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SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

SPATIAL MAPPING OF WATER QUALITY LEVEL IN KEBENA RIVER

A Thesis in Water Supply and Environmental Engineering

By

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A Thesis

Submitted in partial Fulfillment of the requirements for the Degree of Master of Science

The undersigned have examined the thesis entitled '**SPATIAL MAPPING OF WATER QUALITY LEVEL IN KEBENA RIVER**' presented by **ZENASH MULUALEM**, a candidate for the degree of **Master of Science** and hereby certify that it is worthy of acceptance.

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DECLARATION

I certify that research work titled "**SPATIAL MAPPING OF WATER QUALITY LEVEL IN KEBENA RIVER**" is my own work. The work has not been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged / referred.

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ABSTRACT

In Ethiopia, most wastewater effluent is directly released in to rivers. Kebena River is one of the rivers, which is affected by municipal wastewater generated from different households, hospitals, hotels of Addis Ababa city. The study was conducted to evaluate and map water quality status of Kebena River from upstream (Entoto) up to the downstream (Saris Abo). Water quality index was used to analyze the overall water quality status. The water quality index was determined by considering 11 parameters at 28 station (i.e. total of 308) tastes were obtained. The outcome of the study showed that two sample points at the upstream part of the river is relatively in good conditions. Three out of the twenty-eight sample points have acceptable quality and the remaining sites have shown unsuitable result.

Laboratory result for each(11) parameter indicates that the range of PH(6.35-7.67mg/l), Electricconductivity(433_1425us/cm),Totalcoliform(22_2292mg/l),Dissolvedoxgen(0.1_4.4mg/l),COD(12_649mg/l),Nitrite(<0.0001_20.3mg/l),lead(0_0.00838mg/l),chromium(0_0.2608mg/l),manganese(0.1792_4.8436mg/l) ,reactive phosphors(2.3_75.1mg/l) and Total coliform(22_2952mg/l). At all sampling sites except upstream of kebena river the Physico- chemical, Heavy metals and bacteriological results of water samples were not fulfill the Ethiopian and WHO standard limit

The critical sources of pollutions are toilets from households, hospitals, a lot of hotels and restaurants among others. And also to the rivers in the city there is a constant addition of storm water. As the wastewater from many households is disposed directly to the storm water system are leads to a constant addition of domestic waste water. Solid waste and human faeces are present everywhere in and around the river.

It is therefore concluded that the river in the study area is highly polluted and not fit for domestic use. It is recommended that the water of Kebena River should not be used directly for domestic purposes and also Kebena River health restorative work is require for multiple importance such as ecosystem regeneration, water quality improvements, reduce any negative impacts on the water resources.

Keywords: Physicochemical parameters, Water Quality Index, Ethiopian effluent guideline

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ABBREVIATIONS AND ACRONYMS

BOD_5---------------------------------------Biological Oxygen Demand

COD--------------------------------------- Chemical Oxygen Demand

DO-- Dissolved Oxygen

TSS-- Total Suspended Solids

TDS-- Total Dissolved Solid

EC--------------------------------------- - Electric Conductivity

GPS---Geographical Position System

GIS-- Geographical Information System

EMDHS --------------------------------The Ethiopia Mini Demographic and Health Survey

WHO------------------------------------- World Health Organization

EMS-------------------------------------- Environmental Management System

EEPA------------------------------------ Ethiopian Environmental Protection Authority

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CHAPTER 1 INTRODUCTION

1.1 Background

Rivers are large natural stream of water emptying into an ocean, lake, or other bodies of water and usually fed along its course by converging tributaries. Although they contain only about 0.0001% of the total amount of water in the world at any given time, rivers are vital carriers of water and nutrients to areas all around the earth (Wetzel, 2001).

Pollution of river bodies has become a major and global problem that is more critical in developing nations of the world. The inadequacy existing sanitation practices and lack of proper protection measures has highly contributed to such problems. In most urban development, lagoons, rivers, and streams are considered to be sinks for wastes. Wastes are discharged into the receiving water bodies with little or no regard to their assimilative capacities. With over 70% of the planet covered by oceans, it is erroneous to believe that these bodies of water could serve as a limitless dumping ground for wastes, but it is not so. However, discharges of raw sewage, garbage, as well as oil spills are threats to the diluting capabilities of the oceans, lagoons, and rivers in major cities while most coastal waters are grossly polluted (Krantz, D. and B. Kifferstein 2005)

According to the world commission on water for the 21st century, more than half of the world's major rivers are depleted and contaminated. As a result, they threaten human health and poison the surrounding ecosystems (Nyasulu, 2010). Contaminated drinking water can cause various diseases such as typhoid fever, cholera and other intestinal diseases (Danquah, 2010). The problem is more pronounced in developing countries, where about 1.8 million people, mostly children, die every year because of water-related diseases (WHO, 2016).

Rivers are often at the center of urban development due to the many services they provide (Cohn 1998). As a city grows bigger, the environmental pressure on its local rivers increases, especially if the city does not have the resources to manage solid waste and wastewater adequately. This is often the case in cities in developing countries, where wastewater from industries and households may be discharged in untreated form to rivers, and where solid waste may accumulate at the course of the rivers (Strandberg, 1971).

These uncontrollable urban changes around the Ethiopian towns can increase 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).

The city of Addis Ababa is one of the fast-expanding cities in the country and presently covers an area of about 540Km^2 of which 18.2 Km^2 are rural (Addis Ababa City Council, 2016).Addis Ababa was established as the capital city of Ethiopia in 1886 and has grown to become the largest urban and commercial center in the country, hosting a population of 3,384,569 according to the 2007 population census with annual growth rate of 3.8%. It is located in the central part of the country surrounded by mountains such as Mt. Enteto in the north (3199m a.s.l.), Mt. Wochacha in the west (3385m a.s.l.), Mt. Furi (2839m a.s.l.) in the southwest and Mt. Yerer (3100 a.s.l.) in the south east(UNEP 2003); at the edge of the Ethiopian Rift with its rivers flowing from north to south. Addis Ababa is the seat of the African Union and other many International organizations. (Alemayehu T, 2001).

The main surface bodies within and in the vicinity of Addis Ababa are basically big Akaki and Little Akaki. The big Akaki River has main tributaries among which Ginfile, Kebena, Kchene, Kurtume and Yeka; all of which are found within the eastern part of the boundaries. The little Akaki river basin covers western part of the city. (Alemayehu T, 2001)

According to the Addis Ababa Rivers & Riverside Project Office, one of the departments of the Addis Ababa Environmental Protection Authority, the River banks and Riversides sites has been regarded as Green Area and will be used for recreation purposes after development; however the strong resistance of the residents including some conflicts has been the obstacle for years (Addis Fortune, 2015). This encroachment contravenes article 44 of the national constitutional environmental right of urban dwellers to live in an area with access to clean and environmentally friendly spaces (House of Peoples Representatives of Ethiopia, 1994).

1.2 Statement of the problem

In Addis Ababa almost all rivers, are polluted by domestic, commercial, and institutional wastes. As stated by Hamere & Eyasu,(2017), there is high habitat degradation and lose in most rivers crossing the city which is more pronounced in Kebena. It is also believed that, for sustainable urban river water resources management and safeguarding the public health, it is very important to effectively and monitor the river water quality periodically. Such practices are lacking in the case of Addis Ababa River. Consequently, quantitative evaluations and spatial variations of river water quality were not in place to date.

Among the main tributaries of rivers that drain the Addis Ababa city, Kebena River is expected to be the most polluted one. This is due to the fact that the river crosses almost all sub-cities (9) and about 58 woredas as in which intensive day to day human activities are practiced. Moreover, the sub-cities are densely populated with expected high production of both solid and liquid wastes. Even though the challenge is very clear in view of waste contribution, none of the previous studies have clearly indicated site specific quantity quantitative values of the waste along the river course.

On the other hand, there is lack of integration and collaboration among different stakeholders and organization for proper waste management in the city (Wassihuni 2018). The case is more challenging in Kebena as there are many competing end users in the entire sub-system. Such issues can presumably be solved by proper identification and mapping of the pollution sources so that appropriate top-down collaboration can be established.

Figure 1-1: Kebena River around Kebena Bridge (18/07/2011 E.C))

1.3 Objectives of the study

1.3.1 General Objective

To map the River water quality of Addis Ababa and propose possible mitigation measures in case of (Kebena River).

1.3.2 Specific Objective

- To determine the water quality level of Kebena River using laboratory analysis
- To determine the overall water quality of Kebena River by using water quality index (WQI).
- To map the water quality of Kebena River using GIS tools.
- To evaluate and propose possible mitigation mechanisms of pollution.

1.4 Research Questions

- What is the water quality of kebena river at each site?
- Does the effluent come from different source have effect on the river quality?
- What are the biological, chemical and physical characteristics of the River water?

1.5 Significance of the study

This study will be conducted to evaluate the water quality of Kebena River and map by using GIS. The result of this study will help to water quality management the River and to take actions on Kebena river water quality degradation. It will be also input for the environmental protection authority, keeping ecosystem of water and surrounding community. The water quality and quantity will gradually be decreasing due to climate change and increase in source of pollution. Therefore, this study will serve as base line information for further investigation of related studies in the future. And also, it tells which area is more polluted on map.

CHAPTER 2 LITRATURE REVIEW

2.1 Over view of river water quality

Water pollution is the pollution of water bodies from contaminants being introduced to the natural environment because of humans' activity. Water pollution is often caused by the discharge of inadequately treated wastewater into the natural bodies of water. This can lead to environmental degradation of aquatic ecosystems. In turn, this can lead to public health problems. For example, people living downstream may use the same polluted river water for drinking or bathing or irrigation. Contaminants leading to water pollution include a wide spectrum of chemicals, pathogens, and physical changes such as elevated temperature (Ogundiran and Fawole, 2014).

In Ethiopia, the effluents directly discharged in to water body. The case of Addis Ababa City, Ethiopia Rivers are highly polluted due to increasing human population, uncontrolled urbanization and inadequate sanitation infrastructure and system. The main cause of this pollution is domestic waste, industrial as well as hospital wastes from point and non-point sources (Elias 2017).

There are many types of water pollution because water comes from many sources. Pollution is generally induced by humans. It results from actions of humans carried on to better self. These could be treated under the various activities that man engages in, that lead to pollution. The growth of human population, industrial and agricultural practices is the major causes of pollution. (Eguabor.v 1998).

In Kebena river, there is also organic pollution from domestic, commercial, agricultural and institutional wastes and residential pollutant sources were the main cause of pollution for Kebena River followed by institutional and agricultural sources as reported by Alemayehu et al. and Beyene et al. [3,30].

Surface and groundwater have often been studied and managed as separate resources, although they are related (United States Geological Survey (USGS), 1998). Surface water seeps through the ground and becomes groundwater. On the contrary, groundwater can also feed surface water sources. Sources of surface water pollution are generally classified by origin into two categories

2.1.1 Point source

Water pollution at point sources refers to pollutants emitted by a single identifiable source, such as a pipeline or ditch, entering a water channel. Examples of sources in this category are discharges from a wastewater treatment plant, a factory or an urban storm water runoff. The Clean Water Act of the USA defines the point sources for the application. CWA's definition of the point source was modified in 1987 to include urban rainwater and industrial rainwater, such as construction sites.

2.1.2 Non–point Sources

Non-point source contamination refers to diffuse contamination that does not originate from a single discrete source. NPS contamination is often the cumulative effect of small amounts of pollutants collected over a large area. Contaminated rainwater carried from parking lots, roads and highways, called urban runoff, is sometimes included in the pollution category by NPS. However, this effluent is normally directed to drainage systems and is channeled to local surface waters and is a point source. However, when such water is not channeled and drained directly to the bottom, it is a non-point source.

