JIMMA UNIVERSITY, COLLEGE OF PUBLIC HEALTH AND MEDICAL SIENCES, DEPARTMENT OF ENVIRONMENTAL HEALTH SCIENCES AND TECHNOLOGY

POLLUTION EFFECT OF WASTEWATER DISCHARGED FROM HAWASSA TEXTILE FACTORY ON TIKUR WUHA RIVER, SOUTHERN ETHIOPIA.

By

TEMESGEN ESHETU

A THESIS SUBMITTED TO DEPARTMENT OF ENVIRONMENTAL HEALTH SCIENCES AND TECHNOLOGY, COLLEGE OF PUBLIC HEALTH AND MEDICAL SIENCES, JIMMA UNIVERSITY FOR THE PARTIAL FULLFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN ENVIRONMENTAL SCIENCE AND TECHNOLOGY, *SPECIALTY IN ENVIRONMENTAL TECHNOLOGY*

August, 2011

Jimma, Ethiopia

POLLUTION EFFECT OF WASTEWATER DISCHARGED FROM HAWASSA TEXTILE FACTORY ON TIKUR WUHA RIVER, SOUTHERN ETHIOPIA

By

TEMESGEN ESHETU

A THESIS SUBMITTED TO DEPARTMENT OF ENVIRONMENTAL HEALTH SCIENCES AND TECHNOLOGY, COLLEGE OF PUBLIC HEALTH AND MEDICAL SIENCES, JIMMA UNIVERSITY FOR THE PARTIAL FULLFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE IN ENVIRONMENTAL SCIENCE AND TECHNOLOGY, *SPECIALTY IN ENVIRONMENTAL TECHNOLOGY*

ADVISORS

Dr. ARGAW AMBELU (Associate Professor, PhD)

Mr. SEID TIKU (Lecturer, MSc)

Declaration

I, the undersigned, declare that this research paper is my original work and has not been presented for a degree in this or any other university and that all sources of materials used for the paper have been fully acknowledged.

Name: Temesgen Eshetu

Signature: ____

Name of institution: ________________________________

Date of submission: ________________________________

This Research paper has been submitted for examination with my approval as university advisors.

Name	Signature
Dr. Argaw Ambelu (Associate professor, PhD)	____________________
Mr. Seid Tiku (Lecturer, MSc)	____________________

Abstract

Industrial pollution to water body is one of the serious problems if there is no well established wastewater treatment facility. The main focus of this study was to investigate the effects of wastewater generated from Hawassa Textile Factory on Tikur Wuha River. Composite wastewater samples were taken from the factory outlet and the outlet of lagoon and a grab water sample was collected from each selected ten sampling stations on Tikur Wuha River once per month from April to May 2011. A habitat score was made for each established sampling stations by using habitat assessment checklist. Macroinvertebrate sample was collected together with water sample from each selected sampling sites by using surber sampling method from Tikur Wuha River. The wastewater and river water physicochemical parameters such as Chemical oxygen demand (COD), biological oxygen demand (BOD), total organic nitrogen (TON), nitrate nitrogen (NO_3-N), ammonia nitrogen (NH_3–N), Phosphate (PO_4^{3-}), Sulphate (SO_4^{2-}) and total suspended solids (TSS) were analyzed. Percent comparability of habitat score showed that both upstream and downstream study sites were categorized to good habitat conditions. Multi metric index of Tikur Wuha River was developed using selected metrics. Based on the multi metric score sites such (U1 – U5) fall to very good biological integrity, while the downstream sites such as (D1 & D2) categorized under very poor biological integrity. The results from this finding reveal that the downstream study sites such as (D1 & D2) were categorized as severely impaired than upstream sites. From the correlation matrices metrics that expected to decrease with perturbation had a strong negative relationship with pH, COD, BOD_5 & orthophosphorus at (r= -0.839, -0.889, -0.887 & -0.722 respectively with %EPT) on the other hand metrics that expected to increase with perturbation is % Chironomidae, has strong positive correlation with pH, COD, BOD_5 and orthophosphorus respectively. The study showed that the water qualities of the downstream study sites on Tikur Wuha River were adversely affected and its aquatic biota was impaired due to the strong wastewater or poorly treated wastewater discharged from the textile factory. For sustainable management of this water resource, regional environmental protection agencies in cooperation with the factory manager should take technical measures to alleviate the problem. The environmentalist in the factory should continuously monitor the textile effluents and take necessary actions to change wastewater to environmentally friendly form before discharging it.

Acknowledgment

Before all, I would glad to thank "JESUS CHRIST" the son of God because without him everything is meaningless in my life!!!

My deepest gratitude goes to my advisors Dr Argaw Ambelu and Mr. Seid Tiku for their unreserved support and guidance throughout the study period. It gives me great pleasure to acknowledge my family for their moral support and encouragement throughout my entire graduate study. I would like to thank Mr. Abdulhakim Ahmed for his support in digitizing the study area map. My thank also goes to Mr. Zewdu Teshome and Mr. Zelalem Eshetu for their support in providing constructive comment and field assistant respectively, to make this work valuable. Lastly but not the list I would like to thank all my classmates for their contribution and support on materials and others.

I would like to thank my sponsor organization Dawro Zone Isera woreda head administration for sponsoring this study and Jimma University for giving me a chance and budget coverage of this work.

Table of contents

List of figures

List of tables

Acronyms

AEPA	American Environmental Protection Authority
ATU	Acute Toxicity Unit
BOD	Biological Oxygen Demand
BLO	Biological Lagoon outlet
BMI	Biotic Multi metric Index
%CHIR	percent Chironomidae
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
EC	Electrical Conductivity
%DT	Percent Dominant Taxa
%EPT	Percent Ephemerophtera, Plecoptera, Trichoptera Index
EPA	Environmental protection Authority
GOE	Government of Ethiopia
HTFE	Hawassa Textile Factory Effluent
GPS	Global positioning system
JU	Jimma University
FSS	Fixed Suspended Solid
MCITWR	Macroinvertebrates Community Index Tikur Wuha River
M.a.s.l	Meter above sea level
OP	Orthophosphorus

TDS	Total Dissolved Solid
SS	Suspended Solid
TFO	Textile factory outlet
TN	Total nitrogen
U	Upstream
D	Downstream
TSS	Total Suspended Solid
VSS	Volatile Suspended Solid
UNEP	United Nation Environmental Program
US EPA	United States Environmental Protection Authority
WHO	World Health Organization

CHAPTER ONE:

INTRODUCTION

1.1 Background

Effluent generated from industries is one of the sources of pollution, and considered as the major issues in environmental protection (Derieg, 1999). The textile industry consumes a large quantity of water and generate huge amount of wastewater (Shu et al., 2005). The effluents contain a wide range of contaminants such as salts, enzymes, surfactants, oxidizing and reducing agents. These pollutants contributes to high suspended solids (SS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), heat, color, acidity, alkalinity and other soluble substances (Gebre-Mariam and Desta, 2002).

Pollution of the aquatic environment is defined as introduction of substances (wastes) and/or energy (like thermal) into the system which can result in such deleterious effects as: harm to living resources, hazards to human health, hindrance to aquatic activities including fishing, impairment of water quality with respect to its use in agricultural, industrial and often economic activities and reduction of amenities (Meybeck and Helmer, 1996). According to the World Health Organization (WHO), wastes are usually referred to "something" which the owner no longer wants at a given time and space and which has no current or perceived market value (Mamo, 2004).

Pollution may result from point sources or diffuse sources (non-point sources). An important difference between a point and a diffuse source is that a point source may be collected and treated or controlled (diffuse sources consisting of many point sources may also be controlled if all point sources can be identified). The major point source pollutions to freshwaters originate from the collection and discharge of domestic wastewaters and industrial wastes (Meybeck and Helmer, 1996).

The degradation of water resources with industrial effluent occurs by altering attributes that influence and determines the integrity of surface water resources, such as water quality, habitat structure, flow regime, energy source and biotic interactions that influence the ecological integrity of the system (Karr, 1981).

Ecologists recommend the use of resident organisms, such as insects, arachnids, aligochaets, molluscs that are sensitive indicators of disturbances, in order to achieve and preserve the highest water quality (Karr, 1996).

Biological information is used to evaluate stream impacts from point and non-point sources of pollution; biological monitoring may be the most appropriate means of detecting effects on the aquatic community (Barbour et al., 1996). A more comprehensive approach of biological assessment of water quality recently introduced the Benthic Macroinvertebrate Index (BMI) (Karr, 1981). The BMI is found to be an important tool for assessing the biological integrity of aquatic resources along with information on physical and chemical conditions.

Benthic macroinvertebrates refers to organisms that inhabit the bottom substrates (sediments, debris, logs, macrophytes, filamentous algae, etc) of freshwater habitats, for at least part of their life cycle and those retained by mesh sizes >200 to 500µm (Rosenberg and Resh, 1993) such as mayflies, Caddis flies, Oligochaetae, midges (Barbour *et al,*1999).

The main focus of this study was to assess the ecological impact of textile wastewater on Tikur Wuha River using physicochemical parameters and macroinvertebrates assemblages.

1.2 Statements of Problem

Textile processing activities are the major sources of huge amounts of effluents that have an immediate or long-term harmful effect on the environment and its biological diversity (Sapci and Ustun, 2003).

Effluents from industries had been known to contaminate water, soil and air with associated heavy disease burden and eventual shorter life expectancy in developing countries (WHO, 2003).

