



ADDISABABAUNIVERSITY
SCHOOL OF GRADUATE STUDIES

ASSESSMENT OF ANTHROPOGENIC IMPACTS IN GULLA RIVER USING
MACROINVERTEBRATES AND PHYSICO CHEMICAL PARAMETERS

A THESIS SUBMITTED TO SCHOOL OF GRADUATE STUDIES OF ADDIS- ABABA
UNIVERSITY IN PARTIAL FULFILMENT FOR THE DEGREE OF MASTER OF SCIENCE
IN BIOLOGY (ZOOLOGICAL SCIENCES)

BY

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AUGUST 20017

ADDIS ABABA

Acknowledgment

I would like to thank my advisor Dr Bikila Warkineh for his constructive and critical comments from the beginning up to the completion of this paper. My deepest gratitude also goes to Debremarkos University water quality control laboratory unit for unreserved help in the measurement of water samples. I also appreciate Dembecha Woreda agriculture and rural development office for providing me with information about location, elevation, and amount of rainfall in the study area. I am thankful to Addis Ababa University for funding this work financially.

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ACRONYMS AND ABBREVIATIONS

BMI	Benthic Macro invertebrate Index
CLI	Community Loss Index
DO	Dissolved Oxygen
EC	Electrical Conductivity
EPA	Environmental Protection Agency
EPT	Ephemeroptera, plecoptera and Tricoptera
FAO	Food and Agriculture Organization
FBI	Family Level Biotic Index
H-FBI	Hilsenhoff Family Level Biotic Index
IBI	Index of Biotic Integrity
KM	Kilometer
m. a. s. l	meter above sea level
Mg/l	milligram per liter
NPS	None Point Source
NTS	Nephelometric Turbidity Unit
pH	a measurement of acidity or alkalinity
POM	Particulate Organic Matter
RBP	Rapid Bio assessment Protocol
SD	Sediment Deposition
SPSS	Statistical Package Software for Social Science
TDS	Total Dissolved Solid
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VP	Vegetation Protection
WHO	World Health Organization

$\mu\text{S/cm}$ Micro Siemens per Centimeter

Title- Assessment of anthropogenic impacts in Gulla River using macro invertebrates and physicochemical parameters.

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August, 2017

Abstract

Gulla River is one of the rivers impacted by anthropogenic activities. The most important factors affecting the river were land use modification, small scale irrigation system, town runoff, dumping of household wastes and organic debris. Data were gathered two times in December and May to observe the seasonal effects on macro invertebrates. Three sampling sites were selected to gather data through habitat, physicochemical and biological assessments. The habitat scores showed differences between the impacted and reference sites. The scores 52.92 and 51.25 put site-3 and site-2 into very poor category while the score 72.5 puts the reference site into good. There were significant differences ($p < 0.05$) in most of the physicochemical parameters between stressed and reference sites. However, the value of EC, NO_3 and DO were within the permissible limit set by WHO (1996) and Ethiopia EPA (2003). In this study the value of H-FBI also showed differences among the three sampling sites -Site-1(good), site-2(fair) and site-3(very poor) categories. A total of 297 macro invertebrates belonging to 25 families were collected and identified to compare the stressed sites to the reference site. The highest taxa were recorded in the reference (site-1) whereas the least was recorded in site-3. The BMI, percent EPT and percent Coleopterans tend to decrease as perturbation increased downstream in site-3 and site-2, but they increased in the reference site. On the other hand percent Chironomidae, Diptera, Oligochaeta, non-insect taxa, CLI and dominant taxa increased downstream as perturbation increased. Thus, macro invertebrates are good indicators of anthropogenic perturbation.

Keywords: Macro invertebrates, Water pollution, physicochemical parameters, Aquatic ecosystem, anthropogenic activities.

1. INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Humans depend on the entire biosphere to satisfy their needs (Mackean, 1986) as people use the natural resources, the ecosystems become changed. The number of population was previously limited by the amount of food they collected. However, after the development of agriculture the number of population was dramatically increasing along with environmental deterioration. From the beginning of this time the balance between humans and their environment was upset (Mackean, 1986). The challenge was intensifying with rapid population growth, expansion of urbanization, modern agricultural practices and industrialization. Humans have altered the earth system adequately to indicate the emergence of a new environmental condition (Ellis, 2011).

The major consequences of mans' activities on the environment is revealed by water pollution, habitat degradation or deterioration of aquatic ecosystem (BayeSitotaw,2006).Aquatic ecosystem pollution is a major global problem due to human activities that compromises the survival of human beings and other aquatic species. Water can be polluted by natural and anthropogenic activities. However, it is referred to as polluted when it is impaired by anthropogenic contaminants. Water pollution and habitat degradation are caused by many factors but the most common ones seen in Ethiopia are addition of pollutants, diversion of water / irrigation system, soil erosion, sedimentation, sewage disposal and sometime over abstraction of water.

The Ethiopia highlands have favorable climatic conditions for settlement and agricultural activities since they account for 45 percent of the total country land mass and support about 85 percent of the human, and 75 percent of the livestock population (Shiene, 2012) Thus, high population growth with the association of intensive farming, grazing and urbanization across

nearly the entire highland scape have led to high rates of environmental degradation. The highly populated Ethiopian highlands with their natural resources are exploited at a maximum rate, even people are using the marginal lands for cultivation and grazing which result in deforestation, severe soil erosion and alarming environmental degradation (Tamene Lulseged *et al.*, 2006). Today it is clear that the cultivated land mass has been increased along with an increasing of human population that causes high degradation rate than its restoration rate. According to FAO (2005) resource over exploitation and inappropriate land use such as overgrazing, deforestation, expansion of agricultural land and grazing into marginal areas, and practices of backward agricultural activities are considered as the major cause of ecosystem degradation including aquatic ecosystems in many parts of the world.

Gulla River originates from one of Ethiopian highlands known as Choke Mountain, a primary head water of the upper Blue Nile River (Belay Simane *et al.*, 2012). People who live in Choke Mountain and its surroundings affect the rivers through land use modification and small scale irrigation. In relation to this, Ambelu *et al* (2010) described those activities around the drainage areas as the potential cause of pollution of aquatic ecosystem. Moreover, washing of chemical fertilizers and pesticides from farmlands especially during the rainy season can have a potential to damage the aquatic organisms as well as their habitats. The most important factor contributing to the decline of aquatic diversity is the degradation of habitats (Miller *et al.*, 1989). The degradation of aquatic ecosystem diminishes the capacity to provide critical ecosystem functions and the use of clean water by most peoples who rely on the highland streams and rivers.

The government of Ethiopia has set a policy that encourages the extensive irrigation system to assure food security. However, irrigation causes local ecological change by modifying energy (Vannot *et al.*, 1980) and sediment chemistry (Kagawn, 1992) below the diversion point. The

irrigation system also play a due role in the reduction of water level in the downstream water course (Ambelu, 2009) and damages the structures and functions of the stream ecosystems by limiting aquatic habitats, shifting the interaction of species or eliminating species, and allowing the introduction of invasive species. Therefore, the food web of the aquatic ecosystem may be altered (Poff et al., 1997). Thus, Gulla River is one of the victims of impacts of the local irrigation systems.

Land disturbances around the highlands of which rivers (including Gulla) originate have a potential to influence the magnitude of storm water runoff which transports the non point source of contaminants into the river. The high degree elevation exposes water sources for severe sedimentation as a result of ecological degradation of the surrounding watershed (Temesgen Alemneh, et al., 2012). Sedimentation in turn affects the aquatic organisms since excess sediment load is thought to be a major contributor to the decline of stream benthic community (USEPA, 1990).

Gulla River is highly exposed to anthropogenic activities. The major threats on the river are inappropriate land use, cultivation of steep slopes, overgrazing and over cultivation. The runoff from agricultural farmlands is rich in Nitrates and phosphates that lead to eutrophication. Siltation caused by erosion is another stressor of the river. The source of erosion is typically soil degradation due to intensive and inadequate agricultural practices.

The removal of riparian zone along Gulla River is another threatening factor. Moreover, the small scale irrigation system (diversion or pumping rivers' water) into agricultural fields near to the river in the dry season to grow commercial vegetables and crops is another problem in decreasing the amount of water flow down the diversion point and water pumping. Gulla River

passes through Dembecha town and therefore it is polluted by domestic wastes especially during the rainy season. Even, during the study time, rubbish heaps were clearly seen at the edge of a river stretch. Those residents live too near the river and use the river as a dumping site of their domestic wastes due to the absence of proper solid waste disposal site and sewer lines constructed by municipal. In addition, traditional tanners who are working near the river placed a hide in the river until the hairs are easily scraped away. This makes the river polluted by organic residual pollutants. Organic debris contains hairs and pieces of meat produced from the process of tanning are also dumping in to Gulla River. Because of the above major threatening factors, the criteria in the course of the study was primarily land use type, domestic wastes diffused in to the river and residual organic wastes dumping in to the river by traditional tanners.

Unless measures are taken to restore the negatively impacted aquatic ecosystem, the health of human beings will be affected and the other ecologically important organisms may be lost forever. Therefore, regular assessment of stream and rivers waters should be carried out in order to avoid the life threatening problems. Data gathered from the assessment of physical, chemical and biological characteristics are used to make diagnosis of current condition of water that enables to predict the future environmental outcomes. The continuous diagnosis of river and stream water therefore promoting the sustainable development of the river ecosystem that ensures the adequate freshwater quality for humans and ecological needs. This is an important aspect of integrated environmental management and sustainable development (Srebotnjak et al., 2012). Among the methods of water assessment, the biological monitoring system is efficacious because it is suggested that this system is less cost and more reliable than others in the process of river basin management.

1.2 STATEMENT OF THE PROBLEM

Surface water and head water resources are generated from highland ecosystems. However, these highlands including Choke Mountain are not in a good condition to support healthy human and aquatic life due to environmental degradation caused by factors such as improper agricultural practice, overgrazing, deforestation and other misuses of the natural resources (FAO, 2005)

Even though , Ethiopia has a variety of ecosystems and diverse topography that provides a wide range of habitat types and ecological niches for many fauna and flora species (Hillman, 1993), the unwise use of natural resources has lead the highland ecosystems to be deteriorated which also affect the quality and quantity of surface waters with the biodiversity they contain. This indicates that there is a gap within the community to develop a positive attitude in conservation or restoration of natural resources of highland watershed including Choke mountain watershed, a source of Gulla River.