2.2 Types of pollutant

2.2.1 Pathogens

Pathogens can be bacteria, protozoa or viruses. Bacteria, for example, are commonly found in water; it is when they start to increase in numbers that are above safe levels that contaminant occurs. Two of the most common pathogenic bacteria are coliform and E- coli bacteria. Coliforms are normally present in the environment in safe level and can actually be used to detect other pathogens in water. However, if coliforms increase in number, they can be dangerous for the health of the environment. The presence of E-coli bacteria usually indicates that water has been contaminated with human or animal waste (B.T. Alo 2018).

2.2.2 Inorganic Material:

Inorganic material particular heavy metal like arsenic, mercury, copper, chromium, zinc and barium through harmless in very small concentrations, act as pollutants when they end up concentrated in water. This can be due to leaching from waste disposal, increased human activity or industry accidents this kind of water pollution, especially in higher concentrations, can cause severe health problems in humans and other organisms, up to and including death. (B.T.Alo 2018).

2.2.3 Organic Material

Organic materials contain molecules that have carbon in there make up. One of the most frequently detected volatile organic chemicals was methyl tert-butyl ether (MTBE).MTEB was formulated used as an air-cleaning gas additive. Although it is now a banned chemical, it will take year before MBTE is thoroughly removed from contaminated water systems. Water contamination with organic chemical can cause leukemia, lymphoma and tumors in the testicles, thyroid gland and kidneys.(B.T.Alo 2018).

2.2.4 Macroscopic pollutants:

Macroscopic pollutant is large, visible items in waterways or bodies of water. The first common pollutant is trash: especially plastic wastes. Plastic wastes is often thrown directly in to large bodies of water illegally, but can also end up collecting in oceans and lakes after being deposited in stream and rivers by accident. Other types of macroscopic pollution include nurdles (small plastic pellets), pieces of wood, metal, and even obvious things like shipwrecks and shipping containers. This form of water pollution is arguably the most manageable; however, it is an urgent environmental issue that his large pollutant be removed in order to avoid disruption of aquatic ecosystems and contamination upon the chemical break down of these objects.(B.T.Alo 2018).

2.3 The Main Sources of Contamination River in Addis Ababa

2.3.1 Industrial wastes

Addis Ababa is home to more than 2,000 industries which comprises 65% of all industries in the country and most of them located along the river banks which are mostly found in the western and southern parts of the city and discharge these effluents directly to the river, as much as 90% of these industries do not have any kind of treatment plant and discharge their solid, liquid and gaseous wastes untreated into the environment. Others have some degree of on-site treatment plant, and subsequently discharge effluents into adjacent streams. Rivers in Addis Ababa are contaminated with heavy metals due to different industrial waste, therefore depositing solid and liquid wastes dangerous substances in rivers and river side’s. (Yohannes H, Elias E 2017)

2.3.2 Municipal wastes

Despite generating large amounts of solid waste from domestic activities, Addis Ababa does not have adequate waste management facilities. As a result, solid waste is often piled on available open grounds, stream banks and near bridges, where it is washed off into rivers. The Ethiopia Mini Demographic and Health Survey (EMDHS) showed has been a common practice in Addis Ababa. That only 4.5% Percentage of population with access to flush toilet, ventilated improved pit latrine in 2014. And 65% of the societies have pit latrine. 25% of the city’s residence do not have toilet. As a result, the residents use the river as toilet. In addition, houses that are built at the edges of the city’s rivers link their toilets directly to them. Therefore, status of river pollution is increasing as time elapsed. Therefore, the city’s rivers are lacking aquatic animals and plants (aquatic diversity). Moreover, most of the residential houses, service giving institutions, commerce and the like have directly linked their liquid waste systems including their latrines and septic tanks to the main rivers and their tributaries without any treatment. Furthermore, most of the river surrounding of the city are occupied by illegal settlers and quarry developers.(Yohannes H, Elias E 2017)

2.3.3 Medical waste

A study by FEPA found that 430.7 tons of contagious waste is generated by the 29 hospitals located in Addis Ababa. Examples of the contagious clinical waste include laboratory cultures, wound dressings, blood and other body fluids, and needles. Although most of the hospitals have waste treatment facilities, some of the clinical waste finds its way into the nearby streams that are tributaries.(Yohannes H, Elias E 2017)

2.4 Water quality parameters

Water quality testing is an important part of environmental monitoring. When water quality is poor, it affects not only aquatic life but also the surrounding ecosystem as well. The parameter that affects the quality of water in the environment can be physical, chemical or biological factors. Physical property of water quality includes Temperature, Transparency, Turbidity and Odor. Chemical characteristics involve parameter s such as PH, Electrical conductivity (E.C), Total Solid(TS),TotalDissolved solid(TDS), TotalHardness, Dissolved Oxygen(DO),Biological Oxygen Demand(BOD),Chemical Oxygen, Demand(COD).Biological indicators of water quality include algae and phytoplankton.(Foundamentals of Enviromental Mesurments 2016).

Temperature

Temperature affects all water uses; the solubility of gases such as oxygen and CO_2decreases as water temperature increases; Biodegradation of organic material in water and sediments is accelerated with increased temperatures, increasing the demand on DO. Fish and plant metabolism depend on temperature most chemical equilibrium are temperature dependent. Important environmental examples are the equilibrium between ionized and unionized forms of ammonia, hydrogen cyanide, and hydrogen sulfide. Temperature regulatory limits are set to maintain a normal pattern of diurnal and seasonal fluctuations, with no changes deleterious to aquatic life. Maximum induced change is limited to a 38 °C increase over a 4hr period, lasting for 12hr maximum. (WeinerE.R 2007)

PH

Acidic, basic, and neutral water solutions are measured by a quantity called PH. As shown below, PH is a measure of the hydrogen ion (H^+) concentration in water solutions. Hydrogen ions arise in water from dissociation of the water molecules themselves or from dissociation of other molecules containing hydrogen that are dissolved in water. (WeinerE.R 2007)

Dissolved oxygen (DO)

Sufficient dissolved oxygen (DO) is important for high-quality water. DO is crucial for the survival of fish and most other aquatic life forms. It oxidizes many sources of objectionable tastes and odors. Oxygen becomes dissolved in surface waters by diffusion from the atmosphere and from aquatic–plant photosynthesis.

On average, most oxygen dissolves into water from the atmosphere; only a little net DO is produced by aquatic–plant photosynthesis. Although water plants produce oxygen during the day, they consume oxygen at night as an energy source. When they die and decay, dead plant matter serves as an energy source for microbes, which consume additional oxygen. The net change in DO is small during the life cycle of aquatic plants.(WeinerE.R 2007)

Chemical oxygen demand (COD)

Chemical oxygen demand (COD) refers to the amount of oxygen consumed when all the organic matter in a given volume of water is chemically oxidized to CO^2 and H_2O by a strong chemical oxidant, such as permanganate or dichromate. COD is sometimes used as a measure of general pollution. For example, in an industrial area built on fill dirt, COD in the groundwater might be used as an indicator of organic materials leached from the fill material. Leachate from landfills often has high levels of COD.(WeinerE.R 2007)

Biological oxygen demand (BOD)

Biological oxygen demand (BOD) refers to the amount of oxygen potentially consumed if all the biologically degradable organic matter in a given volume of water were biodegraded. BOD is an indicator of the potential for a water body to become depleted in oxygen and possibly become anaerobic because of biodegradation. BOD measurements do not take into account Re-oxygenation of water by naturally occurring diffusion from the atmosphere or mechanical aeration. Water with a high BOD and an active microbial population can become depleted in oxygen and may not support aqua tic life, unless there is a means for rapidly replenishing DO. (WeinerE.R 2007)

Total suspended solids (TSS)

Total suspended solids (TSS, sometimes called filterable solids) in water are organic and mineral particulate matters that do not pass through a 0.45mmfilter. They may include silt, clay, metal oxides, sulfides, algae, bacteria, and fungi. TSS is generally removed by flocculation and filtering. TSS contributes to turbidity, which limits light penetration for photosynthesis is and visibility in recreational waters. (WeinerE.R 2007)

Total dissolved solids (TDS)

Tot al dissolved solids (TDS); sometimes called non-filterable solids) are substances that will pass through a 0.45 mm filter. If the water passed through the filter is evaporated, the TDS will remain behind as a solid residue. TDS may include dissolved minerals and salts, humic acids, tannin, and pyroxene. TDS is removed by precipitation, ion exchange, and RO. In natural waters, the major contributors to TDS are carbonate, bicarbonate, chloride, sulfate, phosphate, and nitrate salts. Taste problems in water often arise from the presence of high TDS level s with certain metals present, particularly iron, copper, manganese, and zinc.(WeinerE.R 2007)

Hardness

Originally, water hardness was a measure of the ability of water to precipitate soap. It was measured by the amount of soap needed for adequate lathering and served as an indicator of the rate of scale formation in hot water heaters and boilers. Soap is precipitated as a gray ‘‘bathtub ring’’ deposit mainly by reacting with the calcium and magnesium cations (Ca 2þ and Mg 2þ) present, although other polyvalent cations may play a minor role. (WeinerE.R 2007)

Coliform

The five indicator species most commonly used are total coliforms, fecal coliforms, Escherichia coli (E. coli), fecal streptococci, and enterococci. All are bacteria normally present in the intestines and feces of warm-blooded animals, including humans. All but E. coli consist of groups of bacterial species that are similar in shape, habitat, and behavior. E. coli is a single species within the fecal coliform group. Some strains of E. coli are pathogenic but the other indicators are usually not pathogens and do not pose a danger to humans or animals. However, if any of the indicators are present in water; the accompanying presence of a dangerous population of enteric pathogens is a possibility. All the indicator species are easier. (WeinerE.R 2007)

Nitrite

Nitrite is an intermediate in the oxidation of ammonia to nitrate. Many effluents, including sewage, are rich in ammonia, which in turn can lead to increased nitrite concentrations in receiving waters. Therefore, high levels of nitrite in river waters may indicate pollution. This form of nitrogen can be used as a source of nutrients for plants and its presence encourages plant proliferation. Nitrite is also toxic to aquatic life at relatively low concentrations. In unpolluted waters, nitrite levels are generally low (<0.01 mg/l N). Nitrite is normally determined using spectra photo metric methods and may be reported as mg/l N or NO_2. The following conversion factor applies:

Phosphorus

Phosphorus (P) is generally considered to be the limiting nutrient for plant growth in freshwater with small quantities occurring naturally mainly from geological sources. Phosphorus in natural waters & wastewaters is usually found in the form of phosphates (PO_4^3).

Lead

Lead, a metal found in natural deposits, is a highly toxic metal that was used for many years in products found in and around homes (Chino, 1981). Lead is among the most recycled non-ferrous metals and its secondary production has therefore grown steadily in spite of declining lead prices. Its physical and chemical properties are applied in the manufacturing, construction and chemical industries. Acute effects of lead are inattention, hallucinations; delusions, poor memory, and irritability are symptoms of acute intoxication. Lead absorption in children may affect their development and also results in bone stores of lead.

2.5 Ethiopian Guidelines for Ambient Surface Water Quality Standards

The government of Ethiopia has mandated the Ethiopian Environmental Protection Authority (EEPA) to set such standards and Guideline Ambient Environment Standards for Ethiopia (GAESE) represents the guideline standards with respect to the ambient environment. In practice, standards can be set from either first principles or based on the existing national or international guidelines. Driving such standards from first principle requires classification, and prioritization of pollutants, derivation of pollutant exposure processes and their ecological effects. Since these processes require resource to derive country specific standards from the first principle, the EEPA standards are generally derived based on the exiting published standards of WHO, UNEP, ANZECC, EEC and others. The information upon which our national guidelines are based are derived predominantly from extensive epidemiological and toxicological studies to determine the observed health and environmental effects of a pollutant in question (EEPA, 2003). If there were sufficient national baseline information available, the guideline values prepared by the international bodies might be further modified to take account of particular national criteria prior to their implementation as a national standard. Thus, additional national baseline data collection shall be undertaken to improve the initial standards to own country situation.