Textile processes produce multi component wastewater which can be difficult to treat (Paul, 2008). Treatment is highly complex and very difficult for textile wastewater effluent due to an intensive application of different chemicals in bleaching, mercerizing, dyeing and finishing & single treatment option is not advisable; the use of combined processes has been suggested recently to overcome the disadvantage of individual unit processes (Paul, 2008).

In Ethiopia most of the textile factories lack wastewater treatment plants. Instead, they directly discharge untreated colored and toxic effluent into the nearby canals, rivers, lakes, and streams (Gebre-Mariam and Desta, 2002).

Hawassa textile factory discharges an average of 50 m^3 of wastewater per hour, rising to120 m^3/hr at full capacity (Desta, 1997). Chemical composition & waste generation of Hawassa textile factory wastewater was investigated by different scholars in Ethiopia but its effects on the aquatic life forms was not yet studied & the factory has no wastewater treatment facilities; effects of effluent on the water sources are the major problems in the area that initiated to conduct research on it.

This study mainly focuses on assessing pollution effect of Hawassa Textile factory wastewater and determines its ecological impacts on aquatic biota using macroinvertebrates and physicochemical parameters.

1.3 Significance of the study

Industrial pollution in water body is the major environmental and health challenges especially in developing countries. These problems are the major obstacles that minimize water quality and ecological well being of the environment and have strong effect on macroinvertebrates abundance and diversity in the water body. This study is significant for the factory owner to give great attention on the wastewater treatment options. The current study is also significant for providing baseline information for further research on the area. This study was therefore aims to investigate the pollution effect of Hawassa textile factory effluent discharge on Tikur Wuha River using physicochemical and macro invertebrate parameters.

1.4 Limitation of the study

Some parameters such as Cr, Pb, Fe, and Zn were not analyzed due to lack of instrumental set up and standard solution for heavy metals.

CHAPTER TWO

LITERATURE REVIEW

2.1. Characteristics of Textile Wastewater

Textile effluents are complex mixtures of chemicals, varying in composition over time and from factory to factory as well as on a temporal basis at individual factory. According to (PRG, 1998), textile effluents are highly colored and saline, contain non- biodegradable compounds, and are high in Biological and Chemical Oxygen Demand (BOD, COD). They also have high concentrations of suspended solids, extreme pH and elevated temperatures (Shu *et al.,* 2005).The variety of raw materials, chemicals, processes and also technological variations applied to the processes cause complex and dynamic effect of the wastewater (Sapci and Ustun, 2003).

2.2. Sources of Pollution

The major source of pollutants in textile processing are primarily associated with the wet processes such as sizing, fabric preparation (desizing, scouring, bleaching, mercerizing), dyeing, printing and finishing (Yusuff and Sonibare, 2004). These processes involve treating grey or greige goods with chemical baths and often require additional washing, rinsing and drying steps.
At the pretreatment stage, desizing is the industry's largest source of pollution. During desizing, all the sizes used during weaving are removed from the fabric and discarded into the wastewater. In scouring, dirt, oil, waxes from natural fibers are removed from the fabric and washed into wastewater stream. Normally desizing and scouring are combined and these two processes may contribute to 50% of BOD in the wastewater in the wet processing.

Dyeing process generate the largest portion of the total wastewater. The source of wastewater is from the dye preparation, spent dye bath and washing processes. Dyeing wastewater contains high salt, alkalinity and color. Finishing processes generate organic pollutants such as residue of resins, softeners and other auxiliaries. A composite wastewater from an integrated textile plant consist of the following materials such as starches, dextrin, gums, glucose, waxes, pectin, alcohol, fatty acids, acetic acid, soap, detergents, sodium hydroxide, carbonates, sulfides, sulfites, chlorides, dyes, pigments, carboxymethyl cellulose, gelatin, peroxides, silicones, fluorocarbons, resins and others (NIIR Board, 2003). Pollutants at various stages of manufacturing of polyester and cotton blended woven fabric are presented in table 1.

Table 1. Effluent characteristic from textile industry (Source: (PRG, 1998))

Major process	Effluent composition	Nature of the effluent
Sizing	Starch, waxes, carboxymethyl cellulose (CMC), polyvinyl alcohol (PVA), wetting agents	High in BOD, COD
Desizing	Starch, CMC, PVA, fats, waxes, pectins	High in BOD, COD, SS, dissolved solids (DS)
Bleaching	Sodium hypochlorite, Cl2, NaOH, H2O2, acids, Surfactants, NaSiO3, Sodium phosphate, short cotton fiber.	High alkalinity, high SS
Mercerizing	Sodium hydroxide, cotton wax	High pH, low BOD, high DS
Dyeing	Dyestuffs urea, reducing agents, oxidizing agents, Acetic acid, detergents, wetting agents.	Strongly colored, high BOD, DS, low SS, heavy metals
Printing	Pastes, urea, starches, gums, oils, binders, acids, thickeners, cross-linkers, reducing agents, alkali.	Highly colored, high BOD, oily appearance, SS slightly alkaline

2.3. Legislation for the control of discharge of industrial effluents in Ethiopia

Environmental standards and effluent regulations for textile industries need to cover all parameters with adverse effects on the environment specifying numerical limits that are attainable by available treatment technologies, and involve a compliance monitoring system that is practical in technical and economical terms (UNEP, 1991). It may be easy to enact environmental standards with sets of limitation protocols with all conceivable pollutants in Ethiopia at present, but these rules and regulations will have no real value, at least in the short term, unless they can be enforced.

Environmental pollution derived from domestic and industrial activities is the main threat to the surface and groundwater qualities in Ethiopia (EPA, 2003). It is reported that the majority of industries in the country discharge their wastewaters into nearby water bodies and open land without any form of treatment (EPA, 2003). Likewise, in Ethiopia all of the textile factories have no effluent treatment plants. However, the survival of the ecosystem depends on the ability to manage wastes in an environmentally sound manner. This can only be achieved through establishment and enforcement of appropriate standards and guidelines set to ensure that one does not destroy the environment (EPA, 2003). This necessitates the formulation of regulations and standards for discharge limits of the effluents before they are released into the environment (GOE, 2002). According to (EPA, 2003) the guideline standards of textile wastewater limit values for discharges to water bodies are summarized in Table 2.

Table 2. Textile wastewater limit Values for discharges (Source EPA, 2003)

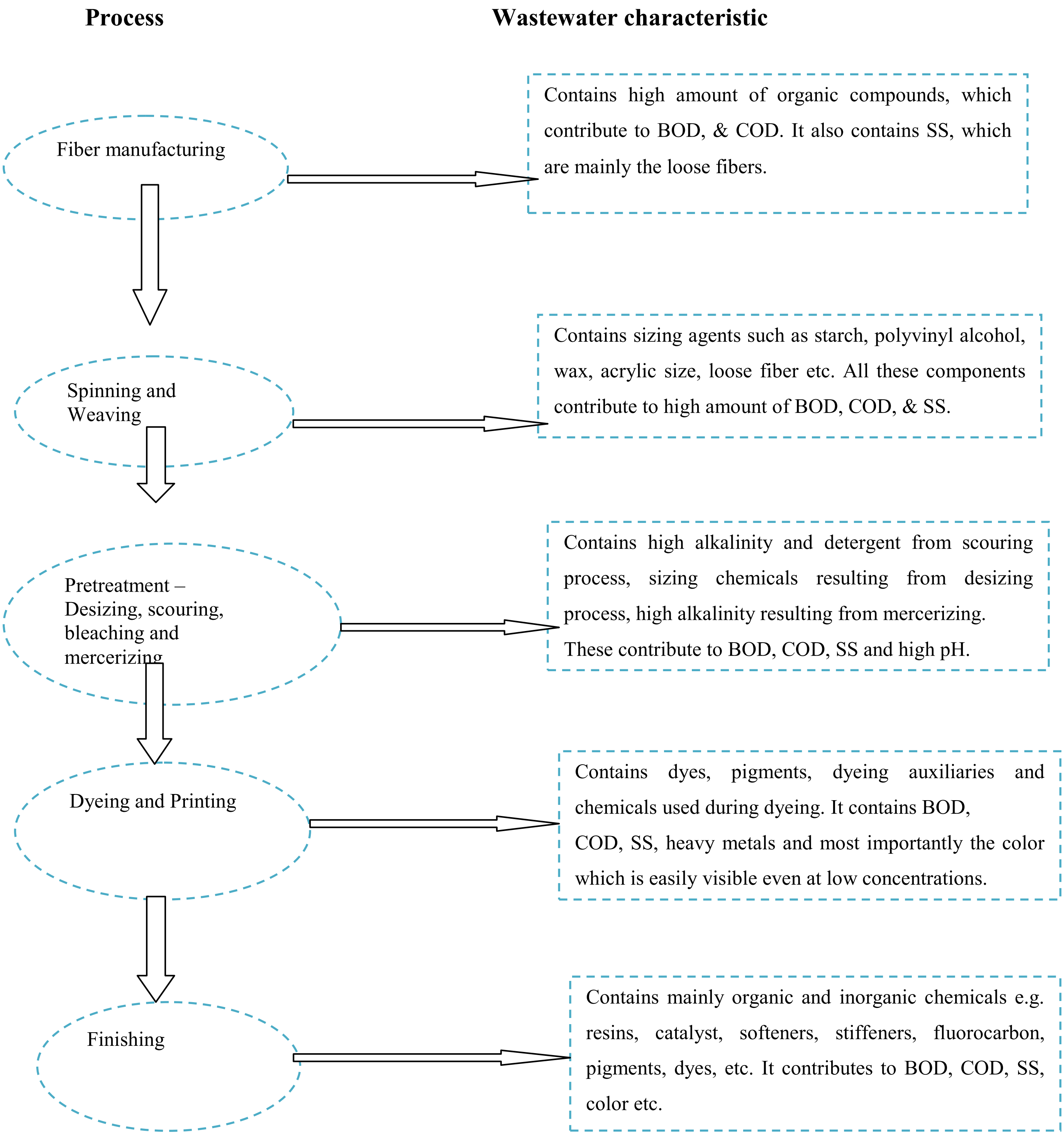
Parameters	**Limit values (MPL)**
pH	6-9
Temperature (oC)	**$40^{0}{}_{c}$**
Total Dissolved Solids (TDS)(mg/l)	80
Conductivity (EC)	1000 µs/Cm (at 20 0C)
BOD5 at 200C	50 mg/ l>90% removal
COD	150 mg/l >80% removal
Ammonia (NH3-N)	30mg/l
Nitrate (NO$_3$-N)	50 mg/l NO3
Orthophosphorus	10 (>80% removal)
Total Nitrogen (as N)	40 mg/l >80% removal
Sulfate (SO4)	200 mg/l SO4
Total Suspended solids	30 mg/l

