ASSESSMENT OF WATER QUALITY OF EJERSA RIVER USING PHYSICO CHEMICAL PARAMETERS AND BENTHIC MACRO INVERTEBRATES IN WOLISO TOWN, OROMIA REGIONAL STATE, ETHIOPIA

MSc THESIS

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Assessment of Water Quality of Ejersa River using Physico Chemical Parameters and Benthic Macro Invertebrates in Woliso Town, Oromia Regional State, Ethiopia

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APPROVAL SHEET
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As thesis research advisors we hereby certify that we have read and evaluated this thesis prepared under our guidance by ***Wodajo Jifara Mideksa*** entitled **Assessment of Water Quality of Ejersa River using Physico Chemical parameters and Benthic Macro Invertebrates in Woliso Town, Oromia Regional State, Ethiopia.** We recommend that it can be submitted as fulfilling the Thesis requirements.

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As member of the Board of Examiners of the *MSc* Thesis Open Defense Examination, we certify that we have read evaluated the Thesis prepared by ***Wodajo Jifara Mideksa*** and examined the candidate. We recommended that the Thesis can be accepted as fulfilling the Thesis requirement for the Degree of Master of Science in Biology.

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DEDICATION

This thesis is dedicated to my wife Bogelach kebede, brother Mamo Jifara, my mother Desta Bedasa and father Jifara Mideksa for nursing me with affection and love and for their dedicated partnership in success of my life.

STATEMENT OF THE AUTHOR

First, I declare that this thesis is my original work and that all sources of materials used for this thesis has been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirement for MSc degree at the Haramaya University and is deposited at the University library to be made available to borrowers under rules of the library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any other academic degree, diploma or certificate.

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BIOGRAPHICAL SKETCH

The author was born in November 20, 1985 in Oromia Regional State, South West Shoa Zone, Wonchi Woreda, Fitte Wato *Kebele*. He completed his elementary school education at Chebo Wonchi Primary School and high school education at Deja Geresu Duki Comprehensive Secondary School at Woliso Town. After completion of his high school he joined Jimma Teachers Training College (2003-2004) and graduate with diploma in Biology. Then after he joined Jimma University (2006-2009) and graduated with Bachelor of Education (B.Ed) degree in Biology in October 11, 2009.

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ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
APHA	American Public Health Association
BOD	Biological Oxygen Demand
CLI	Community Loss Index
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
EC	Electrical Conductivity
EPA	Environmental Protection Authority
FAO	Food and Agricultural Organization
GFF	Glass Fiber Filters
H-FBI	Hilsenhoff Family Biotic Index
MOH	Ministry of Health
MWR	Ministry of Water Resources
NTU	Nephelometers Turbidity Unit
SPSS	Statistical Package for Social Sciences
TDS	Total Dissolved Solid
TSS	Total Suspended Solids
TCU	True Color Unit
UNEP	United Nations Environmental Program
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WHO	World Health Organization

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ABSTRACT

The level of water pollution and ecological disturbance of Ejersa river was assessed using physico-chemical parameters and benthic macro-invertebrates. Ejersa river which is part of the Omo-Gibe basin is used for various activities such as irrigation, washing and cattle watering. But it is exposed to wastewater discharge from municipal sewage, nearby prison institution and abattoir. Three sites selected randomly at upstream as site one, at the back of prison institution in middle of the town was site two and below abattoir at exit point as site three along the river during the period of March to May 2016. Eleven physico-chemical parameters were assessed. Moreover, macro invertebrates were also sampled using D-frame net and identified to the family level. There was significant difference in most of the physico-chemical parameters between site one, site two and site three ($p<0.05$). For instance higher value of phosphate (2.626 mg/L), pH (8.8), nitrate (163.7mg/L), salinity (227.53mg/L), turbidity (246.2 NTU) and electrical conductivity (378.2µs/cm) were recorded at site two than site one and site three. A total of fourteen families (325 macro-invertebrates) belong to six orders were identified during the present study. Chironomidae the most dominant in site two (69.5%), site three (66%) and site one (54.7%), followed by syrphidae (21.9% and 23.3%) in site two and three respectively.

Dytisidae was found in site III (6.7%), site I (5.98%) and site II (0.95%), the one that present in all sites. The Shannon-weaver community index showed that the family abundance was higher in site one (4.3) than site two (2.5) and site three (2.6). The waste water discharges from municipal sewage, prison institution, anthropogenic activity and abattoir has been a direct impact on aquatic life, urban and rural communities living near to the river. Physico-chemical parameters were increases with disturbance which leads to poor water quality whereas macro invertebrate assemblage decreases.

Keywords: *Benthic macro invertebrates, Ejersa river, Physicochemical, Water quality*

1. INTRODUCTION

The earth contains approximately 1.39 billion cubic kilometers of water, with 96.5 percent stored in the oceans of the world. Approximately 1.7 percent is stored in glaciers, permanent snow, sea ice and polar ice caps, while another 1.7 percent exists as ground water and in rivers, lakes, wetlands and soil (Smol, 2002).

Water is one of the most important and abundant compounds of the ecosystem. All living organisms on the earth need water for their survival and growth. As of now only earth is the planet having about 70% of water. But due to increased human population, industrialization, use of fertilizer in agriculture and man- made activity it is highly polluted with different harmful contaminants. Therefore, it is necessary that the quality of water should be checked, because due to contaminants, human population suffers from varied of water born diseases (Basavaraja, 2011).

In Ethiopia, only 42% of the population has access to an improved water supply, and only 11% of the population has access to adequate sanitation services. In rural areas, these numbers drop even further below these figures. Most of the water sources in Ethiopia are heavily contaminated with environmental wastes such as human and animal excreta, washed by runoff from heavy precipitation. Most people collect water from shallow unprotected ponds which are also shared by animals. Others collect water from shallow wells. Both of these sources are subject to contamination as rain water washes waste from surrounding areas into the source (Anonymous, 2009).

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

Rivers are the most important fresh water resources. They support and maintain macro and micro-ecosystem. Urban centers and the world's most productive agricultural lands are tied to rivers. They serve as source of water for recreational activities such as bathing and fishing. They are also the most suitable media to clean, disperse, transport and dispose of domestic and industrial wastes (Meybeck and Halmer, 1996).

Rivers are open dynamic ecosystems whose physical, chemical and biotic characteristics are greatly influenced by anthropogenic activities taking place within their drainage basins (Mokaye *et al*., 2004). A number of rivers and streams flow through urbanized areas across the world and are profoundly impacted by changes associated with urbanization (Bernhardt and plamer, 2007).

A study made by Getachew (2009) clearly indicated that most of the rivers crossing big cities or towns of Ethiopia are suffering from both anthropogenic and industrial wastes. Hence, there is an urgent need for continuous monitoring of these valuable aquatic systems. Urban centers put huge amount of organic and synthetic waste into rivers with little or no treatment. With ever increasing population and industrialization, human societies affect rivers and their ecosystem structure and function in an ever alarming way (Roy *et al*., 2003). In general, the effect of human activities in rivers and their ecosystem affect one or more of the five attributes of watersheds and streams water quality, which include habitat structure, stream flow patterns, sources of energy and nutrients, and biotic interaction (Karr, 1991).

A river in which its ecosystem cannot sustain itself not only troubles the aquatic biota, but also it cannot support human affairs (Karr and Chu, 1997). It is possible to assess the quality of the water using both physico chemical attributes as well as biological components. However, the former one has its own draw back related to the cost and other similar scenarios (Getachew, 2013).

Today, most of the water bodies including even temporal ponds are heavily polluted by domestic as well as industrial wastes. Many of the industries discharge huge quantities of chemically or thermally polluted water into rivers which disturbs the biodiversity of these fresh water habitats. Benthic macro-invertebrates which are main faunal component playing an important role in nutrient recycling and energy flow are primarily affected by this activities (Chakravorty *et al*., 2014).

Recently, benthic macro-invertebrates have been found as the most common faunal assemblages for bio assessment and provide more reliable assessment of long term ecological changes in the quality of an aquatic system compared to its rapidly changing physicochemical characteristics. Well developed water quality monitoring programs involve measurements of physical, chemical and biological parameters and provide valuable information on the impact of water quality. The benthic macro invertebrates respond differentially to biotic and abiotic factors in their environment. Consequently, the structure of macro invertebrate has long been used as bio indicators to assess the quality of a water body (Duran, 2006).

More recently detailed work on the use of benthic macro invertebrates as indicator of water quality for some prominent basins in Ethiopia was worked out by Admasu (2007), Getachew and Seyoum (2010) and Getachew (2013). This is a good start but a lot is remaining as there are many un-touched lotic and lentic systems in the country. A study carried out by Tesfaye (1988) has also indicated that the benthic macro invertebrate composition and abundance varies along river *kebena* as pollution gradient increases. This clearly indicates that macro invertebrates in Ethiopia could be as good evidence for developing bio assessment methodology, especially using macro invertebrate as indicators.

However, there was no previous similar study done on Ejersa river of Woliso Town, South West Shoa, Oromia, Ethiopia. That means there was no documented data on water quality assessment using physicochemical parameters and benthic macro invertebrates in the selected river in present study area. The purpose of this study was therefore, to assess the water quality of Ejersa river using physico chemical parameters and benthic macro invertebrates.

The general objective of this study was:

- To assess water quality of Ejersa river using physico chemical parameters and benthic macro invertebrates in Woliso Town, Oromia, Ethiopia.

The specific objectives of the current work were:

- To evaluate the physical and chemical status of the Ejersa river.
- To identify macro invertebrates which are indicators of some form of pollution in the Ejersa river.
- To assess the status of benthic macro invertebrate community index along the river gradients in the study area.
- To correlate physico chemical with that of biological parameters of the Ejersa river.

2. LITERATURE REVIEW

2.1. Sources of Water Pollution

Pollution may result from point sources or diffuse sources (Non-point sources). An important difference between a point and a diffuse source is that a point source may be collected and treated or controlled. Diffuse sources (Non-point sources) are mostly agricultural activities like pesticide spraying or fertilizers that directly or indirectly pose to soil. The major point source pollutions to fresh waters originate from the collection and discharge of domestic waste waters and industrial wastes (Meyback and Helmer, 1996).