Baseline national surface water quality data is important for the implementation of EPA's environmental quality standards. Nevertheless, there is currently insufficient baseline data available within Ethiopia to allow modification of guidelines for ambient surface water quality standards (EEPA, 2003). As such, the guideline standards for surface water quality have been adopted directly as recommended for developing countries. The EEPA surface water quality guideline standards (Table: 2-1) are being introduced to be used all throughout the county subjected to amendments, as more information on the state of water pollution is made available through the Ecological Sustainable Industrial Development (ESDI) project. The regional states can also establish more stringent standards taking into consideration particular ecological conditions in their localities provided EPA's standards are used as the minimum (EEPA, 2003).

The guideline standards for surface water primarily aimed of ambient surface water quality within all components of Ethiopia (EEPA, 2003).

The guideline standards provided in the GAESE document of the EEPA are not based on water use criteria (water for abstraction, as a source of drinking water or for irrigation purposes). Moreover, the WHO guidelines are brought to observe the extent of pollution of the river water samples collected in this study.

Table 2-1: 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 SO_4)	mg/l	250	250
Ammonia (NH_3)	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

Table 2-2: Guidelines of some physicochemical parameters for stream waters (EEPA, 2003).

Parameters	Ambient Environmental standard
BOD_5	≤5 mg/l
COD	≤150 mg/l
EC	100 - 1000µS/cm@200C
NH_3-N	≤ 0.025 mg/l
NO_3-N	≤ 10 mg/l
Temperature	5 - 300C
PH	6.0 - 9.0
SO_4^{2-}	≤ 200 mg/l
PO_4^{3-}	≤ 0.005 mg/l
DO	≥4 mg/l
TSS	≤ 50 mg/l

2.6 Impacts of River pollution

2.6.1 Environmental impact

Pathogens, organic compounds, synthetic chemicals, micro-plastics, nutrients and heavy metals are some elements that pollute fresh water. Unregulated discharge of wastewater undermines biological diversity, natural resilience and the capacity of the planet to provide fundamental ecosystem services. Addis Ababa City Rivers highly affected by pollution and has significant impact on macro-invertebrates' composition since water quality deteriorates. The contamination of surface water by heavy metals is a serious ecological problem as many heavy metals such as Hg, As, Pb, Sb, Ni, Sr and Cd are toxic even at low concentrations. They are non-degradable and can accumulate in the human body and causing damage to nervous system and internal organs. Though some metals such as Cu, Fe, Mn and Zn are essential as micronutrients for living organisms, they can be detrimental to their physiology at higher concentrations. Heavy metal affects highly the water biota. Anthropogenic sources of heavy metal are associated mainly with industrial and domestic effluents, surface runoff, landfill leachate, mining of coal and ore, atmospheric sources and inputs from agricultural activities.

As surface and groundwater are intimately linked to each other, there might be leakage from the highly polluted River. In the area, where large-scale industries have been

expanding, pollution due to disposal of untreated industrial waste seems to be forth coming. Different studies point out that quality of surface water is affected by waste disposal and these would have also potential impact on the quality of groundwater.
Another environmental effect of the pollution of the water sources of Addis Ababa is Eutrophication. Caused by excessive use of phosphorous and nitrogen in agriculture, and effluents from sewerage and pit latrines and municipal wastes, Eutrophication causes growth of algae and weeds, which deplete the oxygen level of the water bodies, and in turn affect aquatic fauna and flora.(Yohannes H, Elias E 2017).

2.6.2 Social impact

Industries are contributing to the loss of the well-being of society and are one of the causes for society's health problems. In principle development activities of a country are meant to make the lives of citizens better off. But if the benefits people get out of development activities such as the development of industries is overwhelmed by the problems they face, it is considered as undesirable to society. The harmful industrial waste liquids when mixed with rivers and streams endanger public health through different uses.

Heavy metal has a capacity to accumulate in the food web especially in fishes and vegetables and threat living organisms. The number of researches has so far been conducted in vegetable grown in polluted soil and irrigated by waste water in Addis Ababa and the results shows that the vegetables have a capacity to accumulate large concentration of heavy metals above the recommended maximum limit. large number of people use the water to water their livestock and for other household purposes.(Yohannes H, Elias E 2017).

2.6.3 Economic impact

Polluted water bears two kinds of economic costs: Firstly, pollution reduces the total amount of adequate water available for household consumption or agricultural and industrial usage. Thus, there are economic costs of water held back from supply. Secondly, there are costs related to the use of polluted water for consumption and production. The costs of using contaminated water for production refer to the decrease in both quality and quantity of products. In Africa, due to water Pollution and lack of sanitation, the overall economic loss is estimated to be 5% of the gross domestic product (UNESCO, 2009).

2.7 Models used for mapping

2.7.1 GIS as Decision Making Tool

Geographic Information System (GIS) has the capability for capture, storage, manipulation, analysis and retrieval of multiple layer resource information occurring both in spatial and non-spatial forms (Mishra, P.C. and Patel, R.K 2001).GIS can act as a powerful tool for modeling water quality. Various Thematic maps which are helpful understanding and managing water resources can be prepared with the use of GIS. (Bindu Bhatt and Janak P. Joshi 2012).

Mapping the water quality parameters using the decision support system like GIS, can be useful for taking quick decisions as graphical representation would be easy to facilitate policy makers in taking a decision. A spatial decision support system (SDSS) is a computer-based system design to assist the decision system. Typically, such a system will include spatial data relevant to the decision, analytic tools to process the data in ways meaningful for decision makers, and output or display functions. Geographical information system (GIS) is an information system that is specially designed for handling spatial (or geographical) data.GIS has advantage of handling attribute data in conjunction with spatial features, which was totally impossible with manual cartography analysis. it combines a set of international software components that create, edit, manipulate, analysis and display data both in text and graphics forms (Kumar 2003).

2.7.2 Description about Water quality index

Water quality index is a unit less number varies between zero and 100-ahigher index value represents good water quality. There for numerical index is used as a management tool in water quality assessment (Shah and Joshi, 2017). WQI basically, acts as a mathematical tool to convert the bulk of water quality data in to a single digit, cumulatively derived, and numerical expression indicating the level of water quality. Water quality index combines several important water quality parameters that give an overall index of the water quality for a specific use. Although WQI has the potential to summarize complex scientific information on the water quality in to a simpler form for assessment, communication and reporting purposes, there are merits and demerits of using WQI approach.

Water quality index (WQI) is one of the most effective tools to aggregate and communicate information on the quality of water to the concerned citizens and policy makers (Puri et al., 2011). It numerically summarizes the information from multiple water quality parameters into a single value that can be used to compare data from several sites and months. The use of WQI simplifies the results of analysis related to a water body as it aggregates in one index of all parameters analyzed (Warhate and Wankar, 2012). A water quality index is a means to summarize large amounts of water quality data into simple terms (e.g., good) for reporting to management and the public in a consistent manner. Similar to the ultra violet (UV) index or an air quality index, it can tell us whether the overall quality of water bodies poses a potential threat to various uses of water, such as habitat for aquatic life, irrigation water for agriculture and livestock, recreation and aesthetics, and drinking water supplies. WQI is a set of standards used to measure changes in water quality in a particular river reach over time and make comparisons from different reaches of a river. A WQI also allows for comparisons to be made between different rivers. This index allows for a general analysis of water quality on many levels that affect a stream's ability to host life (Ashwani Kumar and Anish Dua 2008).

Advantages of Water quality index

- WQIs can be used to show water quality variation;
- Provide a simple, concise and valid method for expressing the significance of regularly generated laboratory data;
- Aid in the assessment of water quality for general uses;
- Allow users to easily interpret data with respect to certain parameters;
- Can identify water quality trends and problem areas based on selected variables;

- Improve communication with the public and increases public awareness of water quality conditions;
- Assist in establishing priorities for management purposes

Limitations of water quality index

- Proved only a summary of the selected parameters;
- Cannot provide complete information on water quality;
- Cannot evaluate all water quality risks;
- Can be subjective and biased in their formation;

2.8 Previous Studies on Addis Ababa River

River pollution is one of the main problems in Addis Ababa; there are different cases for the pollution like waste from House, Industry, Hospitals, hotels, schools and so on. Some studies that had conducted in different rivers found in different part of Addis Ababa shown that there was high river pollution problems in the city and some of them are reviewed in this section.

Table 2-3: Investigation of The Ionic Composition of Addis Ababa Drinking and Surface Water by Abrham G/kidane, 2000

		PH	COD	HCO_3	NO_2	NO_3	SO_4	Cl	PO_4	S	SiO_2	F
Kebena	Up stream	6.1	14.4	6	ND	531	23	9	ND	ND	27	0.6
	Mid stream	7.2	27.2	220	0.05	188	20	106	ND	ND	34	0.8
	down stream	7.6	20	122	0.35	9	9	32	2.1	2.1	34	0.24

Table 2-4: physicochemical and bacteriological analysis of some selected sites from kebena river and its pollution status in Addis
Ababa by Efrem Benito Salam,2016

		PH	Tempreture	Turbidity	DO	BOD	Conductivity	TDS
Kebena	Up stream	4.6	17	<5	4.29	1.5006	44.06	40.43
	Mid stream	1.8	18	<5	6.91	0.6002	110.1	71.25
	down stream	21	21	<5	0.05	6.002	642	640

Table 2-5: Contamination Of River and Water Reservoirs in and Around Addis Ababa City and action on combat it, by Hamera Yohanise and Eyasu Eliyas.2017

		PH	Na mg/l	Ca mg/l	Mg mg/l	PO_4 mg/l	NO_3 mg/l	COD mg/l	Cr	Mn	Ni	Zn	AS	Pb
Kebena Stream	Up stream	6.08	15	6	15	Nd	531	14.4	0	12.3	0	0	1.24	0
	Near German Embassy	7.22	74	21	67	Nd	188.14	27.2	0	6532	0	0	0	0
	Near Ureal Church	7.48	28	17	36	2.09	8.96	20	0	1219	0	0	0.59	0

Table 2-6: Storm Water impact on Water quality of rivers subjected to point source and urbanization-the case of Addis Ababa, Ethiopia by D. Adugna et al.2018

		DO	PH	Turbidity	NO_2	NO_3	NH_4	PO_4	Cr	Mn	Cu	Zn
Shegole	Dry Sesson	0.18	7.8	239	0.9	2.39	2.56	45.55	0.021	0.37	0.07	0.32
Little Akaki		3.16	7.9	35	2.74	1.31	2.24	20.97	0.071	0.32	0.01	0.09
Jemo		2.49	8	54	2.62	1.46	3.16	41.46	0.063	0.59	0.02	0.1
Shegole	wet sesson	5.43	8.2	376	5.37	1.88	0.97	14.77	0.055	0.043	0	0.05
Little Akaki		7.29	8.3	661	10.26	2.05	0.75	8.92	0.06	0.058	0.01	0.07
Jemo		5.16	8.5	302	11	2.36	1.76	16.55				

Table 2-7. The impact of uncontrolled west disposal on surface water quality of Addis Ababa, by Tamiru Alemayehu, 2001

		PH	Na mg/l	k mg/l	Ca mg/l	Mg mg/l	HCO_3 mg/l	SO_4 mg/l	PO_4 mg/l	NO_3 mg/l	SiO_2 mg/l	COD mg/l	Cr	Mn	Ni	Zn	AS	Pb
Kebena stream	Up stream	6.08	15	6	15	5	6.1	23	Nd	531	27	14.4	0	12.3	0	0	1.24	0
	Near German Embassy	7.22	74	21	67	35	219.7	19.7	Nd	188.14	34.1	27.2	0	6531.6	0	0	0	0
	Near Ureal Church	7.48	28	17	36	15	122.04	9.26	2.09	8.96	33.6	20	0	12.19	0	0	0.59	0
Kolfe Stream	Minch saloon	6.1	31	3	25	12	57.96	Nd	0.13	86.19	55.5	8	0	34.1	44.5	0	0	0
	Near Kera	7.68	76	28	53	26	219.7	8.3	3.65	23.51	32.9	80	5.5	123	9.2	0	0	0
	Near Behere Tsiga	7.51	90	24	50	23	176.7	0.44	3.03	9.66	16.23	24	14.1	1756.7	4.8	0	2.3	0
Kechene stream	Up stream	6.5	12	7	7	3.6	18.31	10.2	0.29	99.6	25.2	16.5	5.76	63.115	0	54.21	1.005	7.873
	Near Ras Mekonene Bridge	7.63	45	24	43	24	152.6	22.11	3.54	17.3	47.3	46.12	0	1141.6	0	0	0.126	0
	Near Zewditu Hospital	7.6	44	23	44	23	158.7	24.11	3.78	9.53	47.08	40	0	1550.8	0	81.53	0.096	0

CHAPTER 3 MATERIAL AND METHODOLOGY

3.1 Description of the Study Area

3.1.1 Location

Kebena River is located within the northern part of Addis Ababa, Ethiopia. The latitude and longitude demarcations of Kebena is 8°55'59.99" N and 38°46'59.9" E respectively above (to the North of) the Equator. The estimate terrain elevation above sea level is 2162 meters. The River is one of the six rivers crossing Addis Ababa that are tributaries of the big rivers of Akaki Teleku and Akaki Teneshu, both of which flow to the Aba Samuel Reservoir (T.Alemayehu 2001).

