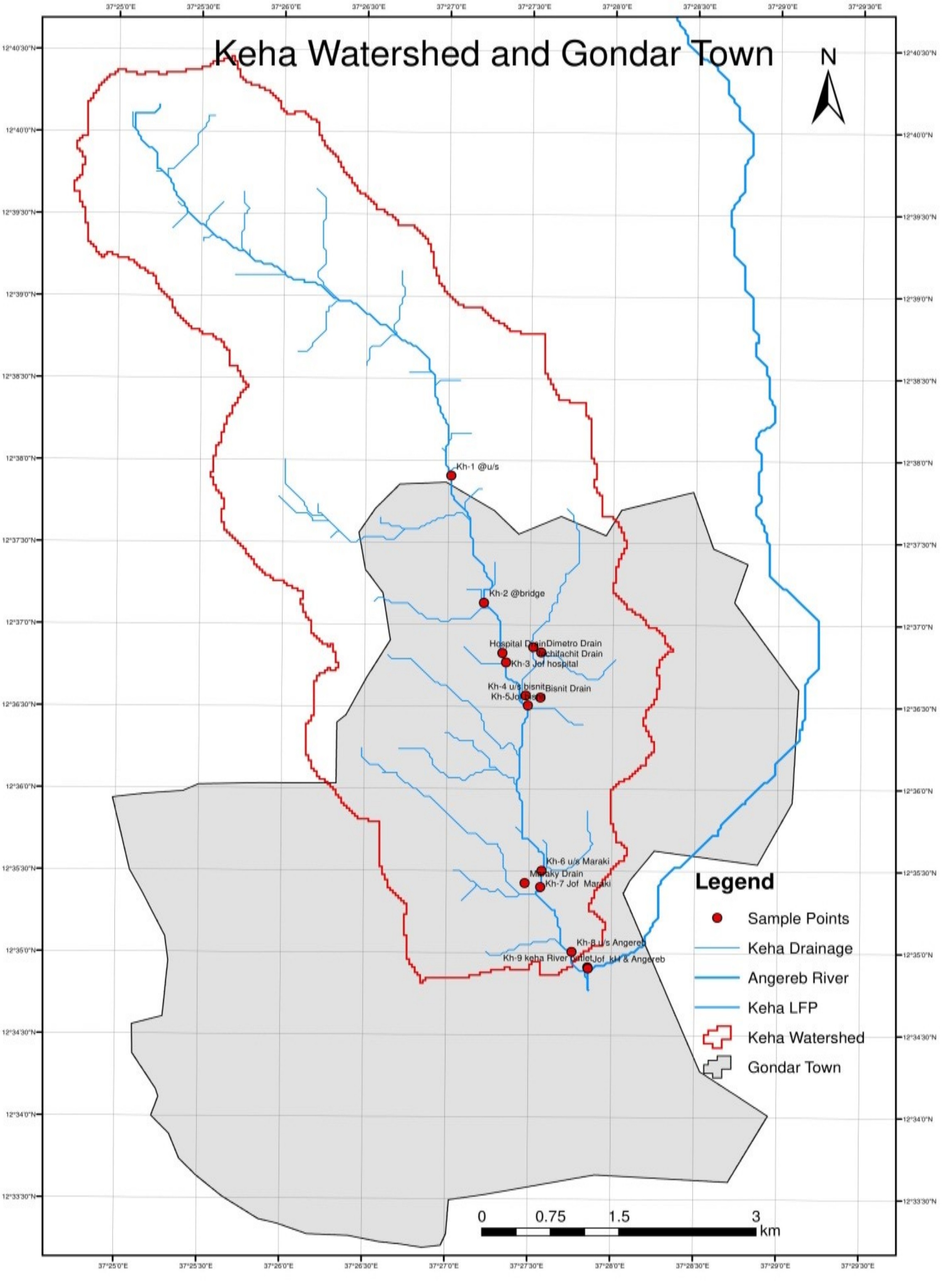


Figure 10 .Sampling points in Keha River

Figure 11. Upstream of Keha River sampling out of the town

Figure 12. Field surveying using GPS and measuring of samples along Keha River

3.4.3. Selection of parameters

The following physical, chemical and biological parameters were measured from the fourteen sampling sites namely: pH, Electrical Conductivity, Turbidity, Temperature, Total Dissolved Solids, Dissolved Oxygen , BOD, Nitrates, Phosphates, Hardness, Total Alkalinity, Iron, Manganese, Chromium, Bacteriological parameters like total coliform and E-Coli. Characteristics of these parameters give either a direct or an indirect indication of the type and occurrence of pollution in water and the parameters provide an overall view of the health of a river (Amah-Jerry *et al.*, 2017). In water quality, Total Coliform is a sign for the presence of pathogens in the water (Environmental Protection Agency, 2001). E.coli bacteria serves as an excellent sign for faecal pollution in water and failing septic tanks, leaking sewer pipes, broken wastewater treatment plants, open defecation and storm water runoff are possible E.coli sources in river water (Olorode *et al.,* 2015).

Temperature is a critical water quality parameter, since it directly influences the amount of dissolved Oxygen with solubility increasing with decreasing temperature, PH and heavy metal ions. PH measurement indicates the acidity or alkalinity of the water. TDS is an indicator of non-point source pollution problems associated with various land use practices though point sources also contribute(Chapman, 1996). Domestic wastewater contains high levels of nitrogen which can be converted to nitrate in water resources, thereby causing eutrophication (Mishra *et al.*, 2009). Dissolved Oxygen (DO) is vital because it supports the lives of aquatic organisms (Ding *et al.*, 2015). BOD reduces the amount of DO available for aquatic organisms and the levels of BOD in receiving waters is directly increased by the discharge of waste that is high in organic matter (Kgabi N., 2015).

3.5. Data collection methods

3.5.1. Sampling

The samples were placed in 500 ml polyethylene sterilized bottles and transferred to the laboratory at 4 °C (ice box) for chemical analyses. According to standards methods for water and wastewater (APHA, 2005) 500 ml polypropylene bottles for physicochemical parameter and 500 ml pre-treated glass bottles are recommended for biological sampling, therefore these were used in the study. The collected samples were kept in a cool box with ice cubes/ice packs during transportation and were cooled at 4 ^{o}C. The samples were taken four consecutive different days in the morning during optimum temperature time in the study area. The water was collected at the beginning of the second week almost at the middle of dry season and wet season at different depths using a sampler specifically designed for depth integrated samples. Water samples from each of the fourteen sampling points was collected by direct immersion of bottles in the water. Sterilized sample containers were used and rinsed with samples before sampling. Then, samples from the sites were taken by pouring into the sample containers without any hand contact.

3.5.2. Water quality testing

Water quality was tested on site (Keha River) and in university of Gondar water quality laboratory and environmental health laboratory. Physico-chemical parameters like Conductivity (E.C), Total Dissolved Solids (TDS), Temperature and pH were measured in-situ using Multi-parameter water quality checker (Seba Hydrometerie multi parameter water quality checker). Turbidity was also measured using Turbidity meter on site. The water quality parameters were examined by means of the standard methods prescribed (APHA, 2005). Parameters such as 5 day biological oxygen demand, Total coliforms, E.coli*,* alkalinity, Iron, Chromium, Manganese, dissolved oxygen, hardness, nitrates and phosphate, were analyzed in the Laboratory.

3.5.3. Quality assurance

Quality Assurance and Quality Control plans were incorporated both in the field and laboratory. Before sampling, all sampling bottles were pre-labeled and sterilized a day before sampling in order to reduce contamination of the samples. The multimeter was tested, recalibrated and prepared prior to sampling. Onsite water quality measurements were done immediately after collecting water sample as also recommended (APHA, 2005). Samples were put away in a cooler containing ice cubes and packs to minimize the influence of temperature on the water quality parameters during transportation. Laboratory analysis begun on the same day of sampling for accurate measurements of the water quality parameters.

Figure 13. Onsite measurements at Keha River, Bisnit and Hospital outlet respectively

3.5.4. Analysis of physico-chemical parameters

To assess surface water quality the collected sample had been tested in university of Gondar water quality laboratory and environmental health laboratory. Parameter like Electrical Conductivity (EC), Turbidity, pH, Temperature, Total Dissolved Solids(TDS), Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Nitrates, Phosphates, Hardness, Total Alkalinity, Iron (Fe), Manganese (Mn), Chromium, Bacteriological parameters like total coliform and E-Coli which are expected in industrial effluents released to the rivers catchments analyzed following the standard methods. Physico-chemical parameters like Conductivity (E.C), Total Dissolved Solids (TDS), Temperature and pH were measured in-situ using Multi-parameter water quality checker (Seba Hydrometerie multi parameter water quality checker). Turbidity was also measured using Turbidity meter on site.

For Nitrate the Hach DR 2000 Spectrophotometer was used. Again the user manual for the spectrophotometer was used and specific codes and instructions were followed. For nitrates, the reagent used was NitrVer 5 reagent powder. The analysis was carried out by following procedures. 25 ml graduated mixing cylinder was filled with 15ml of sample and the contents of one NitraVer 5 Reagent Powder Pillow was added to the cylinder. The sample and reagent were mixed and reacted for 3 minutes by shaking of the cylinder. Then, after 2 minutes was elapsed 10 ml of the sample was poured in to a clean square sample cell and the contents of one NitraVer Nitrate Reagent Powder pillow to the sample cell to check whether nitrates was present or not by observing its colour (pink colour formation if nitrate was present in the sample). Then, the blank (the pure sample) was inserted in the cell holder with the fill line facing right used for calibration to be zero. Finally, the prepared sample was inserted in to the cell holder with the fill line facing right and the value of nitrate contents were obtained in mg/l by Hach DR 2000 Spectrophotometer. For Phosphate test was conducted by Ascorbic acid method was employed to analyze phosphate parameter and measured using Hach DR 2000 Spectrophotometer. The following procedures were taken to determine Phosphate levels.25ml sample was taken by graduated cylinder. Following to samples taking, phosphate reagent was added to it and it was shaken for 2min to mix sample with the reagent. Then, the blank (the pure sample) was used for calibration to be zero. Finally, the value of Phosphate was obtained and recorded in mg/l by using photometer.

Total coliforms and feacal coliforms were analyzed using membrane filtration method which made use of 100 ml of sample water, filter media, membrane filters, vacuum pump and oven for incubation within 48 hours at 37^{o}C. Due to the nature of the river water and high coliform count, the sample water was diluted (10 ml sample and 90 ml distilled water).

At the water quality laboratory DO, BOD and E.coli were analyzed using standard methods. Dissolved oxygen is recommended to be measured in situ. However, after failing to get a multi meter with a dissolved oxygen probe, the dissolved oxygen was analyzed at the laboratory. Immediately after sample collection, the polythene bottle containing sample was closed and kept inside a cooler box with ice cubes. Laboratory analysis begun 3 to 4 hours after sample collection on the same day. According to APHA, for preservation of dissolved oxygen, if analysis is not possible to be done immediately after sample collection, the sample should be kept below 10 ^{o}C to arrest any biological activity in the water that may deplete the dissolved oxygen and analysis should be carried out within 6 hrs.

3.6. Data analysis and interpretation

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

Chapter Four: Result and discussion

This chapter presents the results of the findings in the field and the discussions on these findings in accordance to the specific objectives. The physical, chemical and biological laboratory results are shown in the tables of appendix I for dry season and appendix II for wet season.

4.1. Physico-chemical and biological results of Keha River

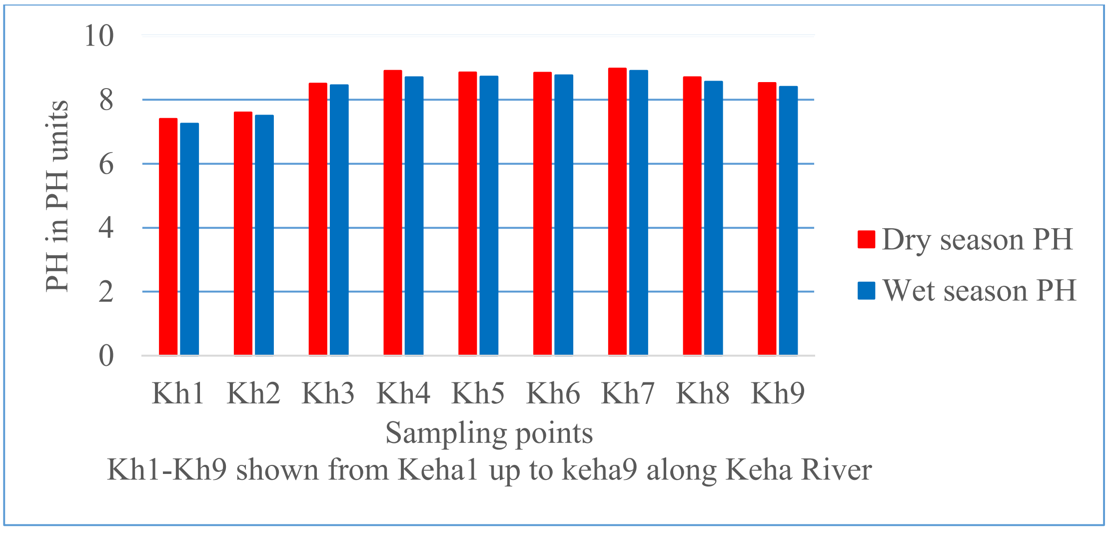
Keha River before entering the Gondar area of the town relatively has a clean and clear water with no odour at upstream sampling station. Whereas at downstream station, Keha River water seems to be dirty, having grey-black colour with offensive odour. Some people used the Keha River water for washing clothes, for bathing, for irrigation, some of the people also such as daily laborers, street children and the like used this Keha River for drinking purpose. Water for drinking should have no visible colour thus the water was not acceptable to residents for domestic consumption (WHO, 2008). The physico-chemical and biological parameter quality analyzed findings were compared with WHO and maximum permissible level prescribed by Ethiopian standards for drinking water(ES, 2001). There is distinct change observed in most of water quality parameters, as river flows upstream to downstream station in Gondar town.

4.1.1 PH

The spatial values varied between 7.4 and 8.97 (figure14). The spatial trend showed slightly increasing pH values as one moves from upstream to downstream of Keha River (Keha1 to keha7 and Hospital outlet). This trend was due to the industrial effluents discharged through tributaries such as Hospital, Bisnit, Fechfachit, Demetro and Kedame Gebeya which increased the concentration of chemicals in water, thus raising the PH. It can be observed that the Hospital outlet and dawn stream of Keha River at keha4, keha5, keha6, keha7 the values recorded the most alkaline wastes pH values ranging from 8.9, 8.85, 8.84, 8.97 and hospital outlet the value of 8.97 above the Ethiopian drinking water Guide line and WHO Guide line of 6.5-8.5.The PH values at Kedame Gebeya and Bisnit stream the values of 5.9 due to Moha soft drink factory effluent release through Bisnit and different wastes discharged to the river from Kedame Gebeya Market.

The temporal values varied between 7.25 and 8.97. The highest value was in dry season when the flows were lowest. The lowest value was in wet season due to the dilution effect of the floods. The temporal trend showed a general decrease of pH values during wet season and this was due to dilution effect. Most of the temporal values were also above the recommended limits of WHO and Ethiopian drinking water Guide line for drinking water. PH is a measure of the degree of acidity and alkalinity of water. This is influenced by the concentration of the hydrogen ion. On the pH scale of 0-14, a pH of 7 indicates neutral condition and values above and below this denote alkalinity and acidity respectively. Water with a pH of 7 is neutral; lower pH levels indicate increasing acidity, while pH levels higher than 7 indicate increasingly alkaline solutions. It is important to consider the effects of pH on other potential toxicants.

The PH of most the samples of Keha River in both dry and wet season was above the standard limits that indicates alkaline and Bisnit, Kedame Gebeya, Fechfachit and Demetro varied from 5.9 to 6.4 indicate acidity that was below the WHO and Ethiopian water quality standard. The decrease in pH value at the Bisnit site might be due to use of acids in industries as sterilizer of bottles and for other purposes, in MOHA soft drink factory and others.



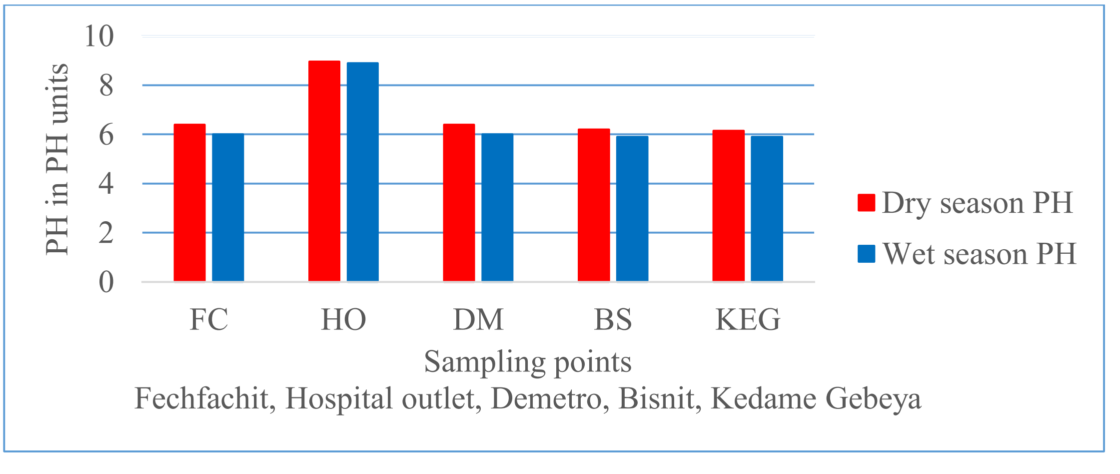


Figure14. PH values of Keha River and tributaries at sample points

4.1.2. Turbidity

The results showed very high levels of turbidity at all the sampling points and at all times. The spatial variation of the values showed a trend of increasing values downstream, that is less values at keha1upstream of the river and higher values as we go downstream due to the high contribution of Hospital outlet, Bisnit outlet, Kedame Gebeya, downstream of keha river and middle stream of keha river respectively (Figure 15). Kh8 and kh9 turbidity values slightly decreased because these sites located the end of the town the outlet of the river at rural area. The lowest value was 8 NTU at keha1 chosen to represent upstream conditions. The values at Kedame Gebeya Market, Gondar hospital outlet and Bisnit outlet were higher than the values at upstream of keha river sampling point keha1. This was due to effluents from the industrial activities that surround these places. Industries that contributed to the increased value at these place was the Moha soft drink industry wastes from hospital ponds, open markets, restaurants, hotels and domestic wastes among others that discharged the effluent in to Bisnit stream and Keha River. There were a lot of different activities that cause erosion and increased turbidity.

The temporal variation, during wet season the turbidity values higher than dry season. The values increased because the river was in flood, which caused a lot of runoff that meant a lot of siltation, erosion and debris were carried along from the catchment area of the river under study. All the loose materials carried by the runoff ended up in Keha River, hence an increase in the values of turbidity. The Ethiopian and WHO standard limit of turbidity in water for domestic use is < 5 NTU but all values were above the Ethiopian and WHO standard limit.

This research finding turbidity values were at upstream 13 NTU, at middle stream 732 NTU, at downstream 845 NTU, at Hospital outlet 1072 NTU, at Bisnit outlet 1023 NTU and Kedame Gebeya outlet 987 NTU. These values were higher central Gondar Zone laboratory result that was done in 2003 the turbidity values were of at upstream 5.5 NTU, at middle stream 22 NTU, at downstream 34 NTU, at Hospital outlet 57, at Bisnit outlet 65 NTU and at Kedame Gebeya 364 NTU. The results from all the sampling points were much higher than the recommended value. However some people used this water for domestic use and it meant that their health was at risk.

Turbidity is a measure of the clarity of a water body and it is commonly recorded in nephelometric turbidity units (NTUs).Turbidity in water is caused by suspended and colloidal matter such as clay, silt, finely divided organic matter and other microscopic organisms. It is also due to Sediment which comes largely from shoreline erosion. High turbidity results in reduced light transmission into the water, thus depriving aquatic organisms of light. Suspended sediments can damage the gills of some fish, causing them to suffocate, thus limiting their ability to find food (Environmental Protection Agency, 2001).The turbidity sample result values of Keha River exceed the acceptable range of both WHO and Ethiopian standards for wet season. This high turbidity value is due to erosion, domestic waste and industrial effluents discharge into the river.

The temporal variation of the wet season result is higher than dry season for sampling point this is because the river was in flood, which caused a lot of runoff that meant a lot of siltation and debris were carried along from the catchment area of the river under study. High turbidity can have an effect on the health of river organisms such as the clogging of fish gills. Figure illustrates the variation of turbidity with distance from the source.