Streams and rivers can be affected by natural phenomena (drought, over flood, landslides, and algal blooms) but the major causes for water pollution are anthropogenic activities through agricultural activities, urbanization and industrialization. The most common practices around the study area that affect the river are land modification disturbance, removal of riparian zones, the application of inorganic fertilizers and pesticides, small scale irrigation system, and addition of domestic wastes and dumping of organic debris.

Human populations and their use of land have already threatened habitats, and degraded most of the terrestrial and aquatic ecosystems (Ellis, 2011) and this phenomenon has also happened in Choke Mountain. The surrounding watershed also threatened by non-point source of pollution such as discharges from domestic activities, grazing fields and agricultural runoff (Beyene

Aemiro, et al., 2009; Ellis, 2011) so that it can be assumed that Gulla river is one the victims of anthropogenic activities on Choke mountain. This was one of the reasons for the assessment of Gulla River in this study..

The unwise use of natural resources by communities living nearby Choke watershed and Gulla River is due to their poor understanding of conservation causes elimination or reduction of sensitive but ecologically important macro invertebrate taxa and fishes. According to Harrison and ynes (1988) some fresh water insects are reduced or eliminated from Ethiopia water body due to degradation of aquatic ecosystems. On the other hand, the number of pollution tolerant macro invertebrates' might be increased. Thus, the diversity of species which are adapted to live in fresh water ecology could be severely affected. According to Niraula (2012) land degradation, pollution, drainage and overuse of rivers and streams affects the species found in freshwater habitats. So that macro invertebrate assemblages were used in the assessment of Gulla River to verify the appearance of this problem. Because macro invertebrates are widely used in many parts of the world for providing reliable information than other aquatic animals, they were used in the assessment of Gulla River.

The existence of species and the formation of population structure are related to hydrological variation characteristics of streams and rivers. The magnitude, frequency, and the rate of flow of river water have significant effect on aquatic organisms including macro invertebrates. Moreover, riparian zones are part of the aquatic ecosystem as they surround water bodies they play a vital role in the creation of healthy biological integrity in aquatic ecosystem by facilitating the transfer of nutrients, moderate water temperature through shading, protecting sedimentation and formation of stabilized bank. Therefore, this study was assessed the habitat characteristics of Gulla river through direct observation to relate with physicochemical parameters and macro

invertebrate metrics to show the degree of perturbation in downstream compared to the reference site

Siltation or sedimentation was another contributing factor for pollution of Gulla River. Siltation usually originates from soil erosion accelerated by humans and it causes loss of aquatic animals as the result of destruction of spawning areas, gill abrasion of breathing system and/ or loss of productivity. It is obvious that siltation/ sedimentation/ increases water turbidity when water draining from farmed land and ploughed soils, and released waste discharges into the river. Thus, this study also assessed the turbidity of Gulla River in the study sites.

One of the threatening factors in Gulla River was the release of domestic wastes from Dembecha town, which was exacerbated during the rainy season in the form of town run-off and makes the river more turbid. Moreover, residents who are living very near the river directly dump their domestic household wastes into the river. Gulla River also highly exposed to organic debris produced by traditional tanners who work very near to the river. These local tanners macerate the cattle hides in the river until it becomes soft to be scrapped. The scrapped hairs with the emollients are then dumped into the river that can damage the river ecosystem. Thus, this study has been tried to assess the effects of dumping of organic debris and town runoff in Gulla River along with an assessment of physicochemical and habitat characteristics, using macro invertebrates to assess impact of stressors.

1.3 OBJECTIVES OF THE STUDY

1.3.1 GENERAL OBJECTIVE

The general objective of this study was to assess the impacts of anthropogenic activities on Gulla River in Dembecha-Woreda, West-Gojjam, Amhara-region using physicochemical parameters and biological indicators of macro invertebrates.

1.3.2 SPECIFIC OBJECTIVE

- Evaluating the physiochemical characteristics (EC, pH, NO₃, PO₄temperature, turbidity and DO) in each sampling sites
- Evaluating habitat integrity of the river by using rapid bio assessment protocol
- Relating the macro invertebrate community index with physicochemical parameters and habitat scores.
- Calculating multimetric indices of benthic macro invertebrate community in Gulla River
- Identifying the most important factors that affect water quality and habitat quality of Gulla River.

1.4 SIGNIFICANCE OF THE STUDY

Gulla River is one of the tributaries of upper Blue Nile (Abay) and originates from the Choke mountain watershed. Gulla River flows down and joins with other streams and rivers such as Temecha River and finally joins Abay dam which is known as the Ethiopian Renaissance Gird. However, Gulla River is under the pressure of human activities which are revealed by extensive agricultural activities adjacent to stream corridors with improper agricultural practice. Clearance of riparian vegetation, over grazing, local water irrigation system and factors following these activities such as soil erosion and siltation are the major threatening factors around the study

area. Addition pollutants of non-point sources especially from urban runoff, dumping of domestic wastes, addition of organic debris from traditionally processed tannery wastes produced by local tanners who are working near the river. All the above described factors are the most common threatening factors in Gulla River. Thus, this research assessed the current status of Gulla River in respect to quality of water, habitat degradation, and the possibility of compromising human health and other aquatic organisms through biological, chemical and habitat assessment. Therefore, this study has tried to indicate the possible solutions that may help to minimize the deterioration of Gulla River ecosystem. The findings of this study also provide information for stakeholders to enable them to take any remedial action in the process of restoring the river ecosystem as it was before that ensures the sustainable use of the river and the capability of supporting biodiversity and maintaining healthy ecology.

1.5 LIMITATION OF THE STUDY

1. Difficulties in finding the real reference sites around the study area
2. Inadequate sampling sites for study
3. Collection of more number of macro invertebrates was preferable
4. Time and money constraints

2. REVIEW OF RELATED LITERATURE

2.1 ANTHROPOGENIC EFFECTS ON ETHIOPIAN HIGHLAND STREAMS

As long as humans' interference and poor management of the natural resources, the ecosystem cannot continue to meet the needs of living organisms including our community. Human interference within the ecosystem affects the distribution of flora, fauna and its productivity as well as the quantity and quality of water resources. Roy et al. (2003) argued that an ever increasing of human population affect rivers and their ecosystem structure and function in an ever alarming way.

As it is already mentioned that the Ethiopian highlands cover 45 percent land mass of the country and support about 85 percent of human and 75 percent live stocks. However, many ecological impacts have been observed with the association of high population density. According to Whol (2000a) the direct or indirect impacts of human actions on aquatic and riparian biota are great concern in many mountainous areas. The growing population pressure creates enormous hazards and thus affects the sustainable of water resources and biological integrity of the whole river ecosystem.

High exploitation of water resources are used unwisely by the local community around the watershed. Communities view in using water resource is poor, considering the water resource as it serves forever without any limitation but the reality is that at the most basic level human communities around the water shed even the individuals should have to decide what balance they find acceptable between resource protection and resource use (Wow, 2001)The community perspective, culture, the interest of income generation system, lack of adequate education and

knowledge, and poor understanding of utilization of water are important factor that contribute the over exploitation of the water resources in the water shed.

2.2 EFFECTS OF HUMAN ACTIVITIES ON SURFACEWATER

The surface water in rivers and streams in Ethiopia are poor in quality and decreasing in quantities as a result of for example land disturbances which directly influence the magnitude of storm water runoff. The high flow rates cause sedimentation from disturbed area, bank erosion and channel scouring. Sedimentation increases concentration of pollutants in the runoff which affect the aquatic species including macro invertebrates. According to Friedrich et al. (2012) the intensification of agricultural land use results a considerable impact on water quality and continuous decreasing of water quantity. Beyene Aemiro, et al. (2008) also indicated that “situation as accelerated pollution and eutrophication of rivers and streams because of human activity are a concern throughout the world and sever in Africa where Ethiopia is case in point.”The major factors contributing water pollution in rivers and streams are described as follow:

2.2.1 DIVERSION OF WATER

Today many farmers have used small irrigation system/diversion of water across the country to increase their annual crop yields. However, irrigation / diversion have an effect on the removal or reduction of stream flow which results change in ecological processes below the diversion point. Water flows from dam in to channels or ditches for agricultural purposes may cause elimination of water below the diversions except during the major precipitation seasons mainly from June-September in Ethiopia. This situation could seriously damage the structure and function of the aquatic ecosystem .Thus, the structure and biomass of macro invertebrate communities with their food webs (Poff et al, 1998) also altered as a result of habitat limitation,

elimination of species and introduction of invasive species. Most of the Ethiopian rivers and streams flowing through larger communities become heavily pollute when they are widely used for domestic irrigation purposes (Beyene Aemiro, et al., 2009). Aquatic habitats are considered highly vulnerable and exposed ecosystems (Collen et al., 2012) that are experiencing greater biodiversity loss than other habitats (Sanders et al., 2012) cited in (David et al., 2013).

2.2.2 HYDROLOGICAL CHANGES

The hydrological changes also alter the habitat and geometry of the streams and rivers, and increase the amount of sediment pollution (Knighton, 1984). Research on the relationship between the life of river and their support system is becoming one of hotspot in eco hydrology (Dong et al., 2009). The existence of species and the formation of their population structure are closely related to hydrological variation characteristics of streams and rivers. According to Poff and Allan (1995) in streams network hydrological events play highly important roles in aquatic eco system that extremes and patterns of flow variability influence local community structure directly. Variables such as magnitude, frequency, duration, timing and rate of flow changes, all have a direct and significant effect on organisms(Mathews and Richter, 2007) so that for better understanding of ecological and hydrological effect on aquatic species , it is important to study the streams/rivers and their association characteristics briefly. Muneeppeerakul et al. (2008) also indicated that the hydrographic data should be used as precise indicators of biodiversity. From this perspective it can be understand that there must be a linkage between hydrology, ecology and biodiversity for better understanding of the whole eco system of the streams/rivers.

2.2.3 REMOVAL OF RIPARIAN ZONES

The riparian zones are part of the aquatic ecosystems that surround water bodies such as streams and rivers in watershed. They are important transition areas that connect water edge with land and they are the host of a wide species of plants and animal life. Vegetations in the riparian zones are adapted to wet soil condition and tolerate the periodic flooding. Riparian zones are therefore considered as flooded part of the flood plain adjacent to the stream, and they are often one of the most productive areas on land that has a high biodiversity (FISRWG, 1999).