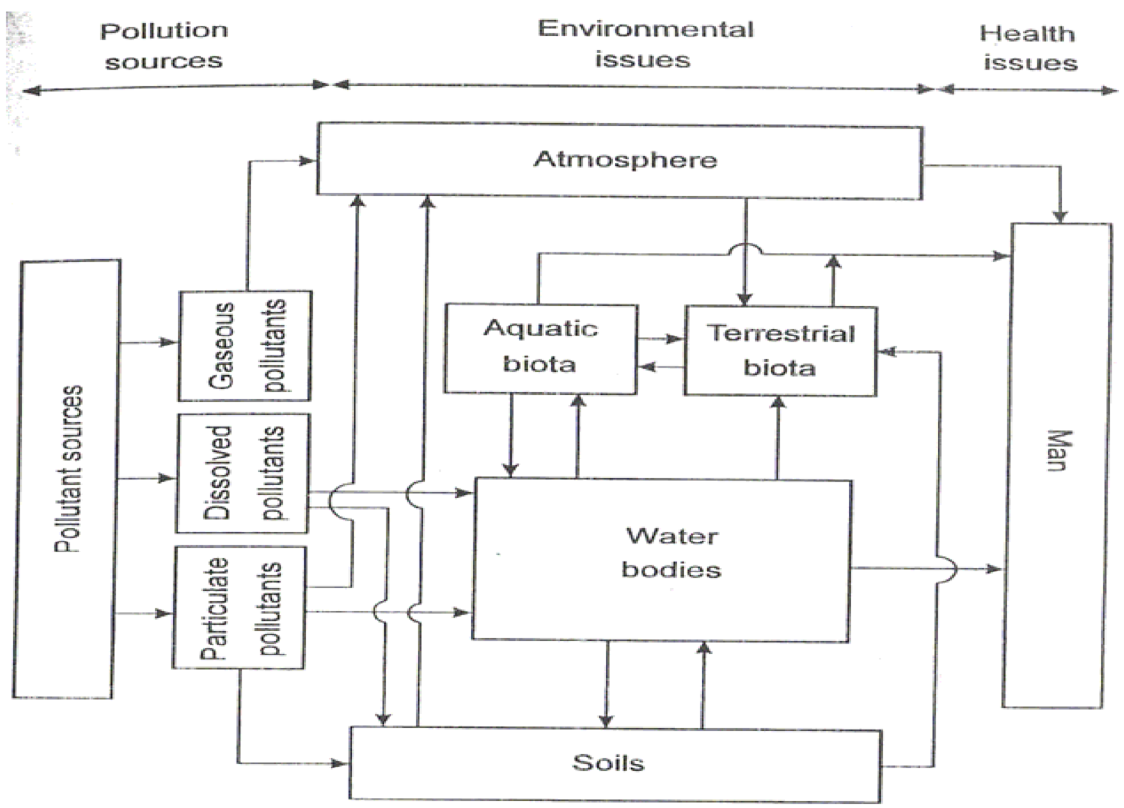

Figure 1. Sources of water pollutants and their effect on aquatic and terrestrial biota (Source: Meyback and Helmer, 1996)

Ultimately, pollutants reach the aquatic environment through variety of pathways including, the atmosphere and the soil (Fig.1). Water runoff, a non-point source of pollution, carries fertilizing chemicals such as phosphates and nitrates from agricultural fields and yards into lakes, streams, and rivers. These combine with the phosphates and nitrates from sewage to speed the growth of an algae. The water body may then become choked with decaying algae, which severely depletes the oxygen supply. This process, called eutrophication, can cause the death of fish and other aquatic life (Meyback and Helmer, 1996).

Sediment, soil particles carried to a streambed, lake, or ocean, can also be a pollutant if it is present in large enough amounts. Soil erosion produced by the removal of soil-trapping trees near waterways, or carried by rainwater and floodwater from croplands, strip mines, and roads can damage a stream or lake by introducing too much nutrient matter. This leads to eutrophication. Sedimentation can also cover streambed gravel in which many fish, such as salmon and trout, lay their eggs. Excessive sediment load as the result of adverse human activities in the water shed, the riparian side and head waters is a major factor for decline of benthic communities in rivers and streams (USEPA, 1990).

Sediments affect the instream biotic community by reducing habitat, altering water movement, food quality and interstitial spacing (Minshall, 1984). Fine sediments decreases the diversity of instream biotic communities since the suspended solids absorb heat from sunlight, causing to increase and ultimately reduction in dissolved Oxygen (Murphy, 2000).

Domestic wastes are those waste generated from commercial establishments and residential activities. They are primary source of organic waste released in to freshwater. Pollution of rivers and lakes with organic matter results in depletion of dissolved oxygen, and destruction of aquatic invertebrates and extensive fish kill (Tesfaye, 1988). Industrial wastes polluting water bodies may contain inorganic nutrients, detergents, minerals compounds such as inorganic salts, heavy metals and natural organic compounds like carbohydrate, lipid and protein (UNEP, 1991).

The presence of high organic matter in waste water has also an adverse impact on aquatic life. High biological oxygen demand levels lead to higher consumption of dissolved oxygen (DO) by aerobic bacteria robbing the oxygen that other aquatic organisms need to get. Therefore, depletion of DO can cause major shifts in the composition and abundance of aquatic organisms. Families that cannot tolerate low levels of DO like mayfly, stone fly and caddis fly will be replaced by few kinds of pollution tolerant taxa such as worms and fly larvae (Delzer and McKenzie, 1999; Barbour *et al*., 1999).

Water consisting of high DO is usually considered healthy and capable maintaining stable ecosystem with Mayfly the dominant organisms. However, a fall in DO level is an indicator of organic pollution. Inorganic nutrients like nitrates and phosphate have negative impact on aquatic ecosystem and human health when they are exceeds above normal limit. Nitrate is one of the contaminants in ground water. Since it is not strongly absorbed by sediments, it may move up to contaminate adjacent surface and ground waters. An excessive amount of nitrate and phosphate in rivers can induce eutrophication of surface waters leading to change in aquatic algal and macrophyte species composition and consequently decrease the level of dissolved oxygen (USGS, 2004; Murphy, 2005).

Suspended solids and colloidal matter discharged with industrial wastes and sewage reduce water clarity and contribute to a decrease in photosynthesis in surface waters. In addition, they bind with toxic compounds and heavy metals, and rise water temperature by absorbing sunlight. They may also clog the gills of fishes and benthic organisms, the benthic macro invertebrates are more adversely affected than fishes because of their small sizes and less mobility (USGS, 2003; Murphy, 2005).

2.2. Nature and Types of Water Pollutants

Aquatic ecosystems are threatened world-wide by pollution, as well non-sustainable land use and water management practices that are reaching critical (Table 1). Pollution of the aquatic environmental is defined as introduction of substances (wastes) and/or energy (like thermal) in to the system which can result in such deleterious effects as;

harm, to living resources, hazards to human health, hindrance to aquatic activities including fishing, impairment of water quality with respect to its use in agricultural, industrial and often economic activities (Meybeck and the Halmer, 1996).

Throughout history, the quality of drinking water has been a factor in determining human welfare. Fecal pollution of drinking water has frequently caused waterborne diseases that have decimated the populations. Currently, waterborne toxic chemicals pose the greatest threat to the safety of water supplies in industrialized nations. This is particularly true of groundwater in the USA which exceeds in volume the flow of all U.S. Rivers, lakes, and streams. In some areas, the quality of groundwater is subject to a number of chemical threats. There are many possible sources of chemical contamination. These include wastes from industrial chemical production, metal plating operations, and pesticide runoff from agricultural lands (Stanley, 1999).

Table 1 The Major sources of pollution in aquatic system (Source: Stanley, 1999)

Class of pollutant	Significance
Trace Elements	Health, aquatic biota, toxicity
Heavy metals	Health, aquatic biota, toxicity
Inorganic pollutants	Toxicity, aquatic biota
Algal nutrients	Eutrophication
Acidity, alkalinity, salinity (excess)	Water quality, aquatic life
Trace organic pollutants	Toxicity
Polychlorinated biphenyls	Possible biological effects
Pesticides	Toxicity, aquatic biota, wildlife
Sewage, human and animal wastes	Water quality, oxygen levels
Biochemical oxygen demand	Water quality, oxygen levels
Pathogens	Health effects
Detergents	Eutrophication, wildlife, esthetics
Chemical	Carcinogens Incidence of cancer
Sediments	Water quality, aquatic biota, wildlife

2.3. Health Impacts of Water Pollution

Water contaminated with human feces are generally regarded as greater risk to human health, as they are more likely to contain human-specific enteric pathogens and animals can also serve as reservoirs for a variety of enteric pathogens. Water used for the preparation of food is a source of pathogenic agents. Contaminated water can create a public health risk when it is used for drinking, washing of foods, incorporated in the food as an ingredient and used in the processing of food or used for washing equipment, utensils and hands. It is a well known vehicle for enteropathogens and other pathogen. Disease related to water sanitation and hygiene problems are among leading causes of morbidity and mortality accounting for large portion of death of 500,000 children each year. The contaminants are mainly biological pathogens. In urban areas of Ethiopia the main contaminants are from human excreta, animals waste, liquid waste from factories, flourmills, garages, pesticides from different sources. Water sources contaminated with these wastes is not fit for human use, unless it is treated (MOH, 2007).

In rural areas and villages of Ethiopia, water for human consumption, drinking, washing (bathing, laundry), for preparation of food etc, is obtained from rivers, streams, shallow wells, springs, lakes, ponds, and rainfall. Unless water is made safe or treated for human consumption, it may be hazardous to health and transmit diseases. The main contaminants of these water sources are from human excreta because of open field defecation practices, animal waste and effluent from sewage system. Thus, the majority of rural communities use water from contaminated or doubtful sources, which expose the people to various water-borne diseases (MWR, 2004).