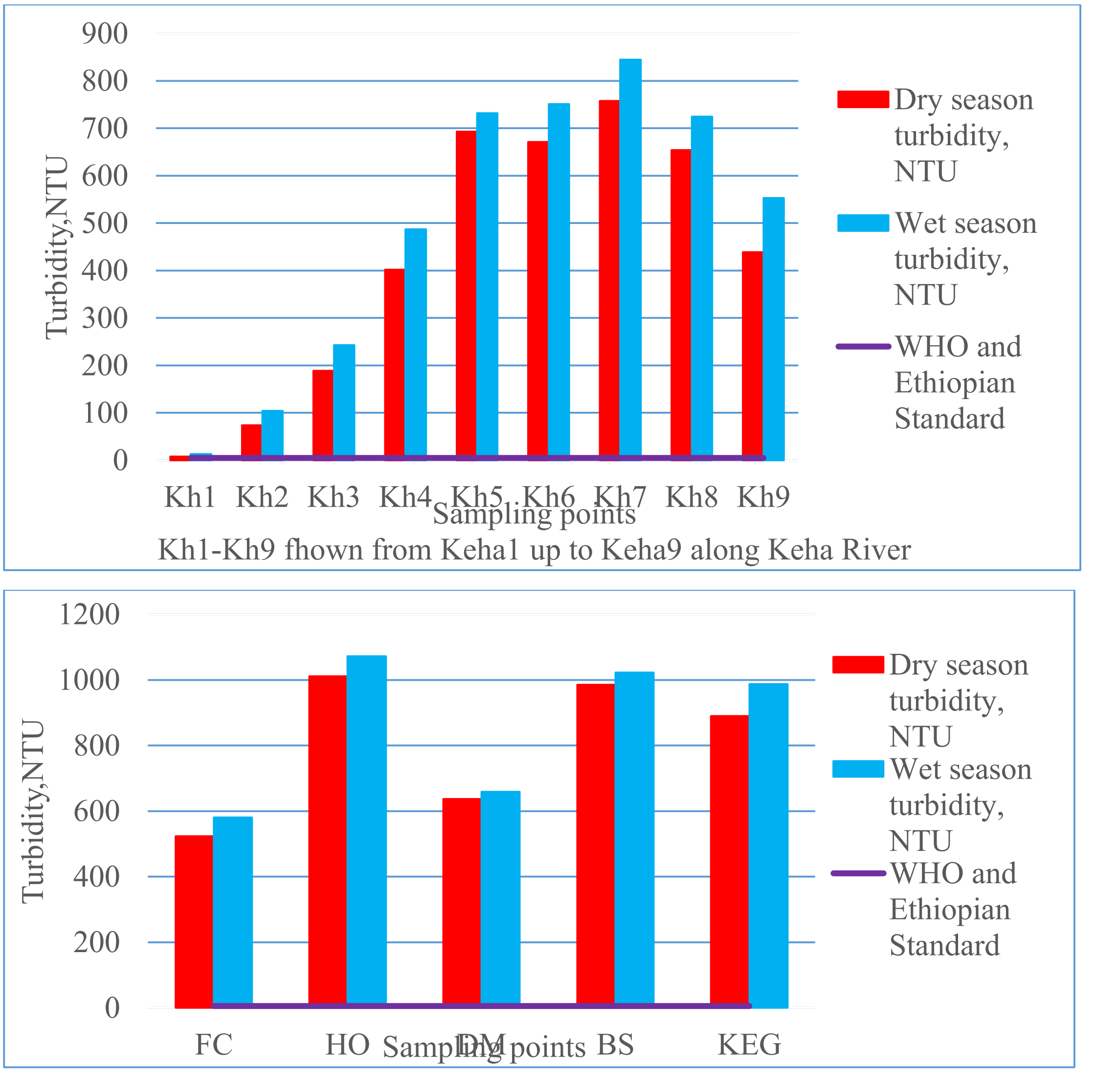


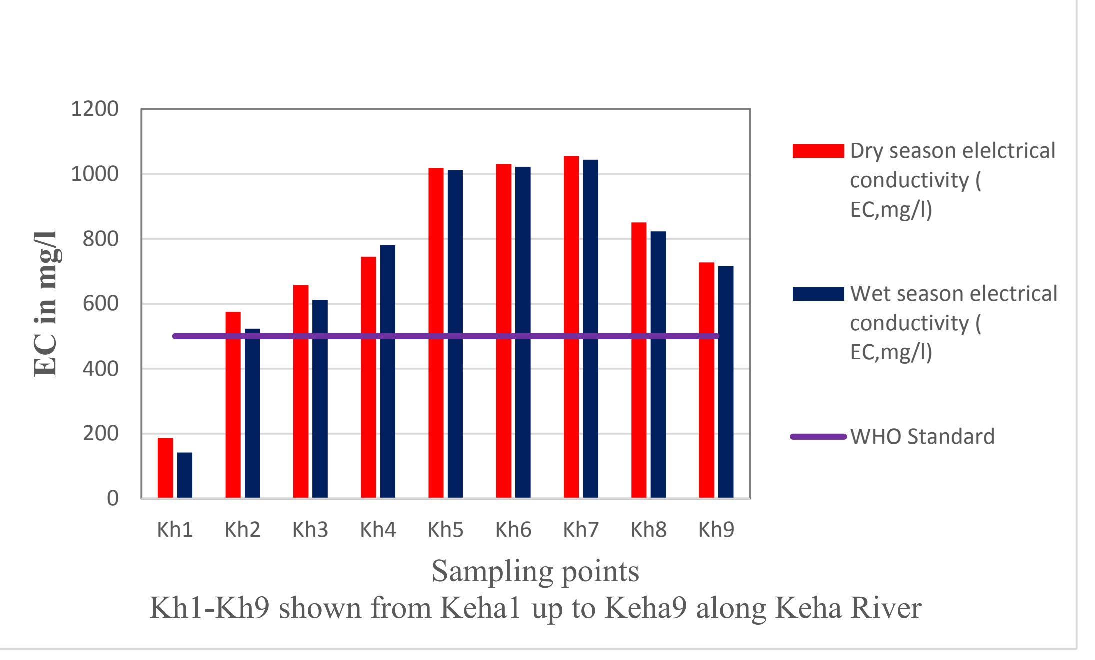
Figure15. Turbidity values of Keha River different sample points

4.1.3. Electrical conductivity

The spatial variation results showed the minimum value of 142 µS/cm at keha1 upstream of the river and the maximum values of 1231 µS/cm at Hospital outlet, 1197 µS/cm at Bisnit outlet, 1190 µS/cm at Kedame Gebeya, 1175 µS/cm at downstream of keha river and 1152 µS/cm at middle stream of keha river. The highest value of at middle stream and downstream due to the release of effluents coming from hospital outlet, Kedame Gebeya outlet and at Bisnit was caused the high concentration of chemical constituents from the industries and institutions around this area. Such industries included the hospital laboratories, workshop garbage and domestic effluents amongst others. The minimum value at keha1 was as a result of non-industrial activities which could contribute to chemical pollution of the water.

The temporal concentration of electrical conductivity in dry season high Electrical Conductivity was recorded the sapling points HO, Bisnit outlet, Kedame Gebeya outlet (MO), Keha-5and Keha7. The seasonal variation along the river sampling point the dry season showed relatively higher concentration peaks which could be due to the small flow during dry season and the higher evaporation rate. The higher values within the sampling point have resulted from different domestic wastes, untreated sewerage and mostly untreated industrial effluent from industries. The minimum value at keha1 was as a result of non-industrial activities which could contribute to chemical pollution of the water.

Electrical conductivity is essential as it can be used as an indicator of total dissolved organics, bases, acids and salts in water. Low values are characteristic of high-quality, low-nutrient waters and High values of conductance can be indicative of salinity problems. Very high values are indicators of possible polluted sites. The recommended EC level for surface water is less than micro Siemens per centimeter1000 µS/cm (Environmental Protection Agency, 2001). The WHO standers for electric conductivity for drinking water is 500 µS/cm. Ethiopian Environmental Protection Authority, (2003) the stream waters guideline set an Electric conductivity in a range of 100- 1000µS/cm.



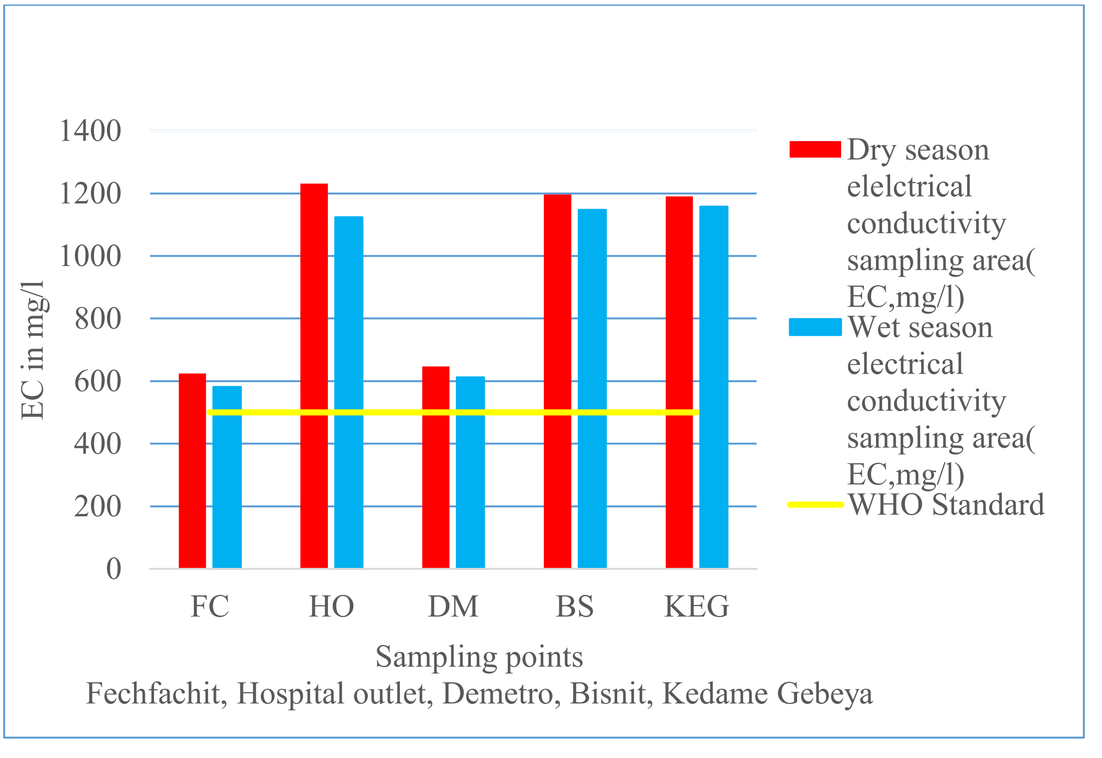
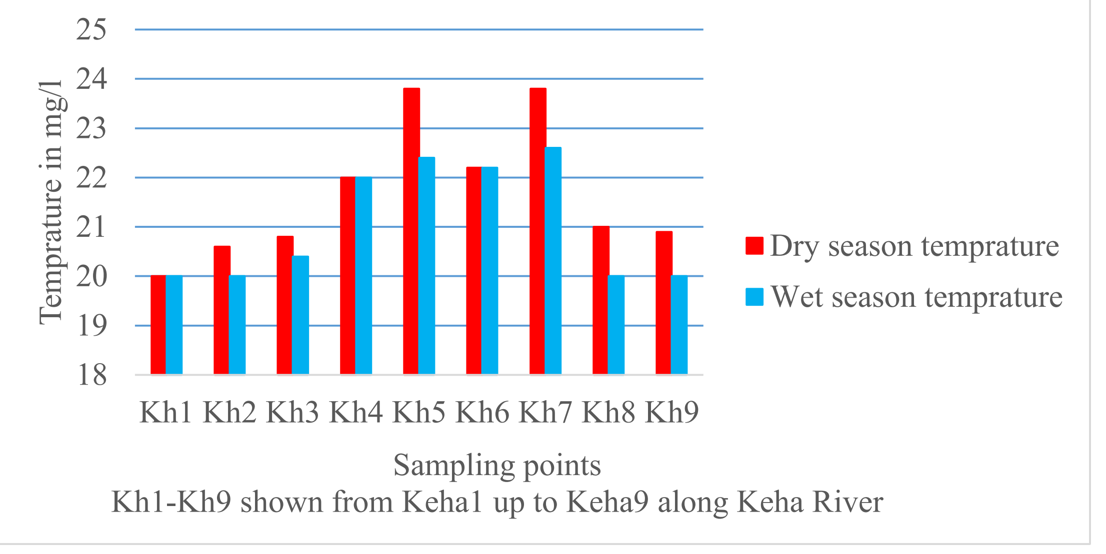


Figure16. Electric conductivity of Keha River and tributaries different sample points

4.1.4. Temperature

Temperature ranged from 20°C to 24.8°C during dry season and 20°C to 23.9°C during wet season respectively. The spatial trend shows that temperature increased as we go downstream due to discharging effluents of hospital, Bisnit and Kedame Gebeya. The temporal variation of temperature also showed the increasing trend during dry season.



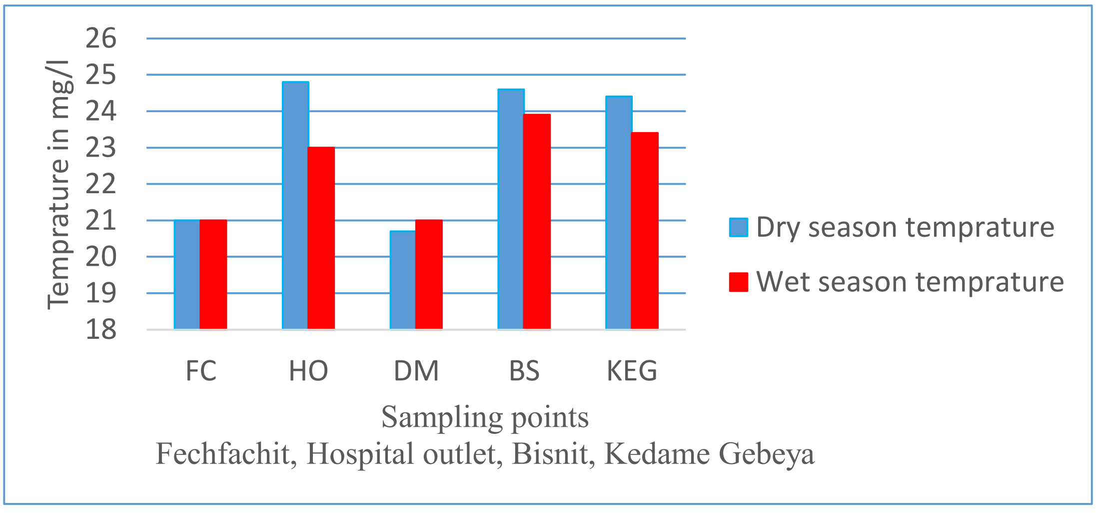


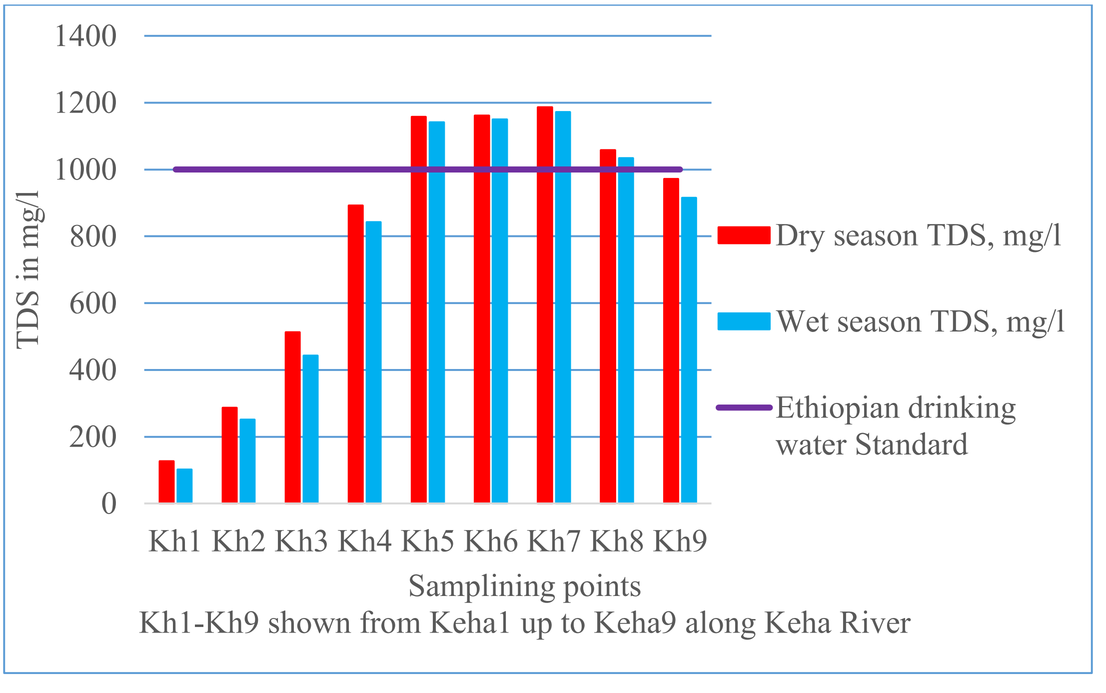
Figure 17. Temperature values of Keha River and tributaries different sample points

4.1.5. Total dissolved solids

The spatial and temporal variations of TDS are presented in Figure18. The spatial results showed the highest value of 1298 mg/l at hospital outlet, 1296 mg/l at Kedame Gebeya 1287 mg/l at Bisnit outlet, 1187 mg/l at downstream of keha river and 1158 mg/l at middle stream of keha river, the lowest value of 102 mg/l at upstream of keha river(figure18). The values were generally increasing downstream due to the effluents of Hospital, Bisnit, Kedame Gebeya, Fechfachit and Demetro. This trend was attributed to the fact that upstream of Keha River was less polluting activities to raise the concentration of the dissolved solids. While from the Kedame Gebeya market there were a lot of commercial activities which resulted in a lot of solid and liquid wastes being discharged into the river and increasing the amount of dissolved solids.

This trend of increasing TDS concentration is an indication of chemical pollution caused by the industries of different types in this part of the river. Temporal variation shows decreasing TDS values in wet season due to the dilution effect of the continued flooding of the river.

Total dissolved solids (TDS) are a measure of the amount of particulate solids that are in solution. This is an indicator of non-point source pollution problems associated with various land use practices though point sources also contribute. High EC and TDS values are good indicators of possible water pollution sites in water quality determination. The WHO and Ethiopian drinking water quality guide lines for TDS is1000 mg/l. The Keha River TDS results of in dry season ranges from 127 mg/l to 1298 mg/l and in wet season ranges from 102 mg/l to 1265 mg/l respectively. In the study area except upstream of Keha River and keha2 all sample points results were higher than the WHO and Ethiopian drinking water quality guide lines for TDS is1000 mg/l. The values were generally increasing downstream. This trend was attributed to the fact that at keha1, there were less polluting activities to raise the concentration of the dissolved solids. While from the Kedame Gebeya market there were a lot of commercial activities which resulted in a lot of solid and liquid wastes being discharged into the keha river and increasing the amount of dissolved solids. In this area there was lot of solid wastes. This trend of increasing TDS concentration is an indication pollution caused by the different wastes have been discharged into Keha River.



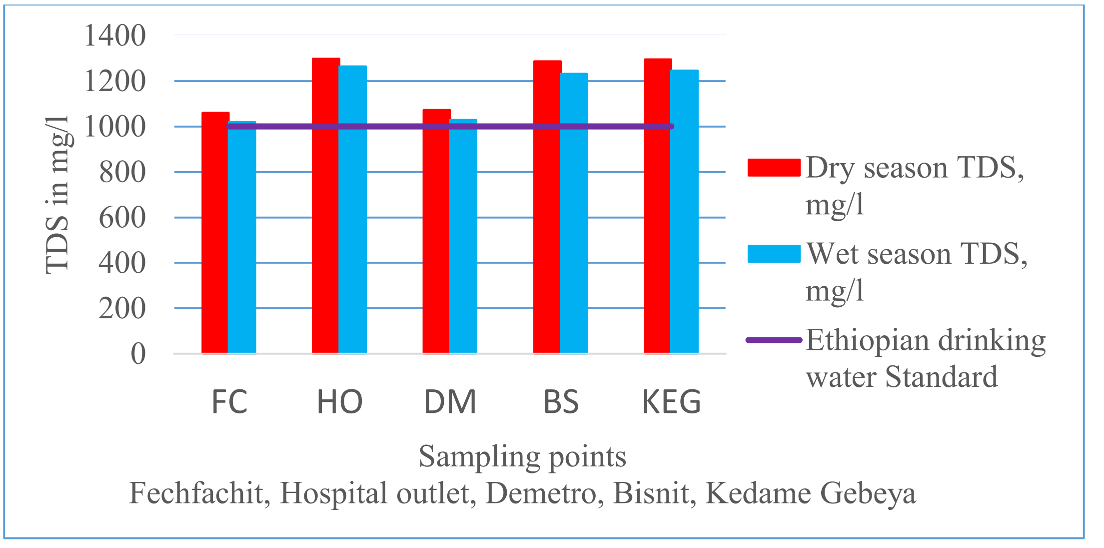
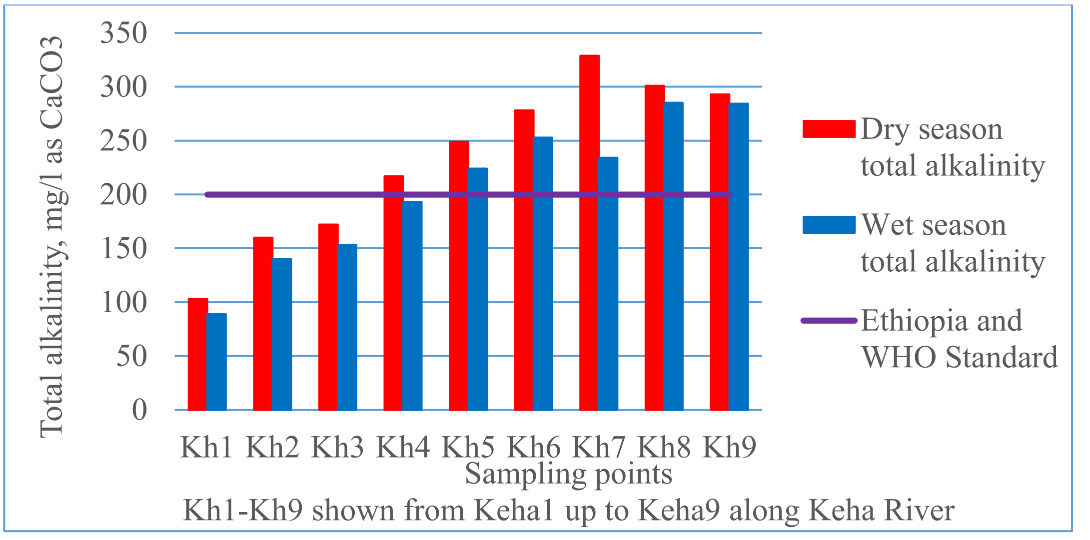


Figure18. Total dissolved solid values of Keha River and tributaries sample points

4.1.6. Total alkalinity

The spatial variations of total alkalinity raged between 103 mg/l as CaCO3 to 508 mg/l as CaCO3. The spatial results showed the highest value of 508 mg/l as CaCO3 at Kedame Gebeya, 471 mg/l as CaCO3 hospital outlet, 329 mg/l as CaCO3 at downstream, 249 mg/l as CaCO3 at middle stream, 301 mg/l as CaCO3 at(keha8), 293 mg/l as CaCO3 at (keha9), 278 mg/l as CaCO3 at (keha6), 254 mg/l as CaCO3 at fechifachit, 235 mg/l as CaCO3 at Demetro, 217 mg/l as CaCO3 at (keha4). All these values were higher than the WHO and Ethiopian drinking water standard limit Guide line of 200 mg/l as CaCO3. The minimum value was recorded 89 mg/l as CaCO3 at upstream of keha river. The values were generally increasing downstream.

Measuring alkalinity is important in determining a stream's ability to neutralize acidic pollution from rainfall or wastewater. The alkalinity of natural water is influenced by the soil and substratum through which it passes as it moves through the hydrological cycle. Total Alkalinity (TA) is the ability of water to neutralize acids added to the water and is expressed in mg/l(Environmental Protection Agency, 2001). TA is composed mainly of bicarbonate (HCO3), carbonate (CO3) and hydroxyl (OH-) ions and is expressed as mg/l of CaCO3.The WHO and Ethiopia Water quality standards, desirable limit of total alkalinity is 200mg/l as CaCO3. The total alkalinity of the study area was ranged from 103 as CaCO3 to 508 mg/l as CaCO3 in dry season and from 89 as CaCO3to 448mg/l as CaCO3in a wet season.