The riparian zones provide many functions to the aquatic ecosystem such as in circulating nutrients among the land and river ecosystems, in moderating water temperature through shading and cooling effect of evaporation and transpiration. The roots of plants along the river collect sediments and prevent banks and shores from being washed away. Leaves and twigs that fall in to rivers and streams provide nutrients to aquatic invertebrates which in turn nourish fish. Bestchta(1991) described the benefits of riparian zone to streams and rivers as follows: Protection against temperature extremes, Bank stabilization, source of Allochthonous materials and protection against sedimentation and recycling of nutrients

Unfortunately, removal of riparian vegetation along the river is one of the anthropogenic activities affecting streams and rivers. Such human activity may cause loss of riparian's benefits mentioned above. Water temperature for instance rises above the normal level due to loss of shading so that it can hold less dissolved oxygen and cannot support aquatic life. Moreover, it increases the solubility of pesticides that facilitate the uptake of pesticides by aquatic animals. Clearance of plants along the edge of river causes the water to be turbid through soil erosion from intensively farmlands containing nitrates and phosphates. This condition results in eutrophication that cannot support aquatic animals longer. Excessive sediment load also appear

with no riparian vegetation and thus affects the benthic community by altering water movement, food quality, and interstitial spacing (Minshall, 1984). Moreover, fine sediment decreases diversity of aquatic life since the suspended solids absorb heat from sunlight and cause rising in temperature and ultimate reduction in dissolved oxygen (MIDEQ, 2000). Allochthonous organic matter is a source of energy for biological production in the river that comes from outside a river and may be interrupted due to loss of plants along a river. This condition diminishes the population size of aquatic organisms to a large extent.

2.3 MONITORING OF POLLUTED STREAMS / RIVERS

Pollution of aquatic ecosystems is currently one of the major global problems since it affects the aquatic living organism and their habitats as the result of degraded aquatic ecosystem function, or biological integrity. The deterioration of water quality resulting adverse effects on human health and reduction or loss of species and increase in treatment costs. All these challenges are mainly brought by human activities through the use of natural resources to meet their needs. Addition of pollutants, diversion of water, soil erosion and sedimentation, over abstraction of water, sewage disposal are the major threatening factors around the study area. According to Dudgeon et al. (2006) over exploitation, flow modification, degradation of habitats, and invasion by competitor species are the five major cause of the alarming decline of fresh water biodiversity. The recent remarkable biodiversity losses from fresh water ecosystem are attribute to prevailing anthropogenic pressure that threaten biodiversity (Spangenberg et al., 2009).

Unless measures are taken to restore the negative impacted aquatic ecosystem, many important aquatic organisms and their habitats would be disappeared, and the human health will be suffered, so that the ecology of aquatic ecosystem and habitats as well as characteristics of aquatic species should be understood. Thus, for the sustainable management of aquatic

environment ecological assessment requires based on monitoring of the structure and functioning of aquatic ecosystem (Baye, 2000)

Besides to studying streams and rivers ecology, monitoring of water bodies performed through the assessment of physical, chemical and biological methods. The data gathered from these methods are used to provide important information for diagnosing source of degradation and enable us to predict the future environmental outcomes. Srebotnjak et al. (2012) pointed out that “we have to be ensuring that adequate fresh water quality for both humans and ecological need is an important aspect of integrated environmental management, and sustainable development.”

2.4 PHYSICOCHEMICAL CONDITION OF THE STREAMS /RIVERS

Composition and concentration of nutrients, temperature, PH, conductivity, erosion- deposition processes, the substrate and turbidity are among physical chemical characteristics of the river ecosystem (Admasu Tassew, 2007). These factors play a vital role in the aquatic ecosystem to determine the existence of aquatic life as well as their distribution and abundance.

2.4.1. NUTRIENTS

The concentrations of nutrients such as nitrate and phosphate have an effect on aquatic plants and animals. For example; Algal growth and eutrophication are the result of excessive concentration of nitrates, especially if it is greater than 0.3mg/l (Beyene Aemiro, et al., 2008) due to the use of commercial fertilizers by communities on their farmlands around the water shed. The increase of nitrogen concentration in the water body usually indicates water pollution by human or animal waste or fertilizer runoff (Chapman and Kimstach, 1996). The environmental protection authority of Ethiopia set a standard of 10mg/l nitrate-nitrogen for surface waters (Admasu Tassew, 2007). Phosphorous is another important nutrient which is actively taken up

by plants however it is found rarely. In most natural waters phosphorous ranges from 0.005 to 0.02 mg/l. according to Chapman and Kimstach (1996) concentrations as low as 0.001mg/l may be found in some pristine waters and as high as 200 mg/l in some enclosed saline waters.

2.4.2. DISSOLVED OXYGEN(DO)

Another important physicochemical feature of streams and rivers is the status of dissolved oxygen (DO) which able to determines the abundance and distribution of aquatic organism of the river ecosystem (Getachew et al., 2012). In the river ecosystem, the availability of DO vary with respect to turbidity, temperature, atmospheric pressure, turbulence, photo synthetic activities, salinity and altitude. DO in unpolluted waters are usually close to, but less than 10mg/l (Admasu Tassew, 2007). High amount of soil erosion, sludge accumulation, nutrient load and high temperature seriously affect the DO concentration, hence it affects aquatic life as a result of depletion of DO. The decrease of oxygen make the physical and chemical conditions of water more challenging for macro invertebrates and other aquatic animals (Castillo, 2000). Dissolved oxygen concentration below 5 mg/l may adversely affect the functioning and survival of biological communities (Chapman and Kimstach, 1996).

2.4.3. BIOCHEMICAL OXYGEN DEMAND (BOD)

Another important factor in relation to DO is biochemical oxygen demand (BoD). Ecologists use BoD to measure the amount of food used by bacteria live in water associated with DO because BoD directly affects the amount of DO. For example, if there are greater BoD there may be more rapid depilation of DO. The consequences of high BoD are the same as those for low DO meaning that aquatic organisms become stressed, suffocate, and die (USEPA, 2006).

2.4.4 TURBIDITY

Turbidity is another measurement of water quality. It is a measure of cloudiness of water. This is mainly caused by soil erosion from intensively farmland and chemical fertilizers which results eutrophication and deoxygenated water that can no longer support aquatic animal life. Turbid waters become warmer as suspended particles absorb heat from sunlight, causing oxygen level to fall (Ambelu, 2009). Adequate light needed for photosynthesis cannot penetrate the turbid water; hence sufficient amount of oxygen could not be produced to support life. Photosynthesis decreases with less light, resulting in even lower oxygen levels which affect the biota in the water body (Zinabu et al., 2002).

2.4.5 TEMPERATURE

Temperature is the most important physical factor that affects the diversity of aquatic life as well as quality of fresh water. In most fresh water habitats the temperature remains fairly constant and suitable, but if it rises above normal level it can hold less dissolved oxygen and thus breathing of some aquatic animals become impaired. Temperature also associated with the rate of physiological process of organisms in the water. Rate of photosynthesis, metabolic rates of animals and sensitivity of organisms to toxic substances are changed due to changing in temperature. When temperature increases, the solubility of pesticides also increases and thus the up taking of pesticides by animals also increases. In running waters, temperature usually increases gradually from source to mouth with few irregularities in the presence of effluents (Meybeck et al., 1996) cited in (Admasu Tassew, 2007).

2.4.6 ELECTRICAL CONDUCTIVITY(EC)

In addition to the above physicochemical parameters, electrical conductivity (EC) is highly associated with Total Dissolved solids (TDS) and ions in the water. Electrical conductivity in fresh waters range between 10 and 1000 $\mu\text{s}/\text{cm}$, but it may exceed the maximum value of the range in polluted waters (Chapman and Kimstach, 19996) but if EC is more exceeds than 1000 $\mu\text{s}/\text{cm}$, the ecosystems become deteriorate.

2.4.7 TOTAL DISSOLVED SOLIDS (TDS)

TDS is a measure of the solid materials dissolved in water. It includes salts, some organic materials, and oxygen demanding wastes, undissolved matter and a wide range of other things from nutrients to toxic materials.

2.4.8 pH

pH is another important factor because it can be cause of significant effect on river and stream biota, Low P^{H} (acidic) rivers affect aquatic life by increasing the solubility of many elements such as Al, Cu, Fe, Cd, Mn, Zn, e.t.c (Wohl, 2010;Deshu, 2004). On the other hand when the P^{H} level is high (alkaline), the toxicity of water will be increased. For instance, ammonia at high values ($\text{P}^{\text{H}} > 8.5$) will be toxic to aquatic biota than NH_4^+ .

2.5 Limitations of physicochemical parameters

It is known that chemical analysis of water alone does not provide sufficient information to detect or resolve all surface water problems because the chemistry data of streams and rivers only tell us what is in the water at the moment, it does not give any indication of what was in the water before time of sampling. The second reason would be that the physical and chemical

interaction of water sample with sample container or another intermediate device may change the chemical nature of sample water. So that chemical analysis alone is inadequate for assessment and management of river water quality and aquatic ecosystem (Cairns, 1994). In order to get a general reading of water quality, the streams/rivers should be assessed using chemical and biological methods together. The data gathered from chemical, physical and biological tests are used to provide important information for diagnosing sources of degradation.

2.6 Biological Monitoring

Biological monitoring involves the use of animals, plant or microbial indicators to assess the health of an aquatic ecosystem. Their status, presence or absence, abundance and distribution reveal what degree of ecological integrity is present. A well balanced and functioning biological community is the best indicators of healthy stream capable of providing vital ecosystem service. Thus, biological integrity is a very important indicator of water quality. Biological integrity refers to the ability to support and maintain a balanced integrated and adaptive community (Karr and Dudley, 1981).

Biological species in water body are natural monitoring of environmental quality and can reveal the effects of sporadic as well as cumulative pollution and habitats degradation (Barbour et al., 1981) this is because their population density and diversity give an indication by what degree the streams and rivers affected.

Among the aquatic dwellers the most important and widely used aquatic organisms are benthic macro invertebrates. They provide reliable and close to comprehensive information on water and habitat quality. They have proven to be important indicators to determine the status of rivers,

since differences in environmental requirements among taxa produce community characteristics that reflect ecological conditions of the water (Mereta et al., 2013).

2.5.1 BENTHIC MACRO INVERTEBRATES

Benthic macro invertebrates are small invertebrate animals that live in water for at least part of their life cycle, but they are large enough to be seen with our naked eye. According to Bode et al. (1996) there are reasons why they are preferable for water quality assessment.