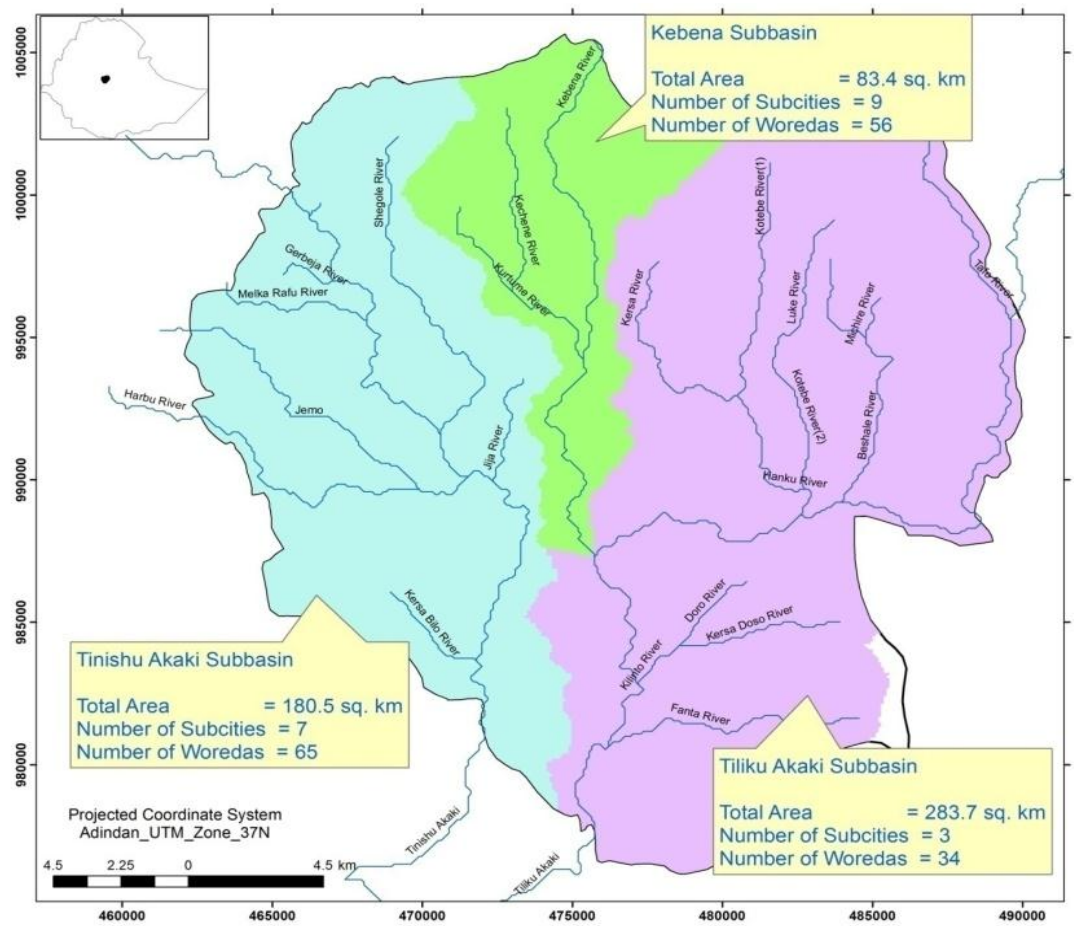

Figure 3-1**:** Addis Ababa Rivers and River Basin Map

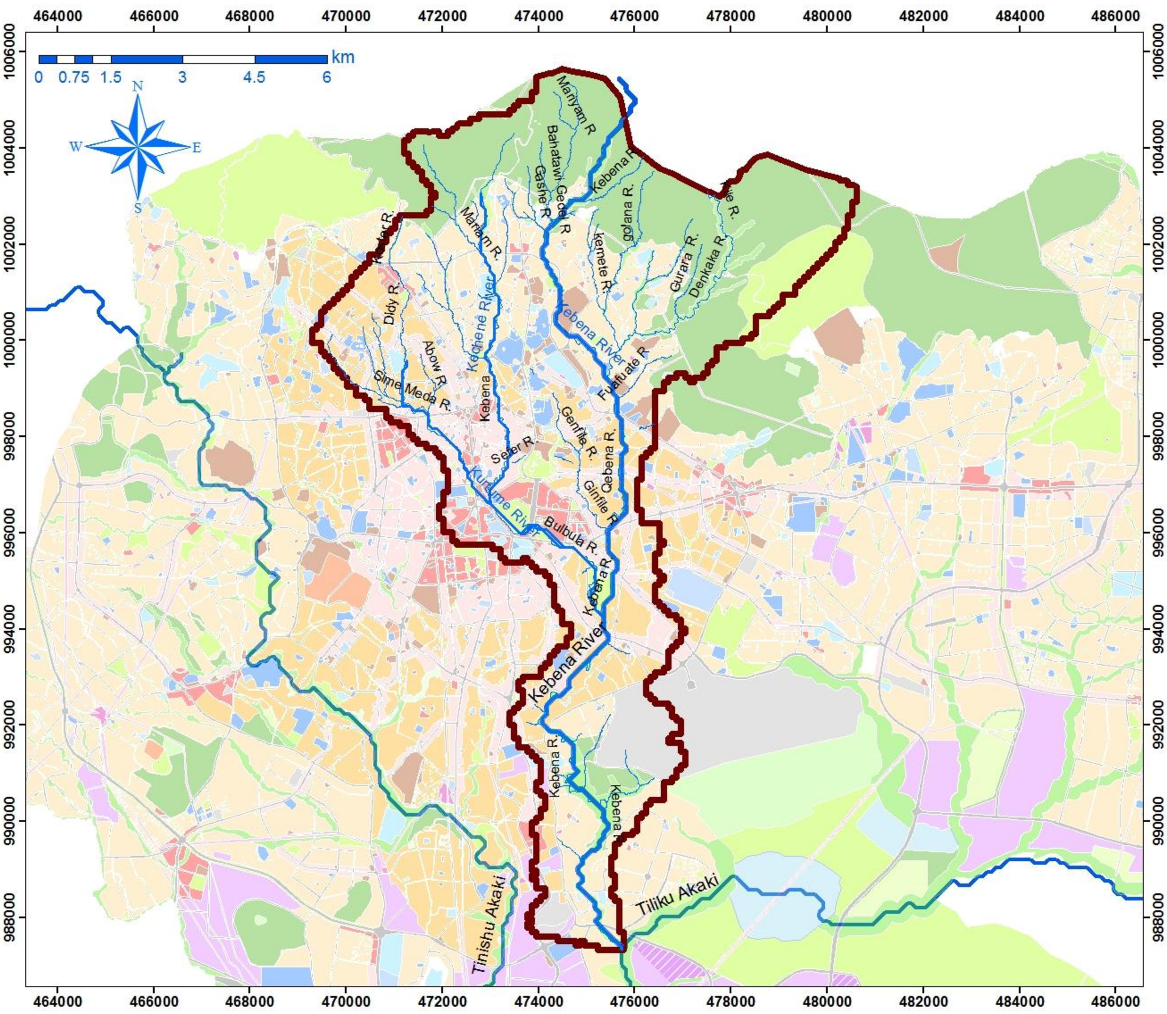

Figure 3-2: Kebena River and its catchment boundaries

Topography

The River emanates from Entoto Mountain. The topography slopes down from the Entoto Mountain in the north to the south with a number of steep-sided valleys. The Topography is undulating and form plateau in the northern part of the city. As a result, the stream drains towards south from the Entoto ridge. It is permanent and Perennial River. On the tops of the hills and ridges, the River forms radial drainage pattern, whereas on the slope and most part of the study area. At the source of the river, the area is more or less covered with woodland; whereas, the middle and lower section of the river is highly dominated with mixed and densely populated urban settlements.

Addis Ababa is home to 25% of the urban population in Ethiopia and is one of the fastest growing cities in Africa. It is the growth engine for Ethiopia and a major pillar in the country's vision to become a middle-income, carbon-neutral, and resilient economy by 2025. The city's economy is growing annually by 14% as a result of which it contributes approximately 50% towards the national GDP, highlighting its strategic role within the overall economic development of the country.

Moreover, Addis Ababa is located on the central highlands at the heart of the country. Its growth has accelerated radically in the past three decades. Its population increased from 2.7 million (in 2007 CSA record) to more than four million having the population growth rate of 3.8% which is attributed by natural growth and rural-urban migration. In addition to this, the city also has grown extensively, more than double in size, since 1984, to cover an area of approximately 530 km^2 (Bjerkli, 2013).

Climate

Despite its proximity to the equator, Addis Ababa enjoys a mild, Afro-Alpine temperate climate. The lowest and the highest annual average temperature are between 10^oC and 25^0C. April and May are the driest months. The main rainy season occurs between mid-June and mid- September; this season is responsible for 70% of the annual average rainfall of 1400mm. It is characterized by intense rainfall of short duration. During the dry season, the days are pleasantly warm and nights are cool; in the rainy season, both days and nights are cool (Belachew Tolla, 2006).

Vegetation

The land coverage of the catchment areas of the rivers crossing Addis Ababa is on one-hand characterized by the large urban area of Addis Ababa; on the other hand cultivated area, woodland and grassland are found. The eastern part (Hanku river basin) is mostly covered with grassland. The northern part (Little Akaki, Kechene and kebena basin) is more or less covered with woodland but a certain part is intensively cultivated land and the urbanization is closed to the basin boundary and expands further (Dierig, 1999). After the foundation of the city, a number of eucalyptus plantations were found in Addis Ababa and on the hills around entoto in order to cover the demand of wood of the city. For almost all forestation programs only eucalyptus was used during the past 100 years. This sort of tree has several negative impacts. Eucalyptus uses up large quantity of water and produces a chemical component in its leaves and roots which prevents the growth of other sorts of tress, bushes, and grasses. Consequently, there only be a monoculture with no undergrowth; together with the steep slope of the mountain erosion will be accelerated (Muschalla, 2001).

waste management

Addis Ababa, the capital city of Ethiopia, has one of the fastest growing populations in the world. The population has leaped from 15,000 to 4 million since its establishment 100 years ago (IGNIS, 2016). With all the socio-economic problems growing parallel, waste management in the city can take a great portion. Due to the insufficient waste management system in Addis Ababa, the habitants suffer the site and consequences of accumulated waste piles on the streets and drains all around the city. These piles pollute the surrounding vegetation, ground water and soil from the leachate. Due to weather variation and chemical reaction between materials fire ignites. The emission from the smoke pollutes the atmosphere. Moreover, these piles provide a breeding ground for insects and rats who can potentially cause the outbreak of an epidemic. They also cause a nauseating smell and are quite unpleasant to see.