2.4. Environmental impact of textile wastewater

Environmental pollution is an inevitable consequence of economic development and people's desire to improve their quality of life (Kumar, 2000). Industries contribute to the pollution of the environment, especially in the absence of regulations that force manufacturers to reduce their hazardous impact. Moreover, accelerated water quality change due to industrial pollution is one of the major environmental concerns throughout the world. Industrial effluents and domestic sewage contribute large quantities of nutrients and toxic substances that have a number of adverse effects on the water bodies and the biota (Gebre-Mariam and Desta. 2002).

The effects of industrial activities on the environment in the country are becoming evident through the pollution of water bodies and human habitat in the major cities, rivers and lakes (Derieg, 1999). An estimated 90 % of wastewater in developing countries is still discharged directly into rivers and streams without any waste treatment or after retention period of sometime in stabilization ponds (Shu *et al*., 2005).

The major environmental impacts of textile wastewaters are the unit processes that take place in the textile industry and generate wastewater with varying composition and colors to the environment with different pollutanting substants such as higher BOD, COD, TSS, pH and TDS. These can be depicted in the following figure 1.



Process	Wastewater characteristic
Fiber manufacturing	Contains high amount of organic compounds, which contribute to BOD, & COD. It also contains SS, which are mainly the loose fibers.
Spinning and Weaving	Contains sizing agents such as starch, polyvinyl alcohol, wax, acrylic size, loose fiber etc. All these components contribute to high amount of BOD, COD, & SS.
Pretreatment – Desizing, scouring, bleaching and mercerizing	Contains high alkalinity and detergent from scouring process, sizing chemicals resulting from desizing process, high alkalinity resulting from mercerizing. These contribute to BOD, COD, SS and high pH.
Dyeing and Printing	Contains dyes, pigments, dyeing auxiliaries and chemicals used during dyeing. It contains BOD, COD, SS, heavy metals and most importantly the color which is easily visible even at low concentrations.
Finishing	Contains mainly organic and inorganic chemicals e.g. resins, catalyst, softeners, stiffeners, fluorocarbon, pigments, dyes, etc. It contributes to BOD, COD, SS, color etc.

Figure 1. Sources of pollution in textile manufacturing (NIIR Board, 2003)

2.5. Benthic macroinvertebrates as pollution indicators

Bio-monitoring is monitoring the state of the environment through the performance of living organisms. It depicts the impacts of pollution on organisms, and can potentially detect the long-term exposure of a site to environmentally harmful chemicals. In addition, they provide an overall picture of the impact of environmental factors that often cannot be detected by physiochemical variables (Davis, 1995; Barbour *et al*., 1996). They developed the idea of saprobity (the degree of pollution) in rivers as a measure of the degree of contamination by organic matter and the resulting decrease in dissolved oxygen. Since then, benthic macroinvertebrates as bioindicators have been used in many bio-monitoring and bioassessment programs (Bode and Novak, 1995; Barbour *et al*., 1996; Fore *et al*., 1996).

Benthic macro invertebrates are stream-inhabiting organisms, easily viewed with naked eye. They spend at least part of their lives, in or on the stream bottom and are retained by mesh sizes 200 to 500µm (Rosenberg and Resh, 1993).

2.5.1. Macroinvertebrates metrics

Metrics allow the investigator to use meaningful indicator attributes in assessing the status of assemblages and communities in response to perturbation. The definition of a metric is a characteristic of the biota that changes in some predictable way with increased human influence (Barbour et al., 1995). For a metric to be useful, it must have the following technical attributes: (i) ecologically relevant to the biological assemblage or community under study and to the specified program objectives; (ii) sensitive to stressors and provides a response that can be discriminated from natural variation. The purpose of using multiple metrics to assess biological condition is to aggregate and convey the information available regarding the elements and processes of aquatic communities. All metrics that have ecological relevance to the assemblage under study and that respond to the targeted stressors are potential metrics for testing. From this "universe" of metrics, some will be eliminated because of insufficient data or because the range of values is not sufficient for discrimination between natural variability and anthropogenic effects. This step is to identify the candidate metrics that are most informative, and therefore, warrant further analysis. The potential measures that are relevant to the ecology of streams within the region or state should be selected to ensure that various aspects of the elements and processes of the aquatic assemblage are addressed. Representative metrics should be selected from each of 4 primary categories: (a) richness measures for diversity or variety of the assemblage; (b) composition measures for identity and dominance; (c) tolerance measures that represent sensitivity to perturbation; and (d) trophic or habit measures for information on feeding strategies and guilds. (Karr and Chu. 1999) suggest that measures of individual health be used to supplement other metrics. Karr et al, 1987) has expanded this concept to include metrics that are reflective of landscape level attributes, thus providing a more comprehensive multi metric approach to ecological assessment.

2.5.2. Index calculation for assessment

The multi metric index value for a site is a summation of the scores of the metrics and has a finite range within each stream class and index period depending on the maximum possible scores of the metrics (Barbour et al., 1996c). This range can be subdivided into any number of categories corresponding to various levels of impairment. Because the metrics are normalized to reference conditions and expectations for the stream classes, any decision on subdivision should reflect the distribution of the scores for the reference sites.

CHAPTER THREE:

OBJECTIVES

3.1. General Objective

The main objective of this study was to investigate the effects of wastewater generated from Hawassa Textile Factory on Tikur Wuha River using macroinvertebrates assemblage and physicochemical parameters, as indicators.

3.2. Specific Objectives

The specific objectives of this study are:

- to assess effects of Textile effluent on Tikur Wuha River using physicochemical parameters
- to determine the effects of textile effluent on the abundance and diversity of macroinvertebrates community.
- To compare the Tikur Wuha river water quality and macroinvertebrates assemblage at upstream and downstream from the point of wastewater discharge.

3.3. Hypothesis

The water quality and macroinvertebrates assemblages of Tikur Wuha River were affected by the wastewater discharge from Hawassa textile factory.

CHAPTER FOUR

MATERIALS AND METHODS

4.1. Study Area and period

This study was conducted at Hawassa textile factory wastewater generated on Tikur Wuha River from to May 2011. Tikur Wuha River is found around four (4) km from south of Hawassa textile factory.

4.2. Study design

Cross-sectional study was conducted to determine the pollution effect of the Hawassa Textile factory wastewater on Tikur Wuha River basically by field and laboratory analyses.

4.3. Sampling sites

The wastewater samples were collected directly from the factory outlet (TFO) and outlet of the lagoon (BLO). In total 10 sampling sites at Tikur Wuha River was established: five from upstream (U_1– U_5), and five downstream (D_1 –D_5) were selected having approximately 1km distance between them. Figure 3 shows the location of the study area and sampling sites.