1. Their population structure, physiology and behavior indicate the state of contamination and the status of the ecosystem.
2. They are easy to collect and identify because they are large enough to be seen and small in size.
3. They are tending to stay in one area unless environmental conditions change. They spend in stream/river up to one-year or more therefore they can indicate water conditions over the preceding days, weeks, or months. They provide valuable comprehensive information that could be gathered from physicochemical tests.
4. They have little mobility (fairly sedentary) and therefore cannot escape pollution events, even the flying adult stage of many insects have mobility they are only able to survive in aquatic larvae.
5. Since they are abundant and diverse, the declining of their number indicates that a pollution incident has occurred.
6. Since they retain toxic substances (bio accumulation), their chemical analysis will allow detection where levels are undetectable in the water resources.

7. Sampling of macro invertebrates under a rapid assessment protocol is easy, requires few people and minimal equipment, and does not adversely affect other organisms.
8. A healthy macro invertebrate community is important to the normal functioning of water body since they occupy a central position in the food web of streams and rivers.
9. They also play a great role in recycling nutrient tied up in detritus.
10. The presence or absence of certain species in streams and rivers indicate good or poor quality of water. Some species cannot survive in polluted water but others can survive. A variety of pollution sensitive macro invertebrates found in a healthy stream, however few types of non-sensitive macro invertebrates are found in unhealthy stream. By studying the type and abundance of macro invertebrates it is possible to predict environmental conditions of water.

Macro invertebrates are classified in to three major groups based on their tolerance ability to water pollution. These are:-Highly sensitive, moderately tolerant and Pollution tolerant

2.5.1.1 HIGHLY SENSITIVE MACRO INVERTEBRATES

They are oftenly serving as bio indicators of good water quality. They require cold water, neutral pH and high dissolved oxygen level without turbid water .When they are found in large number, they indicated a stream/river is in a good condition. They may be predators and require an ample source of prey. This group includes Ephemeroptera (e.g. May fly), Plecoptera (e.g. Stone fly) and Trichoptera (e.g. Caddis fly).

2.5.1.2 POLLUTION TOLERANT MACRO INVERTEBRATES

These groups of macro invertebrates are living in poor water quality. They often have adaptations that allow them to survive in low dissolved oxygen, higher warm, turbid and

nutrient-enriched water. An abundance of these macro invertebrates indicates the presence of environmental deterioration.

2.5.1.2 MODERATELY TOLERANT MACRO INVERTEBRATES

Macro invertebrates belong to this group have the ability to tolerate some degree of water pollution, this means they can survive in fair water quality. Their abundance and diversity show whether a river is in fair to good conditions or not.

2.5.2 DRAWBACKS OF USING BENTHIC MACRO INVERTEBRATES

Even though macro vertebrates are using widely in the assessment of aquatic ecology, they have their own limitations .According to Bode et al.(1996) there are some limitations of using macro invertebrates as bio indicators. These are:-

- They do not respond to all impacts
- Their abundance and distribution may vary seasonally
- Their presence or absence may be determined by factors such as water current(drifting), substrate, drought, etc than pollution
- Certain groups are difficult to identify to the species level so that in this study family level identification was carried out.

2.5.3 HABITATS OF MACRO INVERTEBRATES

Streams and rivers are heterogeneous system with significant variation in macro invertebrate communities. The distribution of macro invertebrates is governed by the availability of different habitats and food resources as well as biotic interactions (Giller and Malmqvist, 1998). The

heterogeneity (Tolkamp, 1980) and substratum characteristics such as particle size (Stanford and Ward, 1983) are likely to influence macro invertebrate distribution and colonization in streams and rivers. In the study of aquatic habitats (Barmuta, 1989) described that hydraulic parameters are also analyzed in terms of water depth, water discharge and current velocity. Some habitats are erosive meaning that they have high current velocity and large substrate particles like cobble. Some others are depositional meaning that they are characterized by low current velocity and smaller substrate particles such as clay and silt. Vegetations around the streams and rivers provide more diversity of habitats. As water passes through the vegetation, it slows down the high flow of water. So that water drop silt, sand and gravels. This condition helps to build and maintain stable banks. The higher stable bank allows the water to create deeper pools and cleans the sands and silts at the bottom. The smallest branches lying in pools and roots also provide habitat structure for aquatic species.

According to Barbour et al. (1999), the major stream habitat types that are colonized by macro invertebrates and generally support the diversity of the macro invertebrate assemblage in stream eco system are:-Cobble(hard substrate), Snags, Vegetated banks, Submerged macrophytes and sand and other fine sediments.

3. METHODS OF THE STUDY

3.1 THE STUDY AREA

The study was conducted in Gulla River; 349 km North West of Addis Ababa near Dembecha, a small town in west Gojjam-Amhara region .The river originates from the Highland of Choke Mountain primary head waters of upper Blue Nile (Abay).The elevation of Choke Mountain ranges from 800 to 4200 m.a.s.l (Zaitchk et al., 2012). Gulla River is a perennial river that flows throughout the year and it passes across Dembecha town and joins to Temecha River a few km down to Dembecha to join Abay River.

Dembecha town is located $10^{\circ} 33' 33.75''$ N and $37^{\circ} 29' 47.93''$ E at an elevation of 2100 m.a.s.l. The average annual temperature is ranges from $18C^{\circ}$ to $25C^{\circ}$, and its mean annual rainfall is about 1006 mm. The main rainy season falls usually from June to September and small rainfalls from around February to April

3.2 SAMPLE SITE SELECTION

Preliminary survey was conducted in October along Gulla River to gather information on the physical characteristics of the study area described in Table-1. Three sample sites were selected along Gulla River using the criteria and denoted as site-1, site-2, and site-3. The criteria used to choose the reference site/site-1 were low level impairments following the criteria described by Gibson et al (1996) to denote as a benchmark for biotic integrity assessment. These are: - 1.No known discharges or contaminants; 2.No known spills or other polluted incidents; 3.Low human population density;4.Minimal non-point source problems; 5.Best water shade and riparian vegetation cover; 6.No upstream impoundments. However, it was difficult to find out a real reference site because the source of Gulla River has already under the pressure of anthropogenic impacts so that minimally impaired reference site was selected based on the above criteria. The second study site (site-2) was selected based on land use type such as inappropriate agricultural activities near the river, over grazing, clearance of vegetation, small scale irrigation system, bank instability, rural domestic wastes and cultivation of steep slopes.



The third study site (site-3) was selected based on exposure to domestic wastes such as dumping of residual organic wastes by traditional tanners, household domestic wastes and town run-off.



The reference is located upstream at around the vicinity of Gulla River. The second site (site-2) was located below the reference site and about 2km above Dembecha town. The third sampling site (site-3) was located about 1.5km down to Dembecha town below Addis Ababa-BahirDar highway. The distance between site-2 and site-3 is about 3.5 Km. Even though there was no significant influent of sewages to the river during the course of the study (dry season), a heap of rubbish and household wastes was seen very near the river at site-3 that could be pollute the water. The traditional tanners, locally named as “faki”, were deepening raw hairy hides in the river for several days to make it smooth for the process of scraping off hairs, this condition with the association of residual organic wastes and emollents through the process of tanning seriously affecting the river. This was one of the reasons to select sampling site (site-3) near the town down to about 1.5Km.

The study area stretches 100 meters in each sampling sites. Multihabitat approach was used in the selection of replicates, 50% of riffles, 35% pools and 15% of runs in proportional representation within all the three sampling sites to collect as many varieties of macro invertebrates as possible by using targeted design and professional judgment method.

Table - 1 Physical characteristics of the study sites

Physical character	Site -1/ Reference/	Site -2	Site -3
Watershed features			
<ul style="list-style-type: none"> • Predominant surrounding land use 	Agricultural and residential	Agricultural Residential Field/Pasteur	Field/Pasteur and residential
<ul style="list-style-type: none"> • Watershed NPS pollution 	Less potential source	Some potential sources	Obvious source
<ul style="list-style-type: none"> • Watershed erosion 	Moderate	Heavy	Heavy
Riparian vegetation <ul style="list-style-type: none"> • The dominant species present 	-Shrubs -grasses -trees	--Shrubs -grass(not dense) -tress (sparse)	Trees (Sparsely)
In stream features <ul style="list-style-type: none"> • Canopy cover • Dam present 	Partly shaded No	Open No	Open No
Substrate type <ul style="list-style-type: none"> • Bed rock 	Boulder Cobble Gravel	Boulder Cobble Gravel	Boulder Cobble Gravel
Sediment / substrate <ul style="list-style-type: none"> • Odor 	Normal	Normal	Sewage
<ul style="list-style-type: none"> • Deposit 	Modest deposition of sand, no silt	Heavy deposition of sand, moderate silt	Heavy deposition of sand high silt

3.3 SAMPLE COLLECTION AND LABORATORY PROCESSING

3.3.1 MACRO INVERTEBRATE SAMPLING, PROCESSING AND IDENTIFICATION

Macro invertebrate samples were collected after taking samples of water for physicochemical test in each sampling sites of a 100-meter reach along the river for two months, December and May, represent the dry/low flow and wet/moderate flow seasons enabling to collect as many macro invertebrates as possible against seasonal effects. This is because seasonal variability affects the community structure and productivity of macro invertebrates and many species have annual or short life cycle that they may be found in one season but absent in the other season. Therefore, collecting sample of macro invertebrates at least for two months possibly increase the accessibility of targeted assemblage (Barbour et al., 1999). A circular frame dip net with 500 µm

opening mesh size was used to collect macro invertebrates. In accordance with methods for assessing biological integrity of surface waters, macro invertebrates were collected based on multihabitat approach (Barbour et al., 1999) which enables the major habits such as riffles, pools and runs to be sampled in approximate proportion between sampling sites. Fortunately, all the three sampling sites have these major habitats. Because riffle communities are more diverse than others (Gerth and Herlihy, 2006 cited in Abebe Beyene 2008) about half of the total selected habitats (50%) were riffles. The rest 35% and 15% were represented by Pools and runs respectively in each sampling site based on accessibility of macro invertebrates. But, habitats less than 5% were not taken as sampling site.

The kick net was placed in the river on the opposite direction of the course of flow. During sample collection the river bed was continuously disturbed by kicking with the feet to displace the hidden macro invertebrates. Furthermore, larger substrates were picked and rubbed by hand to remove attached organisms.