There has never been a sufficient waste management system capable of addressing the multidirectional waste problem in the city. There are many reasons for the poor urban infrastructure and service in Addis Ababa. For many years, the need for a waste management system has not been recognized by the administrators. Neither has there been any waste management know-how. In the beginning, the administrators were not concerned with the matter as the number of habitants was relatively low and the waste generated was not grave in both amount and type. Therefore, disposing of waste at a far site was an easy tactic. However, with the fast expansion of the city, the far site has become somebody's back yard.

3.2 Data collection and laboratory analysis

Data Collection

The data were collected from December to February 2018, which was a dry season. The data collection Is good during dry season because pollution has the highest impact on the receiving stream due to its dry weather flow (Mehrdadi 2006).

Representative river water samples were collected from 28 sampling sites from Entoto to the downstream of the river. The sites were chosen based on land use characteristics, agricultural activities, population density, and other possible sources of pollutants. At each sampling stations 2 liters and 250ml of river water samples were collected by pre-cleaned polyethylene bottles for physicochemical and trace metal analysis. Sterilized bottles were used for bacteriological analysis and samples were stored in a refrigerator at $4^{o}C$ and subjected to analysis within 24 hours.

Primary data: the primary data were collected from river upper stream to its downstream. The place which are more populated (non-point source); tributaries join and point sources. Some of the primary dates' such as temperature (T), pH and EC (Electrical Conductivity) was collected using on site measurements, Nitrite(NO3),COD (Chemical Oxygen Demand), Reactive phosphorus, Total coliform (TC),Lead (Pb), Manganese (Mn) and Chromium (Cr) on laboratory of Addis Ababa University and Addis Ababa City Government Environmental protection and green area development commission.

selection of parameters

The following physical, chemical and biological parameters were measured from the 27 sampling sites namely: temperature (T), pH and EC (Electrical Conductivity) was collected using on site measurements, Nitrite(NO3),COD (Chemical Oxygen Demand), Reactive phosphrus, Total coliform (TC),Lead (Pb), Manganese (Mn) and Chromium (Cr) 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) 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. 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).

Secondary data - Datasets like weather condition of Addis Ababa town was collected from Addis Ababa metrological stations and some relevant information's were collected by reading manuals, reports and related research documents. The land use data sets were also collected from the city administration.

Figure 3-3: photos taken during field observation and data collection

Table 3-1: Sample collection spots

FID	POINTX	POINTY	Local Name (Nearby)
K0	475079.1740	994472.2659	In front of Peacoc
K1	475507.0803	994663.2698	At Irr. Farm
K2	475551.0509	995034.2762	Betsegah Hospital Outlet
K3	474670.0809	995718.4002	Near Bambis Bridge
K4	475445.9038	996004.5982	Near Urael Bridge
K5	475681.4167	997236.5160	Adwa Breidge
K6	475584.4772	998866.9774	German Embassy
K7	476205.7294	999371.8567	Metekya Bridge (Italian 2)
K8	475537.4973	999686.4643	Italian Embassy to French Embassy Bridge (Italian1)
K9	474666.3354	1000073.6266	French Embassy
K10	475046.6916	988443.7259	Near Saris Abo
K11	474153.4565	991940.8896	Mamo Sefer
K12	474581.1563	992699.1869	Near Bole Michal Church
K13	475457.7226	993866.3060	WelloSefer
K14	475863.0607	997982.5430	Tributary from British Embassy
K15	477771.7510	1001321.8295	Out of Urban
K16	474451.9512	1001080.0351	U/S of French Embassy
K17	474514.1548	1002725.8526	Kebena U/S
K18	473864.3787	996116.0428	Near Estifanos Church
K19	473050.3203	996559.0752	D/S Ambassador Park
K20	472876.5769	996711.7401	U/S Ambassador Park1
K21	472321.8107	997736.2695	Tewodros Round to Teklehaymanot bridge
K22	472975.0374	996764.9204	U/S Ambassador Park2
K23	473387.7882	997599.6824	Near PM Office
K24	472949.3728	999637.3486	Afincho Ber
K25	473110.8792	1000987.3933	Near KecheneMedhanealem
K26	471222.2207	998792.6668	AbakoranSefer
K27	471278.8417	1001036.6026	Around Shegole
K28	471156.6039	1002435.1929	Near Enteto

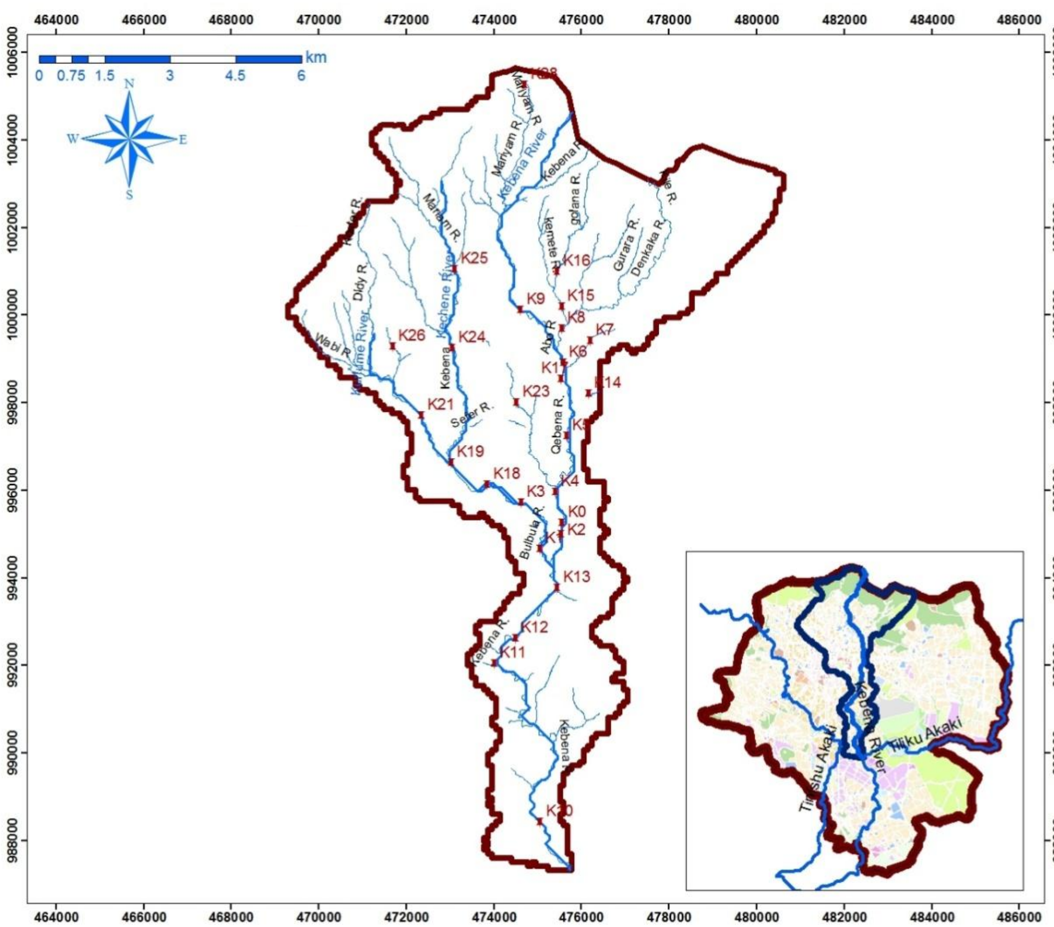

Figure 3-4: Locations of Sampling stations within the Kebena catchment

3.3 Water Quality Index Calculation

A water quality index (WQI) helps in understanding the general water quality status of a water source and hence it has been applied for both surface and ground water quality assessment all around the world is the last few decades (Shah and Joshi, 2017). The water health can also examine by using water quality index. Interpretation of complex water quality data is difficult to understand and to communicate during decision-making process. Assembling the various parameters of the water quality data into one single number leads an easy interpretation of data, thus providing an important tool for management and decision-making purposes. The purpose of an index is to transform the large quantity of data into information that is easily understandable by the public. Water quality index exhibits the overall water quality at a specific location and specific time based on several water quality parameters. WQI is a set of standards used to measure changes in water quality in a particular river reach over time and make comparisons from different reaches of a river. This index allows for a general analysis of water quality on many levels that affect a stream's ability to host life and whether the overall quality of water bodies poses a potential threat to various uses of water (Ogundiran and Fawole, 2014). Horton developed WQI in the early 1970s; it is a mathematical means of calculating a single value from multiple test results. The index result represents the level of water quality in a given water basin, such as lake, river or stream. After Horton, a number of workers all over the world developed WQI based on rating of different water quality parameters. Basically, a WQI attempts to provide a mechanism for presenting a cumulatively derived, numerical expression defining a certain level of water quality (Sahoo, 2014). The different statistical approaches were followed for analyzing water quality data based on rank order of observations and factor for analysis and evaluation of water quality, WQI was applied to river water (Bora and Goswami, 2017). The calculation of water quality for river water, the importance of various water quality parameters depends on the intended use of water and from the point of view of suitability for domestic purposes. The proposed intended use of this water quality for environment was compared with standards permissible limit values of various water quality parameters of world health organization (WHO) and Ethiopian environmental protection authority (EEPA) or surface water.

3.3.1 Water Quality Index Development Procedure

The following procedure was used to develop water quality index:

***Step I*:** the water quality parameters of interest were identified and ranged according to the acceptability for their intended uses in a water body

Step II: The measured values of parameters were calculated by the developed equations for every parameter in MS Excel and were compared with subjective rating curves, which concluded on a dimensionless sub-index value ranging from 0-100 for every parameter (Mahesh Kumar, 2012).

Step III: The weighing factors were defined for each parameter and were considered while building an overall water quality index

Step IV: The algorithm for calculation and formulation of water quality index was selected with the available data and assumptions.

Essentially, a WQI is a compilation of a number of parameters that could be used to determine the overall quality of a river. The parameters involved in the WQI are dissolved oxygen, pH, Dissolved Oxygen, Electrical Conductivity, Total Dissolved solids (Shah and Joshi, 2017). The numerical value then multiplied by a weighting factor that was relative to the significance of the test to water quality. The sum of the resulting values was added together to arrive at an overall water quality index.

The Water Quality Index (WQI) was calculated using the standards of drinking water quality recommended by the World Health Organization (WHO, 2006). The weighted arithmetic index method (Brown *et al*., 1970) was used for the calculation of WQI of the surface water. The quality rating scale for each parameter qn was calculated by using the following expression.

$$\boldsymbol{qn} = \frac{\mathbf{100}\,[\boldsymbol{V_n} - \boldsymbol{V_{io}}]}{[\boldsymbol{S_n} - \boldsymbol{V_{io}}]\ldots}$$ ....Equation 1

(Let there be n water quality parameters and quality rating or sub index (q_n) corresponding to nth parameter is a number reflecting the relative value of this parameter in the polluted water with respect to its standard, maximum permissible value).

qn = Quality rating for the nth water quality parameter

Vn = Estimated value of the nth parameter at a given sampling point.

Sn = Standard permissible value of the nth parameter.