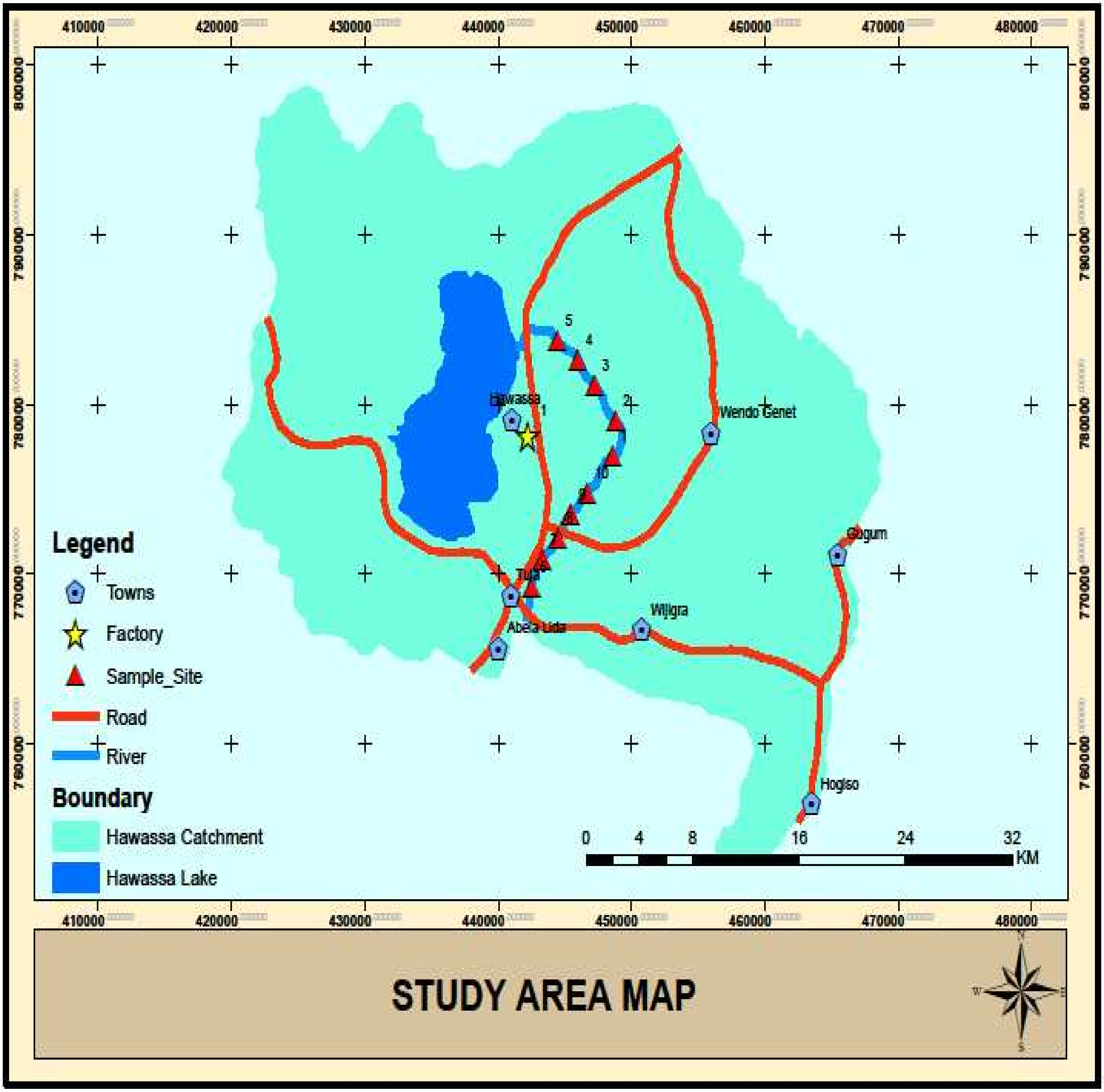


Figure 2. Study Area Map

Table 3. Sampling sites, location and altitude and site description

Site code	Altitude (m. a.s.l)	Northing	Easting	Descriptions
U1	1704	447663	784594	Site 1 a point five 5 km away from the confluence point in upstream sites
U2	1697	448702	784429	Site 2 1km away from site 1
U3	1692	447777	784789	Site 3 the point in which 1km from site 2
U4	1691	446663	784978	Site 4 the point in which 1km from site 3
U5	1689	447659	784983	Site 5 in upstream 20 m from the confluence point of wastewater discharge from lagoon to the river.
D1	1688	442909	784151	Site 1in downstream the point 20m away from the confluence point of wastewater from lagoon to river.
D2	1686	444195	784242	Site 2 the point in which 1km from site 1
D3	1685	443643	784394	Site 3 the point in which km from site 2
D4	1682	445052	783852	Site 4 the point in which 1km from site 3
D5	1680	442758	783917	Site 5 the point in which 1km from site 4

4.4. Sample collection

4.4.1. Wastewater sampling

A composite wastewater ample was collected in 12 hours, by considering the factory working time. Samples were taken from the factory and lagoon outlets at 9:00 AM, 2:00PM and 5:00PM. once per month in between April and May 2011, Sampling bottles were well washed with distilled water and rinsed with nitric acid to protect it from unnecessary contamination, therefore, from each sampling sites one liter wastewater sample was taken per sampling time. During the sampling period there were a total of 3 liters wastewater sample was taken from the point at the outlet of factory & outlet of the lagoon. The samples that collected on different time interval within a day were added in a single container at site and transfer for analysis.

4.4.2. Water Sampling from Tikur Wuha River

Sampling sites were selected from both upstream and the downstream. From the upstream 5 sites and also from the downstream 5 sites were taken. Totally 10 sample sites were established; reference sites (U_1 –U_5) from the upstream and five sites (D_1-D_5) were located in the downstream of from the point where wastewater discharge from the biological lagoon meets Tikur Wuha River. A grab water sample was collected by plastic bottle from each selected sampling sites once per month for the two months from April to May 2011. A two liter water sample was collected from each site and transported to the laboratory of EPA using cold box.

4.4.3. Water and wastewater sample analysis

The in-situ parameters such as temperature & pH was measured by exchanging probes of handled pH meter (370pH meter Jenway, E.U), turbidity (portable Turbid meter and conductivity (conductivity meter; Wagtech International by following the manufacturer's Instructions). Ortho-phosphorous was analyzed by Ascorbic acid standard method according to (APHA, 1999); total organic nitrogen, nitrate nitrogen & ammonia nitrogen were measured using spectrophotometer (DR/2010 HACH, Loveland, USA). Total suspended solids were measured using gravimetric method. Chemical oxygen demand (COD) was measured by using reactor digestion method Model 45600 COD Reactor according HACH, 2004), Biological oxygen demand (BOD) was measured (manometer method according to (APHA, 1997) & Sulfate was measured by USEPA (HACH SulfaVer method 8051) in Addis Ababa Environmental protection Authority laboratory.

4.4.4. Data quality assurance

To assure the data quality all physicochemical parameters were analyzed by laboratory technician in Addis Ababa environmental protection laboratory. Sample was reproduced two times per parameters per month and average was taken per site in per month.

4.4.5. Habitat

The respective GPS data was collected from each site by using (GAIMY GPS+17 Model, JAPAN) to show the elevation of the sites. Habitat features were scored using USEPA Rapid Bioassessment Protocol (Barbour *et al.*, 1999). It qualitatively evaluates 10 important habitat components: epifaunal substrate/available cover, velocity/depth regime, sediment deposition, channel flow status, channel alteration, frequency of riffles (or bends) (channel sinuosity), bank stability, vegetation protection and riparian vegetation zone width. Each habitat quality parameter was scored in 20-point scale to sum up to a score of 220. An overall percent comparability with this maximum possible score was calculated for each site (Gallardo *et al.,* 2006).

4.4.6. Macroinvertebrate samples

Invertebrate samples were collected using rectangular kick net mesh size of 250 µm. Sampling were taken between 10m distance at 5 minutes time interval) for 20 minutes per site. Samples from different habitats were collected then emptied in to a plastic tray. The individual macroinvertebrates were picked out with forceps and placed in separate plastic vials and preserved in 75% ethanol for later identification.

4.4.7. Macroinvertebrate sample Analysis

Macroinvertebrates family level identification was made by using the taxonomic identification keys such as such as Bouchard (2004); Jessup *et al*. (1999), and Thompson, (2004). The basic macroinvertebrate metric selection were done based on representing richness, composition and tolerance measures was considered for the index development.

Among sixteen calculated metrics ten core metrics were selected for index development based on the Spearman correlation coefficient ($r > 0.9$ or $r < -0.9$) was taken as a line to reject a metrics (Mandaville, 2002). For those metrics with $r > 0.9$ or $r < -0.9$, only the one believed to be more informative was taken (Shearer, 2006).The amount of overlap of the interquartile ranges between the values of the upstream reference sites (U1—U5) and the downstream impacted sites (D1—D5) on box plots was then examined to judge the discriminatory power of each metrics (Barbour *et al*., 1999, 1996). Metrics with no overlap of the interquartile ranges were considered for the final macroinvertebrate community index. Those metrics with extensive interquartile range overlap (both medians within the overlap) between the upstream reference sites and downstream impacted sites were rejected (Pond *et al.,* 2003).

4.4.8. Macroinvertebrate Indices (MI)

Two basic types of indices (diversity and composition) well employed to assess Tikur Wuha River health. The expected response of the candidate metrics were given in the table 4.

Table 4. Definitions of candidate metrics and expected direction of metric response

Category	Metrics	Definition	Expected response to increasing perturbation
Richness measures	No. taxa	Measures the overall variety of the macroinvertebrate assemblages	Decrease
	No. Ephemerophtera taxa	Number of mayfly taxa	Decrease
	No. Trichoptera taxa	Number of caddisfly taxa	Decrease
	No. Diptera taxa	Number of "true" fly taxa, which includes midges	Decrease
	No. Coleoptera taxa	Number of beetle taxa (adult or larva)	Decrease
Composition Metrics	%Ephemerophtera	Percent of mayfly nymphs	Decrease
	%Plecoptera		Decrease
	% Chironomidae	Percent of midge larvae	Increase
	% Oligochaetae	Percent of aquatic worms	Increase
	% Coleoptera	Percent of beetle larvae and aquatic adults	Decrease
	%ETO		Decrease
	% Non insect taxa		Increase
	Ratio of EPT to Chironomidae		Increase

4.5. Data analysis

Excel spread sheet and SPSS version 16 were used for the statistical analysis. Spearman correlation coefficients were used to evaluate relationships between physicochemical and biological data.

Biodiversity professional version 2 was used to calculate the macroinvertebrate Diversity indices.

Kruskal Wallis test value used to compare parameters between in the upstream and downstream study sites.

A Bivariate Spearman correlation statistics were used to evaluate interrelationship between physicochemical and biological parameters among the references and impacted sites at the level of significance p= 0.05.