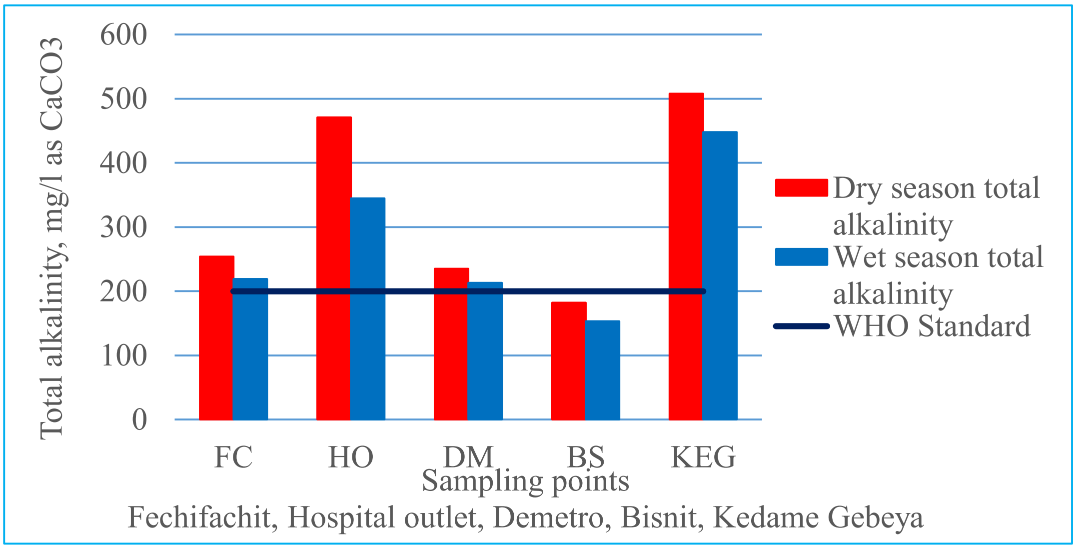
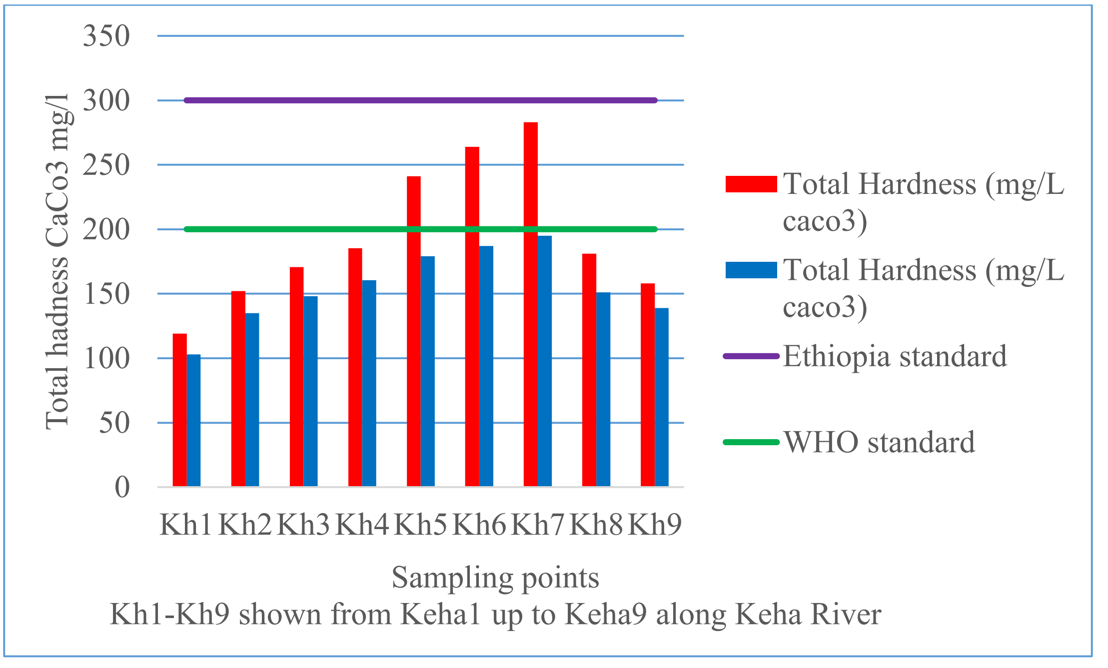


Figure19. Total Alkalinity values of various Keha River and tributaries sample stations

4.1.7. Hardness levels analysis

The spatial and temporal values of hardness along the river are shown in Figure20. The spatial variation showed high values at Bisnit outlet, at Hospital outlet, Kedame Gebeya, at middle stream of keha river and downstream of keha river while lowest values were at upstream of Keha River. This explains that at these places there were industrial activities taking place like Moha soft drink factory, different commercial activities at Kedame Gebeya Market, hospital effluents and hotel effluents hence the increased value of hardness. Whereas at upstream of keha river, there were no anthropogenic activities to raise the hardness. Spatially the values were increasing as one goes downstream. This was because the industries were middle stream and downstream of keha river. The temporal variation showed a general decrease of hardness values during wet season (Figure 20). This was due to the increasing rainfall and increasing flows which resulted in the dilution effects. The hardness values of Bisnit outlet, at Hospital outlet, Kedame Gebeya, keha6 at middle stream of Keha River and downstream were above WHO guidelines of 200 (mg/l caco3) but all the values of hardness were within the acceptable limits of the Ethiopian drinking water guideline the value of 300 (mg/l caco3).



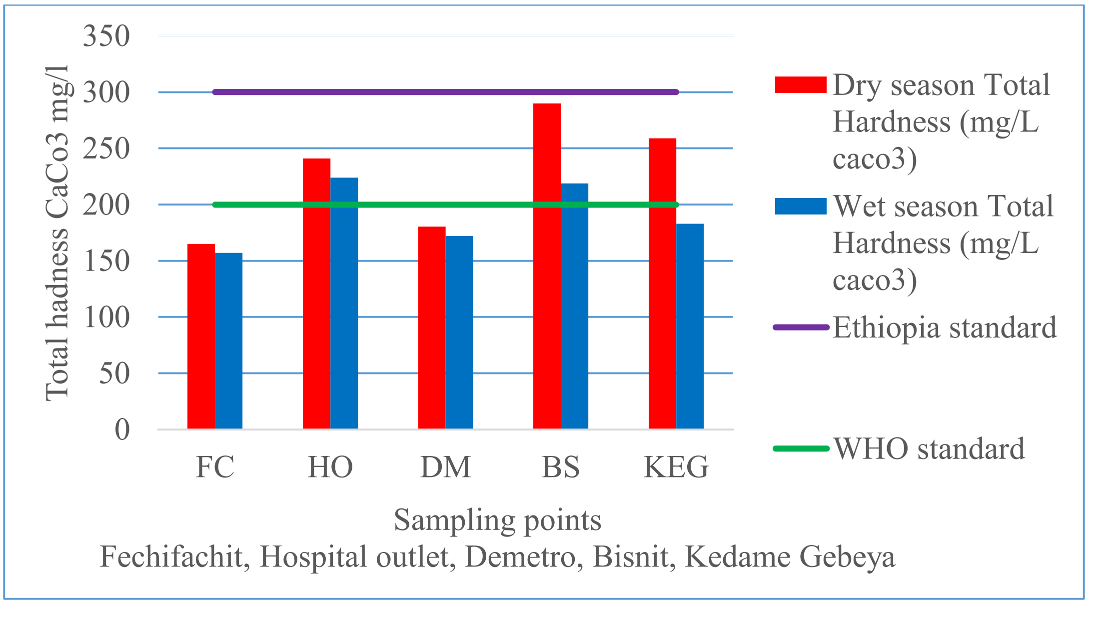


Figure20. Total Hardness values of Keha River and tributaries sample points

4.1.8. Nutrients

The main nutrients that will be discussed are phosphates and nitrates. Excess levels of nutrients in water can create conditions that make it difficult for aquatic insects or fish to survive. The process through which there is dissolved nutrients enrichment of a water body that encourages the growth of aquatic plant life usually resulting in the depletion of dissolved oxygen is termed eutrophication (Environmental Protection Agency, 2001). As the algae die and decompose, high levels of organic matter and the decomposing organisms deplete the water body of available oxygen, compromising the survival of other organisms, for instance fish.

4.1.9. Nitrate

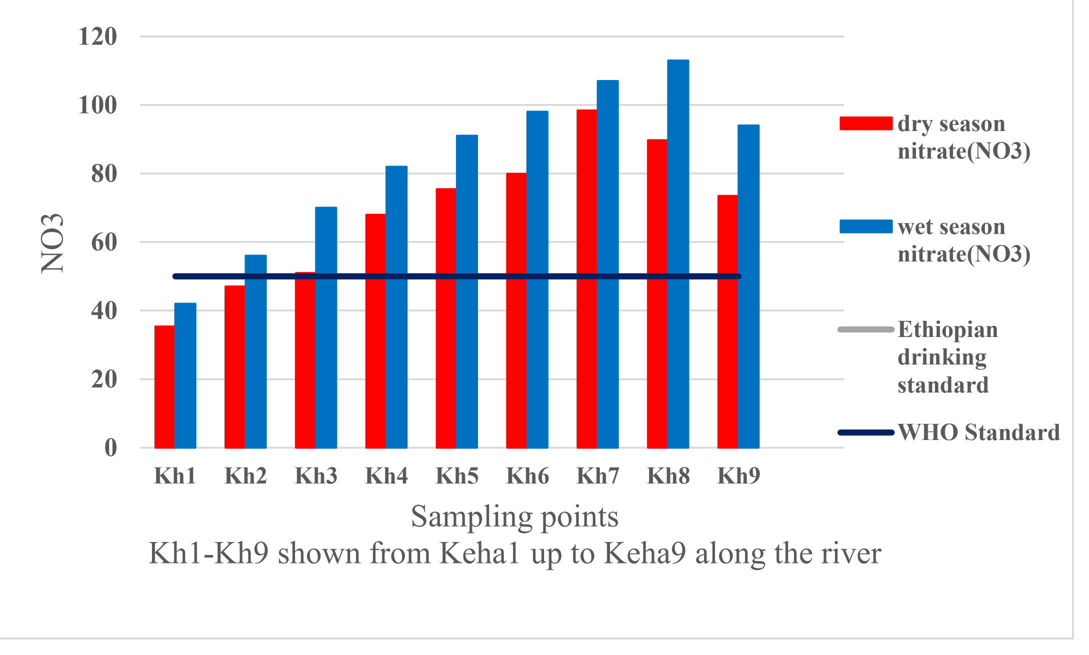
The spatial variations values of Nitrate showed the highest value 178 mg/l at Kedame Gebeya Market, 169 mg/l at Bisnit outlet, 153.5 mg/l at Hospital outlet. High nitrate values 113 mg/l at Downstream of Keha River and 81 mg/l at middle Stream due to the effluents from the surrounding industries, as well as the fertilizers from fields above this point and gardens of some residential compounds. It was also due to the garbage that was deposited around the river in this area which got decomposed or filtered depending upon the type of materials in the garbage.

The temporal variation figure21 shown the highest Nitrate values were in wet season due to flooding as it was raining continuously, increasing runoffs carrying with it mineral rich substances especially field fertilizers, domestic wastes and others ended up into the river and this increased the nitrate concentrations.

The presence of nitrates in river water is a sign of agricultural runoff, storm drains and poorly functioning septic systems, thus suggesting the need for immediate action to be taken before the situation worsens. The recommended nitrate level for surface water is less than 50 mg/l (Environmental Protection Agency, 2001).For the possible sources of increased nitrates concentration are the natural decay of dead plants and animals, industrial effluents and animal excreta. Nitrate together with phosphates stimulate plant growth. In aquatic systems elevated concentrations generally give rise to the accelerated growth of algae and the occurrence of algal blooms. Algal blooms may subsequently cause problems associated tastes in water and the possible occurrence of toxicity.

Spatially, the lowest value of 35.4 mg/l was at upstream of Keha River. There was no industrial activities at upstream of Keha River to raise the concentration of nitrates apart from the natural causes of geology, fertilizers carried by run offs from fields and domesticated animal excreta. It should be noted that upstream of keha river was in typical rural area where fertilizer application was also limited due to economic reasons.

Figure21 showed the temporal variation with the highest Nitrate value of 113 mg/l in wet season due to the fact that the river during this season was going through flooding as it was raining continuously, increasing runoffs carrying with it mineral rich substances especially field fertilizers, domestic wastes and others ended up into the river and this increased the nitrate concentrations. It should be noted that the highest value was at the Kedame Gebeya Market. Anthropogenic activities are also mainly concentrated around this area. Most of the nitrate values in the study area Keha River were above the Ethiopian and WHO acceptable limits of 50 mg/l. There were changing increasing manner downstream, it meant that the river was being polluted as one went downstream. Human ingestion of water with nitrate concentrations in excess of the MCL (10 mg/L) can lead to a fatal blood disorder in infants called methemoglobinemia or "blue-baby syndrome(WHO, 2008). The Ethiopian and WHO maximum limit of nitrate standard for drinking water is 50mg/l.



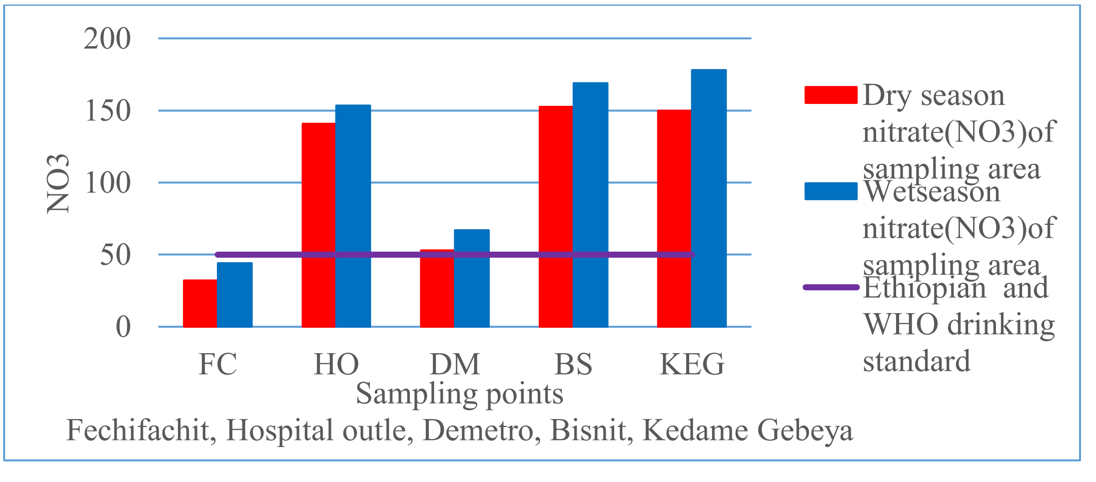


Figure21. Nitrate concentration of Keha River and tributaries sample stations

4.1.10. Phosphate

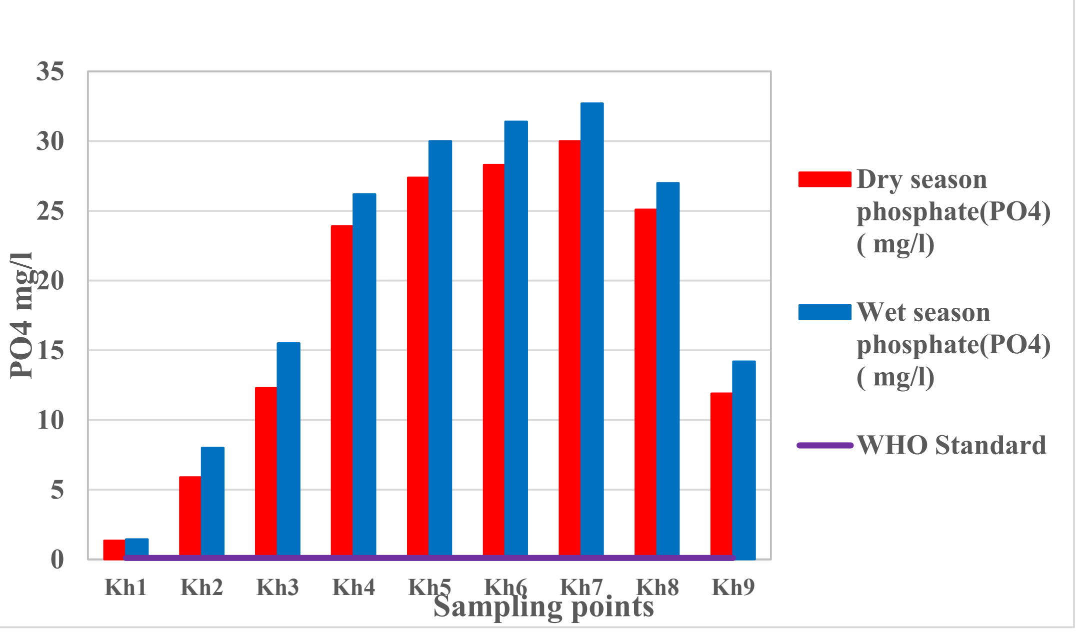
The spatial variation of phosphates showed the highest value of 32.7mg/l and this occurred at Kedame Gebeya Market, 31.4 mg/l at downstream of keha river, 30 mg/l at middle stream of Keha River, 28.9 mg/l at Bisnit outlet, 25 mg/l at Hospital outlet, (Figure 22).This was due to industrial effluents around this area.

The effluents from these industries mostly ended up into the river, increasing the phosphate concentrations. Additionally, there was open drainages and sewerage leakage point discarded directly to the river whose sewage ended up into the river, hence increasing the concentration of the phosphates.

The lowest value of 1.37 mg/l was from upstream of Keha River, as earlier indicated that there were no industrial activities. The spatial values were above the acceptable limits WHO guidelines of 0.1 mg/l.

The phosphates temporal variations (Figure 22) showed the highest values recorded during wet season. This was attributed to the fact that the river was going through flooding, increased runoffs carried with it mineral rich substances especially field fertilizers, domestic wastes and others which ended up into the river that increased the phosphate concentrations.

The concentration of phosphate both dry and wet seasons shows a high variation, both seasons result showed us a concentration above the maximum permissible of WHO limit. If too much phosphate is present, algae and water weeds grow wildly, choke the waterway, and use up large amounts of oxygen. This is called eutrophication and may cause the death of fish and aquatic organisms. The aesthetic values of the river will dwindle; hence, the need to control the amount of phosphates available to a water body. In general, the phosphate concentrations in the river made the water not suitable for domestic purposes. Measures are required to be taken to prevent further damage to the Keha River.



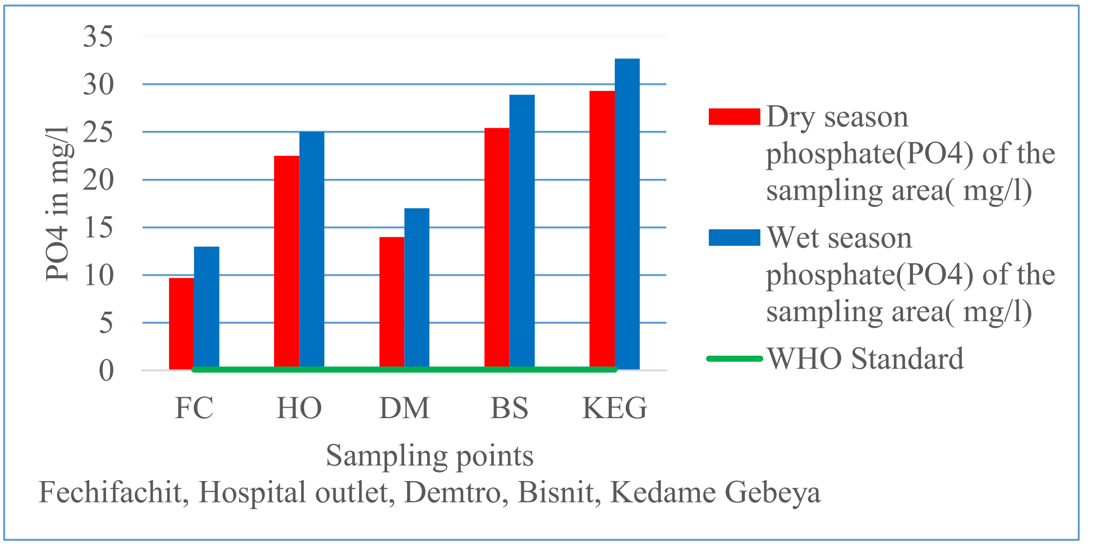
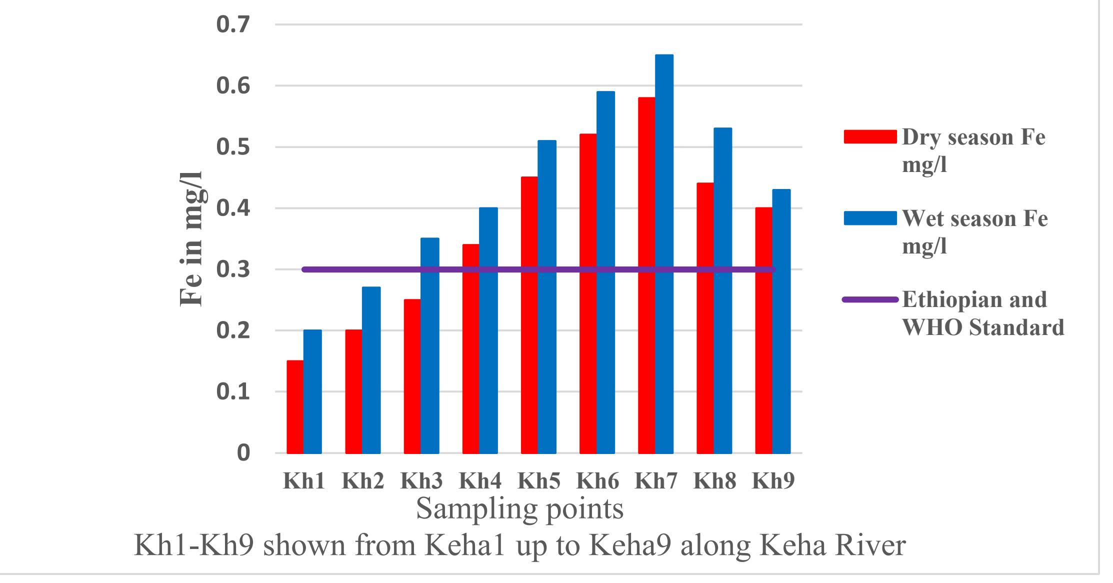


Figure22. Phosphate concentration values of Keha River and tributaries sample stations

4.1.11. Iron

The concentration of iron ranged from 0.15 mg/l to 0.65 mg/1 in the sampling water of dry season and 0.2 mg/l to 0.79 mg/l for wet season. The Ethiopian and WHO maximum limits for concentration of Iron is 0.3 mg/l. when we see the seasonal variation the wet season concentration was high for the some sample site, 0.79 mg/l at Bisnit outlet, 0.74 mg/l at Kedame Gebeya, 0.6 mg/l at Middle stream of keha river, 0.54 mg/l at upstream of keha river, 0.45 mg/l at Hospital outlet, 0.45 mg/l at keha6, 4 mg/l at keha4 and 0.32 mg/l at Demetro were higher the Ethiopian and WHO maximum limits. This variation is may be related to domestic waste, industrial waste and mostly the naturally occurrences of iron in the soil deposit. While other sample sites were within the Ethiopian and WHO maximum acceptable limits.