The term water treatment is used have to mean manipulating the water to remove water-borne pathogen. Control measure may include pretreatment, coagulation /flocculation/ sedimentation, filtration and disinfection. Pretreatment include processes such as roughing filters, micro strain, off-stream storage and bank side filtration. For effective disinfection, it is important that the turbidity should be as low as possible and preferably less than 0.1 nephelometeric turbidity unit. Different types of pathogens can contaminate water, food, air and other environmental media in many different ways. Protection of water sources from contamination is the first line of defense against water borne disease. Because of the essential role water plays in supporting human life, it has great potential for transmitting a wide variety of disease and illnesses if contaminated (WHO, 2004).

2.4. Industrial Effluents Discharged to River

Industrial effluents are the major source of pollution of water and air in the environment. Based on the type of industry, various levels of pollutants can be discharged in to the environment directly or indirectly through public sewer line. Waste waters are generated by many industries as a consequence of their operation and processing. Depending on the industry and their water use, the waste water contain suspended solids, both degradable and non-biodegradable organics; oils and greases; heavy metal ions; dissolved in-organics; acids, bases and coloring compounds (Kanu *et al*., 2011).

Industrial effluents are characterized by their abnormal turbidity, conductivity, chemical oxygen demand, total suspended solids and total hardness. The river residential environment in any industrial effluent site is always under considerable stress due to the prevailing harsh environment conditions, especially high temperature and salinity, restricted benthic fauna diversity and over all development of a fragile intertidal ecosystem. The fauna inhibiting the intertidal zone is most likely dominated by a few species probably living at their limit of tolerance (Kanu *et al.*, 2011).

The industrial discharge carries various types of contaminants to the river, lake and ground water. The quality of freshwater is very important as it is highly consumed by human for drinking, bathing, irrigation and etc. The presence of contaminants from industry within the water may reduce the yield of crops and the growth of plant and it will be harmful to the aquatic organism too (Jonathan *et al.*, 2008).

2.5. Physico Chemical Parameters

Sampling at 3-5 points is usually sufficient and fewer points are needed for narrow and shallow rivers and streams (Bartram and Balance, 2001). Composition and concentration of chemicals and nutrients, gases, temperature, pH, conductivity, erosion-deposition processes, the substrate and turbidity are among physico chemical characteristics making up the integrity of river ecosystem (USEPA, 2002a).

Natural Nitrates (NO_3^-) concentrations seldom exceed 0.1mg/L. The amount may be enhanced by municipal and industrial wastes. The use of nitrogen fertilizers on farmlands on the watershed can also contribute to elevated nitrates concentrations in excess of 5 mg/L nitrates usually indicate pollution by human or animal waste or fertilizer runoff (Chapman and Kimstach, 1996). The Environmental Protection Authority of Ethiopia set a standard of 10 mg/L nitrate-nitrogen for surface waters.

Phosphorus is a limiting nutrient for algal growth and, therefore controls primary productivity. It is rarely found in high concentrations in fresh waters as it is actively taken up by plants. Its seasonal fluctuations in surface waters are considerable. In most natural waters, phosphorus ranges from 0.005 to 0.02mg/L. Concentrations as low as 0.001mg/L may be found in some pristine waters and as high as 200mg/L in some enclosed saline waters (Chapman and Kimstach, 1996). Small amount of phosphate (to the level 0.01mg/L) can have measurable effect on aquatic communities. High phosphate concentration in rivers can lead to eutrophication (USEPA, 2006).

Most aquatic organisms have adapted to survive within a range of water temperature. Organisms like stoneflies and mayflies prefer cooler water, while others like dragonflies need warmer condition. As the temperature of water increases, cool water species will be replaced by warm water organisms. Temperature also affects aquatic life sensitivity to toxic wastes and disease, either due to rising water temperature or the resulting decrease in dissolved oxygen. Water temperature influences aquatic weeds, algal blooms and surrounding air temperature (Gupta and Sharma, 1993).

The metabolic and physiological activity and life process such as feeding, reproduction, movements and distribution of aquatic organisms are greatly influenced by water temperature. pH value of water is important to many organisms. Aquatic insects are extremely sensitive to pH value below 5. The Gastropods, mayflies, stoneflies and caddis flies are some of macro invertebrate groups that prefer pH level from 7-9.5. One of the most significant environmental impacts of pH is involvement on synergistic effects. For example, very acidic water can cause heavy metals, such as copper and aluminum to be released into the water. These heavy metals may accumulate on the gills of fish or cause deformities in young fish, reducing their chance of survival (Sivakumar and Karuppasamy, 2008).

The Environmental protection authority (EPA) standard for electrical conductivity (EC) in surface waters is 1000 µs/cm (EPA, 2003). EC in fresh waters range between 10 and 1000 µs/cm, but it may exceed the maximum value of the range in polluted waters (Chapman and Kimstach, 1996). Adverse impacts are likely in fresh waters when the EC reaches 1500 µs/cm. Higher values of EC generally results due to watershed disturbances like erosion and discharges from industries and urban households. The degree of dissociation, amount of electrical charge on each ion, ion mobility and temperature of the solution matter entering into a river all influence EC. EC is highly sensitive to and is related to total dissolved solids (TDS) and major ions. In natural waters TDS can be estimated as the product of EC and a factor between 0.55 and 0.75 (Marshman and Abbott, 2003).

Turbidity is a measure of the relative clarity of water. In its 2008 Guidelines, WHO recommended turbidity should be maintained at less than 5NTU, but if water was disinfected it would be better to aim for values of less than 1 NTU. Drinking water with turbidity less than 1NTU was considered safe if it was disinfected by chlorine with free residual of 0.5mg/l at pH less than 8.0 (WHO, 2008).

DO in unpolluted waters are usually close to, but less than 10mg/L. High organic and nutrient load reduces DO concentrations as a result of increased decomposer activities. DO concentrations below 5mg/L may adversely affect the functioning and survival of biological communities. The consequent depletion of DO can alter aquatic fauna. Dissolved oxygen determines the abundance, diversity and distribution of zoo benthos and other biotic communities of the river ecosystem. DO in natural waters vary with temperature, salinity, turbulence, the photosynthetic activities of algae and plants and the atmospheric pressure. It declines with increment in temperature and salinity (Chapman and Kimstach, 1996).

2.6. Macro Invertebrates as Indicators

A taxon that responds predictably, in ways that are readily observed and quantified, to environmental disturbance or to a change in the environmental state is a good candidate species for use in biomonitoring. Organisms are used as early-warning devices or to delimit the effects of a disturbance (like an effluent). Organisms can be used as accumulators of chemicals that are used to bioassay the presence or concentration of pollutants. Organisms are used to rank pollutants in order of toxicity. Taxa are used to demonstrate the effects of habitat alteration or fragmentation or climate change, etc. Indicator taxa act as surrogates for the larger community. The response may be a decline in population size, a change in spatial distribution, or any number of life history changes. This response is representative of the response of at least a subset of other taxa present in the habitat. A biodiversity indicator is a group of taxa or functional group, whose diversity reflects some measure of the diversity of other taxa in a habitat. These measures of diversity could include character richness and species richness. The diversity measure of the indicator taxa can be used to estimate the diversity of other taxa (Gerhardt, 2002).

2.7. Biological Indicators of Water Quality

Bio indicator measures the change of biological or non-biological factors in ecosystem focusing on a living thing in some circumstances. Bio indicator indicates a living thing or a group of living things. It is used as a representative to understand and estimate general status of ecosystem. But more specifically or generally, it means the impact of environmental change in habitats, community, or ecosystem as species or group of species representing the status of living things or inanimate objects in the environment. It could also indicate living things or group of living things that show the diversity of taxonomic group in an area or a subset in entire diversity (Gerhardt, 2002).

Benthic macro invertebrates are organisms without backbones that inhabit the bottom substrates. Macro invertebrates are visible to the naked eye and are retained by mesh sizes of 500 micrometers. Benthic macro invertebrates include insect larvae, annelids (leeches), oligochaetes (worms), crustaceans (crayfish and shrimp), mollusks (clams and mussels), and gastropods (snails). Insect larvae tend to be the most abundant benthic macro invertebrates in freshwater aquatic ecosystems. As benthic macro invertebrates tend to remain in their original habitat, they are affected by local changes in water quality. Some are capable of tolerating higher loads of pollution than others. Thus if the pollution is severe, or is moderate but sustained over time, the whole community structure may simplify in favor of tolerant species. Although the abundance of certain species may increase the diversity, and species richness decreases. By assessing indicator species, diversity, and functional groups of the benthic macro invertebrate community, it is possible to assess water quality (Rosenberg and Resh, 1993).

Although water resources with high water quality generally have diverse and rich macro invertebrate fauna, certain pristine environments have low diversity of macro invertebrate fauna because of the cold temperature and/or relatively low nutrient levels. Headwaters and headwater streams may have only few dominant species. Although all classes of invertebrates may be found in headwater streams, crustaceans, caddis flies, leeches, mollusks, flatworms and black flies tend to be found in such environments (Peckarsky *et al*., 2003).

The majority of macro invertebrates are found in the riffles of streams. Riffles range from uneven bedrock to cobbles to boulders. The flow of water over these areas provides plentiful oxygen and food particles. Riffle-dwelling communities are made up of macro invertebrates that generally require high dissolved oxygen levels and clean water. To minimize variation, all samples were collected from the same habitat types of riffle zones of streams in areas where there was the best canopy coverage and side bank macro vegetation. Most are intolerant of pollution (Ravera, 1998, 2000; Ikomi *et al*., 2005).

Some of the general advantages of using biological indicators for environmental monitoring are reflect overall ecological integrity (i.e. chemical, physical, and biological). They integrate the effects of different stressors and thus provide a broad measure of their aggregate impact. They also integrate the stresses over time and provide an ecological measure of fluctuating environmental conditions. Routine monitoring of biological communities can be relatively inexpensive, particularly when compared to chemical and toxicological methods (Barbour *et al.*, 1999).