CHAPTER FIVE

RESULTS

5.1. Physicochemical Parameters

5.1. 1. Physicochemical Parameters of Hawassa textile factory wastewater

Characterization of physicochemical parameters of wastewater generated from the Hawassa textile factory was carried out to determine its pollution effect on the Tikur Wuha River water quality and Macroinvertebrate assemblage. The concentrations of raw wastewaters from textile factory outlet (TFO) and wastewater effluent from lagoon (BLO) are depicted in table 5.

Table 5. Mean values (n=2) of physicochemical characteristics of Hawassa textile factory wastewater in comparison with EPA MPL, Hawassa, April to May 2011.

Parameters	TFO	BLO	%Reduction	EPA standard (MPL; EPA, 2003)
p^H	11.75(0.25)	10.13±0.24*	13.79	6-9
Temp.($^o{}_{C)}$	38.559± 0.895	31.92±0.44	17.19	40
EC (µS/cm)	5509.5±44.50	4125±25.00*	25.13	1000 (at 20 ^{0}C)
TDS(mg/L)	3553.4±75.10	2115±35.00*	40.48	80
TSS(mg/L)	1310.85±17.6	1202.91±4.40*	8.24	30
NO_3-N(mg/L)	17.655±1.205	15.2±3.90	3.68	50
NH_3-N(mg/L)	5.915±0.065	5.51±0.19	6.78	30
TN(mg/L)	354.9±8.900	255.615±17.38*	27.97	40
OP(mg/L)	17.72±0.32	10.32±1.02	41.76	10
SO_4^{2-} (mg/L)	142.315±3.98	51.69±1.68	63.68	200
COD(mg/L)	5034.7±54.70	1008.1±15.10*	79.97	150 >80% removal
BOD_5(mg/L)	1723.6±43.82	142.175±4.175*	91.75	50 >90% removal

* Values above MPL TFO – Textile factory outlet BLO—Biological lagoon outlet

From table 5 Variable such as COD, BOD, TDS, TSS, and SO_4^{2-} were strongly decreased when pass from point TFO to BLO. The parameters such as pH, Electric Conductivity (EC), Total dissolved solids (TDS), Total suspended solid (TSS), NO_3N (Nitrate nitrogen), orthophosphorus (PO_4^{3-}), chemical oxygen demand (COD) and biological oxygen demand (BOD_5) their value are above the maximum permitted discharge limits set by (Ethiopian EPA, 2003). Parameters such as temperature, sulfate and NH_3-N their concentration are within & below the permissible limit values.

5.1.2. Physicochemical Parameters of Tikur Wuha River

Physicochemical parameters measured for the assessment of Tikur Wuha River include; pH, temperature (^{0}C), electrical conductivity (EC) (μs/cm), nitrate-nitrogen (NO_3 -N) (mg/L) and orthophosphate ($PO4^{3-}$) (mg/L), Total nitrogen, BOD_5, COD, TSS & Turbidity. The mean results of each parameter with the standard deviation are given in table 6.

Table 6. Mean of physicochemical Parameters of Tikur Wuha River up and downstream sites, Hawassa, April to May 2011.

	Site codes									
Parameters	**U1**	**U2**	**U3**	**U4**	**U5**	**D1**	**D2**	**D3**	**D4**	**D5**
pH	**7.41±.090**	**7.525±.27**	**7.43±.17**	**7.96±0.24**	**7.335±.035**	**9.9±.40**	**9.35±0.45**	**9±.50**	**9.105±.35**	**8.045±0.93**
Temperature	**24.35±0.95**	**26.25±1.05**	**23±0.20**	**23.5±1.00**	**26.9±.900**	**27.325±0.13**	**25.43±0.13**	**23.88±0.08**	**23.335±1.45**	**23.045±1.16**
COD	**77±12.50**	**79.5±3.80**	**78.925±8.57**	**133.25±9.7**	**210.6±48.60**	**944.35±1.19**	**605.25±6.9**	**544.25±5.5**	**417.5±3.5**	**340.45±2.4**
BOD_5	**16±6.00**	**39.5±5.50**	**31.15±1.15**	**12.5±2.50**	**57.85±9.85**	**91.3±7.5**	**76±3.54**	**59±3.00**	**48.8±5.23**	**36.45±2.34**
NH_3-N	**0.7±.10**	**0.45±.15**	**1.8±.30**	**0.75±.15**	**0.9±.30**	**4.085±0.13**	**3.765±.18**	**5.05±0.20**	**3.54±0.29**	**2.97±0.14**
NO_3-N	**3.58±.120**	**4.01±.11**	**5.05±.145**	**3.12±.21**	**4.33±.23**	**6.655±0.19**	**5.33±0.23**	**5.57±0.39**	**4.8±0.39**	**4.65±0.18**
TN	**26.75±1.75**	**33.75±.75**	**15.25±1.25**	**30±1.00**	**29.5±1.50**	**40.9±1.60**	**30.45±4.55**	**49.55±1.75**	**26.55±1.25**	**25.05±1.15**
OP	**7.765±2.46**	**8.93±1.37**	**5.875±3.57**	**6.58±.98**	**7.35±2.86**	**9.89±3.44**	**8.75±2.22**	**7.505±2.26**	**7.385±.93**	**7.425±1.105**
SO4	**31±6.00**	**43±0.00**	**47.5±2.50**	**44±6.00**	**40.25±.75**	**42.84±21.72**	**40.575±23.95**	**36.245±21.48**	**30.88±18.77**	**27.44±19.54**
TDS	**464±12.00**	**554±35.00**	**486.5±6.50**	**486.5±36.5**	**493.5±17.50**	**1457.35±1.19**	**1189.75±27.45**	**1011.6±32.90**	**665.45±47.15**	**506.25±24.85**
EC	**893.5±55.50**	**1043±0.00**	**962±00**	**836±64.00**	**892±44.00**	**2211.15±3.4**	**2109.1±1.69**	**2164.5±25.00**	**1021.5±65.50**	**867.03±30.00**
TSS	**1085±70.00**	**944.8±32.0**	**771.63±40.0**	**380.35±2.2**	**269.2±25.00**	**1130±25.00**	**958.3±40.00**	**906.63±5.00**	**440.615±99.96**	**234.8±29.90**
Turbidity	**45.7±6.00**	**47.9±0.00**	**37±0.00**	**40.2±14.70**	**81.85±44.15**	**135±40.00**	**144.55±13.45**	**128±15.00**	**121±15.00**	**113.25±14.75**

The highest p^H concentration was recorded at D1 (9.9±0.40) which is downstream immediately below the discharge point where as the lowest measurement was recorded U5 (7.335±.035). There was significantly higher pH in downstream than the rest of all the upstream sites (Chi-Square = 6.818, df = 1, P =0.009 at given on the appendix-1).

The highest temperature measures was recorded at D1 (27.325±0.13^{0}c) which is (immediately downstream from the discharge point of waste from the textile factory biological lagoon) and the lowest temperature was at U3 (23±0.20^{0}c) from table 6. There was no significantly difference between the temperature values both in downstream and the rest upstream study sites (Chi-Square = 0.011, df = 1, P > 0.05).

The maximum concentration of TDS was recorded at D1 (1457.35±1.19850E2) which is immediately downstream from the point of discharge. The minimum concentration of TDS was recorded at the upstream site U1 (464±12.00mg/L). Concentration of TDS in all the downstream sites were significantly higher than the upstream sites (Chi-Square =5.806, df =9, p< 0.05).

The highest concentration of TSS was recorded at D1 (1230±25.00mg/L) which is immediately downstream from the discharge point of wastewater. The lowest mean concentration of TSS was recorded at the site U5 (269.2±25.00mg/L) from table 6. The concentration of TSS in all downstream study site is significantly higher than that of in upstream sites at (Chi-Square=0.098, df =1, p< 0.05).

The highest concentration of COD was recorded at D1 (944.35±1.19mg/L), which is downstream immediately from the discharge point of wastewater from the lagoon and the lowest concentration of COD was recorded at site U1 (77±12.50mg/L) from table 6. The concentrations of COD in all the downstream study sites were significantly higher than in all the upstream sites (Chi-Square = 6.818, df= 1, p<0.05).

The highest concentration of BOD_5 was recorded at D1 (91.3±7.5mg/L) which is in the downstream immediately from the discharge point and the minimum BOD_5 concentration was recorded at U4 (12.5±2.50mg/L). The concentration of BOD_5 in all downstream sites were significantly higher than that of all the upstream sites (Chi-Square = 6.818, df= 1, p< 0.05).

The maximum concentration of EC was recorded at D1 (2211.15±3.47µS/cm) (immediately downstream from the discharge point of wastewater from the lagoon). The lowest Electrical Conductivity was recorded at U4 (836±64.00µs/cm). The concentration of EC in all downstream study sites were significantly higher than the upstream sites at (Chi-Square = 2.455, df = 1, $P< 0.05$).

The maximum concentration of NH_3-N was recorded at D3 (5.05±0.20mg/L) and the minimum concentration of ammonia nitrogen was recorded at site U2 (0.45±.15mg/L) from. The mean concentration of ammonia nitrogen in all downstream study sites were significantly higher than that of the upstream sites (Chi-Square = 6.818, df= 1, $p< 0.05$).

The highest concentration of total nitrogen (TN) was recorded at site D3 (49.55±1.75mg/L) the lowest total nitrogen concentration was recorded at the site in the upstream U3 (15.25±1.25mg/L). The mean concentration of total nitrogen in all the downstream study sites were not significantly vary than the upstream sites (Chi-Square = .535, df= 1, $p> 0.05$).