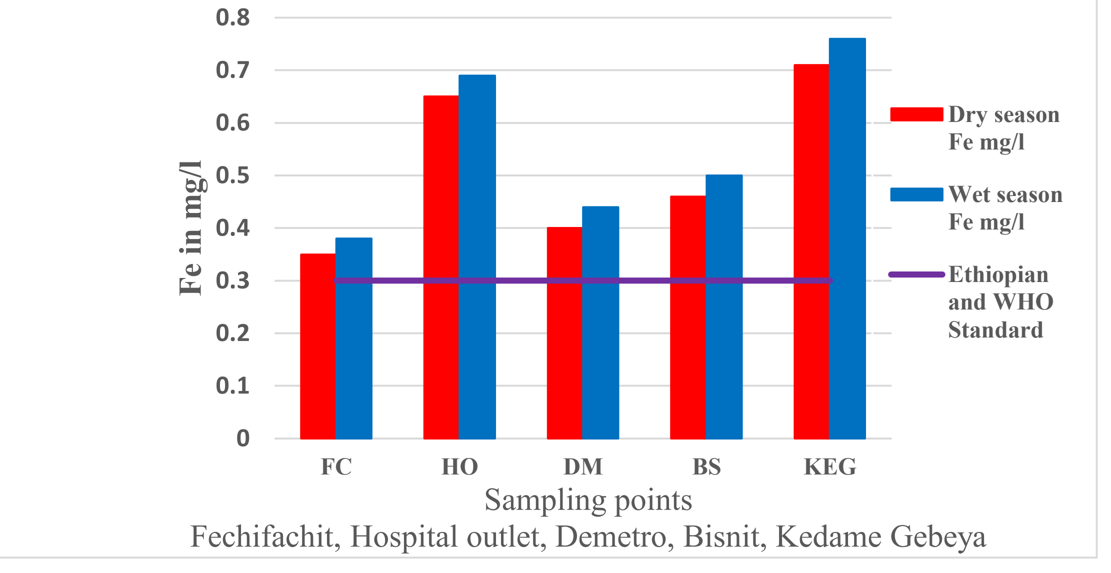
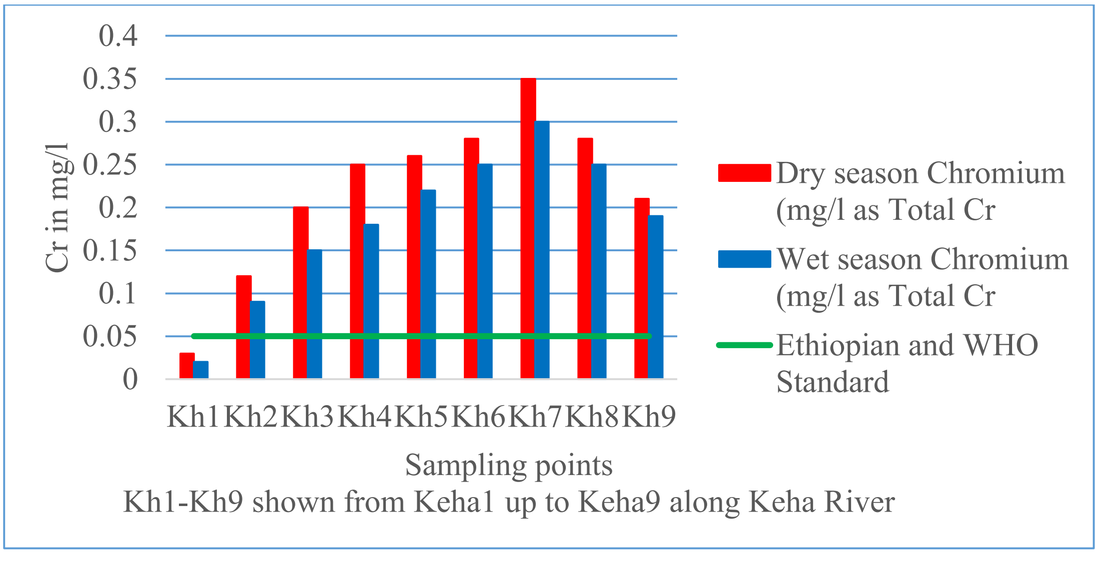


Figure 23. Iron (Fe) values of Keha River and tributaries sample points stations

4.1.12. Chromium

The concentration of Chromium values ranged from 0.03 mg/l to 0.42 mg/1 in the sampling water of dry season and 0.02 mg/l to 0.38 mg/l for wet season. The Chromium values 0.42 mg/1 at Kedame Gebeya, 0.39 mg/1 at Hospital outlet, 0.38 mg/1 at Bisnit outlet, 0.23 mg/1 at Fechifachit, 0.25 mg/1 at Demetrio,0.27 mg/1 at Middle stream of keha river, 0.3 mg/1 at downstream of keha river was above the standard limits during dry season.

The Chromium values in wet season at the sampling points of values 0.38 mg/1 at Kedame Gebeya, 0.36mg/1 at Hospital outlet, 0.37mg/1 at Bisnit outlet, at Fechifachit, ,0.22 mg/1 at Middle stream of keha river, 0.28 mg/1 at downstream of keha river was also above the standard limits during wet season. The other sampling points Chromium values were below the WHO standard limit. The pollution sources of chromium might be industrial effluent and natural occurrences of the chromium in the soil deposit. Chromium is potentially toxic to humans and animals at low concentrations. The national drinking water quality and WHO maximum allowable concentration in river water should not exceed 0.05mg/l.



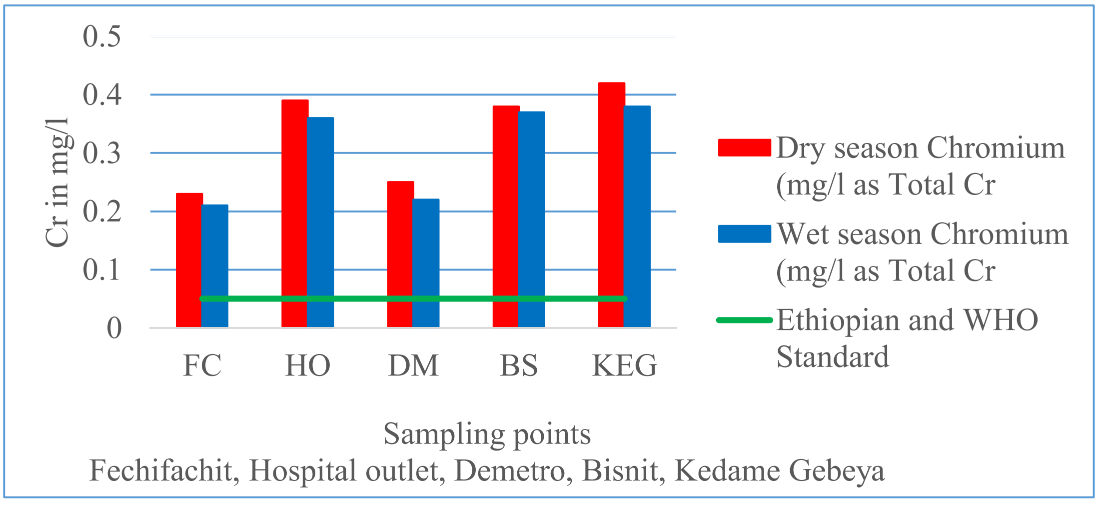
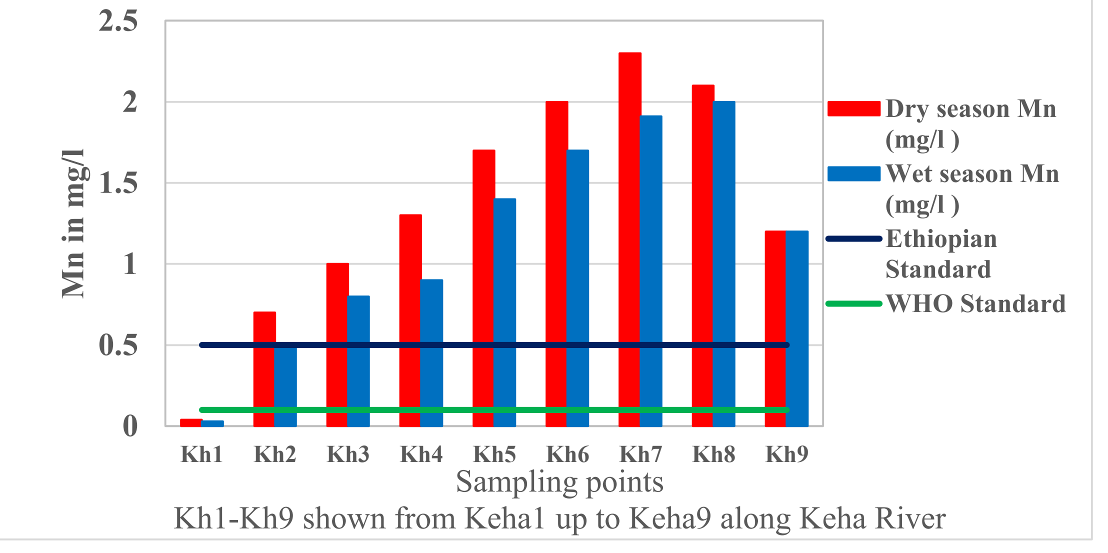


Figure24. Chromium concentration of Keha River and tributaries sample stations

4.1.13. Manganese

The concentration of Manganese values ranged from 0.02mg/l to 3.9mg/1 in the sampling water of dry season and 0.01 mg/l to 3.5 mg/l for wet season. Manganese values 3.9 mg/1 at Kedame Gebeya, 3.4 mg/1 at Hospital outlet, 3.6 mg/1 at Bisnit outlet, 2.2mg/1 at Demetrio, 2 mg/1 at Fechifachit, 0.02 mg/1 at up stream of Keha River,1.7 mg/1 at Middle stream of Keha River, 2.3mg/1 at downstream of Keha River were during dry season. Manganese values in wet season at the sampling points of values 3.5 mg/1 at Kedame Gebeya 2.8mg/1 mg/1 at Hospital outlet, 3.2mg/1 at Bisnit outlet, 2 mg/1 at Demetrio, 1.5 mg/1 at Fechifachit, 0.01 mg/1 at up stream of Keha River, 1.4 mg/1 at Middle stream of Keha River and 2 mg/1 at downstream of keha river were in wet season. All sampling points Manganese values were very low the national drinking water quality and WHO standard limit.



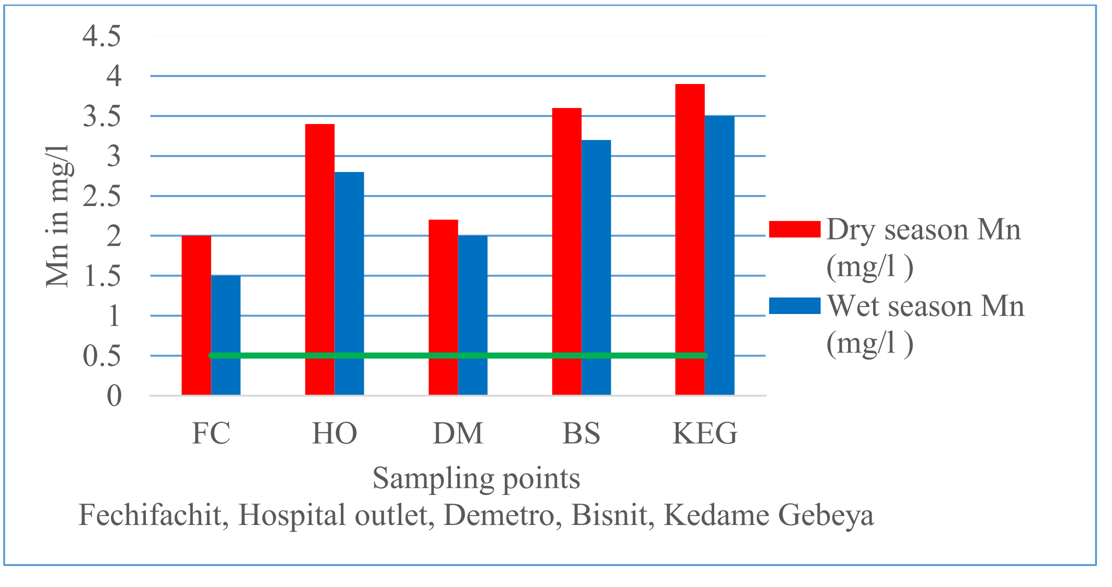


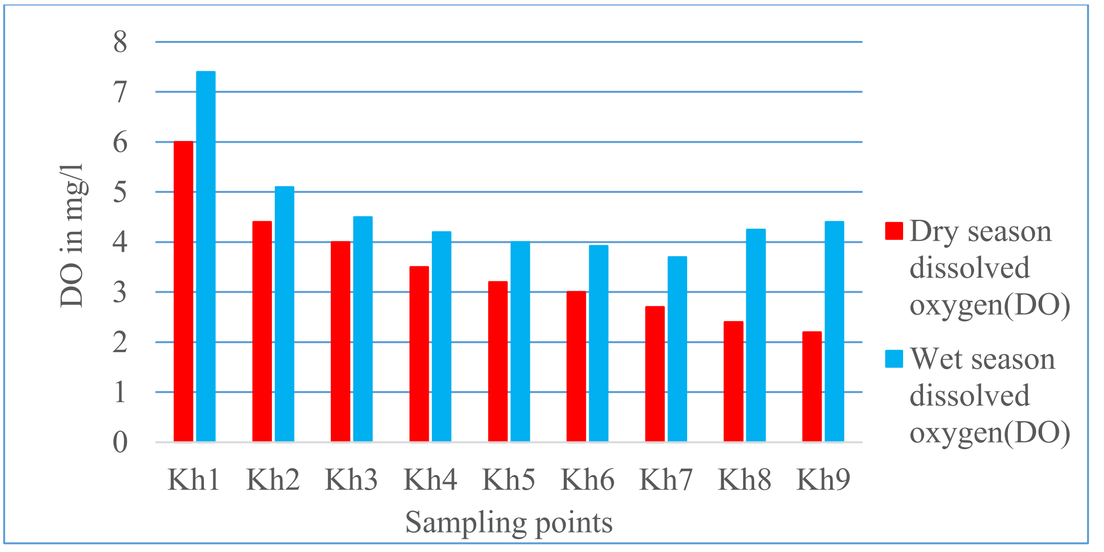
Figure25. Manganese concentration of Keha River and tributaries sample stations

4.1.14. Dissolved oxygen

The spatial distribution showed the highest value of 7.4 mg/l recorded at upstream of keha river and 5.1 mg/l at keha2 while the lowest values were 2.1 mg/l at Hospital outlet, 2.2 mg/l at downstream of Keha River, 2.4 mg/l middle stream of keha river, 2.8 mg/l at Bisnit outlet, 3 mg/l at Kedame Gebeya (Figure12). The high Dissolved oxygen value at upstream of Keha River was the absence of urbanization and anthropogenic activities

While the low values at Hospital outlet, at downstream of Keha River, at middle stream of Keha River, at Bisnit outlet and at Kedame Gebeya were due to commercial and domestic activities surrounding the area which generated a lot of liquid and solid wastes causing pollution which reduced the availability of dissolved oxygen.

The temporal variations showed the highest DO value of 7.4 mg/l in wet season this was due to high discharges caused by the heavy rains (Figure 26). The minimum values were in dry season. In fast moving waters, rushing water is aerated by bubbles as it tumbles over rocks and other barriers thereby falling down hundreds of tiny waterfalls that facilitate mixing with atmospheric oxygen (Cunningham *et al*., 2003). The concentration DO values across the studied area except upstream of keha river and kehat2, others DO values were below the WHO recommended limit of>5.0mg/l. The low Dissolved Oxygen (DO) content indicated the possibility of increased bacterial activity in the river water. The variations of DO within the river course were an indication that pollution was taking place. Dissolved oxygen is important in a water body because aquatic life both plants and animals depend on it for survival (Harrison, 1992).



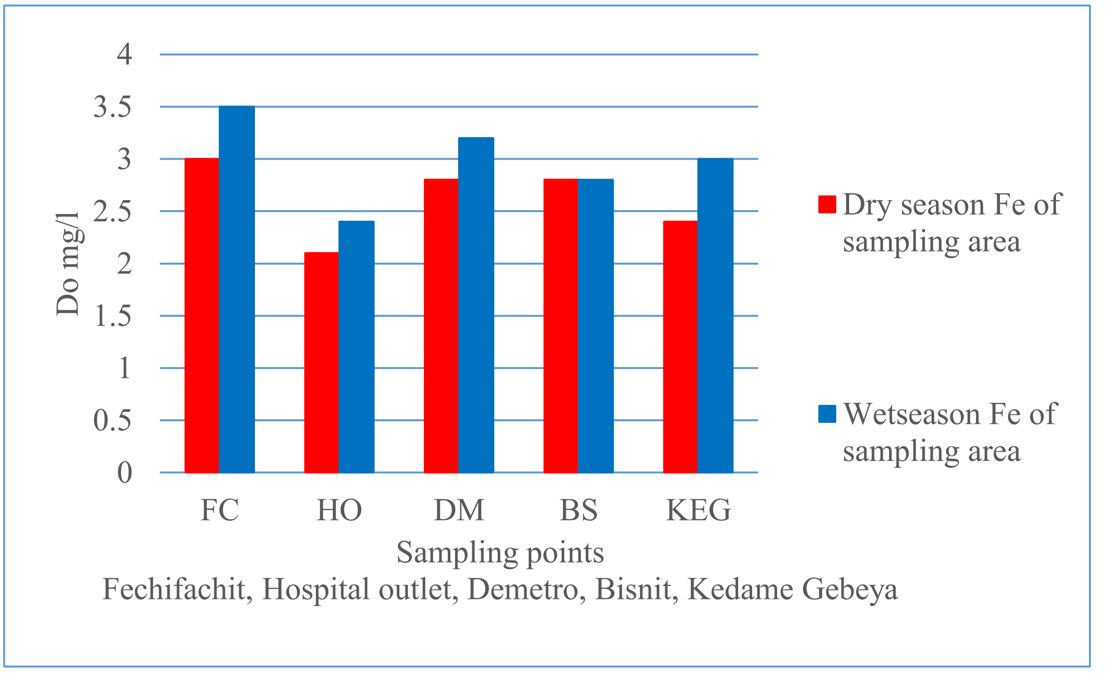
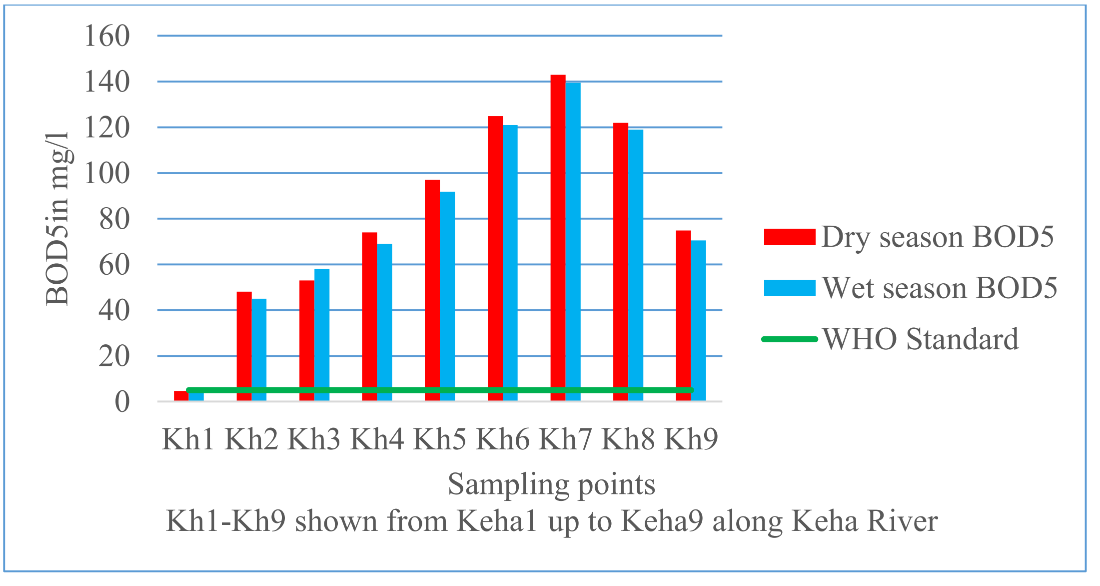


Figure 26. Dissolved Oxygen values Keha River and tributaries sample stations

4.1.15. Biochemical oxygen demand

The temporal and spatial values of BOD5 are shown in Figure. The spatial variation of the BOD_5 values showed the highest values of 201 mg/l at Hospital outlet 186 mg/l at Bisnit outlet, 194 mg/l at Kedame Gebeya, 143 mg/l at downstream of Keha River and 97 mg/l at middle stream of Keha River. This was due to the high concentration of faecal material being discharged at the Moha soft drink factory, at Gondar referral Hospital, Kedame Gebeya and different hotels. Since the major source of high BOD5 is untreated faecal material as more bacteria is required to biodegrade the faecal matter hence more oxygen required for the increased number of bacteria. The lowest value of 4.1 mg/l was at upstream of Keha River. Guideline Ambient Environment Standards for Ethiopia(2003), at (page4) describe as Guideline standards for priority surface water pollutants with regard to protection of aquatic species BOD5 (Biological Oxygen Demeaned) ≤5 mg/l. According to EEPA stream water quality standard the BOD of the stream should be less than 5mg/l. In the spatial distribution, except upstream of Keha River, all the BOD5 values were above the EEPA stream water quality standard the BOD of the stream should be less than 5mg/l. As explained earlier this was due to untreated or poorly treated sewage from the ponds and industries being discharged into the river. The temporal distribution showed highest values of 201 mg/l, 194 mg/l, 186 mg/l and 143 in dry season. This was due to low discharge levels and pollution was heavily caused by discharge of domestic and industrial wastes into the river at a time of low river flow.



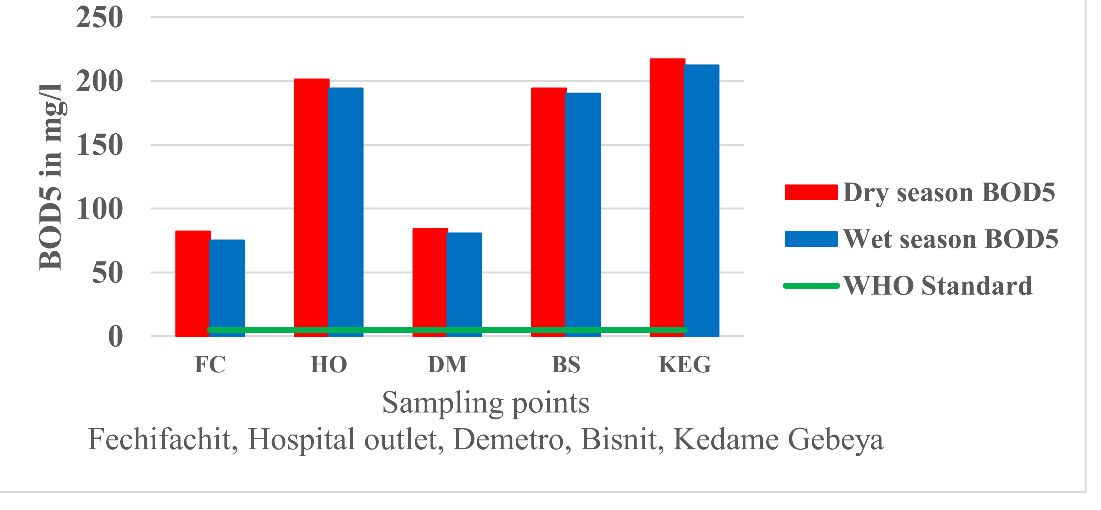


Figure 27. BOD5 of various Keha River and tributaries sample stations

4.1.16. Total coliform

The Total Coliforms (TC) concentration ranged from (3.2 counts/100 ml – 495 counts/100 ml) in dry season and (2.9 counts/100 ml -491.2counts/100 ml) in wet season of the research period in all the sampling sites along the river. The six critical and representative sapling sites were selected for total coliform due to the shortage of regents and the limitation of fund to buy the regents. Accordingly, the total coliform count for all samples were exceedingly high in comparison with that of EPA maximum contamination level (MCL) in drinking water of zero total coliform per 100 ml of water. All of the water samples were not complies with EPA standard for total coliform in water. Generally, the Total Coliforms (TC) concentration was high in all sites sampled with upstream having the least. Again, Kedame Gebeya had the most extreme TC concentration. Combined with open defecation, poor sanitation, livestock droppings, runoff from feedlots and agricultural plantations, these are the influences that might be accountable for the elevated total coliform levels. This could be attributed to faecal coliforms from livestock and other faecal material deposited by runoff into the river.