2.8. Macro Invertebrates and Water Quality Assessment

Benthic macro invertebrates determine water quality because of high number, pollution tolerance, limited mobility, wide range of feeding habit, vary life span and depend on land environment around stream. Collections of macro invertebrates from more than one habitat type may introduce variation that can potentially mask water quality difference among sites (Jeffrey and Charles, 2003). Riffle communities of streams are also more diverse in invertebrate forms than pools (Girth and Herlihy, 2006).

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

According to Maciorowski and Clarke (1977); Metcalfs (1989) and Bode *et al.*, (1996) the criteria and/or advantages why benthos should be used in water quality assessment include:

- Sampling procedures are relatively well developed.
- Can be operated by someone working alone.
- There are identification keys for most groups of macro invertebrates.
- Are reasonably sedentary with comparatively long lives, so that they can be used to assess water quality at a single site over a long period of time.
- The size of benthos is almost ideal for water quality testing, since many are macroscopic and can even be recognized with the naked eye.
- The diversity of aquatic invertebrates provides several attributes that can be utilized as responses in laboratory toxicity test.
- Reproduction and life-cycle may be completed with 2 to 4 weeks with genera such as Daphnia and Chironomus whereas life cycle studies with rapidly reproducing fish may require 3 months to 2 years.
- The group is heterogeneous and so a single sampling technique may catch a considerable number of species from a range of phyla.
- Since taxa differ in their tolerance to pollutants, particular taxa make useful indicators of conditions.
- As benthic invertebrates respond sensitively not only to pollution, but also to a number of other human impacts (physical modification, recreational and others).

In Ethiopia, benthos of streams and rivers has been studied for various reasons. For instance, Baye (2006) studied some benthic macro invertebrate structures in relation to environmental degradation in some rivers; Birenesh (2007) assessed pollution of downstream effluent along Tikur Wuha river using macro invertebrate indicators; Harrison and Hynes (1988) were pioneers to study benthos in Ethiopia, especially the benthic fauna of highland streams; Hayal and Seyoum (2009) studied water quality parameters and macro invertebrate index of biotic integrity of the Jimma wetlands; Tesfaye (1988) studied degradation of Kebena river using macro invertebrate structures and composition and Tujuba (2010) studied macro invertebrates abundance and community structure of Lake Kuriftu.

Evaluating the status of water quality and climate change by examining fauna has been well established in both theory and practice for several decades (Davis, 1995). In this regard, benthic macro invertebrates are useful in evaluating water quality and the overall health of flowing water systems. They are affected by changes in a stream’s chemical and/or physical structure (Karr and Kerans, 1991).

3. MATERIALS AND METHODS

3.1. Descriptions of the Study Area

Woliso is one of the towns found in the South west Shoa Zone, Oromia Regional State of Ethiopia, which was established in 1926. However, the town was officially recognized as municipal town after 4 years in 1930 of its establishment. By now the town is serving as a seat for Woliso *Wereda*/district administration and the center of South west Shoa Zone. It has its own administrative structure that is led by a Mayor (Administration Mayor Office, 2014/15).

Administratively the town is divided in to 4 *kebeles* and 36 small zonal developments (Sub-*kebeles*). According to 2007 population census by Central Statistical Agency (CSA), the population size of Woliso town was 37, 868 and in the year 2014/15 this number is expected to reach about 60,904 out of which males accounts for 29,187 and females accounts for 30,716, since the population growth rate of the town is assumed to grow at 3.8 percent per annum (Administration Mayor Office, 2014/15).

Woliso town is located at a distance of 114 kilometers South west of Addis Ababa and 225 kilometers away from Jimma town along Addis Ababa - Jimma main road. Geographically, the town is located at $8.31^{0}60$” North latitude and $37.58^{0}60$” East longitudes. The main rainy seasons of the area fall in the months of June to August, but small rains are often seen from February to April. The elevation of the town ranges from 1900 to 2000 meters above sea level. The mean temperature of the town is 22.5 ^{0}C and the mean annual rainfall is 1200 mm (Administration Mayor Office, 2014/15).

Ejersa river is crossing the town. Ejersa river is used by the communities inhabiting around downstream for drinking, to irrigate their farm lands, for their cattle and other domestic use. On the other hand, the watershed of Ejersa river is highly exposed to several anthropogenic activities including: agricultural, domestic sewage from prison institution, abattoir and residential areas. Large quantities of untreated municipal sewage, from prison institution and abattoir effluents are directly discharged to Ejersa river. Agricultural activities cover all the watershed of the river and are more likely to affect the habitat qualities of the river. The main victims from this threat are the rural communities found in Fodu Gora and Badesa Koricha farmers association *Kebeles* (Water supply and Sanitation office, 2014/15).

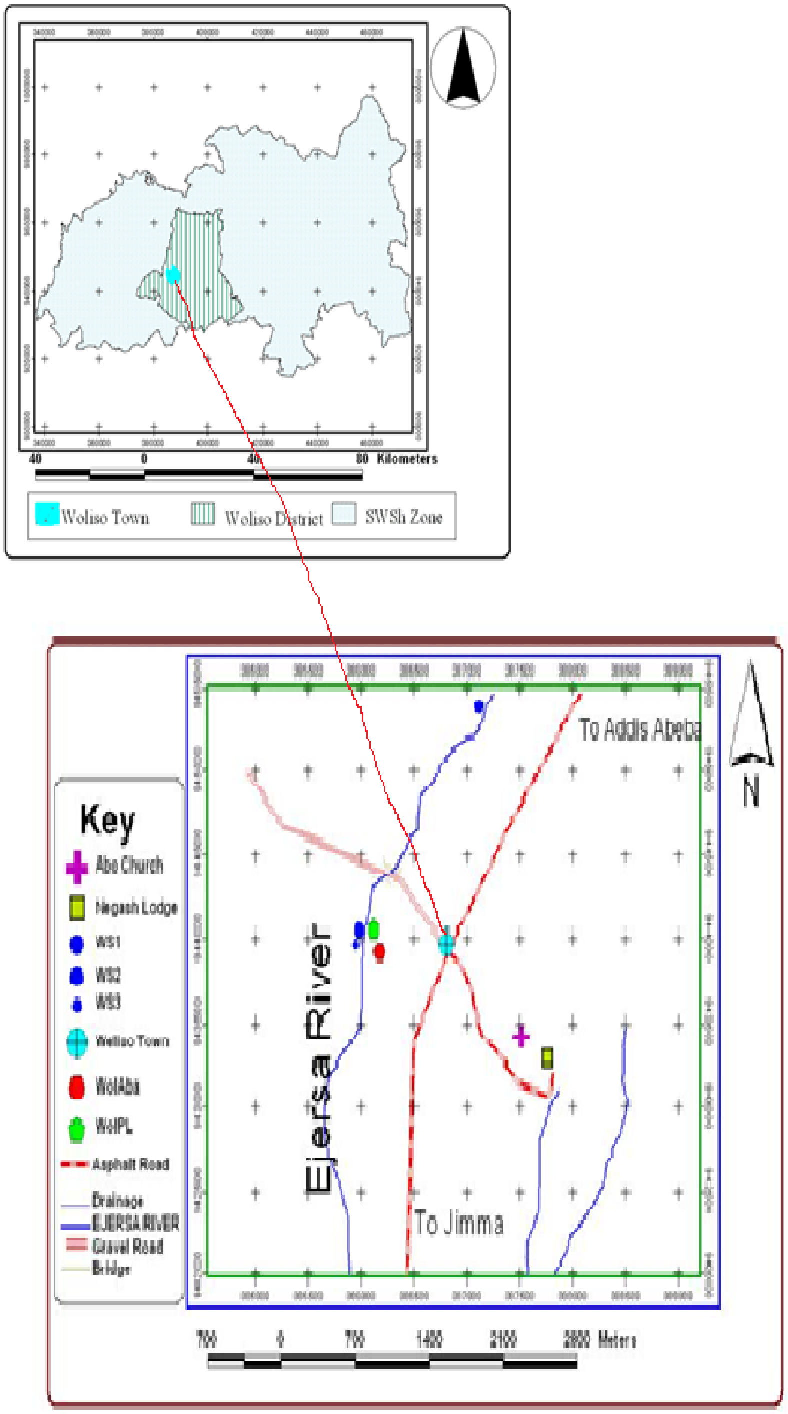

Figure 2. Map showing the three study sites in Woliso town (Developed from GPS)

3.2. Design of the Study

The design of the study was cross-sectional survey and laboratory investigation of the Ejersa water samples to assess the water quality using physico chemical parameters and benthic macro invertebrates in Woliso town, Oromia Regional State, Ethiopia. The design based on laboratory investigation which was carried out by taking water samples from three sites using random sampling techniques and samples from an individual site was taking three times in the first week of three months. Physico chemical measures like temperature, turbidity, pH, electrical conductivity, salinity, total dissolved solids and color on site and nitrate, nitrite and phosphate in Woliso Polytechnic College of water laboratory.

Benthic macro invertebrates were collected using D-net (net with 500 µm mesh size) from three sites and in an individual sites collected three times within the first week of three months. Identification of benthic macro invertebrates was done using a binocular microscope in the biology laboratory of Dejazmach Geresu Duki Preparatory School using available keys or identification keys (Bouchard, 2004) and assigned to their respective taxonomic levels (family level). Sample collections were done during March to May 2016.

3.3. Selection of Sampling Sites

There were three sampling sites selected based on randomly sampling technique, at point of entrance, in middle of the town and at exit point of Ejersa river as site-1, site-2 and site-3 respectively. The reference site was selected based on the following criteria. The reference condition collectively refers to the range of quantifiable ecological elements that are found in minimally disturbed environments. Finding reference sites in streams is a difficult task, because no regions are entirely without areas of human disturbance. However, it was identified based on the following criteria as indicated by Jennifer *et al.*, (2003).

1) The same water body type, size, and chemical characteristics as treated site
2) Within same watershed as treated site

3) Minimal application of aquatic pesticides within the last few years, and

4) Limited anthropological inputs. According to the above criteria, as a reference site one was selected. The river originates from the highlands area, which is located along Woliso town and joins Walga river, then finally Gibe river.

Site-1 (SI) - is located at the upstream of the river near to water station of the town. The area is covered by distinctive vegetation, acacia and grasses. It is a reference site for bio-assessment with less human activity.