The maximum concentration of orthophosphorus was recorded at D1 (35.89±3.44 mg/L) downstream from the discharge point of wastewater from lagoon and the lowest was recorded at U3 (15.875±3.57 mg/L). There was significant difference between the mean total orthophosphorus concentration in both upstream downstream study sites at (Chi-Square = 3.153, df = 1, $P < 0.05$).

5.2. Habitat

The values obtained for the 11 parameters on 20 point-scale were summed up according to the USEPA rapid bioassessment protocols and depicted in appendix 6. The result was expressed in error bar plot of mean with 95% confidence interval to show the difference of habitat score in downstream and upstream study sites. The result in the figure 3 shows that the mean of each parameter was overlap to one another in reference and impacted sites.

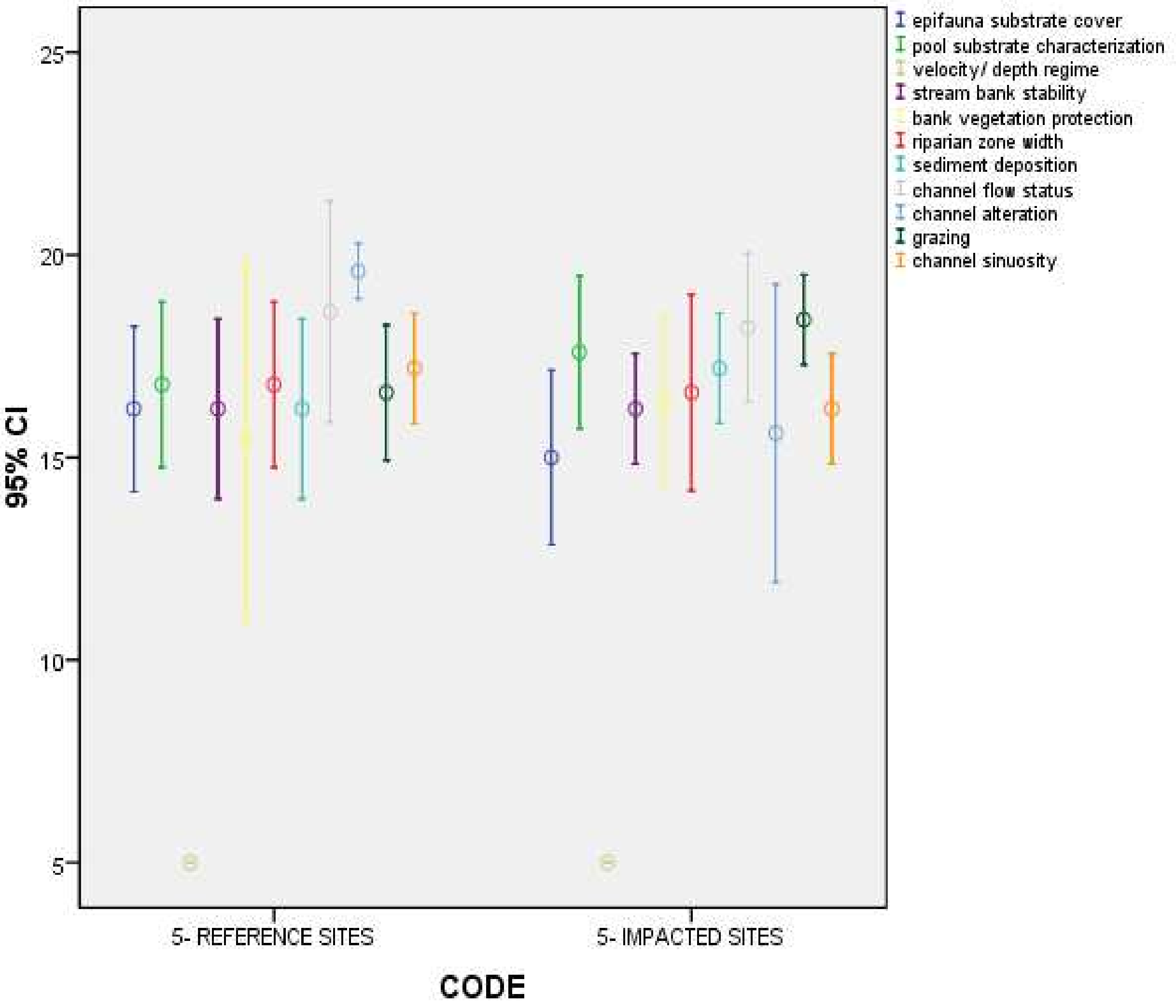


Figure 3. Error bar plot with confidence interval of habitat result, Tikur Wuha River, Hawassa, 2011.

5.3. Macroinvertebrate Structures on Tikur Wuha River

During the study 2,698 Macroinvertebrate individuals belonging to 37 families were collected from 10 sites on Tikur Wuha River and taxonomic groups and their abundance at each site are given at appendix-3. All were identified to family level with exception of class Hirudinae (leech). Three taxa (2 gastropod families and Hirudinae) comprised the non-insect group. Taxa richness at the sites ranged from 13 at (D1) to 27 families at U2.

5.3.1. Macroinvertebrate metrics of Tikur Wuha River

Sixteen candidate metrics including the Shannon, Hilsenhoff family level biotic indices initially selected to develop the Macroinvertebrate community index of Tikur Wuha River are given in table 7.

Table 7. The candidate metrics with their respective values for each site

	Site Code									
Metrics	U1	U2	U3	U4	U5	D1	D2	D3	D4	D5
Simpson's Index	3.828	3.822	3.69	3.602	3.674	3.494	3.62	3.684	3.636	3.725
Shannon-Index (H)	1.39	1.43	1.39	1.34	1.36	1.11	1.28	1.3	1.34	1.32
Family Biotic Index	5.27	6.69	6.75	6.01	5.68	7.47	6.59	6.60	6.69	7.05
%Taxa Richness	70.58	72.97	67.56	62.16	62.16	35.14	48.69	48.69	56.76	45.95
% EPT	19.78	13.84	10.91	19.56	17.64	0	7.72	11.18	6.57	9.77
%Ephemerophtera	41.67	7.69	8.18	14.13	5.15	0	0	8.37	5.37	8.02
%Coleopteran	25.27	19.77	23.64	21.74	37.5	10.80	17.95	17.69	7.17	14.29
%Trichoptera	5.49	1.5	0	0	4.41	0	1.04	1.30	0.59	1.50
%Plecoptera	3.29	6.15	2.72	5.43	8.09	0	6.68	2.23	0.39	0.25
%Dipterans	5.49	18.46	4.54	5.43	5.15	0	0.208	2.23	11.35	5.76
%ETO Index	40.66	23.07	32.72	46.74	19.85	6.27	3.54	16.57	9.76	15.54

Ratio of EPT and Chironomidae	2.17	1.25	2.4	6	3.43	0	0.45	0.57	0.196	0.63
%Chironomidae	1.09	1.5	0	1.08	0	8.01	5.63	0	6.57	3.00
%Oligochaetae	0	0	0	3.26	1.47	7.31	11.06	0	0	0
%Non-Insect Taxa	2.19	10.79	3.64	0	0	12.19	5.21	8.75	4.98	9.52
%Dominant taxa	10.98	15.38	18.18	28.26	22.79	27.52	18.16	13.97	17.33	14.54