Vio = Ideal value of nth parameter in pure water (i.e. 0 for all other parameters except the parameter pH and Dissolved Oxygen (7.0 and 14.6 mg/l respectively).

Unit weight was calculated by a value inversely proportional to the recommended standard value Sn of the corresponding parameter.

$$\boldsymbol{Wn} = \frac{\boldsymbol{K}}{\boldsymbol{S_n}}$$ ....Equation 2

Wn = unit weight for the nth parameters.

Sn = standard value for the nth parameters.

K = constant for proportionality **(**Bashar J.J. AL- Sabah.,2016)

1The overall WQI was calculated by aggregating the quality rating with the unit weight linearly and then compared with the WQI categories (Table1).

$$\boldsymbol{WQI} = \frac{\boldsymbol{\Sigma q_n * W_n}}{\boldsymbol{\Sigma W_n}}$$ ....Equation 3

Table 3-2: Water Quality Index (WQI) Categories (after Chatterji and Raziuddin, 2002).

Water quality index level	water quality status
0-25	Excellent water quality
25-50	Good water quality
51-75	Poor water quality
76-100	Very poor water quality
>100	Unsuitable for drinking

CHAPTER 4 RESULT AND DISCUSSION

This chapter presents the results and finding of the present study and the discussions on these findings in accordance to the specific objectives. The physical, chemical and biological laboratory results are shown in the Appendix A .The spatial mapping of critical results was also presented in line with the WQI analysis outputs.

4.1 Physico-chemical Parameters

4.1.1 Temperature

The samples was collected in the morning between 10am-12am by considering complete mixing of waste in the river at all sampling site. Water temperature was varied from 16.4^{0}C – 22.1^{o}C that was set under the standard of WHO and EEPA limit. All the temperature values were within the EEPA (2003)standards for effluent discharges to surface water and all values were found to meet the WHO (1984) Guideline values (12^{0}C- 25^{0}C). Thus, the slight change of temperature at downstream might be due to altitude, rate of flow, air temperature of sampling time, water volume and so on. Despite slight change in the temperature of the river water at the reference and impacted sites was normal (within the range of ambient standard for surface water) with no significant difference ($p> 0.05$). So, the temperature of the effluent has no effect on the river.

4.1.2 PH Concentration

Naturally, occurring fresh waters have a PH range between 6 and 9; the concentration ranges suitable for the existence of most biological life is quite narrow and critical. Most fresh waters are relatively well buffered and more or less neutral. 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. It also alters the ionic and osmotic balance of individual organism and determines the type of the chemical species (and thus the potential toxicity) of numerous elements and molecules (e.g. ammonia) found in water. Aquatic organisms are very sensitive to the pH of the aquatic environment because most of metabolic activities are pH dependent (Wang et. al., 2002).

In this study, hydrogen ion concentration (pH) values for the downstream ended towards acidity. Minimum mean value of 6.35 and maximum mean value of 7.67 were recorded for sites K17 and K28 respectively. This showed that the microorganisms that help in breaking down biological waste could be able to survive in neutral environment. As a result, the biological wastewater entering to the river can be easily degraded (Awomeso et al., 2010).

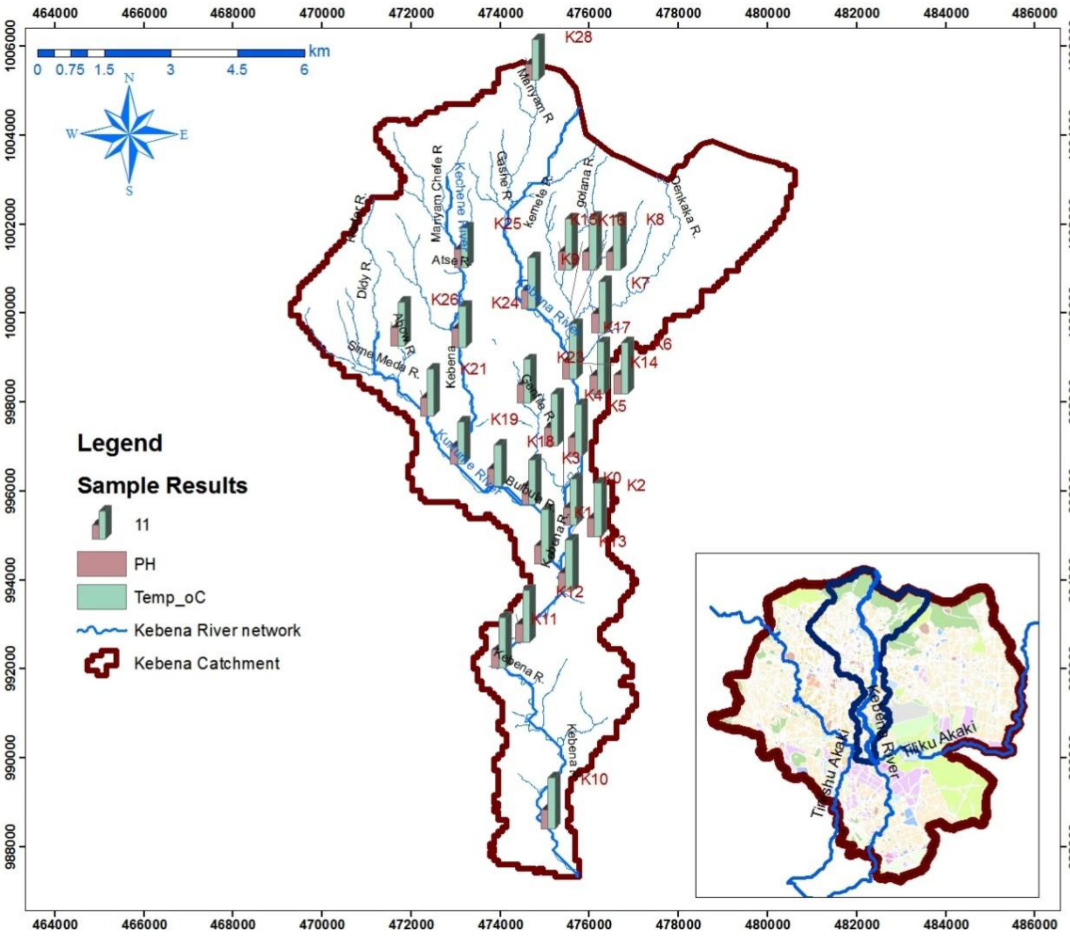

Figure 4-1: Spatial distribution of PH and Temperature of the samples along Kebena

4.1.3 Dissolved Oxygen (DO)

In this study, DO levels in the sites ranged from 0.1 mg/L (K12) to 4.9 mg/L (K15). The lower value recorded for DO in sites K12 might be as a result of organic pollution. This is because the rate of deoxygenating depends on dilution that occurs when effluents mixes with the stream, temperature of the discharge and the streams DO. The high Dissolved oxygen value at upstream of Kebena River was the absence of urbanization and anthropogenic activities While the low values 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 concentration DO values across the studied area 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).

4.1.4 Electrical Conductivity

Conductivity is the ability of the water to conduct an electric current, and is an in direct measure of concentration of ions. The more ions present, the more electricity can be conducted by the water. In this study, electrical conductivity values varied between433µS/cm (K28) and 1425µS/cm (K7). The high conductivity value at sample points K27 (1425µs/cm) and other sampling points indicate the effect of high wastes discharge into the river. The EC value of sitesK7, K23, K25 and K27 is above the range of limits for surface waters and the other site EC values were within the EEPA (2003) standards for effluent discharges to surface water. EC values outside the 100 to 1000µS/cm range are considered detrimental to most macro invertebrates (WQMP). 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 higher values within the city may have resulted from different domestic wastes and sewerage leakage.

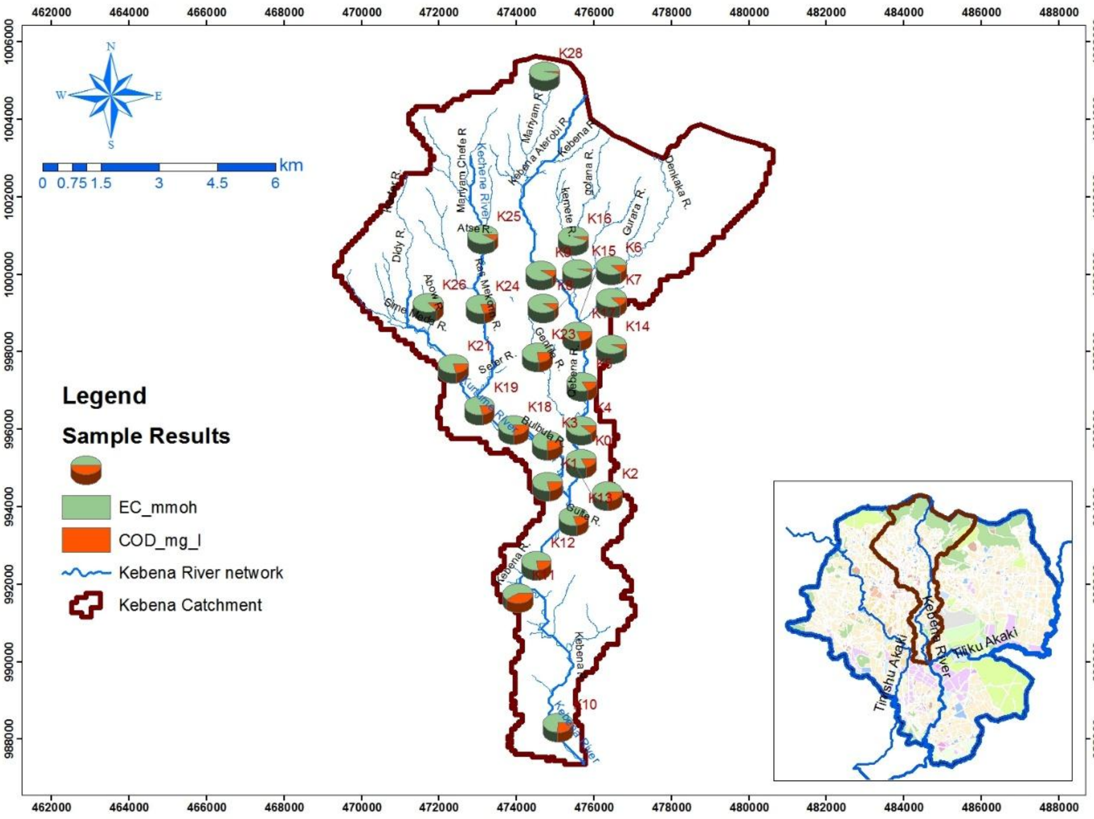

Figure 4-2: Spatial distribution of EC and COD of the samples along Kebena River

4.1.5 Reactive Phosphorus (PO_4^{3-})

Mean phosphate concentration ranged between 2.3mg/L (site K28) and 75.1mg/L (site K11). The levels of phosphate of was high and of great concern. Relatively lower phosphate levels were recorded in the river 2.3mg/L (K28) and 2.6 mg/L (K15). The others sights record higher levels of phosphate recorded in impacted sites. The discharge of phosphate salts and detergents used for washing in the factory is a regular source of phosphate at the discharge point. Water quality standard levels must be below 0.005 mg/L to prevent. In all sample's phosphate concentrations were higher than 0.005mg /L, which is considered as the lower limit for river waters to pose a risk of eutrophication.

The concentration of phosphate in all sampling site 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 Kebena River.

4.1.6 Chemical Oxygen Demand (COD)

The chemical oxygen demand (COD) is used as a measure of equivalent amount of oxygen required to completely oxidize both biodegradable and non-biodegradable organic and inorganic matter. COD mean values ranged between K12, 12mg/L and K28, 649mg/l the level of COD concentration in the sites K4, K6, K8, K9, K14, K15, K16, K25, and K28 within the standards while the other sampling sites were above the EEPA (2003) standards for effluent discharges to surface water.