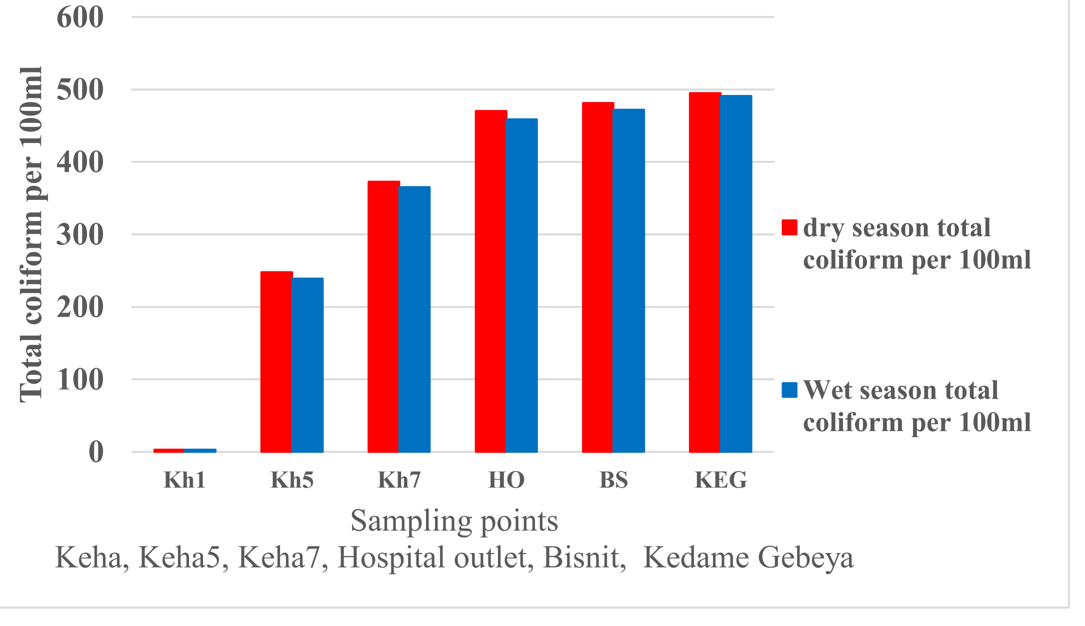


Figure28. Total coliform concentration of Keha River and tributaries sample stations

4.1.17. E.coli

The spatial variations showed a general trend of increasing values of E-coli from upstream to downstream (Figure29). The values at the upstream of Keha River, though less than the values of other sites, were still high above Ethiopian and WHO guidelines acceptable limits. This was due to contamination of run-offs with human faeces which is caused by lack of proper sanitation in the villages around. Also domestic animals contributed to this E-coli contamination of water since the villagers kept domestic animals like goats and cattle. The six critical and representative sapling sites also were selected for E-coli due to the shortage of regents and the limitation of fund to buy the regents.

There was a high increase in the E-coli values between upstream of Keha River (2 counts/100 ml) and the Kedame Gebeya Market (273.8counts/100 ml), hospital outlet (260.8counts/100 ml), Bisnit outlet (268 counts/100 ml), middle stream of keha river (176.5counts/100 ml), downstream of Keha River (197.5 counts/100 ml). The high values at the Kedame Gebeya Market were most likely due to open defecation and shallow temporally toilets at the market.

The E-coli temporal variation showed higher in dry season. With the high E-coli, it meant that the likelihood of occurrence of waterborne diseases like cholera was very high. At lower discharge the E.coli values are high as can be seen from Figure. This could be attributed to the dilution effect of the increase in river discharge diluting the E.coli counts per 100mℓ. The same was observed by Sinclair *et al.* (2009) that during low flows E-coli counts were higher than in high discharge.

Conversion of portions of watersheds from forest to urban cover often elevates sediment and nutrient concentrations by tens to hundreds of times in surface waters. Concentrations of fecal coliform and *E. coli* are frequently elevated in urban streams compared to natural streams (Jonathan E. Jones, *et al*., 2015).

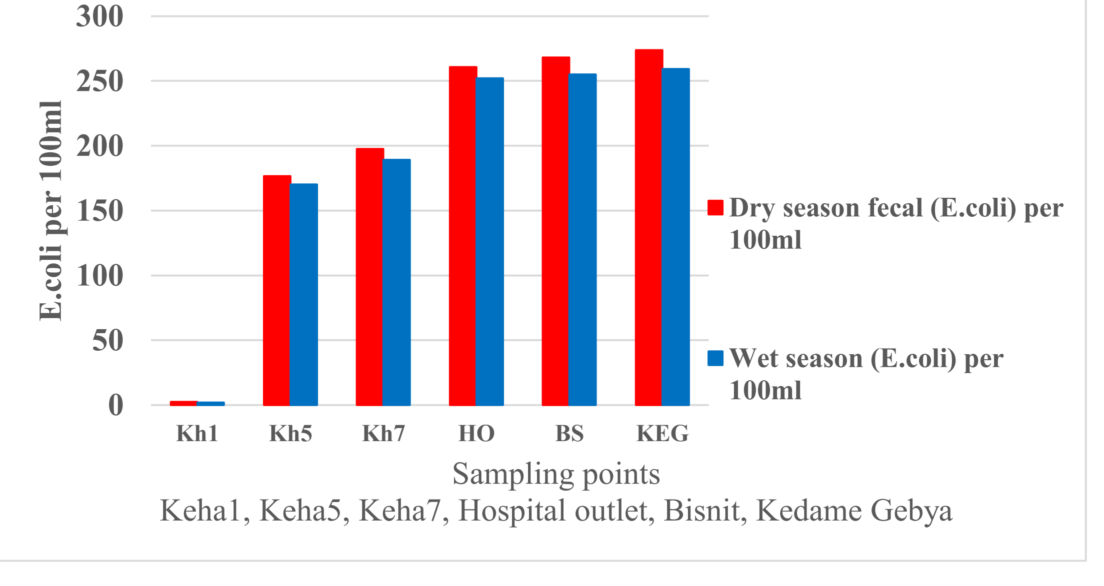


Figure29. E.coli concentration of Keha River and tributaries sample stations

i. Comparative results of TDS Vs Electrical Conductivity

The more Electrical Conductivity ions present the more the electricity that can be conducted by the water. Electrical Conductivity is also an indirect measure of Total Dissolved Solids. Electrical conductivity is directly proportional to Total Dissolved Solids. As shown figure 30, when TDS values increase the EC values also increase. High EC and TDS values are indicators of possible water pollution sites in water quality determination.

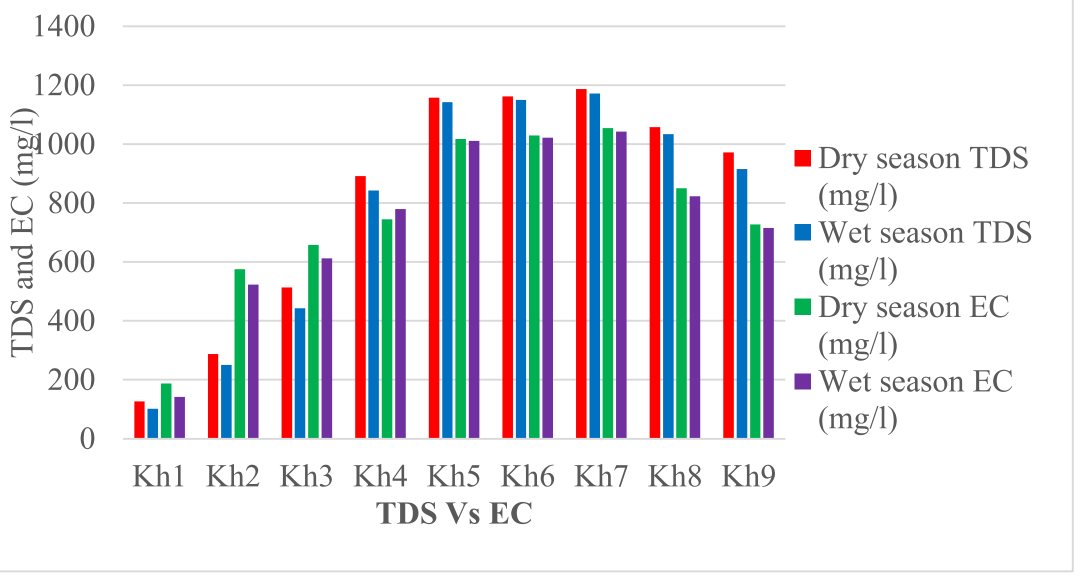


Figure30: Total dissolved solid value Vs Electrical conductivity

ii. Comparative results of Turbidity and EC

Figure 31 shown that EC values were higher than Turbidity values due to the effluents of tributaries such as Hospital, Bisnit and Kedame Gebeya were the cause to rise the result of EC. But both are shown increasing trend at middle stream and downstream.

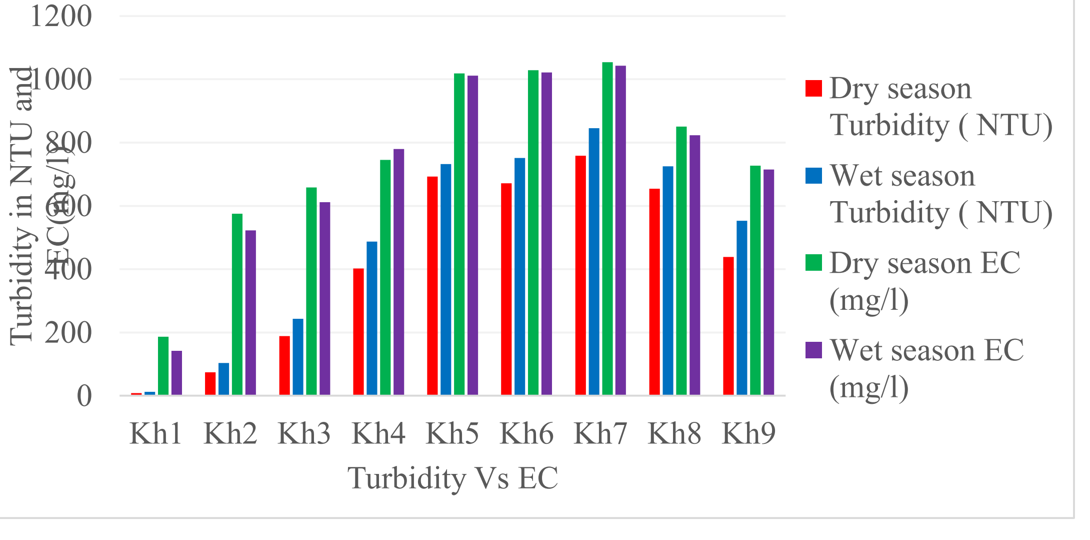


Figure31: Turbidity versus EC

iii. Comparative results of DO and BOD

Biological Oxygen Demand is a measure of how much oxygen is used by microorganisms in aerobic oxidation, or breakdown of organic matter in the streams. The higher the amount of organic material found in the stream, the more the oxygen used for aerobic oxidation. Decreased level of Dissolved oxygen shown in this river but in contrast to this BOD was increased in the same point which indicated that high load of organic pollutants.

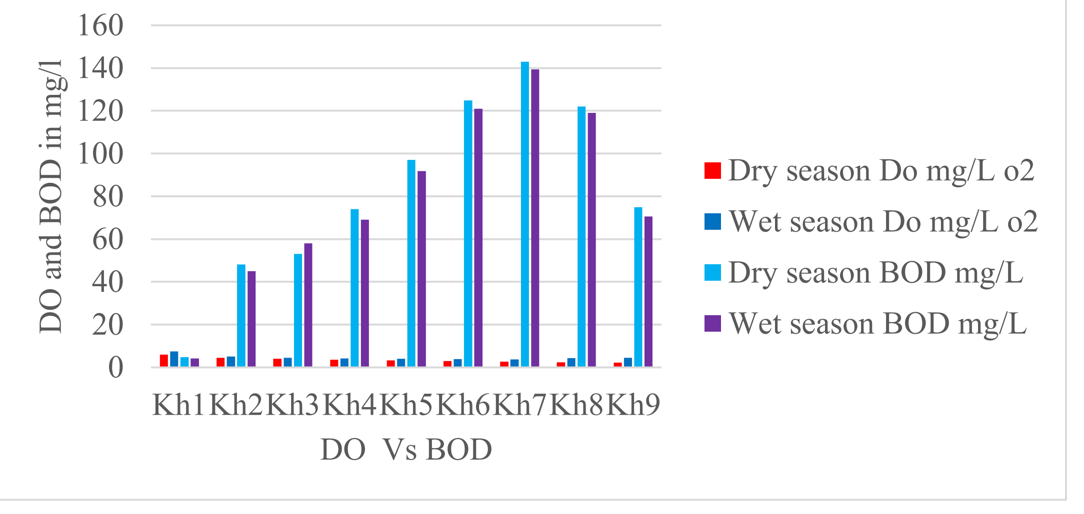


Figure32: DO values versus BOD values

iv. Comparative results of Turbidity and TDS

Figure 33 shown that TDS values were higher than Turbidity values due to the effluents of tributaries such as Hospital, Bisnit and Kedame Gebeya were the cause to rise the result of TDS. But both are shown increasing trend at middle stream and downstream.

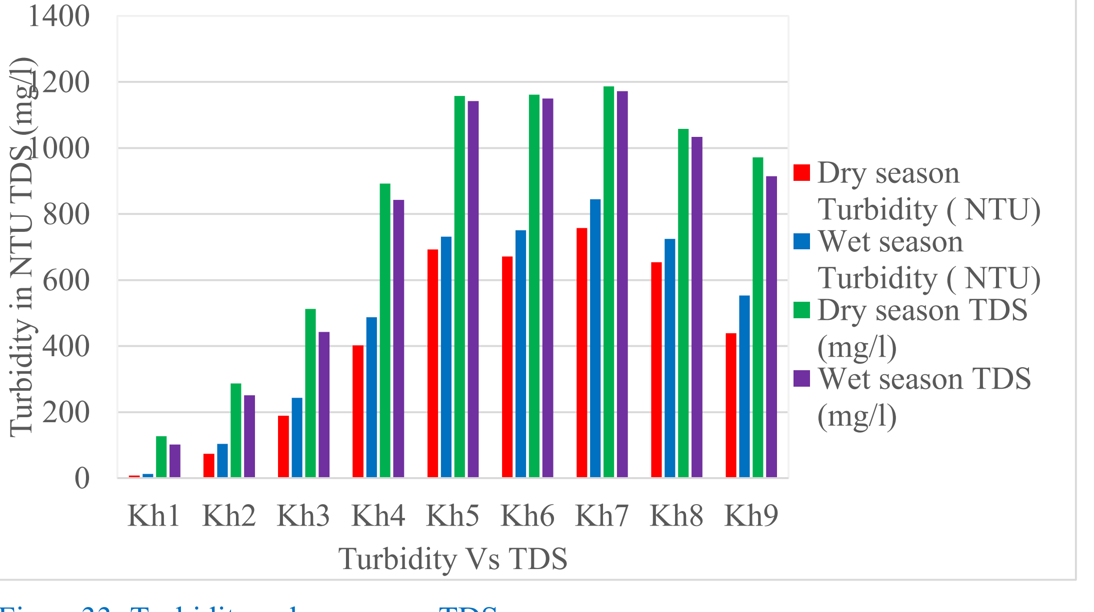


Figure33: Turbidity values versus TDS

4.2. Sources of pollution

The filed study, On-site observations and socio-economic survey identified different sources that are negatively affected keha river. Effluents from industries, residential wastes, hospital waste and Commercial waste were usually channeled to Keha River courses, which often result in pollution, loss of biodiversity in the aquatic ecosystem and health risk to humans.

4.2.1. Anthropogenic activities affecting Keha River

Anthropogenic activities are human activities that negatively affect the water quality mainly affect the rivers making it polluted and hence unsuitable for normal uses. These activities had their wastes ending up in Keha River directly or through runoff during the rainy season. Different industries, institutions, hotels, hospital, commercial markets, groceries, constructions and others were discharged the waste to Keha River. The quality of Keha River was affected by point source and non-point sources. Point source pollution is from a single defined source discharging pollutants at a specific location such as a pipe discharging into a water body. Moha soft drink industry, Kedame Gebeya Market, Gondar hospital, University of Gondar, Fasliedes preparatory school, Lmerger Hotel, Florida hotel, Quara hotel, Maraki Market, welding shops, barber shops and hair salons, under tree motor vehicle works were discharged the waste to Keha River.

4.2.2. Municipal source of pollution

Gondar is one of the rapid urbanized city where urban population growth is very fast. It is obvious that when the population increases the municipal solid and liquid wastes generation also increases. In addition to that the city's municipal waste collection coverage is not efficient as a result it greatly contributes to the pollution of rivers especially during the rainy seasons when the surface runoff gets higher. Wastes from hospital ponds, open markets, restaurants, hotels and domestic wastes among others.

4.2.3. Agricultural activity

The existence of agricultural activity at the banks of the river increase the effect of runoff as the fertilizer is washed into the river. The level of knowledge or fertilizer application and the farming methods influence the amount of fertilizer carried in to the river.

4.2.4. Runoff

Runoff carries waste that is deposited on land in to the Keha River. The lack of proper dumpsites in the study area has negative implications on the water quality of the river. The tributaries of the Keha River pass through high density residential areas, increasing the risk of pollution from varying activities along the banks of the river. .

4.2.5. Land use activities keha river watershed

The effects of watershed changes on water quality are real and frequently of serious consequence. Keha River consists various land uses activities in the form of agriculture, commercial, forestry and domestic use in highly urbanized residential areas. Land use in Gondar, mostly change from agricultural land to urban land use. This occurs due to urban population growth because of rural-urban migration, urban-urban migration, industrialization and an investment in housing construction(Eyaya Belay, 2014).

Table 3: LU/LC of Gondar City in 1986 and in 1999

	year	1986	1986	1999	1999	change
No	LuLC	Area/ km2	percent,%	Area/ km2	percent,%	percent,%
1	Agricultural land	285.14	50.71	266.846	47.46	-3.25
2	Urban	57.89	10.30	171.21	30.45	20.15
3	Vegetation	219.2609	38.99	124.2309	22.09	-16.9
Total area		562.2909	100	562.2909	100	

(Source: Eyaya Belay, 2014)

As indicated the above table in 1999 agricultural land becomes shrinking as compared with 1986. In contrast to this the area of urban is increasing as compared to agricultural land and vegetation cover.

Table 4: LU/LC of Gondar City in 1999 and in 2004

	year	1999	1999	2004	2004	change
No	LuLC	Area/ km2	percent,%	Area/ km2	percent,%	percent,%
1	Agricultural land	266.846	47.46	261.015	46.42	-1.04
2	Urban	171.21	30.45	277.47	49.35	18.9
3	Vegetation	124.2309	22.09	23.3748	4.16	-17.93
4	Water			0.4311	0.08	
Total area		562.2909	100	562.2909	100	

(Source: Eyaya Belay, 2014)

The study shown that agricultural land cover has been decreasing from 1986 to 2004 and urbanization increased. Generally, all the above three tables show that urban areas are increasing from time to time; whereas the area of other LU/LC classes have become decreased due to the increasing rate of urbanization. As it indicated on table2, the years 1986 and 1999, urban area has increased by113.32km2 or by 49.46% within 13 years. In contrast to this agricultural land is decreased by 18.294km2 or 3.3142% with same year interval. This shows that urban expansion in Table 4 also shows the growth of urban area and reduction of agricultural land through time. The transformation of agricultural land to urban area between 1999 and 2004 is 5.831 km2 or 1.105 % within five year interval; that means about 1.105% of agricultural land is transformed to urban area within five years interval. At the same time, the rate of urban expansion between1999 and 2004 is 106.26km2 or 23.68% which means within five years, the area of the city has increased by 106.26km2 of 23.6%. From this we can conclude that about 21.25km2 of agricultural land has been consumed by urban areas in each year.

Table 5 also shows the increasing of urban area from 2006 to 2017 and reduction of other land through time. During the classification of land use/cover maps of the study area it was used GIS software. The classification process starts with adding the different bands of land sat image which was downloaded from http://earthexplorer.usgs.gov.et websites. Next to adding land sat images from that page. Landsat 7 images were used because of their relatively high spatial resolution (90m) and their wide application for land cover classification across the world (yalew, 2018). The Landsat images data was the resolution of 90m and Date of acquisition 20-DEC-06 for 2006 reference year and 17-FEB-17 for 2017 Reference year respectively.

During LULC analysis, supervised classification method was adopted which is the most frequently used for quantitative analysis of remote sensing data. In supervised classification the majority of the effort if done prior to the actual classification. Once the classification is run the output is a map with classes that are labeled and correspond to information classes or land cover types. Supervised classification can be much more accurate than unsupervised classification, but depends heavily on the training sites and the skill of the individual processing the image (Arcata, 2016). Maximum Likelihood algorithm was employed to detect the land cover types. Because it was considered most suitable for minimization of classification error (Clark-Evans, 2018).

Table 5. Gondar town Land use Land change in 2006 and 2017

	year	2006	2006	2017	2017	change
No	LuLC	Area, ha	percent,%	Area, ha	percent,%	percent,%
0	Forest Land	24.936	1.73	81.171	5.61	3.88
1	Shrub Land	119.321	8.24	117.947	8.15	-0.09
2	Grass Land	157.11	10.85	139.575	9.64	-1.21
3	Bare Land	1012.69	69.96	694.842	48.00	-21.96
4	Building	133.454	9.22	413.917	28.60	19.38
Sum		1447.511	100	1447.452	100.00	

4.2.6. Urban development in Gondar and impacts of urbanization on Keha River

Gondar initially developed between Angereb River on the east and Keha River on the west and then expanded towards the south, south east and south west and finally adjoining the earlier settlement of Azezo. Existing built-up area allocated land within the 12 urban sub-cities and part of the 11 rural kebeles of the town and Teda town.

Table6. Sub-cities and urbanization expansion in Gondar

No	Name of sub-city	Area in ha	Percentage	Perimeter
1	Arbegnoch Adebabay	692	12.7	13,133
2	Medihanealem	192	3.5	7,008
3	Adebabay Eyesus	144	2.6	5,422
4	Kirkos	276	5.1	7,962
5	Abajale	30	0.6	2,651
6	Abeyegzi	127	2.33	5,892
7	Gabriel	602	11.04	14,033
8	Mehal Arada	40	0.7	3,051
9	Lideta	594	10.91	13,353
10	Azezo Dimaza	427	7.83	12,438
11	Azezo Ayer Marefia	1465	26.85	21,677
12	Maraki	864	15.84	14,283
	Total	5453	100	120,903

(Source: Amhara National Regional State Urban Planning Institute, 2014)

As shown in the above, Gondar town expand to the east, south and west from initial developed up to now and have expansion plan in the future.