A total of 20 kicks/Jabs were taken over the length of 100-meter reach equally in all sampling sites based on their proportion to their representation of microhabitats. Thus, 10jabs for riffles, 7 jabs for pools and 3 jabs for runs. A single jabs was consists of forcefully thrusting the net in to habitat for a linear distance of 0.5m (Barbour, 1999). Each collection was required 10 minutes

per area with a net up to 10-meter stretch (Gabriel et al., 2010) to collect adequate sample of macro invertebrates because it is suggested that 10 minutes of collection with a small size net is enough to gather macro invertebrates. After every five jabs the collected samples were washing by clean water through the net for two to three times. The jabs collected from the multiple habitats were composited to obtain a single homogenous sample. The homogenous sample was transferred to vials containing 70% alcohol and transported to laboratory. The collected macro invertebrates were subsequently transferred to a white surface table for clear observation, and identified to the family level by observing under the dissecting microscope using taxonomic keys (Gerber and Gabriel, 2002; Javier et al., 2012; Bouchard, 2004). Sub sampling procedure was not used because the numbers of macro invertebrates were not excessive.



3.3.2 PHYSICOCHEMICAL DATA COLLECTION

Water samples for physicochemical analysis were taken in December and May for two months before collection of macro invertebrates from both reference and test sites by inserting clean bottles to a 20-30 cm depth in the opposite direction of water current flow. Samples of water in the polyethylene bottles were stored in the ice box and taken in to Deberemarkos University water quality control Laboratory Unit to measure Nitrate (NO_3), phosphate (PO_4), Dissolved oxygen (DO), Electric conductivity (EC), pH, and turbidity. Nitrate and phosphate were measured using the Wagtech WTD Nitrate test method and Ascorbic acid method, respectively,

with colorimeter using wagtech photometer (Model 7100). Reagents such as Nitrate test tablets and Nitrate test powder were used to test Nitrate. The reagents used to test phosphate were phosphate No.1 LR and phosphate No 2 LR. Conductivity, turbidity and pH were measured using wagtech conductivity meter, wagtech turbidity meter, and PH meter respectively. Temperature and flow velocity were measured in situ by using mercury thermometer and floating method respectively.



3.3.3 HABITAT ASSESSMENT

According to Barbour et al. (1996a), habitat assessment is defined as the evaluation of the structure of surrounding physical habitat that influences the quality of water resource and the condition of the resident aquatic community. Habitat assessment was done using USEPA rapid Bioassessment protocol (Barbour et al., 1999) using the twelve quantitatively evaluated habitat parameters. The parameters include epifaunal substrate, embeddedness, sediment deposition, channel flow status, channel alteration, bank stability, vegetation protection, riparian vegetation zone width, pool substrate characterization, velocity depth combinations, pool variability and channel sinuosity. Each parameter was evaluated and rated on a numerical scale of 0 to 20 for each sampling site. The ratings are then totaled and compared to a reference condition to provide a final habitat ranking out of a score of 240. Scores increase as habitat quality increases. Higher scores indicate better habitat quality where as low scores indicate low habitat quality / habitat degradation (Table 5)

3.4 MACRO INVERTEBRATE METRICS AND BMI

Metric is defined as a characteristic of biota that changes in some predictable way with increased human influence (Barbour et al, 1995). Thus, in this study biometrics were used for macro invertebrate index because an index provides a means of integrating information from a composite of the various measures of biological attributes. Each of the metrics was calculated from the sample data and converted into a standardized score. The criteria for metric selection were based on the ability to assess the level of stress by comparing the sampling sites with a reference site.

For the metrics to be useful, they must have technical attributes such as ecologically relevant to the biological assemblages under the study, sensitive to stressors, and provides a response that can discriminate from natural variation (Barbour et al., 1995). Therefore, multiple metrics were used to assess biological conditions to aggregate and convey the information available about aquatic communities.

Taxa richness, composition, and tolerance / intolerance measures were used among the benthic metrics. Taxa richness refers to the diversity within a sample; composition refers to the relative contribution of populations to the total fauna, and tolerance/ intolerance measures represent the relative sensitivity to perturbation.

Table-2 Benthic metrics and predicted direction of metric response to increasing perturbation (Barbour et al., 1999)

Category	Metrics	Description	Predicted response
Richness measure	Taxa richness	Total number of individual taxa	Decrease
Composition measure	% EPT	Percent of composition of mayfly, stonefly, and caddisfly larvae	Decrease
	%Ephemeroptera	Percent of mayfly	Decrease
	% Plecoptera	Percent of stonefly	Decrease
	% Tricoptera	Percent of caddisfly	Decrease
	% Blood red chironomidac	Percent of blood red midge larvae	Increase
	% Oligochaeta	Percent of aquatic worms	Increase
	% non insect	Percent of non insect BMIs	Increase
	% dominant taxon	Percent of single most abundant taxa	Increase
	Community loss index (CLI)	Measure loss of benthic taxa with respect to a reference site	Increase
Diversity index	Richness		Decrease
	Evenness		Decrease
Tolerance/intolerance	% tolerance	Percent of BMIs tolerant to perturbations	Increase

With the exception of tolerance /intolerance measures all the above metrics were used to calculate the multimetric values (BMI) because it combines several distinctive, stresses influenced community characteristics in to a single aggregate value that can be used to compare the level of stress. The BMI value is, therefore, the sum of character scores. These metrics were scoring as 5, 3, and 1 which are representing the least, intermediate and most stressed communities respectively (Baye Sitotaw, 2006). In this study the B-IBI value has a maximum score of 55 (11 characters x score of 5), and a least score of 11 (11 characters x score of 1). Finally, the BMI values were converted to 100 point scale. 100 indicate the least stressed, 60 for moderate, and 20 for most stressed. The highest score indicates least stressed and the least score indicates most stressed.

Table -3 Methods of water quality classification based on impairment level from BMI data (Barbour et al, 1996).

BMI value	Water quality Characterization	Impairment
20-46	Very poor to poor	Severe to slight
46-72	Fair to good	Moderate to less
72-100	Very good to excellent	Very little to none

In addition to these metrics, Hilsenhoff family level biotic index (H-FBI) (Hilsenhoff, 1988) Was used to summarize the overall organic pollution tolerances of the taxa collected. Individual families of macro invertebrates were assigned an index value, score from 0 to 10. Taxa with H-FBI values of 10 are very tolerant to organic wastes while taxa with H-FBI values of 0 are very intolerant to organic wastes. H-FBI Increase as water quality decreases.

$$\text{H-FBI} = \frac{\sum (x_i * t_i)}{n}$$

Where x_i = number of individuals within a taxa

t_i = tolerance value of a taxon

n = Total number of organisms in the sample

The index (tolerance value) developed by Hilsenhoff (Hilsenhoff, 1988) to summarize the various tolerances of the benthic macro invertebrate community with a single value. This index is generally used to detect nutrient enrichment or high sediment loads with low dissolved oxygen.

Table- 4 Evaluation of water quality using the family level biotic index from (Hilsonhoff, 1987; Plafkin et al. 1989).

FBI	Water quality	Degree of organic pollution
0.00-3.75	Excellent	Organic pollution unlikely (non apparent)
3.76-4.25	Very good	Possible slight organic pollution
4.26-5.00	Good	Some organic pollution probable
5.01-5.75	Pair	Fairly substantial pollution likely (fairly significant)
5.76-6.50	Fairly poor	Substantial pollution likely (significant)
6.51-7.25	Poor	very substantial pollution likely v. sign
7.26-10.00	Very poor	Severe organic pollution likely

In this study, Shannon Diversity Index (H) used to measure the sample diversity which incorporates richness and evenness (Shannon and Weaver, 1963)

$$H' = - \sum_i^s P_i * \ln P_i$$

Where, H=Shannon diversity index

P_i =number of individual species within the total number of species

S=total number of species

ln=log base

The value of species diversity varies from 0 to 5 (Kereb, 1999).Evenness also calculated by using the following formula

$$H = H/H_{max} \quad \text{Where, } H_{max} = \text{Maximum diversity possible}$$

The community loss index (CLI) was also calculated using the following formula.

$$CLI = d-a/e$$

Where, d= the total number of taxa in the reference site

e= the total number of taxa in the impacted site

a= the number of taxa common to both sites

3.5 DATA ANALYSIS

Statistical software SPSS version 16 and Excel spread sheet were used for data analysis. One-way ANOVAs was used to evaluate significant differences between sampling sites, using alpha set 0.05. Pearson correlation coefficient (r) was used to assess the relationships between physicochemical and biological data, and between biological data and habitat scores.

4. RESULT AND DISCUSSION

4.1 HABITAT ASSESSMENT

In this study the habitat of each sampling reach was characterized using the USEPA rapid physical habitat classification format (Barbour et al., 1999). The value of habitat assessment was obtained from 12 parameters on 20 scale points which were summed up according to the USEPA rapid Bioassessment protocol in Table- 5. The twelve habitat parameters were categorized into optimal, suboptimal, marginal and poor (Barbour et al.,1999) based on the given values through direct observation in each site as follow

Habitat assessment category			
Optimal	Suboptimal	Marginal	Poor
20-16	15-11	10-6	5-0

Table-5 Mean of habitat assessment results

No	Habitat parameter	Site-1	Site-2	Site-3
1	Epifaunal substrate(ES)	17	11	11
2	Embededness	20	13	15
3	Sediment Deposition(SD)	20	15	11
4	Channel flow status	15	13	13
5	Channel alteration(CA)	20	18	20
6	Bank stability(BS)	16	10	12
7	Vegetation protection(VP)	10	4	2
8	Riparian vegetation zone width(RVZW)	14	8	4
9	Pool substrate characterization	16	13	11
10	Velocity/Depth combinations	13	11	11
11	Pool variability	12	10	12
12	Channel sinuosity	5	5	5
	Total	174/240	127/240	123/240
	%comparability	72.5	52.92	51.25
	Category	Good	Very poor	Very poor

The result in table 5 shows that the reference site (site 1) was categorized as good (72.5%), and Site -2(52.92%) and site -3(51.25%) were fall in to very poor category as they were stressed sites. Even though, reference site was categorized as good, it was less impaired when it is compared to other studies for example a category of 100 Baye Sitotaw(2006) and 77.9 Admasu Tassew (2007). This might be due to Choke Mountain, a source of Gulla River, was already under the pressure of anthropogenic activities.