4.1.7 Nitrite (NO_3--N)

Nitrite generally occurs in trace quantities in surface waters, most coming from organic and inorganic waste discharges. An excess nitrite in river water promotes high primary productivity and is taken as a warning for algal blooms (eutrophication). A massive growth of aquatic plant life can change the chemistry of water significantly (Ranvidra, 2003).In the present study, the levels of nitrite ranged from <0.0001 mg/l to 20mg/l. The maximum value was occur at site K9(20.8mg/l) and The Minimum concentration of nitrite was on sites K0, K3, K6, K18, K19, K20, K21, K23, K24, K26, and K27 where less than 0.0001 while the other sights are above the EEPA (2003) standards for effluent discharges to surface water. Spatially, the lowest value was at upstream of the River. There was no industrial activities at upstream of kebena River to raise the concentration of nitrites 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 kebena river was in typical rural area where fertilizer application was also limited due to economic reasons.

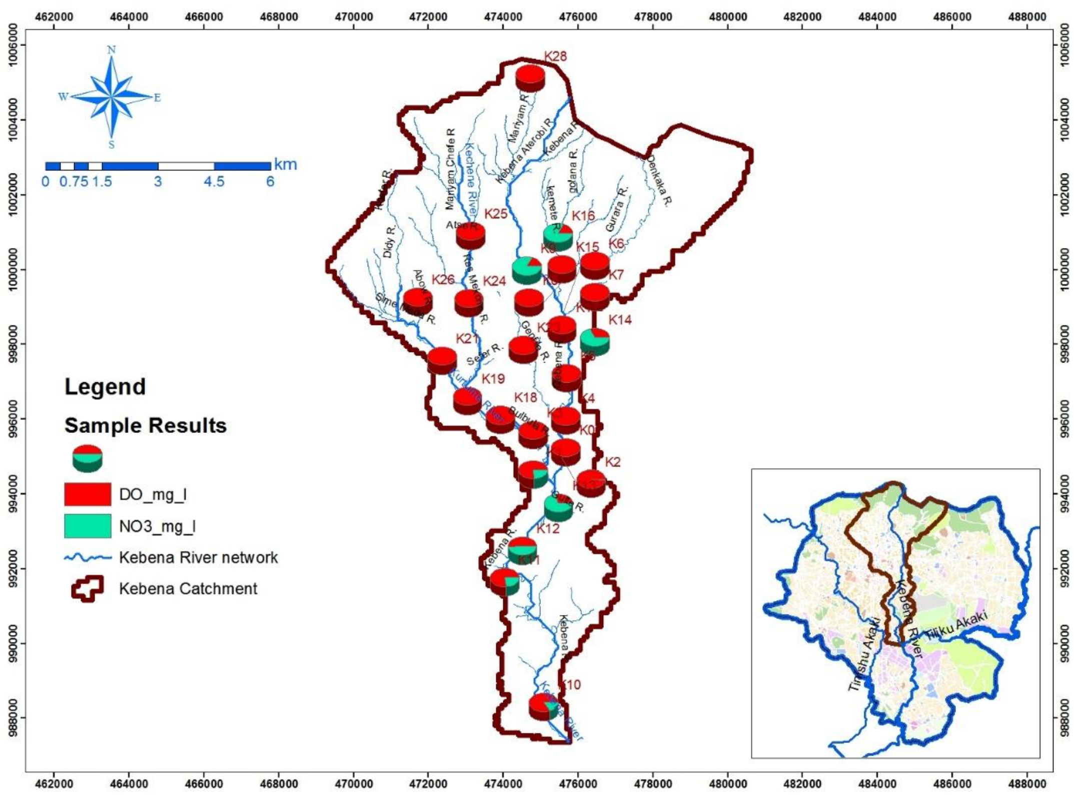

Figure 4-3 **:** Levels of DO and NO_3 in mg/l of the samples along Kebena River

4.1.8 Total Coliform

The significance of various coli form organisms in water has been and is a subject of considerable study. Collectively, the coli forms are referred to as indicator organisms. Identification of bacteria that constitute the coli form group sometimes is necessary to determine the nature of pollution. It is of particular importance in reference to distinguishing the presence of *Escherichia coli*(APHA, 1999).

Bacteriological analysis of samples from the sites showed that all the water sources from Kebena River are positive for total coliform test and are found to be unsafe for drinking as they are beyond the allowable limit of (WHO, 2004a; FDRE, MOWR, 2002) which suggests 0 – Safe water, 1-10 – reasonable quality, 11-100 – polluted, 101-1000 – dangerous, >1000 – very dangerous in terms of CFU/100ml. Besides the water sources all are very dangerous for drinking. And the main source of contamination could be both environmental sources and fecal origin. The minimum value was occur at sample station K28,22 CFU/100ml and maximum value occurs at sample station K1, 3440 CFU/100ml.from 28 sites 23 was above 1000 and 3 are between 101-1000.

The significant possible health impacts due to high level of total coliforms above the standards of WHO guidelines across the River poses health concerns such as cramps, nausea, and possibly jaundice, and any associated headaches, fatigue and diarrhea (gastrointestinal distress) to the society using the River for drinking purpose.

4.1.9 Lead

Lead is defined by the USEPA (United States Environmental Protection Agency) as potentially hazardous to most form of life ,and is considered toxic and relatively accessible to aquatic organisms even at low concentration .low lead concentration affect fish by causing the formation of coagulated mucous over the gills and consequently over the entire body which result in the death of fish due to suffocation. Lead is a toxic element that accumulates in the skeletal structures. The toxic effects of lead to fish decreases with increasing water hardness and dissolved oxygen.

The concentration of Lead at sampling site K4, K6, K9, K14, K15, K25, K26, K27, K28 is nil that means below <0.0001 almost 0.The others sampling sites have high level of Lead concentration. possible source of lead in the river may be due to particulate from the combustion of leaded gasoline, corrosion of lead-containing materials and burning of building and electric wastes with residue washed in to rivers.(ogunfowokan AO,Ajibola RO, Akannis MS) physicochemical quality and trace metal levels of municipal water from three reservoirs in osum state ,Nigeria.

4.1.10 Chromium

The concentration of Chromium values is Nil that means below <0.0001 in all sampling sights except K3(0.2603) and K10 (0.0973) . The sampling points Chromium values were below the WHO standard limit. The national drinking water quality and WHO maximum allowable concentration in river water should not exceed 0.05mg/l. The pollution sources of chromium might be 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.

4.1.11 Manganese

The concentration of Manganese values ranged from 0.1792ppm to 4.8436ppm in the sampling site K28 and K5. At sight K5 (4.84536ppm), K6 (4.2004ppm), K13 (3.0033ppm), K14 (3.3219ppm), K16 (2.2694ppm) and K17 (2.713ppm) Contains High concentration the others have low Concentration. All sampling points Manganese values were greater than the national drinking water quality and WHO standard limit.

Manganese is a very common compound that can be found all over Earth. Manganese that derives from human sources can also enter surface water, groundwater, and sewage water through the application of manganese pesticides. Manganese is one of three toxic essential trace elements, which means that it is not only necessary for humans to survive, but it is also toxic when too high concentrations are present in a human body. Manganese levels in natural waters rarely exceed 1 mg/L, but levels of 0.1 mg/L are sufficient to cause the taste and staining problems .

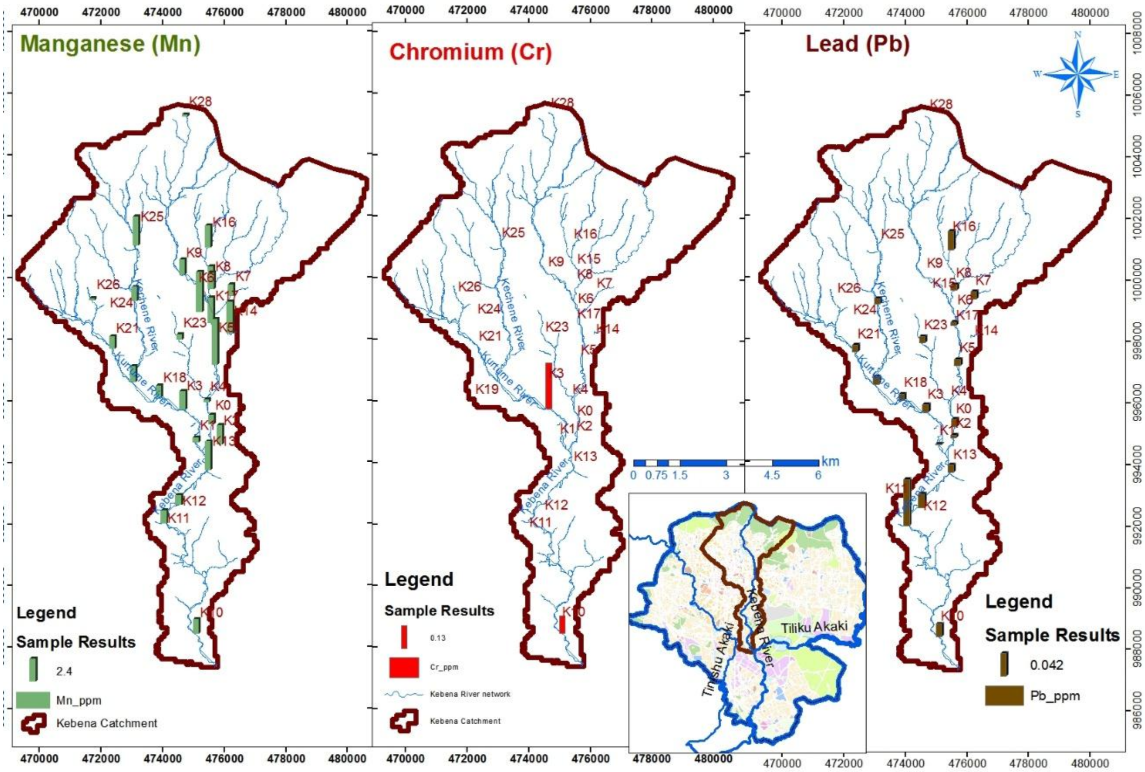

Figure 4-4: Levels of Manganese, Chromium and Lead in mg/l of the samples collected along Kebena River

4.2 Assessment of Water Quality Status of Kebena River using water quality index

The data found in table 4-1 showed that the water quality of Kebena River as affected by the point sources and non-point source of pollution. According to the water quality index sampling site Sampling points at site K4, K26 and K28 water quality was excellent, sample point K0 and K15 are good and the others sights water quality was unsuitable. Due to the wastewater effluents from different homes (highly populated) K11, K16, K13, K10, K5, and K6 sampling sites were badly polluted. It can be concluded the some point sources and non-point sources had significance effect on water quality of Kebena River.