Building of residential House, different hotels, restaurants, hospital, health institutions, schools, colleges, university, different industries, car washing, garages, workshops, different commercial markets, roads, administrations, Social and Municipal Services, Festival sites, Recreation like Sport field, Parks and others are indicators of urban expansion in Gondar town. Due to urbanization and anthropogenic activities there is waste production and release in to rivers. Domestic wastes, Health care wastes, Boarding schools wastes, Commercial market wastes, Hotels and restaurants wastes and industrial wastes release in to Keha River that cause the river water quality degradation.

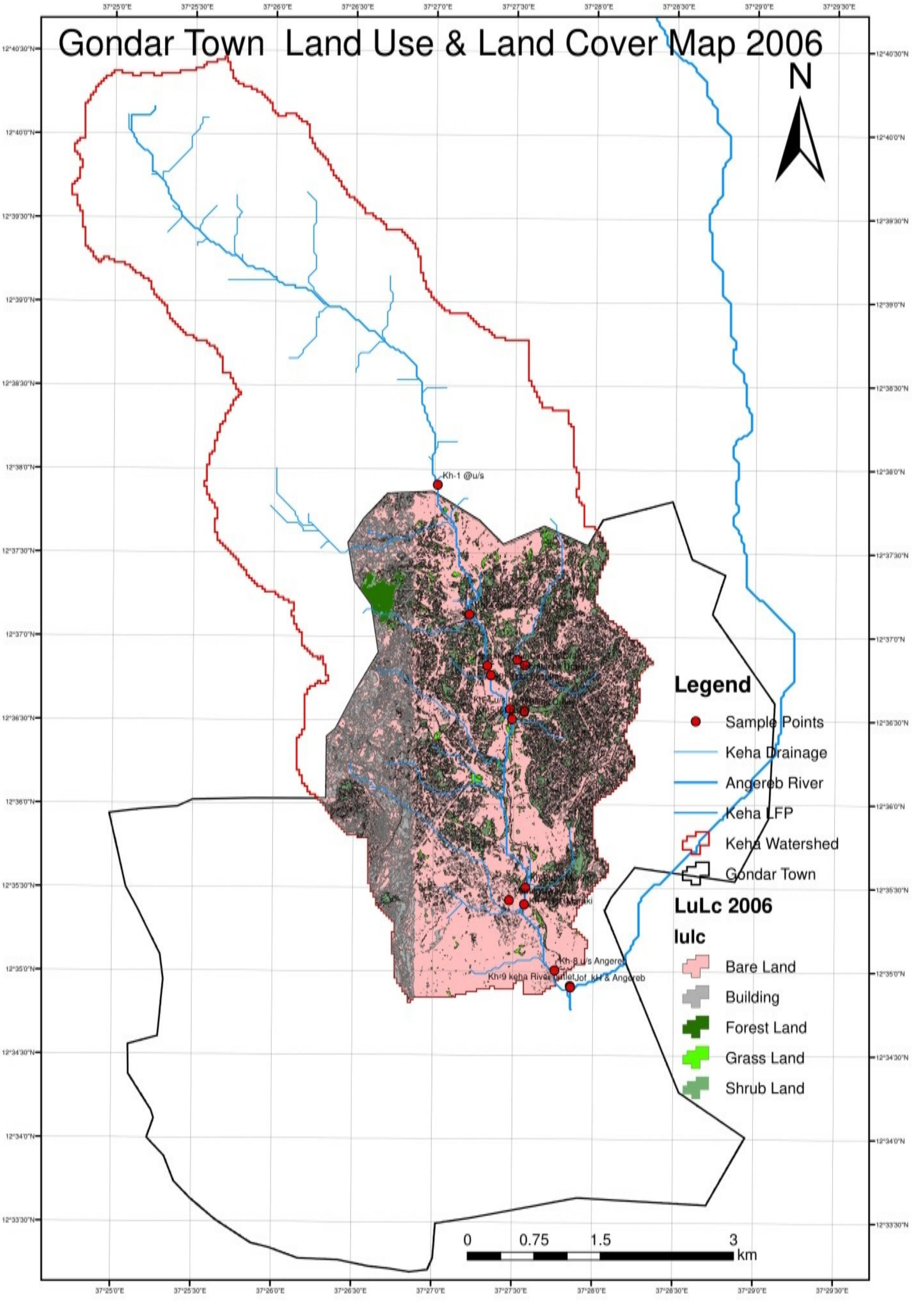


Figure34.Landuse Land cover map2006

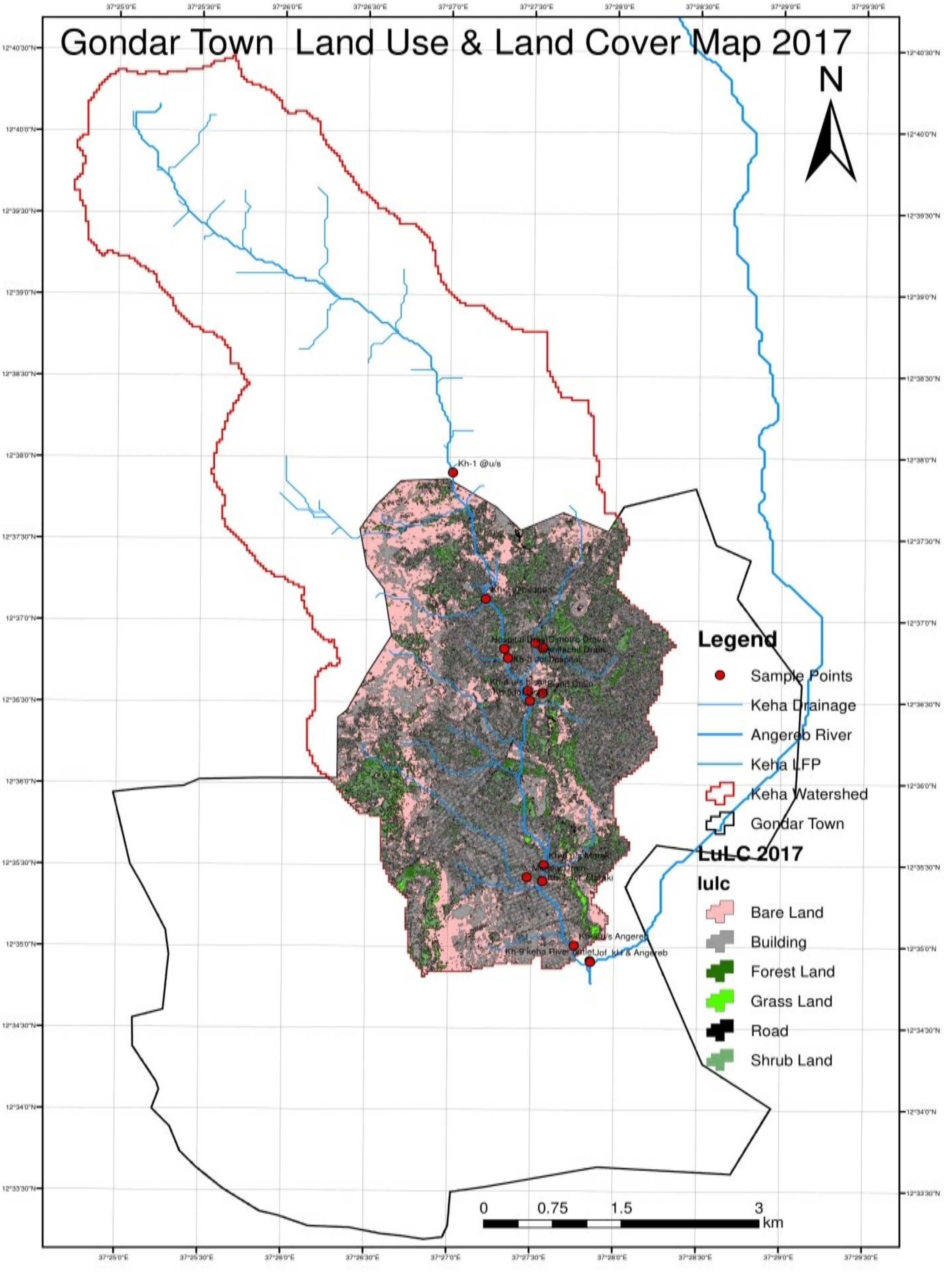


Figure35.Landuse Land cover map 2017

4.3. Impacts of Urbanization on Spatial and Seasonal variations of water quality in Keha River from 2003 to 2018, Gondar town

Urbanization with intense land use and land cover change and population growth has a great impact on water quality. The results showed that water quality in the study area had significant spatial and seasonal variation. Water quality in nonurban area was better than urban areas and the urban water quality was the worst. Land use was identified as the strongest contributor of nitrate and phosphate, increase algal production and decrease concentrations of dissolved oxygen in the Keha River. For example, the concentration of BOD in urban area was 139.4 mg/l mg/L, higher than 4.1 mg/l mg/L in the nonurban area. However, the concentration of DO in nonurban area was 7.4 mg/l mg/L, higher than 2.4mg/l in the urban area.

Based on the keha watershed land use map in 1986,1999,2004,2006 and 2017, it is known that there is a land use change of the bare land and agricultural areas convert into urban land over these years period. Keha river water quality degradation within 15 years. Keha River water quality decreased from upstream to downstream shown that urbanization has significant effect on river water quality. Urbanization modify land surface characteristics, alter runoff volume, change water temperature, generate pollution, and increase algal production and decrease concentrations of dissolved oxygen in water bodies (Niels De Troyer, 2016).

The current thesis research result values were compare with the comparative study that was done by Central Gondar Water, irrigation and Energy department in 2003 at the same six sampling sites namely at upstream, middle stream, downstream, Hospital outlet, Bisnit stream, Kedame Gebeya outlet Gondar Water, irrigation and Energy laboratory technician was help me to sow the 2003 sampling location and the same wet season.

The variation of fourteen parameters were turbidity, electrical conductivity (EC), Total Dissolved Solids (TDS), pH, nitrate, phosphate, total alkalinity, Iren, total hardness, Biological Oxygen Demand (BOD), dissolved oxygen(DO),Total coliform and E-coli were compared in different sampling sites in 2003 to 2018 are shown in (Figure 36-49).

4.3.1. Variations of pH

The variation of pH in different sampling sites from 2003 to 2018 are shown in (Figure 36).Comparative study have found that was done by Central Gondar Water, irrigation and Energy department in 2003.When we compared the current thesis research findings of PH values were higher than the comparative research PH values done by Central Gondar water, irrigation and energy department in 2003 in the Keha River. According to Central Gondar water, irrigation and energy department 2003, the PH at upstream 7.13, at middle stream 7.5, at downstream7.4, at Hospital outlet 7.6 at Bisnit outlet7.8 and at Kedame Gebeya 7.8 respectively during wet season.

But the current research findings PH values at the same sampling points, same Keha River and same season were 7.25 at upstream, 8.72 at middle stream, 8.9 at downstream, 8.9 at Hospital outlet, 5.9 at Bisnit outlet and 5.9 at Kedame Gebeya. We have seen very significant change in PH values.

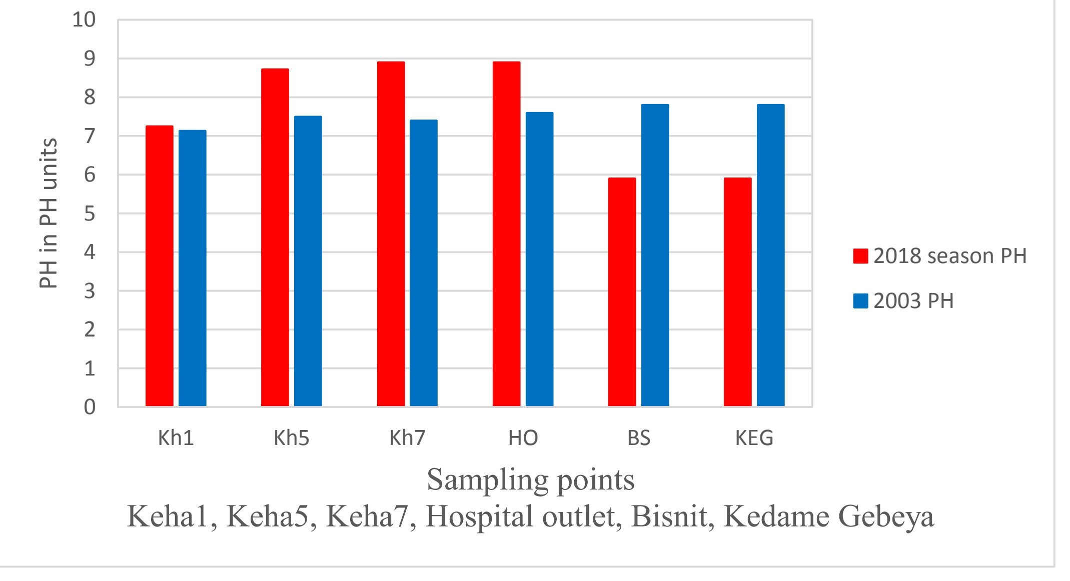


Figure 36. Variation of pH in six sampling sites from 2003 to 2018

4.3.2. Variations of turbidity

The variation of turbidity in different sampling sites from 2003 to 2018 are shown in (Figure 33). Comparative study have found that was done by Central Gondar Water, irrigation and Energy department in 2003.When we compared the current thesis research findings of turbidity values were higher than the comparative research PH values done by Central Gondar water, irrigation and energy department in 2003 in the Keha River. According to Central Gondar water, irrigation and energy department 2003, the turbidity at upstream 5.5, at middle stream 22, at downstream34, at Hospital outlet 57at Bisnit outlet65 and at Kedame Gebeya 364 NTU respectively during wet season.

But the current research findings turbidity values at the same sampling points, same Keha River and same season were 13 at upstream, 732 at middle stream, 845 at downstream, 1072 at Hospital outlet, 1023 at Bisnit outlet and 987 at Kedame Gebeya. We have seen very significant turbidity values.

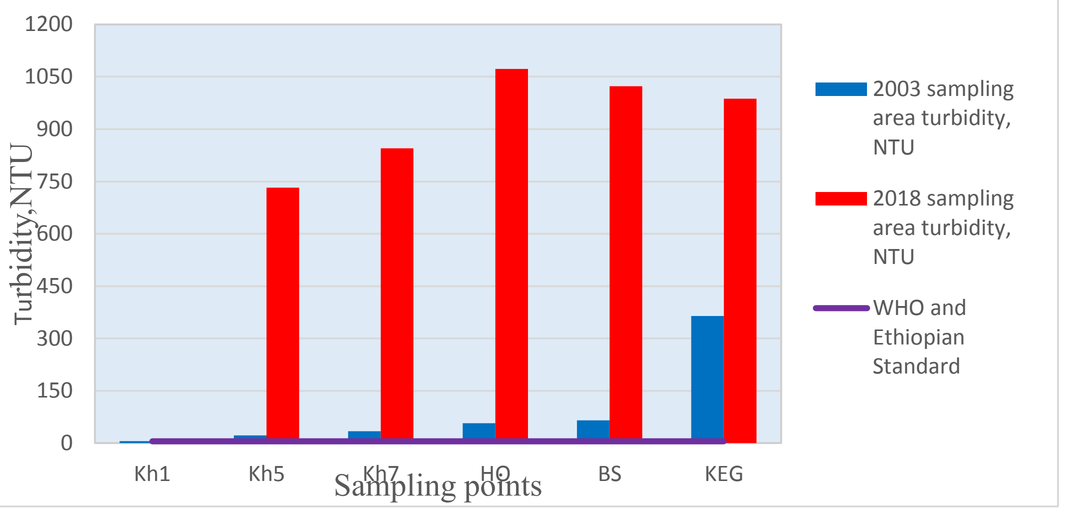


Figure 37. Variation of turbidity in six sampling sites from 2003 to 2018

4.3.3. Variations of Electrical Conductivity

The variation of electrical conductivity in different sampling sites from 2003 to 2018 are shown in (Figure 34). Comparative study was done by Central Gondar Water, irrigation and Energy department in 2003 in wet season. The values of electrical conductivity were at upstream of Keha River 117, at middle stream 302, at downstream 351, at Hospital outlet 445 at Bisnit outlet 579 and at Kedame Gebeya outlet 620 respectively. But the current research showed that higher electrical conductivity values than the 2003 finding result. Current research electrical conductivity at upstream of Keha River 142, at middle stream 1015, at downstream 1020, at Hospital outlet 1124 at Bisnit outlet 1147 and at Kedame Gebeya outlet 1158 respectively. Very high values are indicators of possible polluted sites.

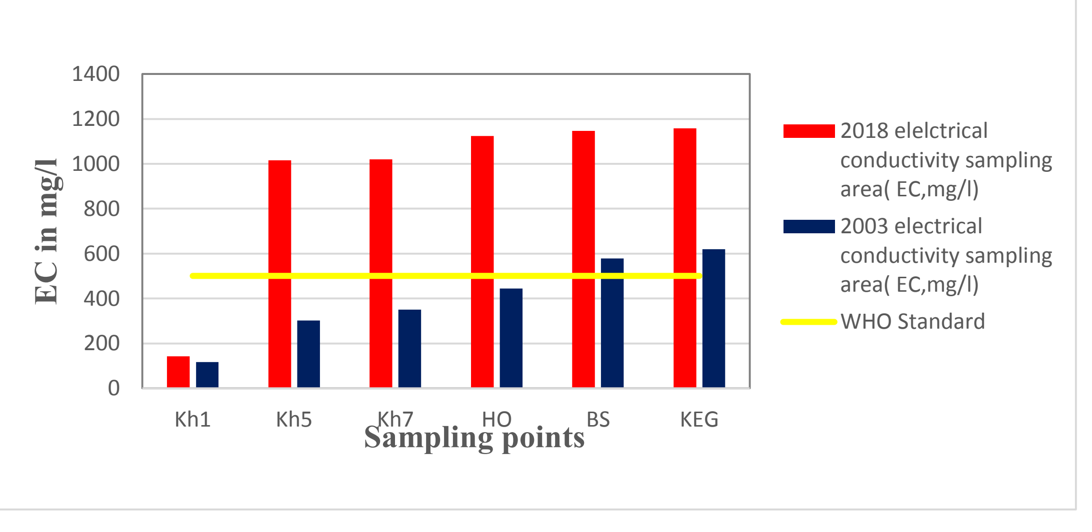


Figure 38. Variation of EC in six sampling sites from 2003 to 2018

4.3.4. Variations of Temperature

The variation of temperature in different sampling sites from 2003 to 2018 are shown in (Figure 35). Comparative study by done by Gondar water resource office in 1995. Temperature values were at upstream 19^{o}C, at middle stream 21 ^{o}C, at downstream of keha river 20 ^{o}C, at Hospital outlet20 ^{o}C, at Bisnit outlet 21^{o}C and at Kedame Gebeya 21 ^{o}C. But we have seen higher Temperature values in this current thesis research after 15 years at the same river and same sampling points the values were at upstream of keha river 20 ^{o}C, at middle stream of keha river 22.4 ^{o}C, at downstream of keha river 22.6 ^{o}C, at Hospital outlet 23 ^{o}C, at Bisnit outlet 23.9 ^{o}C and at Kedame Gebeya 23.4 ^{o}C respectively.

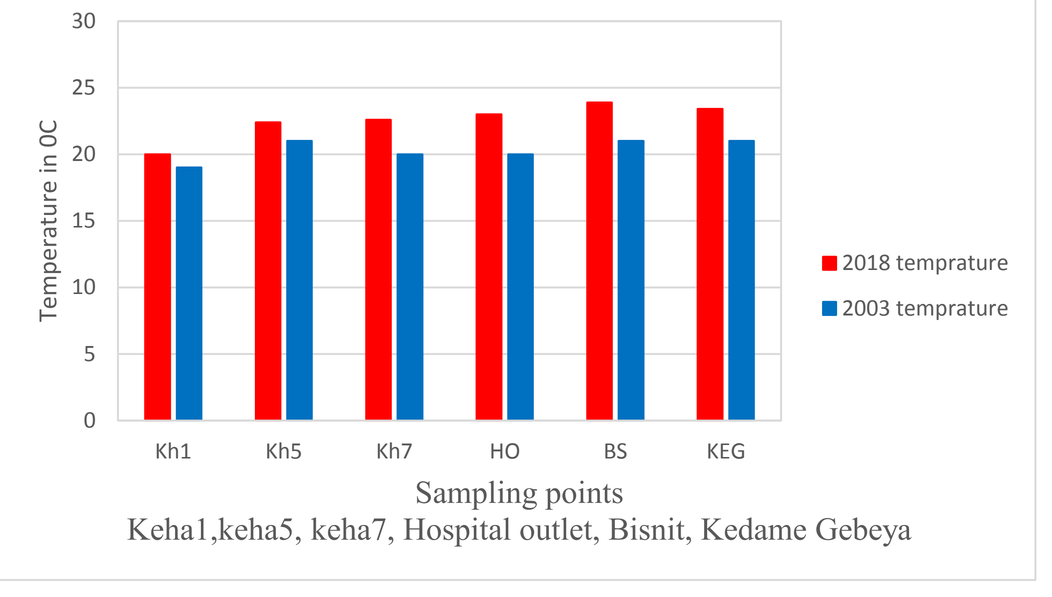


Figure 39.variation of temperature in six sample sites from 2003 to 2018

4.3.5. Variations of Total Dissolved Solids

The variation of TDS in different sampling sites from 2003 to 2018 are shown in (Figure 36). Comparative study was done by Gondar water resource office in 2003 Total dissolved solids (TDS) values were at upstream of keha river 78.5 mg/l, at middle stream of keha river 151 mg/l, at downstream of keha river 179 mg/l, at Hospital outlet169 mg/l, at Bisnit outlet 286 mg/l and at Kedame Gebeya 250 mg/l. But we have seen higher Total dissolved solids (TDS) values in this current thesis research after 15 years at the same river and same sampling points the values were at upstream of keha river 102mg/l, at middle stream of keha river 1142 mg/l, at downstream of keha river 1172 mg/l, at Hospital outlet 1265 mg/l, at Bisnit outlet 1232 mg/l and at Kedame Gebeya 1247mg/l respectively.