Among the habitat parameters, the most important factors that differentiate the impacted sites from the reference site were vegetation protection, riparian vegetation zone width (RVZW), sediment deposition and bank stability due to extensive agricultural activities. The reduction of canopy cover at the down streams was reduced than the reference site. This condition has a direct effect on the survival and distribution of macro invertebrates and other aquatic animals as a result of temperature alteration and lack of providing nutrients. The low number of taxa in site -2 and site-3 may be due to sparse riparian tree vegetation, limiting the exogenous input of nutrients (Dudgeon, 1994). When downstream gets less shading, temperature tends to be raised in some degree which cannot hold adequate dissolved oxygen to support aquatic life.

The short distance of riparian zone width and poor vegetation protection at site-2 and site-3 were significantly affect bank stability as the flood erodes soils at banks and shores that enhance sedimentation and, poor providing of recycling nutrients into the river due to the absence of fall leaves and twigs.

Diversion of water or pumping river water at site- 2 for irrigation purpose caused the aquatic habitats to be damaged. The magnitude and rate of flow of water decreased downstream below the diversion point, this condition caused great loss of biodiversity than the upstream habitats

(Sanders et al., 2012) and the structure and biomass of macro invertebrates altered (Poff et al., 1998). According to (Poff et al., 1997) reduction of stream flow in the natural water course, possibly limiting macro invertebrate habitats and, causes elevation of concentrations of pollutants which might affect species interaction and reduces species richness

Livestock and their wastes along with the domestic household wastes and organic debris might be caused for poor habitat integrity. Highland streams also faced to the non-point source discharges from different sources such as domestic activities, grazing fields and agricultural runoff (Beyene Aemiro *et al.*, 2009). The number of herd of cattle deploying in the field increase from year to year and hence the amount of their wastes diffused in to the river increases. The backward agricultural practices along with animal wastes exacerbate the diminishing of habitats. High livestock loads, low agricultural productivity and severe land degradation decrease the quality and volume of surface water flow (Belay Simane *et al.*, 2012).

Residents of Dembecha town and nearby rural dwellers used the river for different purposes such as cloth washing, bathing, car washing, and even dumping of household wastes. These could be factors that affected the quality of water and aquatic life more at site-3 than the rest two sites. However, deforestation, overgrazing, poor farming practices and dumping of organic debris from traditionally processed hides near the river are the major threatening factors contributing to land degradation and water pollution around the study area.

Suboptimal pool substrate characterization (11) and sediment deposition (11) were recorded at site-3 whereas the optimal pool substrate (16) and sediment deposition (20) recorded at the reference site. This showed that the serious pollution of water and habitat degradation at site-3 may be due to high siltation formed mainly from dumping of organic wastes from different

sources and the presence of mud dominantly at the bottom. Site-2 also falls into suboptimal category due to high exposure to soil erosion and bank instability as shown in Table-5.

Regarding the velocity/depth parameters, all the three sites fell into marginal category. It could be suggested that one of the four velocity/depth regimes i.e. fast-shallow flowing was absent in all the three sampling sites.

4.2 PHYSICO CHEMICAL PARAMETERS

The physicochemical variables of Gulla River were measured to differentiate the impacted sites (downstream) from reference site (upstream). The average results of each variable with their standard errors are recorded in each site (Table-6)

Table -6 Average physicochemical analysis (Mean \pm SE,n=2)

Variable	Site-1	Site-2	Site-3
EC	116.5 \pm 14.5 μ S/cm	461 \pm 80 μ s/cm	761.5 \pm 234.5 μ s/cm
PH	7.29 \pm 0.04	8.12 \pm 0.25	9.73 \pm 0.82
NO ₃	0.84 \pm 0.29mg/l	2.34 \pm 0.7mg/l	4.14 \pm 1.19mg/l
PO ₄	0.04 \pm 0.02mg/l	0.13 \pm 0.06mg/l	1.22 \pm 0.68mg/l
DO	7.75 \pm 0.25mg/l	5.5 \pm 0.1mg/l	2.57 \pm 0.57mg/l
TEMPERATURE	16.75 \pm 0.75°C	18.5 \pm 0.5°C	20.5 \pm 1.5°C
TURBIDITY	156 \pm 60NTU	482.5 \pm 237.5NTU	934 \pm 239NTU

pH– This study showed that the pH at the impacted sites was significantly higher ($P < 0.05$) than the reference site. The higher mean (9.73 \pm 0.82) was recorded at site-3 and the lower mean (7.29 \pm 0.04) was recorded at site-1 followed by site -2 (8.12 \pm 0.25). The PH value at site-1 and site -2 was within the range of the permissible limit of WHO guide line (6.0-8.5) and Ethiopia

EPA (6.0-9.0), but the pH at site-3 was above the standard which might be affecting the aquatic macro invertebrates and fishes by changing the aquatic community structures. The high pH value at site-3 assumed to be cause of elimination of sensitive group of taxa such as Heptageniidae, Hydroptilidae and Perlidae. An increase of pH causes chemicals such as ammonia to be more toxic with only a slight increase in pH, mostly above 9. The toxicity of ammonia especially in the water containing low dissolved oxygen (DO) increased that can adversely affects the very sensitive taxa so that an increase of pH may have stressing effect on sensitive aquatic organisms. Thus, it could be the reason why most common intolerant taxa are not found at site-3 and rarely at site-2. Even though, alkalinity has less effect on public health, though; highly alkaline waters are unpalatable and can cause Gastro intestinal discomforts (www.negrc.org).

In this study the rise in pH was observed in the rainy time (May) than the dry time (December) it might be due to the runoff from surface of extensive farmlands containing fertilizers as well as domestic wastes. Similar studies on pH at the upper and downstream sites of chacha river in Abay basin was 7.91 ± 0.16 and 8.3 ± 0.5 respectively (Baye, 2006); similarly the pH value of sebeta river at site-1 (8.35 ± 0.83) and site-2 (8.17 ± 0.61) was recorded (Admasu Tassew, 2007).

Electrical conductivity (EC) - It is the measurement of water's ability to conduct electricity and measured in a unit of current called micro Siemens per centimeter ($\mu\text{S}/\text{cm}$). The average EC of the study sites showed significant differences between impacted and reference sites ($P < 0.05$). The highest mean (761.5 ± 234.5) was recorded at site-3, and the lowest ($116.5 \pm 14.5 \mu\text{S}/\text{cm}$) and the medium ($461 \pm 80 \mu\text{S}/\text{cm}$) was recorded at site-1 and site-2 respectively (Table-6). The high EC in the downstream possibly due to soil erosion, run off from farmland surfaces containing fertilizers, and dumping of domestic wastes in ionized form. On the other hand conductivity of

water quality depends on the amount of solids that are dissolved in water; therefore, an increase of turbidity and total dissolved solids (TDS) in Gulla River causes an increase of electric conductivity in site-3 followed by site-2. The conductivity of water is more or less linear function of the concentration of dissolved ions (www.negrc.org). Even if all natural waters contain some dissolved solid due to dissolution and weathering of rocks and soils, water with high TDS and turbidity is unpalatable and potentially unhealthy. This might be another cause for elimination of sensitive taxa in the impacted sites. Conductivity was very high in dry season, but decreased in rainy season, possibly due to dilution of dissolved solids (Ambelu, 2009). Similar studies in the upstream and downstream of Sebeta river shows the EC of 160.00 ± 30.55 and $4276.67 \pm 1006.58 \mu\text{m/cm}$ was recorded respectively. High value of EC (1583 ± 48 and $1874 \pm 50 \mu\text{s/cm}$) was recorded in Tsaeda Agam River in Mekele city (Kidu Mezgebet *et al.*, 2015).

Phosphate (P₀₄) – The highest phosphate (1.22 ± 0.68) was recorded at site-3 followed by site-2 (0.13 ± 0.06) and the lowest (0.04 ± 0.02) recorded at the reference site ($p < 0.05$). Naturally it is most readily available to plants but available in very low level. However, the appearance of high concentration in site-3 and site-2 might be due to addition of inorganic fertilizers, domestic use of detergents, cloth washing and bathing, sewage, and clearance of riparian vegetation along the river. The increase of phosphate concentration revealed by the appearance of modest eutrophication in both site-3 and site-2 which may reduce the amount of dissolved oxygen (DO) that could not support the aquatic life. This might be another reason for disappearance of sensitive taxa. Similar studies show the average value of phosphate in Chacha river ($0.410 \pm 1.1 - 3.1 + 1.9$) and Tikur-wuha river ($0.48 \pm 0.1 - 0.4 \pm 1.0$) were recorded (Baye Sitotaw, 2006; Birenes Abay, 2007).

Nitrate (No₃)- The measurement of nitrates Showed a significant differences between reference site and impacted sites ($P < 0.05$). The highest mean (4.14 ± 1.19 mg/l) was recorded at site -3 followed by site-2 (2.34 ± 0.7 mg/l) and the least (0.84 ± 1.19 mg/l) was recorded at the reference site (Table-6). The highest record at site- 3 and site-2 caused possibly by urban runoff containing house hold domestic wastes and human sewages / overflowing pit latrines during rainy time and dumping of organic debris. Moreover, Surface runoff from farm lands containing high concentration inorganic fertilizers and livestock husbandry might be contributed to high load of nitrate. The appearance of algal blooms and eutrophication at the impacted sites may be due to excessive nitrogen that could affect the aquatic organisms. According to Beyene Aemiro, et al. (2004) if the concentration of nitrate greater than 0.3 mg/l, it causes algal growth and eutrophication. Excessive concentration of nitrate facilitates organic decomposition and bacterial respiration results depletion of dissolved oxygen that could not support especially the intolerant taxa macro invertebrates, even the moderately sensitive taxa. This could be a factor to decline the number of pollution sensitive taxa. According to (NGRDC, www.negrc.org) eutrophic waters with high amount of nutrients and carbon tend to be unstable in their chemistry and biology which causes low species richness and diversity. An increase of nitrates can also be linked with blue baby syndrome in infants. Similar studies in Sebeta River showed the least mean of nitrate (0.40 ± 0.06 mg/l) in the reference site and the highest mean (4.99 ± 2.88) at the impacted site (Admassu Tasew, 2007)

Temperature: the study showed a significant difference among reference and impacted sites ($P < 0.05$). The highest mean ($20.5 \pm 1.5^{\circ}\text{C}$) recorded at site-3 and the lowest ($16.75 \pm 0.75^{\circ}\text{C}$) recorded at site-1 (Table-6). The highest record might be caused by low steam flow, removal of

stream side vegetation, complete absence of canopy cover, and turbidity. Turbidity or TDS tends to absorb heat and possibly increase water temperature in which the level of DO fall (Ambelu, 2009). The raising in temperature for example causes photosynthesis and plant growth to be increased that facilitates the decomposition of organic matter that tends to decrease the concentration of DO, and could not be supported the intolerant sensitive organisms. Thus, it could be a reason for the declining of their number in the impacted sites. The absence of canopy cover at downstream may also alter water temperature. This idea was supported by the study conducted in pacific North West streams and indicates that when the entire forest canopies were removed, a temperature was increased up to 8°C above the previous highest temperature (NGRDC.www, negrc.org). Moreover, soil erosion and nutrient enrichment might be other factors in increasing water temperature in the impacted sites of Gulla River.