Site-2 (SII) **-** is found at the back of south west Shoa Zone prison institution situated around Ejersa river in middle of the town and mainly covered with grasses, shrubs and eucalyptus trees.

Site-3 (SIII) - is below abattoir at exit point along the river gradients of the town and mainly covered with grasses, shrubs and acacia.

3.4. Physico Chemical Measurement of Ejersa River Water Samples

One liter plastic bottle was sterilized with in autoclave at $121°_C$ for 15 minutes then soaked with 5% HNo_3 solution, finally washed with distilled water. A composite water sample of one liter was taken from each site using a one liter plastic bottle. Electrical conductivity (μs/cm), TDS (mg/L) and salinity (mg/L) was determined with a field conductivity meter (Elmetron, CC411 Model, Japan). DO (mg/L) measured with probe using Jenway 9150 DO meter that was titrimetric procedure, temperature ($°_C$) by digital thermometer (model 145), pH measure using portable digital pH meter, turbidity (NTU) by digital turbido meter and color (TCU) by comparator was measured on site due to their unstable nature.

The samples were transported to Woliso Polytechnic College of water laboratory within 1-3 hours and then led to filter through glass fiber filters (GFF). The filtered water sample was used for measurements of Nitrate (No_3^-) (mg/L), Nitrite (No_2^-) (mg/L), and Phosphate (PO_4^{-3}) (mg/L) following the standard methods as indicated in APHA (1998). The concentrations of nitrate (mg/L) was analyzed by taking 10ml of water sample by cavet, add Nitraver 5 Nitrate reagent powder pillow, 5 minutes for reaction, Nitrite (mg/L) also taking 10ml of water sample by cavet, add Nit river 3 Nitrite reagent set , 20 minutes for reaction and Phosphates (mg/L) measured by taking 10ml of water sample by cavet, add phosver 3 phosphate reagent powder pillow, 2 minutes for reaction was determined using Spectrophotometer (DR/2800, Japan) according to HACH instructions and using standard pillow.

3.5. Sampling of Benthic Macro Invertebrates

Macro invertebrates were collected using D-net (net with 500 µm mesh size with 0.3m width and height) from three sites that are selected and in each site three times from March to May 2016. Sampling was done following the Wadeable Rivers protocols for streams (Hilsenhoff, 1987; King *et al.*, 1996).

All members of a group in three sites were composited in an individual single bottle and preserved in 70% ethanol, labeled and then transported to laboratory. Samples were transferred to a white tray to remove debris and obscuring detritus. The individual macro invertebrates were picked out with forceps and place in a separate vials containing 70% ethanol. At each site, macro invertebrate's specimens were collected from a river and finally preserved in ethanol. For numerical analyses, samples from each sites of river was grouped separately and labeled as sample site I, II and III, respectively and then counted, sorted and finally identified.

Identification of benthic macro invertebrates was done using a binocular microscope with available keys and assigned to their respective taxonomic levels (family level) identification (Hailu and Legesse, 1997; Gallardo *et al.*, 2006; Hering *et al.*, 2006; Flinders *et al*., 2008). Identification of benthic macro invertebrates are in the biology laboratory of Dejazmach Geresu Duki preparatory school. The specimens were identified using binocular microscope to relate with available keys (identification key) guide to aquatic invertebrates of the upper midwest by Bouchard and Jessup used the Iowater benthic macro invertebrate key first and the upper midwest guide (Bouchard, 2004; Jessup *et al.*, 1999).

3.6. Identification and Quantification of Macro Invertebrates

The macro invertebrate metrics representing composition, richness, rate of organic pollution of the river, and taxa lost (intolerant) due to perturbation. Metrics (or indices) allow the investigator to use meaningful indicator attributes in assessing the status of assemblages and communities in response to perturbation. Metrics were reviewed based on description in the EPA, and Hilsenhoff (1988) from the data.

The criteria for metric selection were the ability to be associated with physical degradation, ability to provide unique information about the river (Chihart, 2003). The indices to be selected were Shannon-weaver diversity index, Hilsenhoff-family biotic index (H-FBI) and Community loss index were done in three sites that are selected.
The Shannon-Weaver Diversity Index (H) was evaluated the abundance and evenness of benthic macro invertebrates among the sites.
This was calculated as: $H = -\sum_{i=1}^{s} -(P_i)(\log_2 P_i)$
Where "Pi" is the proportion of individuals in the "i^{th}" taxon of the community and "S" is the total number of taxa in the community.

To analyze the degree of organic load among the study sites, Hilsenhoff-family biotic index was computed using Hilsenhoff (1988). Although the FBI may be applicable for toxic pollutants, it has only been evaluated for organic pollutants.

Table 2 Evaluation of water quality using the family biotic index (Hilsenhoff, 1988)

Family Biotic Index	**Water Quality**	**Degree of Organic Pollution**
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very good	possible slight organic pollution
4.26-5.00	Good	some organic pollution probable
5.01-5.75	Fair	fairly substantial pollution likely
5.76-6.50	Fairly	poor Substantial pollution likely
6.51-7.25	Poor	Very substantial pollution likely
7.26-10.00	Very poor	severe organic pollution likely

The formula for calculating the Family Biotic Index (FBI) is:

$$FBI = \frac{\sum Xi\ Ti}{N}$$

Where: xi = number of individuals within a taxon

Ti = tolerance value of a taxa

N = total number of organisms in the sample

To measure the loss of benthic taxa and dissimilarity between sample sites, community loss index (CLI) was used. Community loss index measures the loss of benthic taxa in a study site with respect to a reference site. Values range from zero (0) to infinity and increase as the degree of dissimilarity between the sites increases (plafkin *et al*., 1989).

Community loss index was calculated as: $CLI = \frac{D - A}{E}$

Where, A - is the number of taxa common to both sites

D - is the total number of taxa present in reference site (site one)

E - total number of taxa present in the study sites

3.7. Data Analysis

The physico chemical variables and benthic macro invertebrate community structures were analyzed for all of the three sampling sites. One way Analysis of variance (ANOVA) was used to test for significant difference in physico chemical parameters among the study sites and to locate sites of significant difference respectively. SPSS software version 20.0 and Microsoft Excel sheet on computer was used to analyze data obtain from physico chemical and biological parameters. Bivariate Pearson correlation methods were used to inter-relate the physico chemical parameters and benthic macro invertebrates.

4. RESULTS AND DISCUSSION

4.1. Physico Chemical Properties of the Ejersa River Water Samples

The mean results of each physico chemical parameters with standard error of mean are given in table 3.

Table 3 Mean physico chemical values of the three study sites (mean ± SEM, n=3)

Parameters	Site I	Site II	Site III
pH	7.9 ± 0.08	8.8 ± 0.08	8.3 ± 0.05
Temp (°C)	19.4 ± 0 .55	22.8 ± 0.54	21.2 ± 0.8
EC (μs/cm)	171.8 ± 13.34	378.2 ± 28.3	261.6 ± 19.2
TDS (mg/L)	85.9 ± 6.67	189.1 ± 14.15	130.8 ± 9.62
Salinity (mg/L)	105.7 ± 7.12	227.53 ± 27.35	167.3 ± 7.24
Color (TCU)	20 ± 1.15	26.6 ± 0.72	23.9 ± 1.06
DO (mg/L)	7.01 ± 0.34	4.17 ± 0.25	4.9 ± 0.49
Turbidity (NTU)	97.9 ± 3.74	246.2 ± 24.3	181.7 ± 25.6
Nitrate (mg/L)	81.4 ± 10.78	163.7 ± 19.03	110.5 ± 10.02
Nitrite (mg/L)	0.198 ± 0.002	0.451 ± 0.017	0.376 ± 0.03
Phosphate (mg/L)	0.09 ± 0.027	2.626 ± 0.153	2.063 ± 0.05

SEM = Standard Error Mean

Table 4 p-value result of physico chemical parameters between three study sites

Parameters	Site	Result	P-value
PH	I and II	Significance difference	0.0018
	II and III	Significance difference	0.0075
	I and III	Significance difference	0.0183
Temp	I and II	Significance difference	0.011
	II and III	No significance difference	0.184
	I and III	No significance difference	0.129

Parameters	Site	Result	P- value
EC	I and II	Significance difference	0.0027
	II and III	Significance difference	0.027
	I and III	Significance difference	0.0184
TDS	I and II	Significance difference	0.0027
	II and III	Significance difference	0.027
	I and III	Significance difference	0.0184
Salinity	I and II	Significance difference	0.0124
	II and III	No significance difference	0.1
	I and III	Significant difference	0.0037
Color	I and II	Significant difference	0.0085
	II and III	No significance difference	0.105
	I and III	No significance difference	0.0702
DO	I and II	Significance difference	0.0026
	II and III	No significance difference	0.222
	I and III	Significance difference	0.0277
Turbidity	I and II	Significance difference	0.0038
	II and III	No significance difference	0.1419
	I and III	Significance difference	0.032
No_2-N	I and II	Significance difference	0.00016
	II and III	No significance difference	0.128
	I and III	Significance difference	0.0072
No_3-N	I and II	Significance difference	0.0196
	II and III	No significance difference	0.0686
	I and III	No significance difference	0.1188
PO_4^{-3}	I and II	Significance difference	8.33E-05
	II and III	Significance difference	0.0252
	I and III	Significance difference	4.85E-06

-Significance difference ($P < 0.05$)

-No significance difference ($P > 0.05$)

4.1.1. pH

The mean pH value of the study sites varied from 7.9 ± 0.08 to 8.8 ± 0.08. The pH value deviating toward basic medium because greater than seven. The pH value for the study site I (7.9), site II (8.8) and site III (8.3) were almost the minimum acceptable limit set by EPA (2003) for surface water (6.0-9.0). The value of site II which is near to prison institution and site III below abattoir has relatively higher pH value than the site I. This is a clear indication that as one moves from the upstream to downstream sites the pH underwent dramatic increase. High organic content, eutrophication and salinity influence variation in pH. Extremely high or low pH has adverse impact on the quality of the water and may kill the aquatic organisms. pH below 6.5 causing corrosion in pipes resulting in the release of toxic metals (Dodds, 2002).