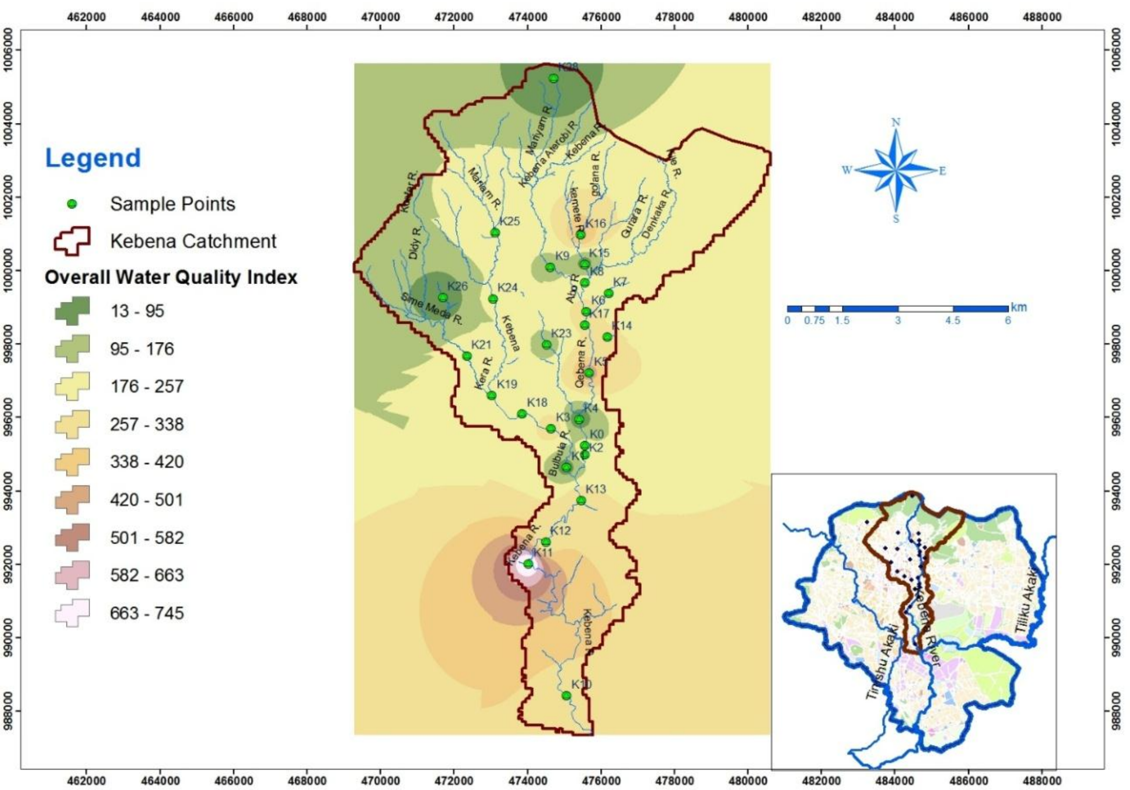

Figure 4-5: Spatial distribution of the overall water quality status of Kebena River

Table 4-1 Water quality status of sampling points (K1-K28) by using WQI, where (E-excellent, G-Good, US- Unsuitable)

Parameters	K1	K2	K4	K5	K6	K7	K8	K9	K10
PH	7.54	7.34	7.44	7.49	7.56	7.51	7.61	7.47	7.67
EC	962	788	744	790	874	1425	771	803	936
DO	0	3	4	4	0	4	4	4	4
NITRITE	0	0	0	0	0	0	0	20	1
COD	275	253	100	166	120	214	81	85	342
Cr	0	0	0	0	0	0	0	0	0
Mn	1	2	0	5	4	1	2	2	2
Pb	0	0	0	0	0	0	0	0	0
Sum of Wn	131	131	131	131	131	131	131	131	131
Wnqn	6347	25276	3101	60589	42108	26425	27733	18385	42825
WQI= (Wnqn/Sum Wn	48	192	24	461	320	201	211	140	326
Water Quality status	G	US	EX	US	US	US	US	US	US

Parameters	K11	K12	K13	K14	K15	K16	K17	K0	K3
PH	7.42	7.48	7.53	7.53	7.32	7.17	7.55	7.17	7.35
EC	935	925	860	825	385	769	866	694	779
DO	3	0	0	4	5	3	1	1	0
NITRITE	1	0	0	9	0	16	0	0	0
COD	649	269	227	60	14	44	220	152	255
Cr	0	0	0	0	0	0	0	0	0.23
Mn	1	1	3	3	1	2	3	1	1
Pb	0	0	0	0	0	0	0	0	0
Sum of Wn	131	131	131	131	131	131	131	131	131
Wnqn	97950	35587	44592	34114	6326	58453	33834	24043	44678
WQI= (Wnqn/sumWn)	745	271	339	260	48	445	257	183	340
Water Quality status	US	US	US	US	G	US	US	US	US

Parameters	K18	K19	K20	K21	K23	K24	K25	K26	K27	K28
PH	7.38	7.21	7.24	7.4	7.57	7.52	7.37	7.15	6.87	6.35
EC	780	930	723	724	1089	584	1008	929	1205	433
DO	0	2	4	1	2	2	2	1	2	5
NITRITE	0	0	0	0	0	0	0	0	0	0.5
COD	254	239	260	196	330	152	95	138	207	12
Cr	0	0	0	0	0	0	0	0	0	0
Mn	2	1	2	1	1	2	3	0	2	0
Pb	0	0	0	0	0	0	0	0	0	0
Sum of Wn	131	131	131	131	131	131	131	131	131	131
Wnqn	23693	26066	25380	26066	16841	24879	31054	2128	22965	1829
WQI (Wnqn/Sum Wn)	180	231	198	193	128	189	236	16	175	14
Water Quality status	US	US	US	US	US	US	US	EX	US	EX

4.3 Mitigation Measures

The disposal of municipal wastewater of Addis Ababa city should include proper design and proper regulation and approval of effluent management options, be the direct discharge of waste to the surface water requires regulatory testing and monitoring to meet the strict local standards on pollution discharge limits of effluent set by National Environmental Standards of Quality standards Ethiopia (EEPA).

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 the 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.

urban drainage management is without proper administration because ACRA(Addis Ababa city road authority) which was consider to manage surface drainage is only responsible for road side, solid management is entirely administrated by the city administration and waste water is for AAWSA(Addis Ababa water and sewerage authority).thus, institutional arrangement shall will be addressed.

CHAPTER 5 CONCLUSION AND RECOMENDATION

5.1 CONCLUSION

The phisico-chemical ,biological and heavy metal result indicated that the range of pH(6.35_7.67mg/l),Conductivity(433_1425us/cm),Totalcoliform(2229_22/100ml),DissolvedOxygen(4.4_0.1mg/l),COD(12_649mg/l),Nitrite(20.3_<0.0001mg/l),lead(0_0.00838),Chromium(0_0.2608),Manganese(4.8436_0.1792)andreactivephosphors (2.3_75.1mg/l) shows those results during that time. At all sampling sites except upstream of kebena river the Physicochemical ,heavy metal and bacteriological results of water samples were above the Ethiopian and WHO standard limit indicated that Kebena River was highly polluted**.**

The water quality index results showed that sampling points of K1, K26 and K28 was excellent, K1 and K14 was found good quality. the reason can be associated with low population density near the sampling points and the sampling points less contamination at the corner of the city. The rest sampling points showed that unsuitable result; this is due to the fact that the river is affected by the different sources of water pollution. This quality of water has an adverse impact on the human life and aquatic life as well. Such issues are more aggravated through food chain that will also affect human beings while they eat green plants grown around the river.

From this study Kebena River can be described as highly polluted due to different activities like domestic wastes solid waste and liquid waste like toilets directly discharge from homes**.** It is therefore concluded that Kebena River in the study area is polluted and not fit for domestic use and has high effect on health of people live around the river.

5.2 RECOMMENDATION

Based on the findings the following things need to recommend

- On the river, there water quality was found highly affected. Therefore, water and soil conservation practices and water quality monitoring should be carried out near to the river.
- In this research only the water quality was assessed. Finally, it is highly recommended to have further study on the wastewater treatment process. The self-purification capacity of the river should be studied before discharging waste water.
- The city administration should focus on treating the polluted rivers by adoption of adequate measures and initiate to expand cleaner production system to avoid further deterioration of the river water quality.
- Generally, it can be recommended projects like what already started, creating green area along the river banks and water quality monitoring should be carried out particularly for the point sources pollutants that are found in the city of Addis Ababa.

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APPENDIX 1

Laboratory Result of Kebena River

Code	X	Y	PH
K1	8.999967	38.774032	7.54
K2	9.003012	38.778487	7.34
K4	9.01166	38.777213	7.44
K5	9.023233	38.779598	7.49
K6	9.03827	38.778898	7.56
K7	9.04285	38.784417	7.51
K8	9.045377	38.77855	7.61
K9	9.049187	38.769985	7.47
K10	8.943628	38.774118	7.67
K11	8.97618	38.764608	7.42
K12	8.981487	38.768916	7.48
K13	8.991817	38.777658	7.53
K14	9.031937	38.784067	7.53
K15	9.049972	38.77848	7.32
K16	9.05722	38.777567	7.17
K17	9.03497	38.77848	7.55
K0	9.005297	38.778608	7.17
K3	9.009527	38.770149	7.35
K18	9.013092	38.763092	7.38
K19	9.017673	38.755558	7.21
K20	9.18647	38.755353	7.24
K21	9.027389	38.74939	7.4
K23	9.03005	38.769147	7.57
K24	9.041414	38.755841	7.52
K25	9.057674	38.756278	7.37
K26	9.041723	38.743393	7.15
K27	9.068907	38.724365	6.87
K28	9.095713	38.770746	6.35

Code	Temperature (^{0}C)	EC	DO(mg/l)
K1	22.10	962	0.3
K2	21.60	788	3.4
K4	21.10	744	4.4
K5	21.20	790	4.35
K6	20.90	874	0.1
K7	20.70	1425	4.1
K8	21.50	771	4.1
K9	21.10	803	4.3
K10	20.80	936	3.5
K11	20.60	935	2.8
K12	21.10	925	0.1
K13	21.00	860	0.2
K14	21.10	825	3.9
K15	21.60	385	4.9
K16	20.70	769	3.4
K17	22.40	866	2.9
K0	18.78	694	1.2
K3	18.20	779	0.8
K18	17.00	780	0.7
K19	17.20	930	1.9
K20	17.20	723	3.7
K21	19.20	724	1.4
K23	17.80	1089	1.6
K24	16.70	584	2.4
K25	16.10	1008	2.3
K26	17.70	929	1.4
K27	15.80	1205	2
K28	16.40	433	4.6

	Reactive Phosphorous (mg/l)	Nitrite(mg/l)	Total Coliform/100ml
K1	47.3	0.096	3440
K2	40.2	0.062	1548
K4	33.1	0.023	1908
K5	32.5	0.01	3268
K6	29.7	<0.0001	994
K7	29.1	0.019	1988
K8	16.3	0.034	1342
K9	21.8	20.3	2064
K10	48.2	0.69	2580
K11	75.1	0.861	2924
K12	43.9	0.097	2952
K13	44.5	0.47	2752
K14	10.1	8.5	516
K15	2.6	0.018	522
K16	14.5	16.2	1551
K17	37	0.003	1341
K0	23.5	<0.0001	2064
K3	34.7	<0.0001	1420
K18	33.9	<0.0001	1278
K19	29	<0.0001	1136
K20	32.8	<0.0001	2580
K21	29	<0.0001	3268
K23	53.9	<0.0001	1204
K24	22.5	<0.0001	1332
K25	12	0.02	2752
K26	17.4	<0.0001	1950
K27	40.1	<0.0001	852
K28	2.3	0.042	22

Code	Cr(ppm)	Mn(ppm)	Pb(ppm)
K1	0	0.5078	0.0194
K2	0	2.0226	0.0048
K4	0	0.3011	0
K5	0	4.8436	0.012
K6	0	4.2004	0
K7	0	1.2623	0.0136
K8	0	1.7466	0.0102
K9	0	1.6283	0
K10	0.0973	1.5541	0.023
K11	0	1.3427	0.0838
K12	0	1.0522	0.0248
K13	0	3.0033	0.0143
K14	0	3.3219	0
K15	0	0.6319	0
K16	0	2.2694	0.0341
K17	0	2.713	0.0065
K0	0	0.9596	0.0143
K3	0.2608	1.9601	0.0144
K18	0	1.225	0.0112
K19	0	1.6271	0.0138
K20	0	1.4013	0.0118
K21	0	1.2896	0.0123
K23	0	0.5628	0.0109
K24	0	1.5043	0.0097
K25	0	3.0968	0
K26	0	0.1994	0
K27	0	2.2754	0
K28	0	0.1792	0