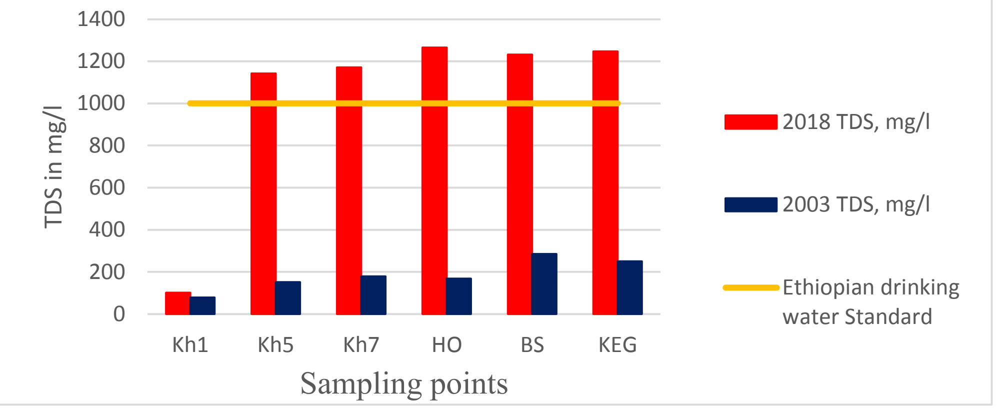


Figure 40. Variation of TDS in six sampling sites from 2003 to 2018

4.3.6. Variations of Total Alkalinity

The variation of Total Alkalinity in different sampling sites from 2003 to 2018 are shown in (Figure 37). Comparative study have found that was done by Central Gondar Water, irrigation and Energy department in 2003.Total Alkalinity (TA) values were at upstream of keha river 82 mg/l as CaCO3, at middle stream of keha river 136 mg/l as CaCO3, at downstream of keha river 130 mg/l as CaCO3, at Hospital outlet128 mg/l as CaCO3, at Bisnit outlet 59 mg/l as CaCO3 and at Kedame Gebeya 226 mg/ as CaCO3. But we have seen higher Total Alkalinity (TA) values in this current thesis research after 15 years at the same river and same sampling points the values were at upstream of keha river 89mg/l as CaCO3, at middle stream of keha river 224 mg/l as CaCO3, at downstream of keha river 234 mg/l as CaCO3, at Hospital outlet 345 mg/l as CaCO3, at Bisnit outlet 153.4 mg/l as CaCO3and at Kedame Gebeya 448 mg/l as CaCO3 respectively.

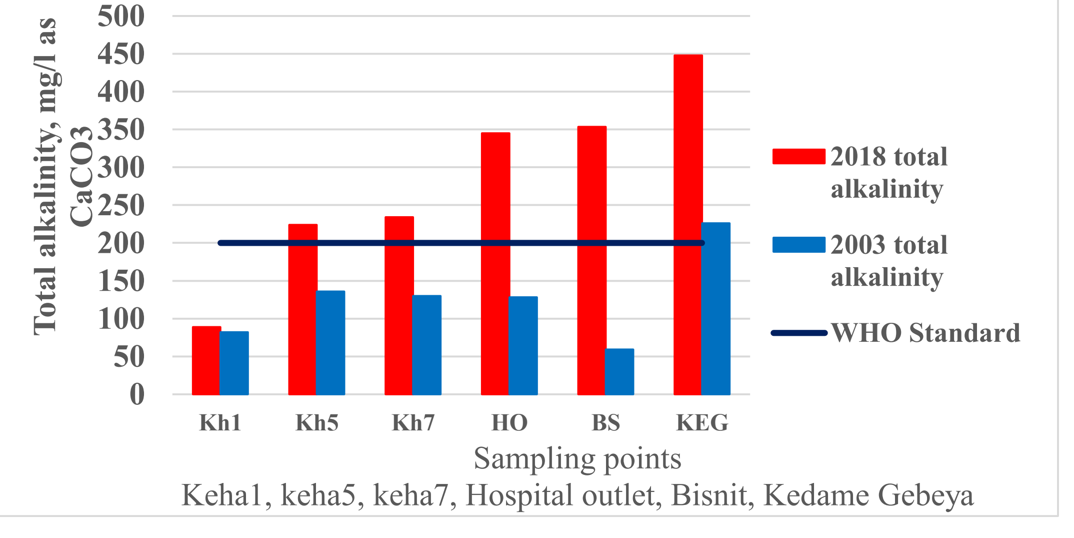


Figure 41.variation of alkalinity in six sampling sites from 2003 to 2018

4.3.7. Variations of Total Hardness

The variation of Total Hardness in different sampling sites from 2003 to 2018 are shown in (Figure 38). Comparative study have found that was done by Central Gondar Water, irrigation and Energy department in 2003. The current research finding Total Hardness values were higher than the comparative research nitrate value done by Central Gondar water, irrigation and energy department in 2003 in this keha river. According to Central Gondar water, irrigation and energy department (2003), the Total Hardness values 98 mg/l at upstream, 116 mg/l at middle stream, 120 mg/l at downstream, 101 mg/l at Hospital outlet, 185 mg/l at Bisnit outlet and 249 mg/l at Kedame Gebeya.

The current research finding of Total Hardness values at the same sampling points, same keha river and same season were 103 mg/l at upstream, 179 mg/l at middle stream, 195 mg/l at downstream, 224 mg/l at Hospital outlet, 218.7 mg/l at Bisnit outlet and 183 mg/l at Kedame Gebeya. We have seen significant change Total Hardness values within 15 year indicates Keha River is polluted.

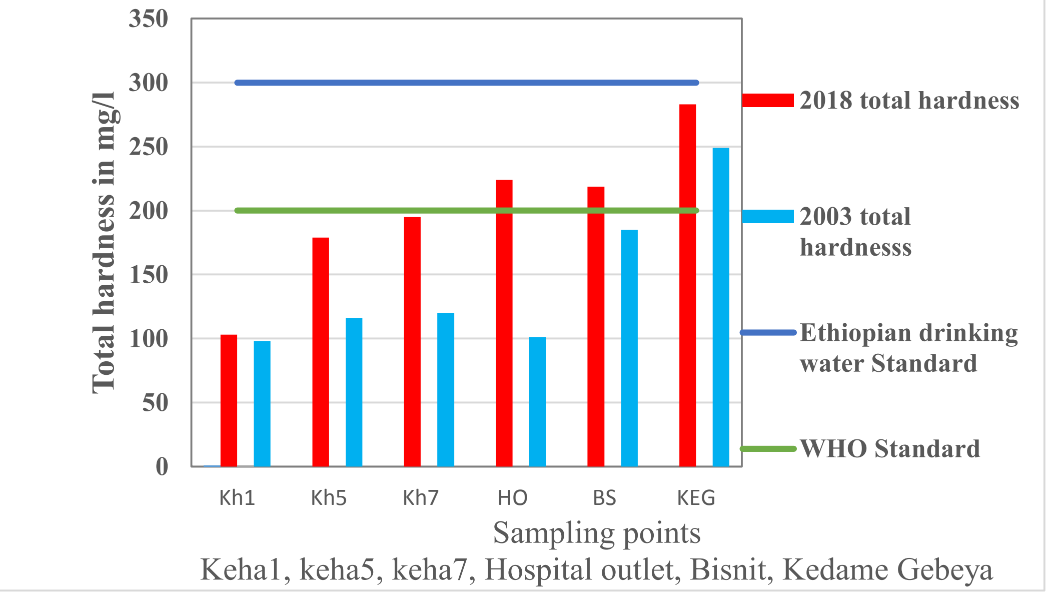


Figure 42. Variation of hardness in six sampling sites from 2003 to 2018

4.3.8. Variations of nitrate

The variation of nitrate in different sampling sites from 2003 to 2018 are shown in (Figure 39). Comparative study have found that was done by Central Gondar Water, irrigation and Energy department in 2003. The current research finding nitrate values were higher than the comparative research nitrate value done by Central Gondar water, irrigation and energy department in 2003 in this keha river. According to Central Gondar water, irrigation and energy department (2003), the nitrate values 23 mg/l at upstream, 84 mg/l at middle stream, 73 mg/l at downstream, 90 mg/l at Hospital outlet, 94 mg/l at Bisnit outlet and 89 mg/l at Kedame Gebeya.

But the current research finding nitrate values at the same sampling points, same keha river and same season were 42 mg/l at upstream, 81 mg/l at middle stream, 107 mg/l at downstream, 153.5 mg/l at Hospital outlet, 169 mg/l at Bisnit outlet and 178 mg/l at Kedame Gebeya. We have seen significant change nitrate values within 15 year indicates Keha River is polluted and created algae that cause eutrophication.

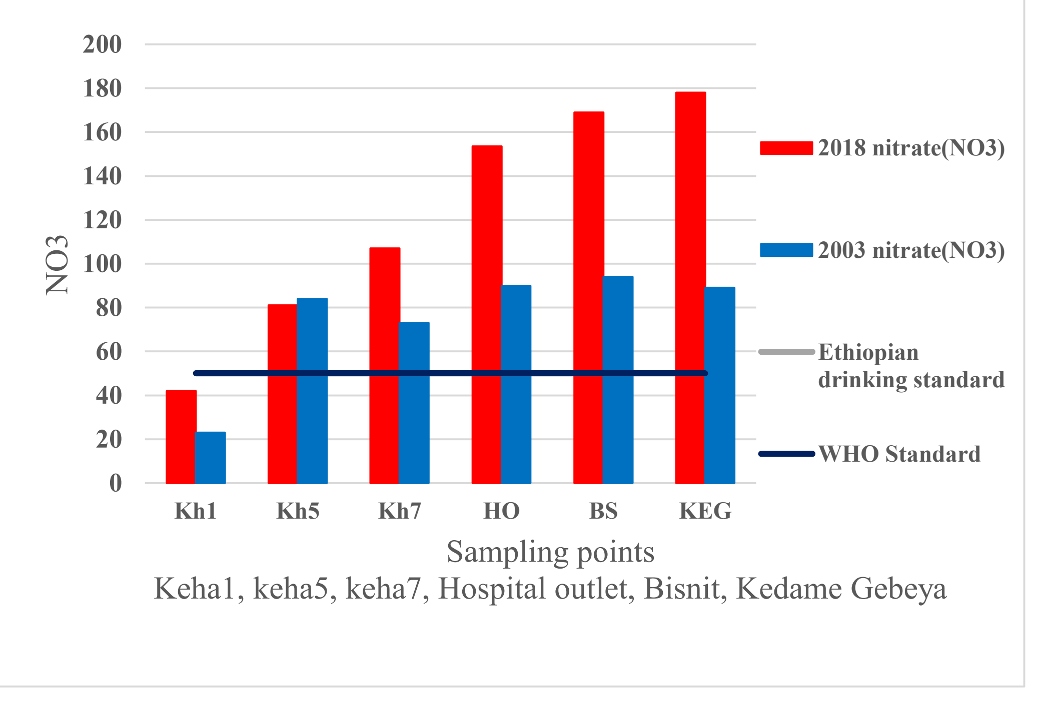


Figure 43. Variation of nitrate in six sampling sites from 2003 to 2018

4.3.9. Variations of phosphate

The variation of phosphate in different sampling sites from 2003 to 2018 are shown in (Figure 40). Comparative study have found that was done by Central Gondar Water, irrigation and Energy department in 2003.The current research finding phosphate values were higher than the Comparative research phosphate values done by Central Gondar water, irrigation and energy department in 2003 in this keha river. The phosphate values 1.2 mg/l at upstream, 18.5 mg/l at middle stream, 11 mg/l at downstream, 15 mg/l at Hospital outlet, 18 mg/l at Bisnit outlet and 13 mg/l at Kedame Gebeya (Central Gondar Water irrigation and Energy department, 2003).

But this research findings phosphate values at the same sampling points, same keha river and same season were 1.45 mg/l at upstream, 30 mg/l at middle stream, 31.4 mg/l at downstream, 25 mg/l at Hospital outlet, 28.9 mg/l at Bisnit outlet and 32.7 mg/l at Kedame

Gebeya. We have seen significant change nitrate values within 15 year indicates Keha River is polluted and created algae that cause eutrophication. The extents of variation in the values showed that the river was being polluted. Hence it was important that the quality assessment of the river be done frequently in order to detect any change that might be harmful to human and aquatic life.

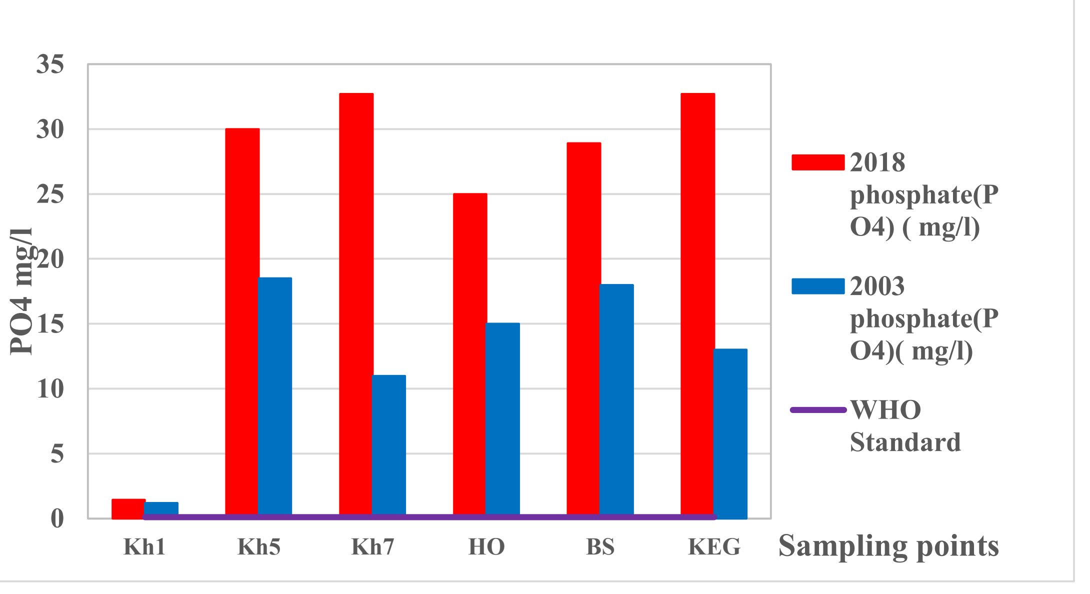


Figure 44. Variation of phosphate in six sample sites from 2003 to 2018

4.3.10. Variations of Iron

The variation of iron in different sampling sites from 2003 to 2018 are shown in (Figure 41). Comparative study have found that was done by Central Gondar Water, irrigation and Energy department in 2003.When we compared this research finding except upstream of keha river all Iron values were higher than the related research Iron values done by Central Gondar water, irrigation and energy department in 2003 in this Keha River. Iron values 0.2 mg/l at upstream, 0.25 mg/l at middle stream, 0.3 mg/l at downstream, 0.26 mg/l at Hospital outlet, 0.6 mg/l at Bisnit outlet and 0.26 mg/l at Kedame Gebeya (Central Gondar Water irrigation and Energy department, 2003).

But this research findings Iron values at the same sampling points, same keha river and same season were 0.2 mg/l at upstream, 0.6 mg/l at middle stream, 0.54 mg/l at downstream, 0.45 mg/l at Hospital outlet, 0.79 mg/l at Bisnit outlet and 0.74 mg/l at Kedame Gebeya. Iron is micronutrients which help plant growth and development but can be detrimental if threshold levels are exceeded.

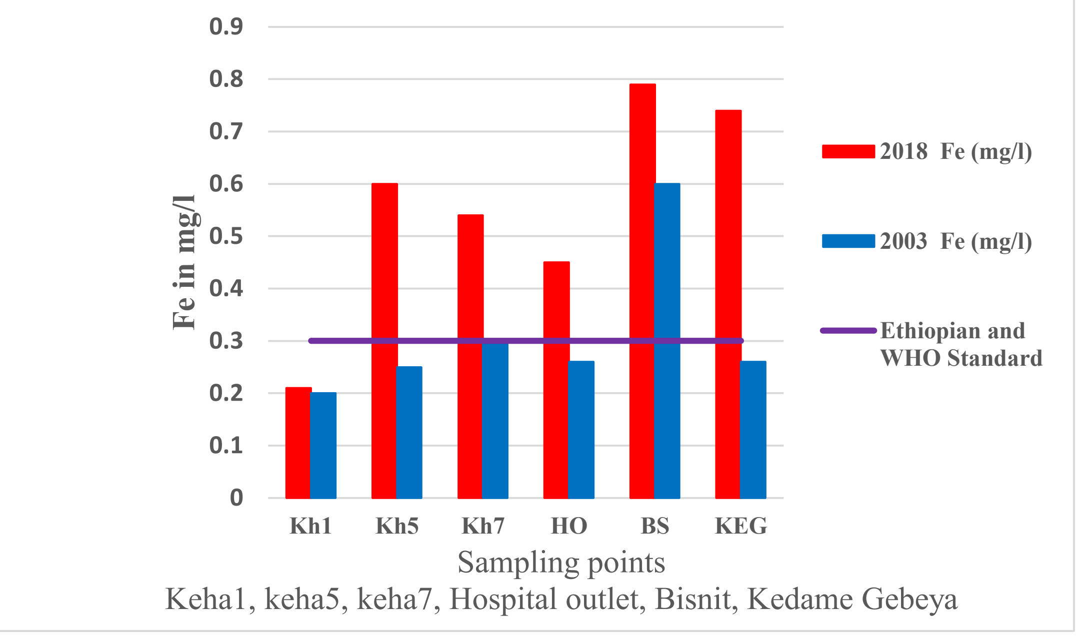


Figure 45. Variation of Iron in six sampling sites from 2003 to 2018

4.3.11. Variations of Dissolved Oxygen

The variation of Dissolved Oxygen in different sampling sites from 2003 to 2018 are shown in (Figure 42). Comparative study have found that was done by Central Gondar Water, irrigation and Energy department in 2003.The current thesis research finding dissolved oxygen (DO) values were very lower than the comparative study dissolved oxygen (DO) values done by Central Gondar water, irrigation and energy department in 2003 in this Keha River. According to Central Gondar water, irrigation and energy department (2003), the dissolved oxygen (DO) 9 mg/l at upstream, 7.4 mg/l at middle stream,6.5 mg/l at downstream, 5.4 mg/l at Hospital outlet, 5.3 mg/l at Bisnit outlet and 6.8 mg/l at Kedame Gebeya. But this research findings dissolved oxygen (DO values at the same sampling points, same keha river and same season were 7.4 mg/l at upstream, dissolved oxygen (DO) mg/l at middle stream, 3.7 mg/l at downstream, 2.4mg/l at Hospital outlet, 2.8 mg/l at Bisnit outlet and 3 mg/l at Kedame Gebeya. We have seen very significant change dissolved oxygen (DO) values within 15 year indicates that there was oxygen depilation and Keha River is polluted. The extents of variation in the values showed that the river was being polluted. Hence it was important that pollution control of the river be done frequently in order to detect any change that might be harmful to human and aquatic life.

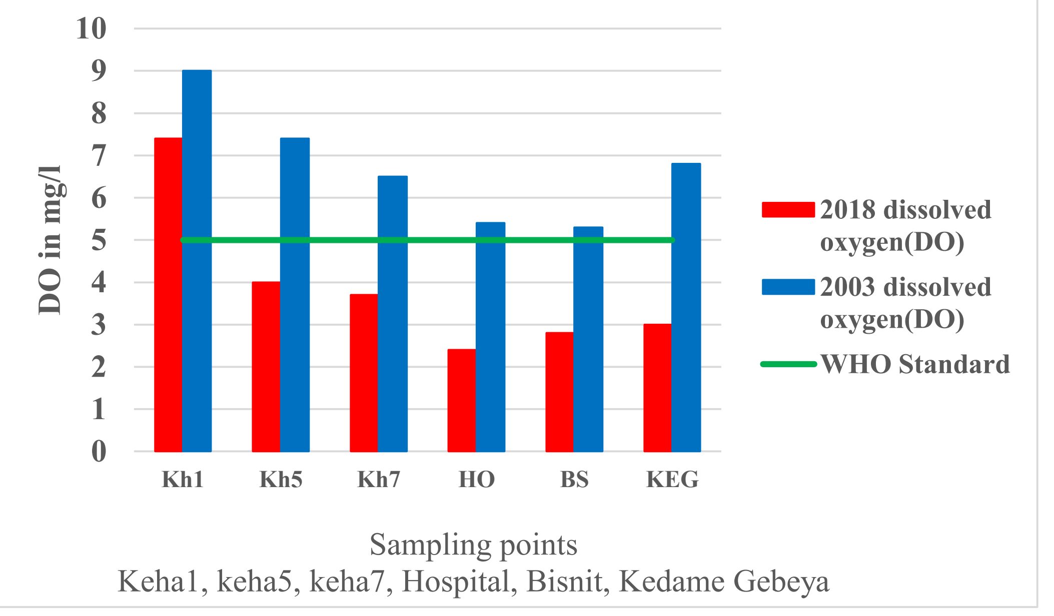


Figure 46. Variation of DO in six sampling sites from 2003 to 2018

4.3.12. Variations of BOD

The variation of BOD in different sampling sites from 2003 to 2018 are shown in (Figure 43). Comparative study have that was done by Central Gondar Water, irrigation and Energy department in 2003.When we compared this research finding Biochemical Oxygen Demand (BOD5) values were higher than the comparative related research Biochemical Oxygen Demand (BOD5) values done by Central Gondar water, irrigation and energy department in 2003 in this Keha River. According to Central Gondar water, irrigation and energy department 2003, the Biochemical Oxygen Demand (BOD5) 3 mg/l at upstream, 54 mg/l at middle stream,82 mg/l at downstream, 116 mg/l at Hospital outlet, 102 mg/l at Bisnit outlet and 94 mg/l at Kedame Gebeya.

But this research findings Biochemical Oxygen Demand (BOD5) values at the same sampling points, same keha river and same season were 4.1 mg/l at upstream, 91.8 mg/l at middle stream, 139.4 mg/l at downstream, 197.2 mg/l at Hospital outlet, 183 mg/l at Bisnit outlet and190 mg/l at Kedame Gebeya. We have seen very significant change Biochemical Oxygen Demand (BOD5) values. The extents of variation in the values showed that the river was being polluted. Hence it was important that pollution control of the river should be done frequently in order to detect any change that might be harmful to human and aquatic life. High BOD level causes dissolved oxygen depletion, which could be detrimental to aquatic life.

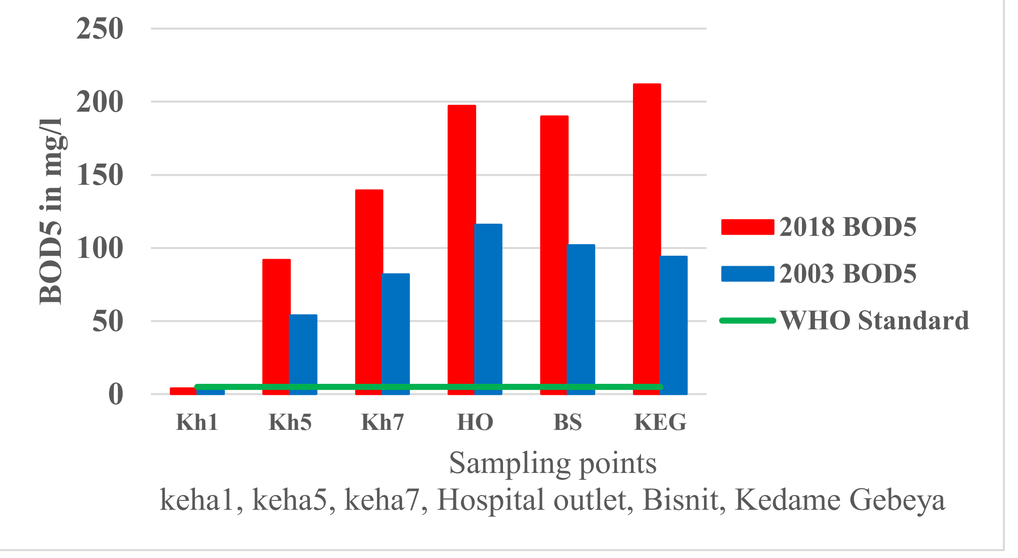


Figure 47. Variation of BOD in six sampling sites from 2003 to 2018

4.3.13. Variations of total coliform

The variation of total coliforms in different sampling sites from 2003 to 2018 are shown in (Figure 44). Comparative study have found that was done by Central Gondar Water, irrigation and Energy department in 2003.When we compared this research findings of total coliforms values were higher than the Comparative research total coliforms values done by Central Gondar water, irrigation and energy department 2003 in this Keha River. According to Central Gondar water, irrigation and energy department (2003), the total coliforms (94 counts/100 ml) at middle stream, (61counts/100 ml) at downstream, (186 counts/100 ml) at Hospital outlet, (324 counts/100 ml) at Bisnit outlet and (287 counts/100 ml) at Kedame Gebeya.