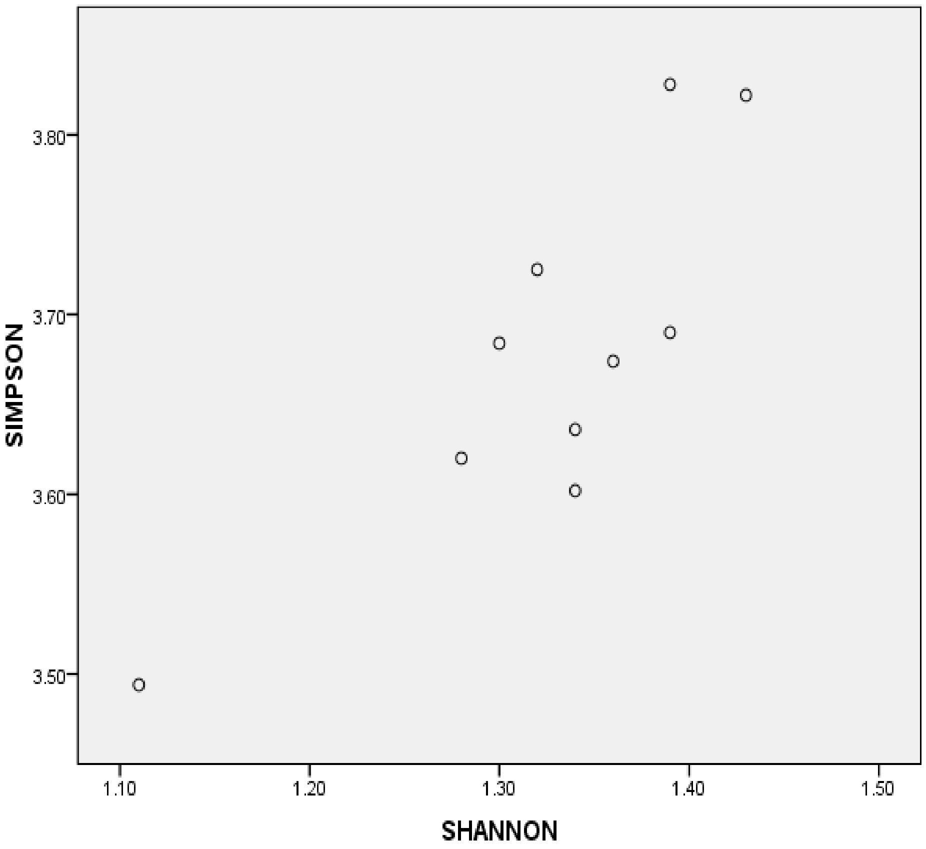
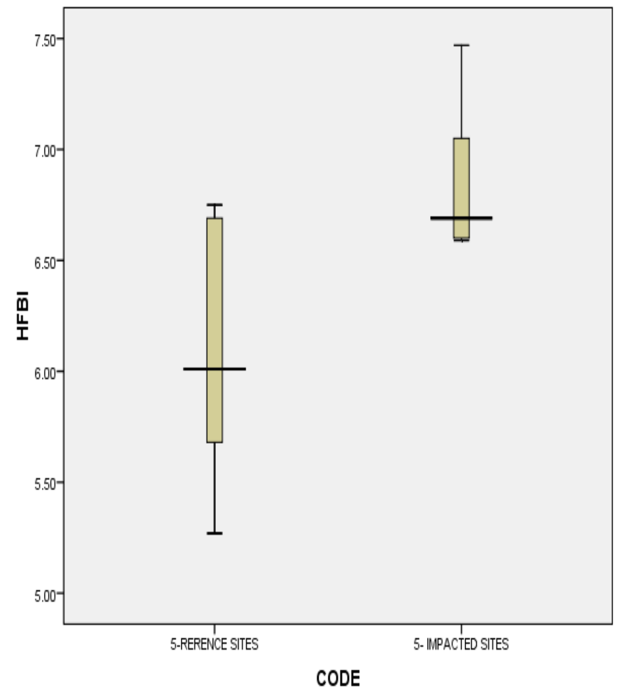
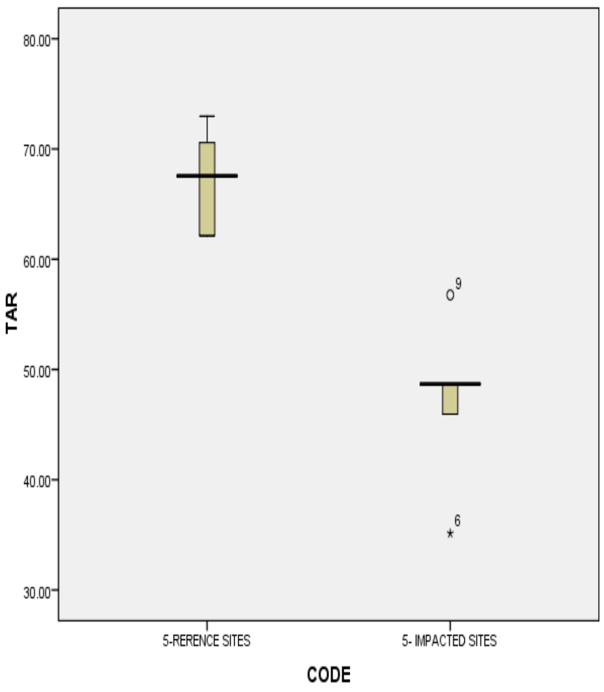
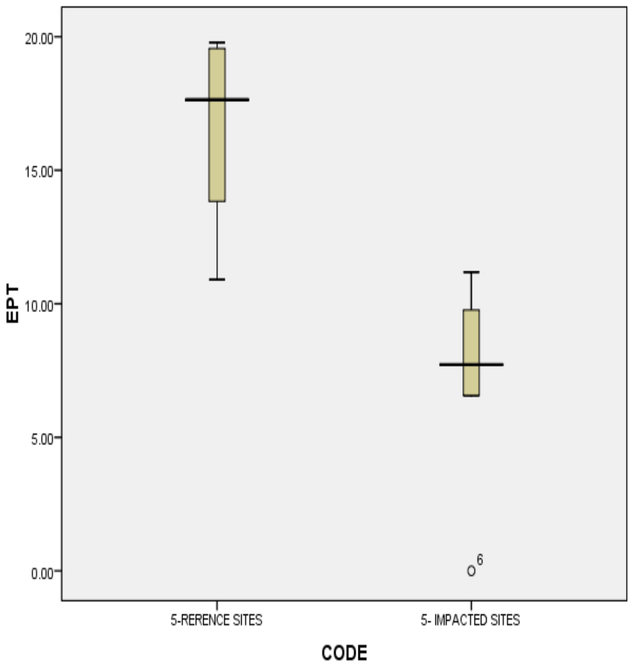


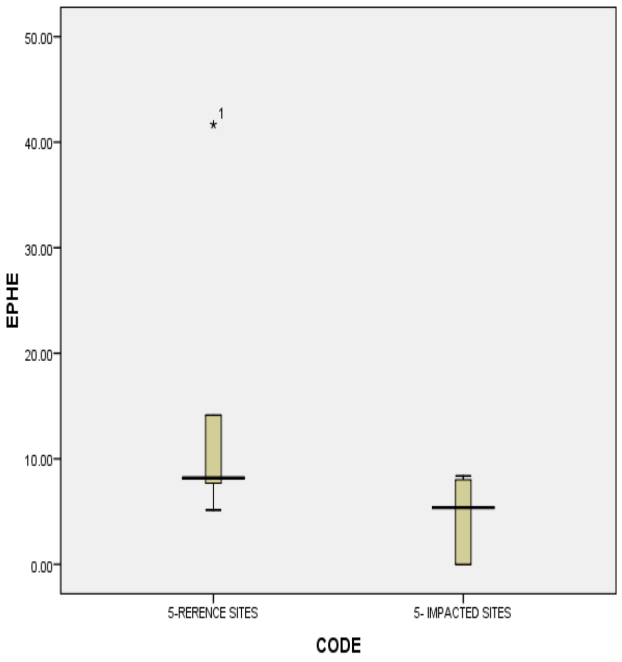
Figure 4 Bivariate scatter plots for metrics that show linearity

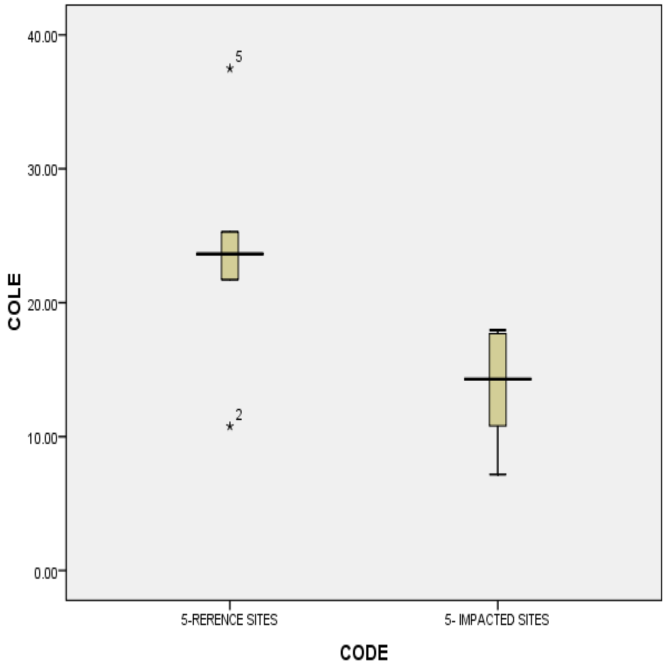
From figure 4 Metrics such as Simpson & Shannon diversity index shows strong linearity between them in both upstream & downstream sites and they did not showed difference in both sites. This means that their metrics values assumed to be zero.