4.1.2. Temperature

Temperature among study sites varied from 19.4 ± 0 .55 to 22.8 ± 0.54$°_{C.}$ There was a variation in mean temperature recorded among site I, site II and site III. The highest value recorded at site II near the area where the prison institution discharges its wastes to river. The optimum temperature for stream water is 11-25°c (EPA, 2003) and 12-25°c (WHO, 2008). Ejersa river falls in the category of optimum temperature for stream. Temperature regulates biological activities, metabolic rate and growth of aquatic organisms, so variation in temperature promotes different biotic features (Zabinski *et al.*, 2009). It also influences the solubility of gases dissolved in water; at higher temperature, less gas, such as oxygen, carbon dioxide can dissolve in stream. The higher the temperature, the lesser dissolved oxygen in the stream (Allan, 1995).

4.1.3. Electrical conductivity (EC)

The mean value of electrical conductivity varied from 171.8 ± 13.34 to 378.2 ± 28.3 µs/cm in which the highest value was recorded at site II (Table 3). In fact their standard value designed by EPA (2003) for EC was 1000 µs/cm for any surface water. Compared to these standards Ejersa river had conductivity in between the minimum permissible limit. The maximum EC record of Modjo river was 910.2 ± 186.6 μs/cm (Baye Sitotaw, 2006). But Ejersa river was lower EC than the above river and discharged from fertilizers, municipal sewage, domestic waste, prison institution and abattoir could be the reason for conductivity in Ejersa river. This is clearly manifested untreated effluent was directly discharged without any treatment into the river. The variation in the level of conductivity is associated with the total dissolved solids in water (Bauder *et al*., 2003).

Conductivity is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions; on their total concentration, mobility, and valence; and on the temperature of measurement. Increasing levels of conductivity and cations are the products of decomposition and mineralization of organic materials (Abida, 2008).

4.1.4. Total dissolved solids (TDS)

The mean value of TDS varied from 85.9 ± 6.67 to 189.1 ± 14.15 mg/L in which the highest value was recorded at site II (Table 3). Minimum average TDS value was recorded at site I (85.9 ± 6.67 mg/L) and site III (130.8 ± 9.62 mg/L). Like conductivity, the increase in TDS might be due to associated watershed disturbance, runoff organic wastes and fertilizers. TDS entering river may affect water clarity, temperature, interstitial space and entrapment of toxic pollutants such as heavy metals (USGS, 2003, Murphy, 2005).

In this study, all the sites showed varying amount of total dissolved solids. But according to Food and Agricultural Organization (FAO) recommendation, the acceptable range for live stock drinking is 100-1,500 mg/L TDS. EC is highly sensitive to and is related to total dissolved solids and major ions. In natural waters, TDS can be estimated as the product of EC (TDS is equal to EC divide by two). That why, the amount of total solids entering the river may be the main reason for elevation of conductivity, temperature and depletion of oxygen. TDS in drinking water should not exceed 1000 mg/L (WHO, 2008).

4.1.5. Salinity

The mean value of salinity varied from 105.7 ± 7.12 to 227.53 ± 27.35 mg/L in which the highest value was recorded at site II and site III. The mean value of site I (105.7 ± 7.12) was lower than site II (227.53 ± 27.35) and that of site III (167.3 ± 7.24) (Table 3). DO in natural water varies with temperature, salinity, turbulence, the photosynthetic activities of algae and plants and the atmospheric pressure. The increment of salinity and temperature decline the dissolved oxygen.

4.1.6. Color

The mean value of color varied from 20 ± 1.15 to 26.6 ± 0.72 TCU in which the highest value was recorded at site II (Table 3). The standard for color was 15 TCU (WHO, 2008). Based on WHO standards all sites were above optimum level. These indicate that due to anthropogenic activity, discharged from prison institution, abattoir and municipal sewage the color of Ejersa river was high.

4.1.7. Dissolved oxygen (DO)

The mean value of DO varied from 4.17 ± 0.25 to 7.01 ± 0.34 mg/L (Table 3). The maximum average concentration of DO in the river water was recorded at site I (7.01 ± 0.34 mg/L) located at the upstream of the river near to water station of the town. The minimum DO measure was from site II (4.17 ± 0.25 mg/L). The DO records of this study at site II and site III was lower compared to Modjo river (min. 6.1 ± 4.01 mg/L but higher than Great Akaki river (min. 3.1 ± 2.4 mg/L) (Baye Sitotaw, 2006).

However, studies on Little Akaki river came up with DO value as low as 0.3 mg/L in its stretch within Addis Ababa. Dissolved oxygen determines the abundance, diversity and distribution of zoo benthos and other biotic communities of the river ecosystem. DO in natural water varies with temperature, salinity, turbulence, the photosynthetic activities of algae and plants and the atmospheric pressure. DO declines with increment in temperature and salinity. High organic and nutrient load reduces DO concentrations as a result of increased decomposer activities (Deshu Mamo, 2004).

Majule (2010) also reported that human, wildlife and livestock activities had significant impacts on water quality of the Mara river through organic matter deposition into the channel, thus probably resulting in the low dissolved oxygen levels observed.

4.1.8. Turbidity

The mean value of turbidity varied from 97.9 ± 3.74 to 246.2 ± 24.3 NTU in which the highest value was recorded at site II (Table 3). The mean value of site I (97.9 ± 3.74 NTU) was lower than site II (246.2 ± 24.3 NTU) and site III (181.7 ± 25.69). The standards for turbidity were 5 NTU (WHO, 2008). Based on WHO standards all the sites were above optimum level. These indicate that due to anthropogenic activity, discharged from prison institution, agricultural activities, abattoir, poor sanitation facilities to the riparian communities and municipal sewage, the turbidity of Ejersa river was high. Continued accumulation of dissolved and suspended solid in aquatic systems reduces water transparency, effectively impacting on primary productivity, thus affecting benthic macro invertebrates (Emere and Narisu, 2007).

4.1.9. Nitrate

Minimum average was recorded at site I (81.4 ± 10.78 mg/L), while higher at site II (163.7 ± 19.03 mg/L) and site III (110.5 ± 10.02 mg/L) (Table 3). High nitrate concentrations are indication of pollution from untreated sewage, sanitary landfills, disposal sites, urban activities, agriculture and fertilizer run-off along with other point and non-point sources of pollution (Carpenter *et al.*, 1998; Meesukko *et al.*, 2007).

The use of nitrogen fertilizers on farmlands on the watershed can also contribute to elevated nitrate-nitrogen concentrations in excess of 5 mg/L usually indicate pollution by human or animal waste or fertilizer runoff (Chapman and Kimstach,1996). The Environmental Protection Authority of Ethiopia set a standard of 10 mg/L nitrate-nitrogen for surface waters. The high concentration of nutrients like, nitrates and nitrites could deplete the amount of dissolved oxygen in the water. This in turn could affect the biomass and species diversity of aquatic organisms. The same scenario could occur in Ejersa rivers since their concentration is very high. Under certain conditions, high levels of nitrate (≥10mg/L) in drinking water can be toxic to humans. High levels of nitrate linked to serious illness and even death in infants as well as death for aquatic organisms (Barbour *et al*., 1999).

4.1.10. Nitrite

The mean value increased from site II (0.451 ± 0.017 mg/L) but slightly decreased at site III (0.376 ± 0.03 mg/L) and site I (0.198 ± 0.002 mg/L) (Table 3). The mean nitrite-nitrogen concentration measured here at site I, site II and site III were lower than the optimum limit. The reason behind here may be lack of microbial assemblage which involved in nitrite (example, Nitrosamines bacteria) conversion from nitrogen containing compounds, lack of oxygen (to undergo chemical process), and high organic load. The standard nitrite-nitrogen concentration is 3 mg/L (WHO, 2008).

4.1.11. Phosphate

Phosphate concentration was varied between all study sites. Minimum average was recorded at site I (0.096 ± 0.027 mg/L) while became higher at site II (2.626 ± 0.153 mg/L) and site III (2.063 ± 0.05 mg/L) (Table 3). Phosphate records of the study site II and site III was higher than the standard limit due to pollution from the farmlands, wastes from prison institution, abattoir and domestic. The slight increase from the natural condition at these sites could be due to diffuse source pollution from the farmlands in the watershed. Significantly higher record at site II could be due to the inclusion of shower or bathing, washing with phosphate based detergents and soaps wastes to the effluent joining the river water (Water watch Australia, 2002; Davies *et al*., 2009).

Very slight increase due to leaching of rock particles from the channel and domestic wastes from the surrounding. High phosphate concentration in rivers can lead to eutrophication (USEPA, 2006). In general, the measured physico-chemical parameters (Table 3) indicated that sharp decline in the quality of the river water especially downstream sites and adversely affect the aquatic ecosystem.

4.2. Biological Parameters

Table 5 Major macro invertebrate families identified in the Ejersa river

Family	Site I	Site II	Site III	Total
Chironomidae (blood red)	64 (54.7%)	73 (69.5%)	68 (66%)	205
Syrphidae	-	23 (21.9%)	24 (23.3%)	47
Perilidae	14 (11.9%)	-	-	14
Lestidae	11 (9.4%)	-	-	11
Capiniidae	9 (7.69%)	-	-	9
Naucorridae	7 (5.98%)	-	-	7
Dytiscidae	7 (5.98%)	1 (0.95%)	7 (6.7%)	15
Heptagenidae	5 (4.27%)	-	-	5
Gyrinidae	-	3 (2.85%)	-	3
Empididae	-	1 (0.95%)	1 (0.9%)	2
Tipulidae	-	1 (0.95%)	-	1
Haliplidae	-	1 (0.95%)	1 (0.9%)	2
Elimidae	-	1 (0.95%)	1 (0.9%)	2
Coenagrionidae	-	1 (0.95%)	1 (0.9%)	2
Total	117	105	103	325

In site I, the family Chironomidae was the most abundant compared to other benthic organisms. From the total macro invertebrates taxa, Chironomidae (54.7%), Perlidae (11.96%), Lestidae (9.4%), Capniidae (7.69%), Dytiscidae (5.98%), Naucoridae

(5.98%) and Heptageniidae (4.27%) identified (Table 5). In site II, the most dominant taxa were Chironomidae (69.5%), Syrphidae (21.9%) and Gyrinidae (2.85%) composition respectively. Haliplidae, Dytiscidae, Tipulidae, Elemidae, Coenagrionidae and Empididae (0.95%) were the least families (Table 5). In site III, the most dominant taxa were Chironomidae (66%), Syrphidae (23.3%), Dytiscidae (6.7%) and Haliplidae, Empididae, Elemidae, Coenagrionidae (0.9%) were identified (Table 5). Most of the individuals were sampled from site II (9 families) followed by site III (7 families) and site I (7 families). Benthic communities with a large proportion of pollution-sensitive organisms usually are associated with water of relatively high quality; whereas large proportions of pollution tolerant organisms (numerous families) have indicated water badly polluted with organic wastes (Tyagi 2006).