But this research findings total coliforms values at the same sampling points, same keha river and same season were (239.2counts/100 ml) at middle stream, (365.5counts/100 ml) at downstream, (459counts/100 ml) at Hospital outlet, (472 counts/100 ml) at Bisnit outlet and (491.2counts/100 ml) at Kedame Gebeya. We have seen very significant change total coliforms values.

However, some communities middle stream and downstream of this sampling point obtain their drinking water directly from the same water source, keha River; this may lead to health problems, because the recommended threshold for drinking water is 0 counts/100 ml (WHO, 2008).The high total coliform count obtained in the samples might be an indication that the water sources are contaminated. The extents of variation in the values showed that the river was being polluted. Hence it was important that pollution control of the river should be done frequently in order to detect any change that might be harmful to human and aquatic life. Poor sanitary conditions and lack of clean water causes diarrhea diseases and related child deaths. Furthermore, many skin diseases are water related, associated with deficiency of water and poor personal hygiene (Admassu, 2002)

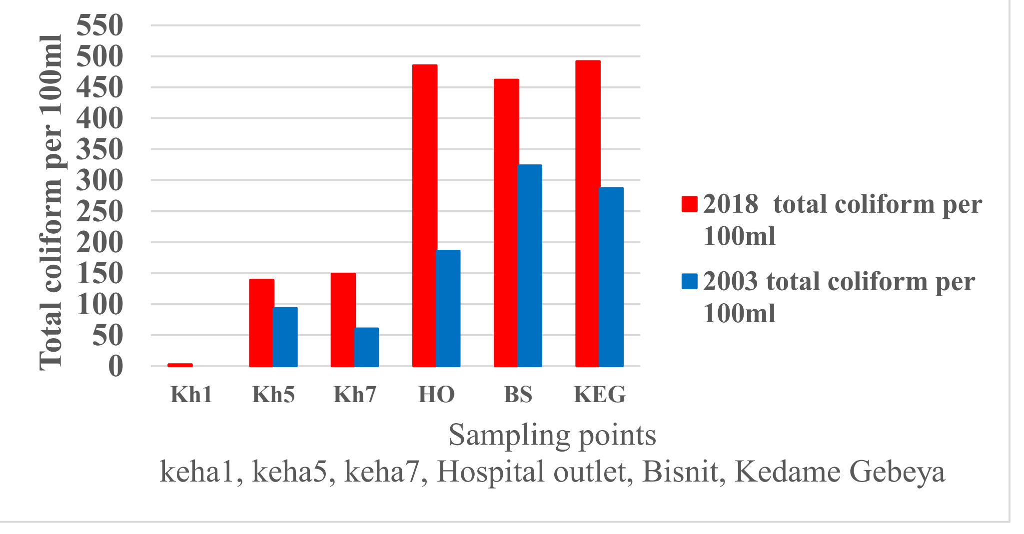


Figure 48. Variation of total coliform in six sampling sites from 2003 to 2018

4.3.14. Variations of E-coli

The variation of E-coli in different sampling sites from 2003 to 2018 are shown in (Figure 45). Comparative study have found that was done by Central Gondar Water, irrigation and Energy department in 2003.When we compared this research findings of E-coli values were higher than the comparative E-coli values done by Central Gondar water, irrigation and energy department in in 2003 in this Keha River. According to Central Gondar water, irrigation and energy department (2003), the E-coli (91 counts/100 ml) at middle stream, (52 counts/100 ml) at downstream, (104 counts/100 ml) at Hospital outlet, (133 counts/100 ml) at Bisnit outlet and (98 counts/100 ml) at Kedame Gebeya.

But this research findings E-coli values at the same sampling points, same keha river and same season were (170.2counts/100 ml) at middle stream, (189.25counts/100 ml) at downstream, (252 counts/100 ml) at Hospital outlet, (255 counts/100 ml) at Bisnit outlet and (259.2counts/100 ml) at Kedame Gebeya. We have seen very significant change faecal coliforms values. The high E-coli count obtained in the samples might be an indication that the water sources are faecally contaminated. The extents of variation in the values showed that the river was being polluted. Hence it was important that pollution control of the river should be done frequently in order to detect any change that might be harmful to human and aquatic life.

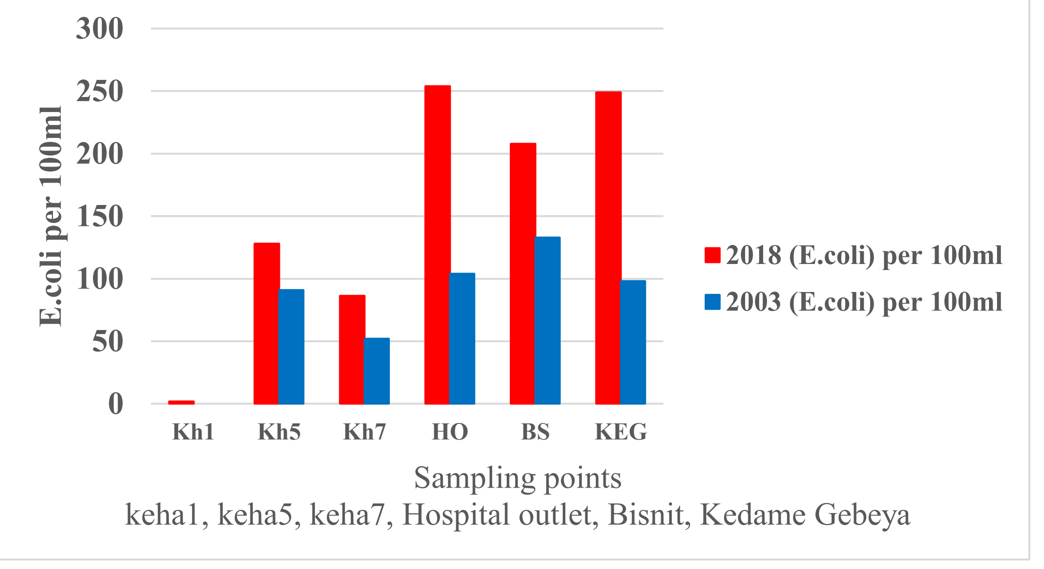


Figure 49. Variation of E-coli in six sampling sites from 2003 to 2018

Based on Keha watershed land use land cover in1999, 2004, 2006 and 2017, the 2017 land use shown that there is significant land use change of the bare land, grassland and agricultural land converted into urban land use the past 18 years. When we compared the 2003 Central Gondar Water and Energy department Keha River water quality laboratory analysis result and the current Keha River water quality laboratory analysis result, the 2018 Keha River water quality has deteriorate in the past 15 years.

Ethiopian and other world countries comparative studies also shown that urbanization is one of detrimental force of surface water quality deterioration. In the City of Cape Town, South Africa, Kuils River is polluted due to rapid urbanization cause high phosphate, nitrate and low dissolved oxygen influenced by human impacts(Mwangi, 2014). In Thailand the U-tapao River Dissolved oxygen Decreased but BOD was increased indicated that high organic pollutants due to Urbanization activities and Waste Disposal into Surface water(Saroj Gyawali et al., 2012). Savanna River is polluted due to sewage release into rivers shown high EC and nitrate values indicating negative environmental impact in Brazil (Nayara Luiz Pires et al., 2015). The spatial and temporal variations of surface water quality was worst in urban areas than rural areas in Shanghai China(Junying Wang et al., 2007). In Kumasi Ghana Urbanization has negative impact on surface water resources due to waste disposal in to rivers (Mohammed, 2004).

Ethiopian rivers are Vulnerable to pollution due to urbanization effect. Mojo River, Little Akaki River, Greater Akaki River, Awash River and Huluka River. The research finding at Mojo River, electrical conductivity values above 1000 µs/cm and total dissolved solid was high value of 1332 mg/l was recorded (Berehanu, 2007). As Berehanu findings, Mojo River was polluted due to direct discharge of industrial and domestic sewage waste led to high BOD, low DO, high total coliform count (**$8*10^7$**), high nitrate and phosphate. Awash River was polluted, high Turbidity results for dry and wet season were recorded the value of 1760 NTU and 5100 NTU respectively(Nugusu, 2015). Raw sewage, solid waste and runoff are responsible for polluted in Greater Akaki River(Solomon Akalu, 2011). Due to weak policy and weak enforcement laws, wastes were directly released into Huluka River west Showa zone (Eshetu, 2012).

4.4. Keha River health restoration

Keha River health restorative work is required for multiple benefits such as ecosystem regeneration, water quality improvements, habitat restoration, aesthetic value, for both safety and visual appeal, water resource protection, sediment management and flood control are considered among the common motives.

Keha river health restoration is require through integrated works with stake holders such as communities, city municipality, environmental protection agency, water irrigation and energy office, universities, the governmental and nongovernmental organizations. Waste management is very important for Keha River restoration because indiscriminate disposal of wastes are the major threat to surface water pollution in Gondar town. In most cases, sewage and waste water from homes are routed into the rivers and streams therefore avoid manage open disposal system. Construct modern waste water treatment plant, waste collection systems to restore Keha River vital source of Gondar town as well as Megech River and Lake Tana.

The importance of river health restorative works to mitigate water pollution which had previously occurred, to reduce any negative impacts on the water resources, hydrology and aquatic life. River restoration schemes could be increase which is necessary integrated approaches to provide rivers for good water quality and ecological potential.

In order to restore Keha river healthy water quality, it must be stop release untreated waste water into Keha River through tributaries such as Hospital, Bisnit, Fechifachit, Demetro, Kedame Gebeya and others they are potential pollutant sources in Keha River

Chapter Five: Conclusion and recommendation

5.1. Conclusion

From this study Keha River can be described as a river highly polluted due to anthropogenic activities. Based on the keha watershed land use map in 1999,2004,2006 and 2017, it is known that there is a land use change of the bare land and agricultural areas convert into urban land over these years period. Land use change has great impact on Keha River water quality has decreased in the past 15 years. The quality of river water decreased from upstream to downstream. In this research paper, water quality changes are characterized and identified the sources of pollutants that determine the changes in the Keha River water quality during dry and wet season. The critical source of pollutions are industries like Moha soft drink industry, Gondar hospital, Kedame Gebeya Commercial market, a lot of hotels and restaurants among others.

The phisico-chemical result indicated that the range of pH (5.9-8.97mg/l), Conductivity (142-1231 us/cm), Turbidity (8-1072 NTU), Dissolved Oxygen (7.4-2.1mg/l), BOD (4.1-201mg/l), TDS (102-1298mg/l), Alkalinity (89-508mg/l), Total Hardness(103-283mg/l), Iron(0.15-0.79), Chromium(0.02-0.42), Manganese(0.02-3.9), Phosphate(1.37-32.7mg/l), Nitrate(35.4-178mg/l), Total coliform counts(2.9-490) and E.Coli counts (2-264.8) for rainy and dry seasons. At all sampling sites except upstream of keha river the Physico-chemical and bacteriological results of water samples were above the Ethiopian and WHO standard limit indicated that Keha River was polluted. The Dissolved Oxygen (DO) deficiency was occurred except upstream of Keha River, at all sites the Dissolved Oxygen (DO) is less than 5 mg/l that is below the WHO and Ethiopian minimum standard limit. Some people of the town used this polluted Keha River for variety of purposes.

The study results indicated that excessive total coliform counts, excessive E.coli counts, high Biological Oxygen Demand, very low dissolved oxygen, high nitrate and phosphate showing pollution from anthropogenic activity. These anthropogenic activities included indiscriminate dumping of waste into Keha River, channeling of raw sewage into the River, open defecation along the banks of Keha River and discharge of untreated effluents into Keha River by the industries. Almost all the measured parameters showed increasing trend from upstream to downstream and deterioration of the water quality. It is therefore concluded that Keha River in the study area is polluted and not fit for domestic use.

5.2. Recommendation

1. Keha River health restoration is require by integrated works with stake holders. Waste management is very important for Keha River restoration therefore avoid open disposal system. It is recommended that immediate actions have to be taken by the concerned authorities to restore the quality of the river by preparing applicable policy, improving the sanitation condition and construct centralized wastewater collection system to control further pollution of surface water resources in Gondar town.

2. It is recommended that there should be a constant update studies looking at the surface water quality and quantity changes as urbanization is increasing in Gondar town because the problem is complex, and therefore the solution is also complex and multi-faceted. Communities living along rivers need to be the key targets for action to mitigate problems related to river pollution programs need to be developed that help the communities take action to improve the condition of rivers. The environmental awareness and the education level of local population should be increased.

3. We Ethiopians even we have a policy, our water resources are under risk to pollution due to weak enforcement policy and inefficient monitoring. There must be continued and consistent monitoring and collection of data to protect our important water resources from pollution and risks. This is crucial for the waste minimization and management of pollution strategies.

4. An Integrated Water Resources Management (IWRM) approach should be used to tackle issues of water pollution. All the stakeholders including the public, communities, interest groups, individuals as well as the government must have the will to participate in tackling the water pollution problem.

5. Finally, from this research I tried to show the quality condition of Keha River and potential sources of pollution. I recommend that further research work to be conducted with in the area by further investigation of the quantity and the remaining quality parameters that may have strong effect on Megech Dam and Lake Tana because Keha River is the tributary of Megech and Megech also inters to Lake Tana.

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Appendix I: Dry Season physicochemical and biological analysis result of Keha River and its tributaries

S No	Parameters	Kh1	Kh2	Kh3	Kh4	Kh5	Kh6	Kh7	Kh8	Kh9
1	Temp ^{0}C	20	20.6	20.8	22	23.8	22.2	23.8	21	20.9
2	EC (mg/l)	187	575	658	745	1018	1029	1054	850	727
3	TDS, mg/l)	127	287	513	892	1158	1162	1187	1058	972
4	pH	7.4	7.6	8.5	8.9	8.85	8.84	8.97	8.7	8.52
5	Turbidity (NTU)	8	74	189	402	693	671	758	654	439
6	Total Alkalinity (mg/l	103	160	172	217	249	278	329	301	293
7	Nitrate (mg/l)	35.4	47	51	68	75.4	79.9	98.4	89.7	73.5
8	Phosphate (mg/l)	1.37	5.9	12.3	23.9	27.4	28.3	30	25.1	11.9
9	Total Hardness (mg/l)	119	152	170.7	185.4	241	264	283	181	157.9
10	Fe mg/L	0.15	0.2	0.25	0.34	0.45	0.52	0.58	0.44	0.4
11	Manganese(mg/l)	0.04	0.7	1	1.3	1.7	2	2.3	2.1	1.2
12	Chromium (mg/l	0.03	0.12	0.2	0.25	0.26	0.28	0.35	0.28	0.21
13	Do mg/l	6	4.4	4	3.5	3.2	3	2.7	2.4	2.2
14	BOD mg/L	4.7	48.1	53	74	97	124.9	143	122	74.9
15	Total coliform per 100ml	3.2				248		373		
16	E.coli per 100ml	2.5				176.5		197.5		

S No	Parameters	FC	HO	DM	BS	KEG
1	Temp ^{0}C	21	24.8	20.7	24.6	24.4
2	EC (mg/l)	624	1231	647	1197	1190
3	TDS, mg/l	1061	1298	1073	1287	1296
4	pH	6.4	8.97	6.4	6.2	6.15
5	Turbidity (NTU)	523	1011	637	985	890
6	Total Alkalinity (mg/l)	254	471	235	182	508
7	Nitrate (mg/l)	32	140.9	53	152.7	150
8	Phosphate (mg/l)	9.7	22.5	14	25.4	29.3
9	Total Hardness (mg/l)	165	240.9	180.5	290	259
10	Fe mg/L	0.35	0.65	0.4	0.46	0.71
11	Manganese(mg/l)	2	3.4	2.2	3.6	3.9
12	Chromium (mg/l	0.23	0.39	0.25	0.38	0.42
13	Do mg/l	3	2.1	2.8	2.8	2.4
14	BOD mg/L	82	201	84	194	217
15	Total coliform per 100ml		470.3		481.5	495
16	E.coli per 100ml		260.8		268	273.8

Appendix II: wet season physicochemical & biological analysis result of Keha River and its tributaries

S No	Parameter	Kh1	Kh2	Kh3	Kh4	Kh5	Kh6	Kh7	Kh8	Kh9
1	Temp ^{0}C	20	20	20.4	22	22.4	22.2	22.6	20	20
2	EC (mg/l)	142	523	612	780	1011	102 2	1043	823	715
3	TDS, mg/l	102	251	443	843	1142	115 0	1172	1034	915
4	pH	7.25	7.5	8.45	8.7	8.72	8.76	8.9	8.56	8.4
5	Turbidity (NTU)	13	104	243	487	732	751	845	725	553
6	Total Alkalinity (mg/l)	89	140	153. 2	193.2	224	253	234	285.2	284.3
7	Nitrate (mg/l)	42	56	70	82	81	98	107	113	94
8	Phosphate (mg/l)	1.45	8	15.5	26.2	30	31.4	32.7	27	14.2
9	Total Hardness (mg/l)	103	135	148	160.4	179	187	195	151	139
10	Fe mg/L	0.2	0.27	0.35	0.4	0.51	0.59	0.65	0.53	0.43
11	Manganese (mg/l)	0.03	0.5	0.8	0.9	1.4	1.7	1.91	2	1.2
12	Chromium (mg/l	0.02	0.09	0.15	0.18	0.22	0.25	0.3	0.25	0.19
13	Do mg/L o2	7.4	5.1	4.5	4.2	4	3.92	3.7	4.25	4.4
14	BOD mg/L	4.1	45	58	69	91.8	121	139.4	119	70.5
15	total coliform (per 100ml)	2.9				239.2		365.5		
16	E.coli (per 100ml)	2				170.2		189.25		

S No	Parameters	FC	HO	DM	BS	KEG
1	Temp ^{0}C	21	23	21	23.9	23.4
2	EC (mg/l)	581	1124	612	1147	1158
3	TDS, mg/l	1020	1265	103 0	1232	1247
4	pH	6	8.9	6	5.9	5.9
5	Turbidity (NTU)	581	1072	659	1023	987
6	Total Alkalinity (mg/l)	219	345	213	153.4	448
7	Nitrate (mg/l)	44	153.5	67	169	178
8	Phosphate (mg/l)	13	25	17	28.9	32.7
9	Total Hardness (mg/l)	157	224	172	218.7	183
10	Fe mg/L	0.38	0.69	0.44	0.5	0.76
11	Manganese(mg/l)	1.5	2.8	2	3.2	3.5
12	Chromium (mg/l	0.21	0.36	0.22	0.37	0.38
13	Do mg/l	3.5	2.4	3.2	2.8	3
14	BOD mg/L	78	194.2	80.5	190	212
15	total coliform (per 100ml)		459		472	491.2
16	E.coli (per 100ml)		252		255	259.2

Appendix III: Drinking Water Quality Standards

Parameter	Unit	Ethiopian standard	WHO Guideline value 1993
Electrical conductivity	µS/cm	-	500
Turbidity	NTU	5	5
Color Unit	TCU	15	15
Odour and Taste		unobjectionable	unobjectionable
Calcium (as Ca)	mg/l	75	
Magnesium (Mg)	mg/l	50	
Sodium(Na)	mg/l	200	200
Aluminum(Al)	mg/l	0.2	0.2
Zink (Zn)	mg/l	5	5
Chloride(as Cl)	mg/l	250	250
Copper (as Cu)	mg/l	2	2
Fluoride(as F)	mg/l	1.5	1.5
Sulphate (as SO4)	mg/l	250	250
Ammonia (NH3)	mg/l	0.1	1.5
Iron (Fe)	mg/l	0.3	0.3
Manganese (Mn)	mg/l	0.5	0.1
Magnesium (Mg)	mg/l	50	
pH	pH meter	6.5-8.5	6.5-8.5
Total alkalinity(TA)	mg/l	200	200
Nitrate (NO3)	mg/l	50	50
Chromium(as Cr)	mg/l	0.05	0.05
Total Coliform	N/100ml	0	0
E. Col	N/100ml	0	0

Appendix IV: Guidelines of some physicochemical parameters for stream water (EEPA, 2003)

Parameters	Ambient Environmental standard
BOD5	≤5 mg/l
COD	≤150 mg/l
EC	100 - 1000µS/cm@20^0C
NH3-N	≤ 0.025 mg/l
NO3-N	≤ 10 mg/l
Temperature	5 - 30^0C
PH	6.0 - 9.0
$SO4^{2-}$	≤ 200 mg/l
$PO4^{3-}$	≤ 0.005 mg/l
DO	≥4 mg/l
TSS	≤ 50 mg/l

AppendixIIV: Phisio-chemical and biological analysis of Central Gondar Water and Energy department Keha River in 2003

S No	Parameters	upstream	Middle stream	downstream	Hospital outlet	Bisnit outlet	Maraki outlet
1	Temp ^{0}C	19	21	20	20	21	21
2	Conductivity (mg/l)	117	302	351	445	579	620
3	TDS, (mg/l)	78.5	151	179	169	286	250
4	pH	7.13	7.5	7.4	7.6	7.8	7.8
5	Turbidity (NTU)	5.5	22	34	57	65	364
6	Total Alkalinity (mg/l CaCO3)	82	136	130	128	59	226
7	Nitrate (mg/l	23	84	73	90	94	89
8	Phosphate (mg/l)	1.2	18.5	11	15	18	13
9	Total Hardness (mg/l caco3)	98	116	120	101	185	249
10	Fe mg/L	0.21	0.25	0.3	0.26	0.6	0.26
11	Do mg/L o2	9	7.4	6.5	5.4	5.3	6.8
12	BOD mg/L	3	54	82	116	102	94
13	total coliform per 100ml		94	61	186	324	287
14	E.coli per 100ml	91	52	104	133	98	

(Source: Gondar water irrigation and energy department water quality laboratory, 2003)

Appendix IIIV: Questionnaire for Industries and Institutions

This questionnaire was used to get the information on the type of wastes that were being produced by an institution or industry (public or private) in the area under study. It was also meant to find out if the institutions were aware of the importance of proper waste disposal by asking mechanisms in place for waste disposal. The information collected would be used by Amsalu Alemu for the purpose of the study of Msc. in Water supply and Environmental Engineering at the Addis Ababa University, Addis Ababa institute of Technology, school of Civil and Environmental Engineering.

The information would be divulged to nobody else. The respondent was to fill or answer orally.

1. Name of Industry/Institution…………………..

2. What activities are carried out in this industry?........................

3. What type of wastes do you generate in your industry?................

4. State the kinds of raw materials that are used in this industry……..

5. How is the waste disposed of?..

6. Do the wastes end up in a nearby water body? Explain the channel….

7. What measures do you take to avoid the entry of wastes into the river?....

8. Any toxic substances used or produced in your industry?............

9. Any technology in place to avoid or reduce the production of toxic/harmful substances in your industry?

10. Are women involved in the issue of Health, Safety, Security and Environment (HSSE) in your organization?..

Appendix V: Erosion and sedimentation affects Keha River