Turbidity- The recordings of turbidity in this study indicates a significant difference among sampling sites ($P < 0.05$). The highest record mean (934 ± 239 NTU) was observed at site-3 and the least mean (156 ± 60 NTU) was observed at the reference site (Table-6). The reason for differences between study sites could be soil erosion, unstable stream bank (bank erosion), urban runoff and slight land sliding downstream of the impacted sites. Turbidity was increased in rainy season than dry season due to high run off from intensive farmlands, construction sites, and organic matter and then suspended silt and clay. The cloudy and warm turbid water causes the level of DO to fall (Ambelu, 2009) and would not be favorable for the survival of sensitive taxa. On the other hand, turbidity causes the fine sediment to be deposited on the stream bed of the impacted sites; it may causes elimination of habitats for some intolerant macro invertebrate

species. Due to the capability of turbidity to reduce light penetration and algal growth and productivity, sensitive taxa might be eliminated from the impacted sites along Gulla River.

Dissolved oxygen (DO)-The amount of dissolved oxygen determines the abundance and distribution of macro invertebrates and other aquatic organisms (Getachew et al, 2012).The records of DO in this study shows the highest mean of DO (7.75 ± 5.25 mg/l) at the reference site followed by site-2 (5.5 ± 0.1 mg/l), and the least mean (2.57 ± 0.57 mg/l) at site- 3. The reasons for least DO at site-3 might be turbidity, warm temperature and low flow velocity. Decreasing in concentrations of dissolved oxygen makes the physical and chemical condition of water more challenging for macro invertebrates (Castillo, 2000). According to Chapman and Kimstach (1996), DO concentration below 5 mg/l may adversely affect functioning and survival of biological communities. Thus, it could be the reason for the absence of sensitive taxa in site- 3 and rarely in site-2. On the other hand the amount of DO in the reference site (7.75 ± 0.25 mg/l) was higher even above the minimum amount needed for aquatic organisms to maintain more or less healthy aquatic ecosystem.

4.3 BENTHIC MACRO INVERTEBRATES

In this study, a total of 297 macro invertebrates belonging to 25 families were collected from the three sampling sites. The macro invertebrates were identified to the family level under the stereomicroscope, using taxonomic keys. Taxonomic group of macro invertebrates, abundance and value of FBI were recorded in Table-7.

Table -7 Types of macro invertebrates collected from each site

Taxa	Site-1	Sit-2	Site-3	Tolerance value
Order Ephemeroptera(mayflies)				
Baetidae(small mayflies)	16	15	8	4
Caenidae(cain flies)	11	11	3	7
Heptagenidae(flat headed may flies)	14	9	0	4
Order Tricoptera(caddis flies)				
Hydropsychidae(caselesscaddisflies)	8	5	2	4
Hydroptilidae(microcaddisflies)	3	0	0	4
Order Coleoptera(Beetles)				
Dytiscidea(predaceous diving beetles)	12	15	0	5
Elimidae(Riffle beetles)	13	10	0	4
Gyrinidae(Whirlinging beetles)	3	1	0	4
Psephenidae(Water penny beetles)	5	0	0	4
Hydrophilidae(Water scavenger beetles)	5	1	0	5
Order Hemiptera(True bugs)				
Corixidae(water boatmen)	0	5	8	9
Veliidae(Broad-shouldered water)	0	3	7	9
Order Odonata(Dragon flies)				
Gomphidae(Dragon flies)	6	1	0	1
Order Diptera(Flies,mosquitoes,midges)	0	3	0	8
Culicidae(mosquitoes)				
Chironomidae(midges)blood red	0	9	11	8
Ceratopogonidae(biting midges)	0	0	5	6
Simuliidae(Black flies)	5	9	0	6
Tipulidae(crane flies)	2	0	0	3
Tabanidae(Horse flies)	0	0	7	6
Syrphidae(Rat tailed maggot)	0	0	3	10
Muscidae(House flies)	0	0	7	6
Order Plecoptera(stone flies)				
Perlidae(stone flies)	11	5	0	1
Class Gastropoda				
Planorbidae(orb snails)	0	0	4	7
Class Oligochaeta(aquatic earth worm)	1	2	7	8
Class Hirudinae(Leeches)	0	2	4	10

Table-8 Abundance, number of taxa and H-FBI values of benthic macroinvertebrates in each site.

Metrics	Site-1	Site-2	Site-3
Abundance	115	106	76
No of taxa	15	17	13
Shannon diversity index(H)	2.54	2.57	2.5
H-FBI value	4.03 (very good)	5.37 (Fair)	7.19(very poor)

In this study different benthic metrics were used to compare the stressed sites from reference site as follow:

Hilsenhoff family level biotic index (H-FBI)-This metric uses tolerance values to weight abundance in an estimate of organic pollution (Barbour et al., 1992). The highest value of FBI (7.19) was recorded at site-3 and categorized as very poor while the least value(4.03) was recorded at site-1 and categorized as good (Table-8). The highest value at site-3 was due to the presence of significant organic pollution caused by diffused organic matter. Dumping of organic debris of traditionally processed hides with its emollient and house hold wastes in to the river may have large effect for the production of organic pollution at site-3. On the other hand the value at the reference site (4.03) showed the absence of apparent organic pollution, hence the reference site was considered as very good category. The value at site-2 (5.37) showed the presence of some organic pollution and categorized as fair (Hilsenhoff, 1988). Even though, FBI was originally formulated to detect organic pollution, its result also showed the habitat degradation in stressed sites with low level of oxygen, high TDS , nutrient enrichment and thermal impact (Barbour et al, 1999).

The Shannon diversity index (H) in this study indicates that the diversity of sampling taxa in site-2 was greater than site-3, the reference site. The number of sampling taxa was greater in site-2 (2.57) followed by the reference site (2.54) which may be due to the presence of moderately enriched nutrients in site-2 that possibly supports more diverse taxa than the reference site and site-3. On the other hand, less number of taxa (2.5) recorded in site-3 may possibly be due to the appearance of more serious water pollution and habitat degradation than the reference site and site-2.

Taxa richness- It is the number of distinct taxa, represents the diversity within a sample (Resh et al., 1995) cited in Barbour et al. (1999). In this study the highest taxa (17) was recorded at site-2, followed by a reference site (site-1) and the least number of taxa (13) was recorded at site-3 (Table-8). Even though, the reference site was expected to inhabit largest number of taxa, it was found next to site-2 by reducing two taxa. The reason for highest number of taxa in site-2 might be due to mild pollution since it contains high inputs of nutrients suitable for plant growth and biological productivity. Thus, it could be supported more diverse fauna than the reference site. Mild pollution has a tendency to increase in total abundance and even diversity (Hauer and Lamberti, 1996 cited in Birenesh Abay 2007). The other suggestion might be based on the concept that there will be a high competition in very less impacted site between fauna; hence there would be a decrease in richness and composition. This concept could be supported by Rosenberg and Resh (1993) as they described that some pristine water streams may be naturally unproductive, supporting only a very limited number of taxa. On the other hand the reference site since it was characterized by less impairment level and oligotrophic water / low inputs of nutrients, it could not be supported the whole or most taxa. The least number of taxa recorded in

site-3 indicates that it was environmentally polluted as the result of habitat degradation that could allow the existence of only tolerant taxa.

Percent EPT- percent EPT represents the Ephemeroptera (may files), Plecoptera (stoneflies) and Tricoptera (caddis files). In this study the % EPT tends to be decreased as the quality of water decreased downstream. The highest value (54.78 %) EPT was recorded at site-1 followed by site-2 (42.45%) and the least recording (18.05) was observed at site-3 (Table-9). This result coincides with the idea of Plafkin et al. (1989) because it explains that percent EPT decreased as perturbation increased. May files, stoneflies and caddis files are good indicator of water pollution as they require high dissolved oxygen and very sensitive taxa to low dissolved oxygen. However, some of them were found in the impacted site-3. This indicated that they were not effective indicator of water pollution as it was explained by Thorp and Courch (1991) because some net spinning tricopterans (e.g. hydropsychidae) and ephemeroptera (e.g.caenidae) thrive in heavy sediment streams.

EPT taxa were found abundantly in the reference site (Site 1) than site-2 and site-3 may be due to they are naturally living in cold, non-turbid, neutral pH, and high dissolved oxygen water. In contrast to this, the least number of EPT at site-3 might be possibly low flow velocity, low level of dissolved oxygen (Do), warm temperature and turbid water. Extensive agricultural activities and clearance of riparian vegetation also could be other factors for declining of EPT taxa in the impacted sites (Baye Sitotaw, 2006)

Percent chironomidae-Some Chironomidae species are commonly known pollution tolerant with a high tolerant value of 8. The highest (15.27) of percent Chironomidae recorded at site- 3

and the least (8.49) was recorded at site-2 but completely absent in the reference site. The highest percent Chironomidae at site-3 might be the presence of severe pollution and low level dissolved oxygen in which Chironomidae could be exist. The pigmented hemoglobin possessed by Chironomidae enables them to breathe enough oxygen from the atmosphere in polluted water. High turbidity and pH as well as warm temperature could be the factors that increase the number of Chironomidae as they are tolerant organisms in such stressed sites but not for sensitive taxa. Chironomidae tends to increase along with the decrease of water quality (Plafkin et al., 1989). The findings of this study also support this fact as the number of Chironomidae increases downstream.

Percent Coleoptera-These taxa are the potential benthic metric that can indicate the quality of water. In this study, high percent coleopteran (33.04%) was recorded at the reference site followed by site-2 (25.5%), however, they were completely absent in site-3 may be due to most members of these taxa are moderately tolerant (Bouchard, 2004) since they can live in moderate(site-2) and less impacted(site-1) sites but not in highly impacted site (site-3) because of the appearance of low level of oxygen, warm temperature, high conductance and low flow velocity in site-3 that could not be support Coleopterans.