Benthic macro invertebrate species are differentially sensitive to many biotic and abiotic factors in their environment. Consequently, macro invertebrate community structure has commonly been used as an indicator of the condition of an aquatic system (Armitage *et al.*, 1983; Rosenberg and Rash, 1993). Chironomidae is among the families of Diptera taxa with the red blood being more tolerant than the pale one. Higher tolerance of the red blood chironomidae is due to its pigment that helps the organism to get oxygen from the atmosphere hence the name “blood red” (Bouchard, 2004). The family chironomidae identified from the study sites I, II and III was the red blood chironomidae which dominating the area being assisted by haemoglobin pigment at oxygen low environments (Iowa watershed Monitoring and Assessment Program, 2010). Since chironomidae was the most tolerant taxa. This implies there was higher ecological impairment due to closeness of the discharging huge amount of waste to the river.

Studies done by Raunio *et al., (*2007) showed that there were some chironomidae genera that were intolerant to organic pollution. The presence of chironomidae in the site was not to mean that the site was under pollution stress or free from pollution but it needs deep study on the genus or species level to determine quality of water because there are some genera or species sensitive to pollution. The family Syrphidae was the most tolerant of organic pollution. This implies that within reduced habitat of lower oxygen and polluted river, the physiological and morphological structure especially respiratory tube enables the family Syrphidae to retain in the habitat of less or devoid oxygen. The more perturbation of the river, and percent of pollution tolerant organisms increases (Barbour *et al.,* 1999, Gallardo *et al*., 2006). The absence of intolerant family indicates that the river Ejersa was so polluted from nearby wastes. The family Dytisidae (site I 5.98%, site II 0.95%, site III 6.7%) was the one that present in all sites. This indicated that they have the tendency to retain in highly and poorly polluted area. Heptagenidae and Perilidae were present only require in high amount of oxygen and are very sensitive to organic pollution and considered very sensitive to environmental stress, their abundance at upstream sites (site I) shows comparatively favour environment conditions (Solimini *et al.,* 2003).

Table 6 Percentage composition of macro invertebrates (MI) in the Ejersa river

% MI family	March	April	May	% Tolerance value
Chironomidae	56.3	62.6	74.1	8
Syrphidae	17.2	13.1	11.7	10
Perlidae	6	5.6	-	1
Dytiscidae	2.3	5.6	7.1	5
Lestidae	3.8	3.7	2.4	3
Capniidae	5.3	1.8	-	1
Gyrinidae	1.5	-	1.2	4
Heptageniidae	2.3	1.8	-	3
Naucoridae	1.5	4.6	-	1
Empididae	0.7	-	1.2	6
Haliplidae	0.7	-	1.2	5
Elemidae	0.7	0.9	-	4
Coenogrinidae	0.7	-	1.2	9
Tipulidae	0.7	-	-	3

Chironomidae (56.3%, 62.6% and 74.1%) and Syrphidae (17.2%, 13.1% and 11.7%) were the dominant families observed during the three study months but Empididae, Halipnidae, Elemidae, Coenogrinidae and Tipulidae (0.7%) were the least families of benthic macro invertebrates, respectively (Table 6).

Table 7 Composition and distribution of benthic macro invertebrates collected from Ejersa river sampling sites

No	Order	Family	SI	SII	SIII	Total	%abundance
1.	Diptera	Chironomidae	64	73	68	205	63.1
		Syrphidae	-	23	24	47	14.5
		Empididae	-	1	1	2	0.61
		Tipulidae	-	1	-	1	0.3
2.	Coleoptera	Haliplidae	-	1	1	2	0.61
		Dytiscidae	7	1	7	15	4.61
		Elimidae	-	1	1	2	0.61
		Gyrinidae	-	3	-	3	0.92
3.	Plecoptera	Perilidae	14	-	-	14	4.3
		Capiniidae	9	-	-	9	2.76
4.	Odonata	Lestidae	11	-	-	11	3.38
		Coenagrionidae	-	1	1	2	0.61
5.	Ephemeroptera	Heptagenidae	5	-	-	5	1.53
6.	Hemiptera	Naucorridae	7	-	-	7	2.15
Total			117	105	103	325	

During the study a total of fourteen families (325 macro invertebrates) belonging to six orders were identified from three study sites (SI,SII and SIII) within three month (March, April and May) (Table 7). As indicates in Table 7, Diptera (78.5%), Coleoptera (6.8%), Plecoptera (7.1%), Odonata (4%), Ephemeroptera (1.5%) and Hemiptera (2.2%) were the macro invertebrates' composition along Ejersa river in the study sites. Diptera where the most dominant, whereas Ephemeroptera and Hemiptera were the least benthic macro invertebrates' composition.

4.2.1. The Macro invertebrates community index in the Ejersa river

Table 8 Diversity index of benthic macroinvertebrates at three study sites

Diversity index	Site I	Site II	Site III
No. of individual species	117	105	103
Shannon-wiener index (H')	4.3	2.5	2.6
Family biotic index (FBI)	5.33	8.24	8.18
Community loss index (CLI)	0.9	1.09	1.11

Biotic index systems have been developed which give numerical scores to specific "indicator" organisms at a particular taxonomic level (Armitage *et al.*, 1983). Presence of numerous families of highly tolerant organisms usually indicates poor water quality (Hynes, 1998). According to the result obtained from Shannon-weaver index showed that the family abundance was higher (high diversity) in site I (4.3) than site II (2.5) and site III (2.6) which was less diversity observed indicating quality differences among the sites (Table 7). High values of "H" would be representing of more diversity community as well as even distribution. This provides valuable clues for water quality monitoring.

The Shannon-weaver diversity index values which normally ranges between 0.0-5.0 decreases with increasing stress of aquatic ecosystem (Mangurran, 2004). As the aquatic stress decreases, the number of macroinvertebrate increases. Nutrient enrichment and organic loading decreases macro invertebrate richness by removal of sensitive taxa mostly insect orders like Ephemeroptera, Plecoptera and Hemiptera (Dura, 2005). This could be the reason why macro invertebrates among the study sites showed considerable variations. An increase in the total abundance does not show better environment because disturbance may favor some tolerant, opportunistic and less competent taxa with reduction in sensitive taxa (community dominated by few taxa). As the number and distribution of taxa (biotic diversity) within the community increases, so does the value of "H" (Gerristen *et al*., 1998).

The Modified Family Biotic Index (FBI) was developed to detect organic pollution and is based on the original species-level index of Hilsenhoff (Hilsenhoff, 1988). In this study, sites II (8.24) and III (8.18) (Table 7) show higher FBI values; suggesting comparatively low water quality and lower FBI was calculated from site I (5.33) suggesting comparatively higher water quality. There was high organic load (high value of FBI) in the river section which is the main reason for poor water quality and reduction in number and distribution of benthic macro invertebrates.

Most tolerant taxa survive and reproduce in such harsh environment due to morphological and physiological adaptation mechanism; the others (less tolerant and less competent) are eradicated from an area. The higher the quality, the lesser organic load a river has. As the rate of organic pollution increases, there are few tolerant taxa that would strive to overcome. This implies higher ecological impairment due to closeness of the discharging waste to the river.

Table 9 Result evaluation of water quality using the FBI (Hilsenhoff, 1988)

Sites	FBI	Water	Degree of organic pollution
I	5.33	Quality Fair	Fairly substantial pollution likely
II	8.24	Very poor	Severe organic pollution likely
III	8.18	Very poor	Severe organic pollution likely

I = One, II = Two, III = Three, FBI = Family Biotic Index

From H-FBI (Hilsenhoff Family Biotic Index) (Table 9), the macro invertebrates collected revealed that the water quality of Ejersa river in site I (upper stream) falls into category of fair substantial pollution likely (5.33). This means that the upper stream site of the river was less impaired relative to the other sites. The main factors are less anthropogenic activity as well as domestic waste released into the river. The downstream sites (site II and site III) which are near discharge from prison institution, abattoir and municipal sewage falls in to category of poor severe organic pollution likely (8.24 and 8.18).

Due to the fact that sewage from households, agricultural waste and anthropogenic activity were contributed to the presence of organic pollution that reduce the quality of water which can affect human, aquatic biota and the environment. According to Hilsenhoff (1988), the presence of pollution sensitive groups rather than pollution tolerant groups can indicate water quality because pollution tolerant groups can inhabit both habitats according to their niche preference.

To measure the loss of benthic taxa and dissimilarity between sample sites, community loss index was used. Table 7 clearly indicates that the degree of CLI increases from 0.9 (site I) to 1.09 (site II) and 1.11 (site III). Site II and III were more similar to each other in terms of loss benthic taxa as well as degrees of similarity. Community loss index (CLI) tends to decrease with increasing water quality to maintain healthy aquatic ecosystem (Mandeville, 2002). Therefore, scores at site I, II and III most probably associated with CLI which confirms ecosystem disturbance at these sites. Accordingly, high EC, TDS, salinity, Turbidity, Nitrate, Nitrite and phosphate could be the main factors for the loss of taxa between sites.