Table-9 Metric scores of macro invertebrate communities at each site

Metrics	Site-1	Site-2	Site-3
%Taxa richness	60	68	52
%Ephemeroptera	35.6	33.01	15.27
%Tricoptera	9.56	4.71	2.77
%Plecoptera	9.56	4.71	0
%EPT	54.78	42.45	18.05
Dipterans	6.08	19.8	45.83
%Bloodredchiro.	0	8.49	15.27
Oligochaeta	0.86	1.88	9.21
%Coleoptera	33.04	25.5	0
Non insect taxa	0.86	3.77	15.27
Community Loss Index(CLI)	0.00	0.65	0.85
%Dominant Taxa	13.91	14.15	15.28

Percent Dipterans-According to Barbour et al. (1996) percent diptera increases as the perturbation increases. This fact was supported by this study because the highest score (45.83%) was recorded at the impacted site-3 where as the least score (6.08%) recorded at the reference site-1. This indicates that diptera taxa were dominant in stressed site than the reference site over the other taxa. According to Bode et al. (1996) high dominant value indicates unbalanced communities and strongly dominated by one or more taxa.

Non- insect taxa-Oligochaeta, Leeches and Orb snails were included in these taxa which were dominantly found down stream at site-3 (15.27%) and rarely found at the reference site (0.86%) and at site-2 (3.77%) (Table-9). This indicated that the downstream water might be polluted by urban runoff and domestic wastes, especially dumping of wastes from traditional tanners might have great effect in the deterioration of the environment.

Percent Plecoptera (stoneflies)-these taxa were completely absent (0%) in site-3 but found in larger number (9.46%) in the reference site followed by site -2 (4.71%). This result indicates that Plecoptera taxa were the best indicator of highly polluted environment than other ETP taxa because as it has already mentioned that Ephemeroptera and Tricoptera among the EPT taxa were found both in less and highly impacted sites but, Plecoptera taxa were not found at highly impacted site (site-3)

The community loss index (CLI)-The highest value of CLI (0.85) was recorded at site-3, followed by site-2 (0.650), and nil value was recorded (0.00) at the reference site (Table-9). Totally the result showed an increase of CLI along with decreasing of water quality. The highest score at site-3 might be related to the loss of few communities when compared to the reference site due to environmental degradation.

Table-10 Standardized score of macro-invertebrates

Metrics	Site-1	Site-2	Site-3
%Taxa richness	5	5	1
%Ephemeroptera	5	5	1
%Tricoptera	5	3	1
%Plecoptera	5	3	1
%EPT	5	5	1
%Dipterans	5	3	5
%Blood red Chironomidae	5	5	5
%Oligochaeta	5	3	3
%Non insect taxa	5	1	1
%Coleoptera	5	3	1
Total(50-point scale)	50	36	20
Total(standardized to 100 point scale)	100%	72%	40%

Table-11 Categorization of sites in to different impairment levels based on BMI result

BMI value	Water-quality characterization	Impairment level	Sites at each impairment level
20-46	Very poor to poor	Severe to slight	Site-3
46-72	Fair to good	Moderate to less impairments	Site-2
72-100	Very good to excellent	Very little to no impact	Site-1

4.4 THE RELATION BETWEEN BIOLOGICAL AND HABITAT INTEGRITY

In the assessment of Gulla River whether it supports a health aquatic community or not, a Pearson correlation between biological communities and habitat parameters was made. The result of the study showed that there was a strong relation between them (Table-12) For instance, a strong positive correlation was observed between Tricoptera and vegetation protection (VP) ($r = 0.99$, $P < 0.01$) On the other hand a strong negative correlation was observed between chironomidae and riparian vegetation zone width(RVZW)($r = -0.999$, $p < 0.01$)The positive relation between Tricoptera and VP clearly indicated that the number of Tricoptera declined with the decrease of VP along Gulla river. Since Tricoptera is one of pollution sensitive taxa, its number was expected to decline in stressed water ecology as it has been observed in this study. Similarly a decrease of RVZW along down a river correlated with an increasing number of chironomidae. An increasing number of chironomidae at downstream (site-2 and site-3) showed the appearance of degraded environment.

Table-12 Pearson correlations between scores of macro invertebrates and habitat parameters

	TAXA RICHN	EPT	CHIRONO	COLEOP	EPHEME	TRICOPT
ES	0.000	0.758	-0.896	0.677	0.598	0.961
SD	0.444	0.969	-0.1000	0.933	0.891	0.984
BS	-0.327	0.502	-0.702	0.398	0.303	0.817
VP	0.240	0.892	-0.977	0.834	0.773	0.999
RVZW	0.397	0.955	-0.999	0.913	0.867	0.992

.Correlation is significant at 0.01 levels (2 -tailed)

.. Correlation is significant at 0.01 levels (2-tailed)

4.5 THE RELATION BETWEEN BIOLOGICAL METRICS AND PHYSICO CHEMICAL PARAMETERS

For the examining of interrelation between biological metrics, bivariate Pearson correlation was made (Table:-13) hence, the biological integrity of Gulla river was assessed. With the exception of DO taxa richness, Ephemeroptera, Plecoptera and coleopteran showed a negative relationship with EC, PH, No3, P04, temperature and turbidity. EPT showed negative strong relation with PH ($r=1.000$, $P<0.01$) while dipteral showed positive relation (1.000 , $p<0.01$) the total result indicated that the number of EPT was declined along with an increase of pH in the downstream. The reason might be due to high organic load and turbidity from farmland run off and animal wastes. These challenges also aggravated by urban runoff, dumping of household wastes and organic debris from traditional processing hides. On the other hand the number of Diptera increased as the PH increased downstream because of their tolerable characteristics to polluted water.

Ephemeroptera showed a negative strong relation with P04 ($r=-.999$, $P<0.05$) but Oligochaeta taxa contrastingly showed a positive strong relation with P04. The reason could be that Oligochaeta are the tolerant taxa that can live in polluted water. However, Ephemeroptera since they are among the sensitive taxa, they cannot exist in such environment with high concentration of PO_4 . Plecoptera showed a strong negative relation to temperature ($r=-.99$, $P<0.05$). The temperature was increased downstream with the decrease of Plecoptera. This might be due to the sparse vegetation along the river, increasing in turbidity and nutrient enrichment, and low altitude. This condition is unfavorable for sensitive taxa like Plecoptera.

FBI showed a strong positive relation with NO_3 ($r=.999$, $P<0.05$), temperature ($r=.999$, $P<0.05$) and turbidity ($r=1.000$, $P<0.01$); however, it was negatively related to DO ($r=-1.1000$, $P<0.01$). An increase of NO_3 , temperature and turbidity cause the value of FBI to be increased, this showed a positive relation. The negative relation with DO may be caused by declining concentration of DO downstream along an increasing of FBI value. Slight pattern was detected that might distinguish effects of physicochemical parameters on macro- invertebrate metrics because of the presence of other unknown factors that could not be assessed in this study.

Table-13 Pearson correlations between macro invertebrates and physicochemical parameter

	taxa ri	ephem	tricopt	EPT	dipt	Chiron	oligoch	coleop	plecopt	FBI	CLI
EC	-0.466	-0.902	-0.979	-0.974	0.977	1.000.	0.900	-0.942	-1.000	0.992	0.967
PH	-0.649	-0.975	-0.911	-0.1000..	1.000..	0.970	0.974	-0.993	-0.982	0.995	0.887
NO_3	-0.545	-0.938	-0.957	-0.991	0.992	0.993	0.936	-0.968	-0.998	0.999.	0.940
PO_4	-0.820	-0.999.	-0.777	-0.969	0.966	0.876	1.000.	-0.991	-0.902	0.939	0.742
Temp.	-0.533	-0.933	-0.961	-0.989	0.990	0.995	0.931	-0.965	-0.999.	0.999.	0.944
Turb.	-0.578	-0.951	-0.944	-0.995	0.996	0.988	0.950	-0.978	-0.995	1.000..	0.925
Do	0.564	0.946	0.950	-0.994	0.995	-0.990	-0.944	0.974	0.996	1.000..	-0.931

. Correlation is significant at 0.05 levels (2-tailed)

.. Correlation is significant at 0.1 levels (2-tailed)

5. CONCLUSION AND RECOMMENDATION

The data gathered from the assessment of biological, chemical and physical characteristics of Gulla River helps to understand the effects of anthropogenic activities. This study really showed that Gulla River was under the pressure of human activities as a result of unwise use of natural resources and discharges of pollutants from various sources. The release of untreated domestic wastes, dumping of organic debris and intensive agricultural practices near the river as well as dumping of traditional processed tannery wastes were the major threatening factors in Gulla River. Moreover, Grazing, clearance of riparian vegetation, local irrigation system and bank instability, which promotes siltation and sedimentation, all these factors were contribute for the deterioration of the Gulla river ecosystem. The usual use of detergents for personal hygiene and car washing in the river also exacerbated the problem.

The pollution of Gulla River was attributed by declining the composition and richness of sensitive taxa along with an increasing of perturbation. Very poor habitat scores and measurement of most physicochemical parameters above a set of standards revealed the unhealthy condition of Gulla River which has a potential to damage aquatic organisms including human health.

Unless these life threatening problems are treated /managed properly, sustainable utilization of the river would be impaired so does the aquatic organisms. Thus, any remedial actions should be taken immediately to restore the degraded ecosystem of Gulla River. The re- establishment of healthy and an integrated river ecosystem help to achieve an optimal situation for future use for domestic, agricultural and even recreational purposes.

Additional studies in Gulla River help to develop scientific monitoring system and developing effective and feasible remedial measures. The results from this study generally invite the stakeholders to implement the following remedial actions:

- ✓ People should be aware how to mitigate or restore environmentally degraded aquatic ecosystem through educational programme for sustainable development.
- ✓ Governmental organization should provide proper waste disposal site to avoid water contamination.
- ✓ Legislative powers and concerning bodies should make enforcing law to ban all water polluting activities.
- ✓ Buffer zone should be established along the river.
- ✓ Extensive afforestation programme should be carried out around watersheds to protect water pollution.
- ✓ The need of gradual replacement of inorganic fertilizers by organic fertilizers should be promoted by using harmless local technologies.

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Declaration

I declare that this thesis is based on my work and all sources of materials used for this thesis have been fully acknowledged.

Signature _____

Date of Submission _____