4.2.2. Correlation of the physico chemical and biological parameters of the Ejersa river water samples

From the result of Pearson correlation analysis (Table 9), Diptera was positively correlated with all of the physico-chemical parameters, but negative correlation with DO (r= -0.994). Reversely, Coleoptera showed negative relation with all physico-chemical parameters especially with pH (r = -0.387), Tem (r = -0.295), TDS (r = -

0.397) and salinity (r = - 0.297) except positive correlation with DO (r = 0.060). Plecoptera were negatively correlated with all parameters. Moreover, there was strong positive attachment with DO (r = 0.969). Number of Ephemeroptera strongly negatively correlated with all physico-chemical parameters. But it became strongly positively related to DO (r = 0.969). Odonata was negatively correlated to all physico chemical parameters but positively correlated to DO (r = 0.969). Hemiptera negatively correlated to physico chemical parameters but positive with DO (r = 1.000).

Number of Diptera was positively correlated with all physico-chemical parameters except with DO (r = -0.994). As they were sensitive to physico chemical, some could not respond to the change in the dissolved oxygen parameters (example-Syrphidae family). As it has been Table 4, physico-chemical parameters and metrics like Chironomidae, Syrphidae, Perlidae and Dytiscidae can be used for rapid monitoring of water quality. Correlation result was represent by regression (r) between negative one to positive one (r = -1 to 1), negative indicates that one variable increases and other decreases but positive, both variables increases and decreases together. If correlation negative one (-1) perfect negative linear relationship, positive one (1) perfect positive linear relationship and finally zero (0) no linear relationship.

Table 10 Bivariate Pearson correlation between physico chemical parameters and benthic macro invertebrates

	Ph	Te	EC	TD	Sa	Co	DO	Tu	Nt	Ni	Po	Di	Cl	Pl	Od	Ep	He
Ph	1																
Te	.995	1															
EC	1.000**	.995	1														
TD	1.000**	.994	1.000**	1													
Sa	.995	1.000**	.995	.994	1												
Co	.986	.998*	.985	.984	.997*	1											
DO	-.944	-.971	-.942	-.940	-.971	-.986	1										
Tu	.990	.999*	.990	.989	.999*	1.000*	-.980	1									
Nt	.957	.981	.955	.954	.980	.992	-.999*	.988	1								
Ni	.995	.980	.995	.996	.980	.963	-.904	.971	.922	1							
Po	.931	.962	.929	.927	.961	.979	-.999*	.972	.997	.888	1						
Di	.900	.938	.898	.895	.937	.960	-.994	.952	.988	.850	.997	1					
Cl	-.387	-.295	-.392	-.397	-.297	-.227	.060	-.256	-.102	-.480	-.023	.053	1				
Pl	-.832	-.882	-.829	-.826	-.881	-.913	.969	-.901	-.957	-.771	-.977	-.991	-.189	1			
Od	-.832	-.882	-.829	-.826	-.881	-.913	.969	-.901	-.957	-.771	-.977	-.991	-.189	1.000*	1		
Ep	-.832	-.882	-.829	-.826	-.881	-.913	.969	-.901	-.957	-.771	-.977	-.991	-.189	1.000*	1.000**	1	
He	-1.000**	-1.000**	-1.000**	-1.000**	-1.000**	-1.000**	1.000**	-1.000**	-1.000**	-1.000**	-1.000**	-1.000*	1.000**	1.000*	1.000**	1.000**	1

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

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

PH is measure of alkalinity or acidity, Te = Temperature, Tu = Turbidity, EC = Electrical conductivity, Sa = Salinity, Co = Color, DO = Dissolved oxygen, Nt = Nitrate, Ni = Nitrite, Po = Phosphate, TD = Total dissolved solids, Di = Number of Diptera, Cl = Number of Coleoptera, Od = Number of Odonata, Ep = Number of Ephemeroptera, He = Number of Hemiptera and Pl = Number of Plecoptera taxa.

5. SUMMARY, CONCLUSION AND RECOMMENDATION

5.1. Summary

The present study aimed to assess water quality of Ejersa river using physico chemical parameters and benthic macro invertebrates in the study area. The specific objectives of the study were: to evaluate the physical and chemical status of the Ejersa river, to identify macro-invertebrates which are indicators of some form of pollution in the Ejersa river, to assess the status of benthic macro invertebrate community index along the river gradients in the study area and to correlate physico chemical with that of biological parameters of the Ejersa river.

The design of the study was cross-sectional survey based on laboratory investigation which was carried out using water samples from the three sites. Physical measurements on site and chemicals determined using Spectrophotometer (DR/2800, Japan) according to HACH instructions using standard pillow. Macro invertebrates were collected using D-net. Identification of benthic macro invertebrates was done using a binocular microscope and available keys to assign the organisms to their respective taxonomic levels (family level). The indices to be selected were Shannon-weaver diversity index, Hilsenhoff-family biotic index (H-FBI) and Community loss index. The results were analyzed using ANOVA, SPSS 20.0 version software and Microsoft Excel.

The mean physico-chemical values of the three study sites were analyzed. For example, the mean pH values of the study sites varied from 7.9 ± 0.08 to 8.8 ± 0.08, temperature among study sites varied from 19.4 ± 0 .55 to 22.8 ± 0.54$°_C$ and electrical conductivity varied from 171.8 ± 13.34 to 378.2 ± 28.3 µs/cm. Nitrate-nitrogen was varied between all study sites, minimum average was recorded at site I (81.4 ± 10.78) while become higher at site II (163.7 ± 19.03) and III (110.5 ± 10.02).

During the study, a total of fourteen families (325 macro invertebrates) belonging to six orders were identified from the three study sites within three months (March, April and May). Chironomidae was the dominant family in site I, II and III but Syriphidae was the second dominant family in site II and site III. Diptera (78.5%), Coleoptera (6.8%), Plecoptera (7.1%), Odonata (4%), Ephemeroptera (1.5%) and Hemiptera (2.2%) were the macro invertebrate's composition along Ejersa river in the study sites.

According to the result obtained from Shannon-Weaver index 4.3 was recorded at site I, whereas 2.5 and 2.6 at site II and site III. The FBI was 5.33 in site I, 8.24 in site II and 8.18 in Site III. Community loss index indicated that the degree of dissimilarity increases from 0.9 (site I) to 1.09 and 1.11 (site II and III), respectively. When physico chemical parameters correlate with biological parameters, Diptera was positively correlated with all of the physico-chemical parameters, except DO (r = -0.994). Reversely, Coleoptera showed negative relation with all physico chemical parameters especially with pH (r = -0.387), Tem (r = -0.295), TDS (r = -0.397), salinity (r = -0.297) but positive with DO (r = 0.060).

5.2. Conclusion

The result, of this study revealed that the water quality of Ejersa river and the biological systems were adversely affected by anthropogenic activities. Physico-chemical parameters increased with disturbance which leads to poor water quality, whereas macro invertebrates assemblage decreases. Biological monitoring of aquatic insects can reflect the degree of impacts of pollution as well as prolonged effect of river disturbance. The physico-chemical parameters, especially biological parameters can be used for rapid monitoring and assessing of the river ecosystems.

Chironomidae was the dominant family in site I, site II and site III but Syrphidae was the second dominant in sites II and III. The Shannon-wiener community index showed that the family abundance was higher in site I than site II and site III. In family biotic index, site I was categorized under fairly substantial pollution due to less anthropogenic activity. The remaining sites II and III categorized as severe organic pollution. CLI increases from site I to site II and site III. A change in land use around the river and the release of municipal sewage, prison institutions, domestic wastes, abattoir and agricultural land were the main threats of the river which will have negative impact on biological parameters. The study also showed the importance of the benthic macro invertebrate in assessing river pollution.

5.3. Recommendation

From the results of the study, wastewater discharged to the nearby river has enormous effect on the degradation of the ecosystem. To sustain the ecological conditions of the nearby rivers, proper disposal of wastewater and environmental audit are suggested. Environmental assessment and environmental auditing enables us to keep humans and the environment safe because it is difficult to maintain a healthy community and carry out development in a degraded environment. For sustainable management of this water resource, environmental protection agencies at different levels and other concerned administrative and non-governmental bodies should take strict as well as technical measures.

Enforcement of law and providing environmental education to the community with special target to those contributors of the present degradation could be one solution. Continuous monitoring using parameters such as those used in this study should be employed to assess timely status of the system. In this circumstance it is recommend:

- Wastewater treatment (pond system): the wastewater has to be treated before it is discharged to the nearby rivers using ponding systems. A combination of physical, chemical and biological process should be operated to remove solids and organic matter.
- Wastewater recycling: wastewater from prison institution has to be recycled rather than disposing to the environment with varieties of pollutants water and soil of the surrounding environment.
- Proper disposal of wastewater: municipal sewage and abattoir has to dispose wastewater after treatment.
- Environmental audit: the process helps in identifying problems before they become serious and establishes a good environmental record. Identifying and addressing environmental risks improves public image and facilitates pollution prevention program.

The national environmental protection policy has come to operation to ensure the protection against pollution from municipal sewage. Maintenance of ecological integrity by controlling anthropogenic activities, protection of the river channel and its basin and increased public education and awareness with regard to environmental is recommended.

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7. APPENDICES

Appendix 1. Average physico chemical data collected at each site

Parameters	Site I	Site II	Site III
PH	7.9	8.8	8.3
Temp.	19.4	22.8	21.2
EC	171.8	378.2	261.6
TDS	85.9	189.1	130.8
Salinity	105.7	227.53	167.3
Color	20	26.6	23.9
DO	7.01	4.17	4.9
Turbidity	97.9	246.2	181.7
Nitrite	0.198	0.451	0.376
Nitrate	81.4	163.7	110.5
Phosphate	0.096	2.626	2.063

Appendix 2. Image showing different study sites

Site one (I) during physical measurements at up stream of river

Site two (II) at the back of zonal prison institution in middle of town

Site three (III) Abattoir of town at exit point of river

Wastes from households to Ejersa river

Sample of three sites

During chemical analysis in the laboratory

Place of benthic macro invertebrate's identification

Family Chironomidae

Family Syrphidae