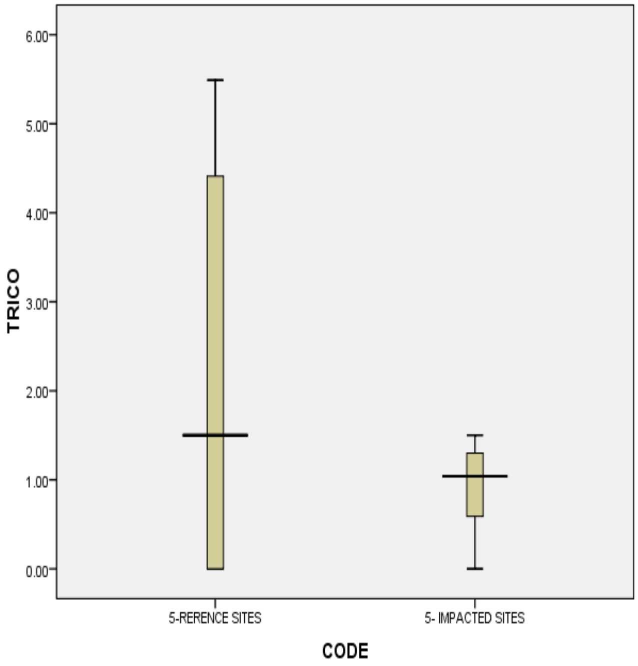

7.50
7.00
6.50
6.00
5.50
5.00
HFBI
5-RERENCE SITES
5- IMPACTED SITES
CODE

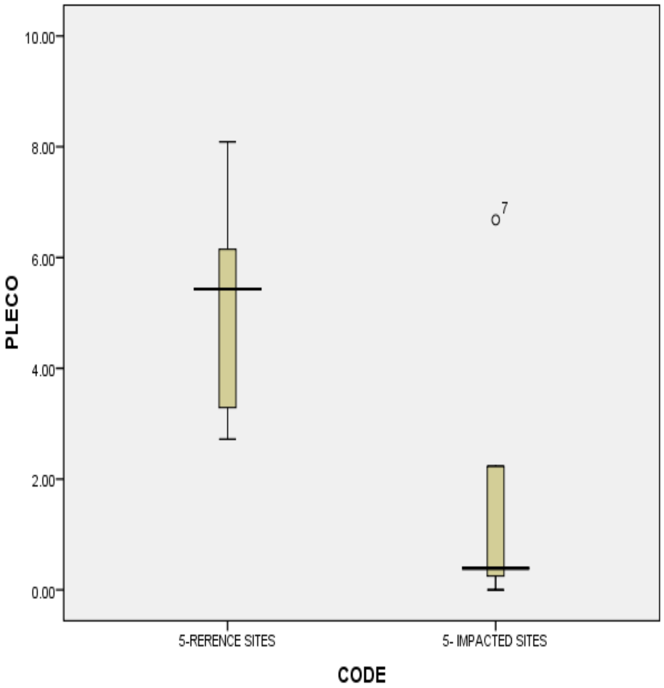

80.00
70.00
60.00
50.00
40.00
30.00
TAR
9
6
5-RERENCE SITES
5- IMPACTED SITES
CODE

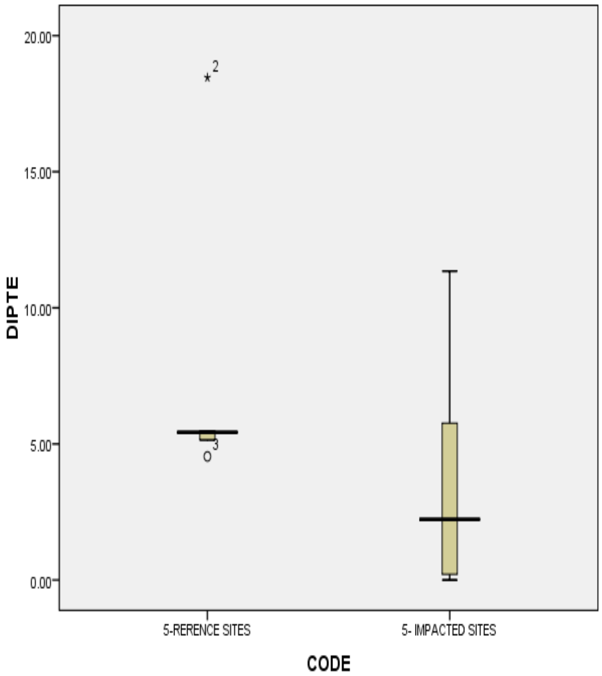

20.00
15.00
10.00
5.00
0.00
EPT
6
5-RERENCE SITES
5- IMPACTED SITES
CODE

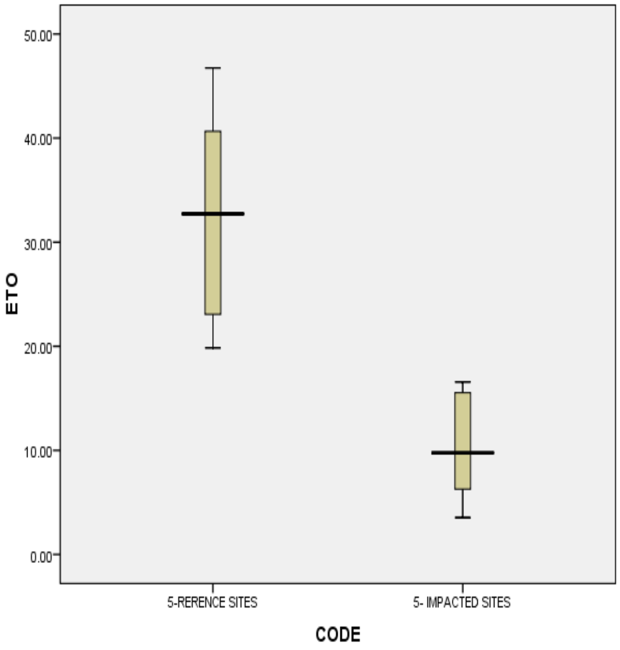

50.00
40.00
30.00
20.00
10.00
0.00
EPHE
1
5-RERENCE SITES
5- IMPACTED SITES
CODE

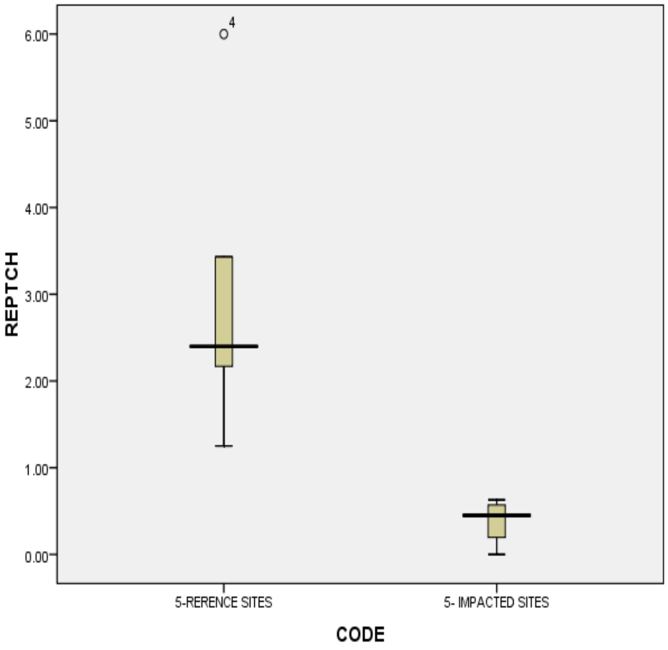

COLE
40.00
30.00
20.00
10.00
0.00
5
2
5-RERENCE SITES
5- IMPACTED SITES
CODE

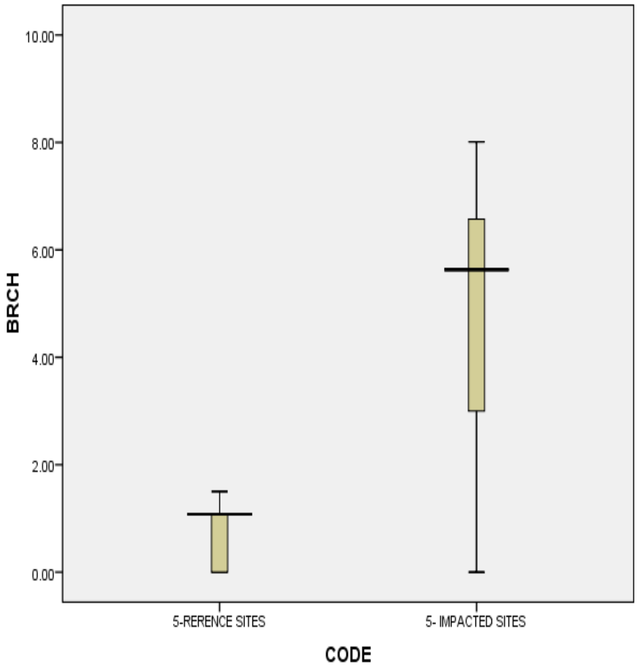

TRICO
6.00
5.00
4.00
3.00
2.00
1.00
0.00
5-RERENCE SITES
5- IMPACTED SITES
CODE

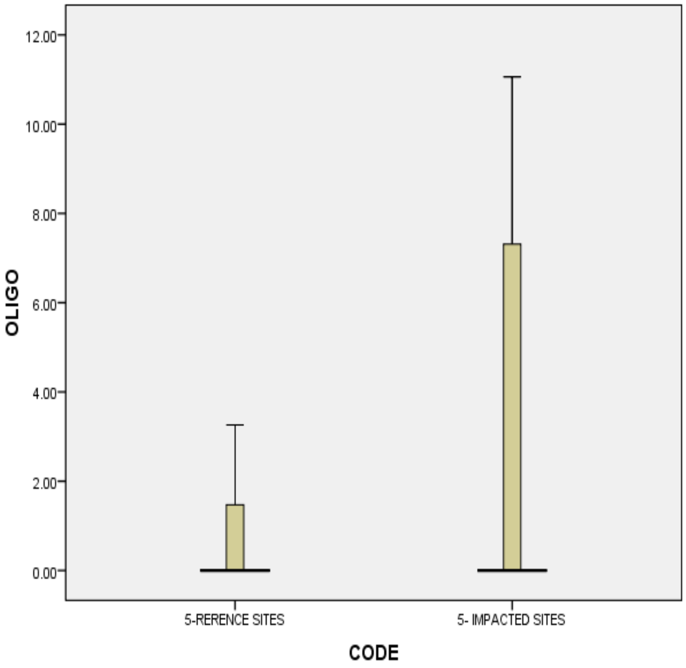

PLECO
10.00
8.00
6.00
4.00
2.00
0.00
7
5-RERENCE SITES
5- IMPACTED SITES
CODE


DIPTE
20.00
15.00
10.00
5.00
0.00
2
3
5-RERENCE SITES
5- IMPACTED SITES
CODE


ETO
50.00
40.00
30.00
20.00
10.00
0.00
5-RERENCE SITES
5- IMPACTED SITES
CODE


REPTCH
6.00
5.00
4.00
3.00
2.00
1.00
0.00
4
5-RERENCE SITES
5- IMPACTED SITES
CODE


BRCH
10.00
8.00
6.00
4.00
2.00
0.00
5-RERENCE SITES
5- IMPACTED SITES
CODE


OLIGO
12.00
10.00
8.00
6.00
4.00
2.00
0.00
5-RERENCE SITES
5- IMPACTED SITES
CODE

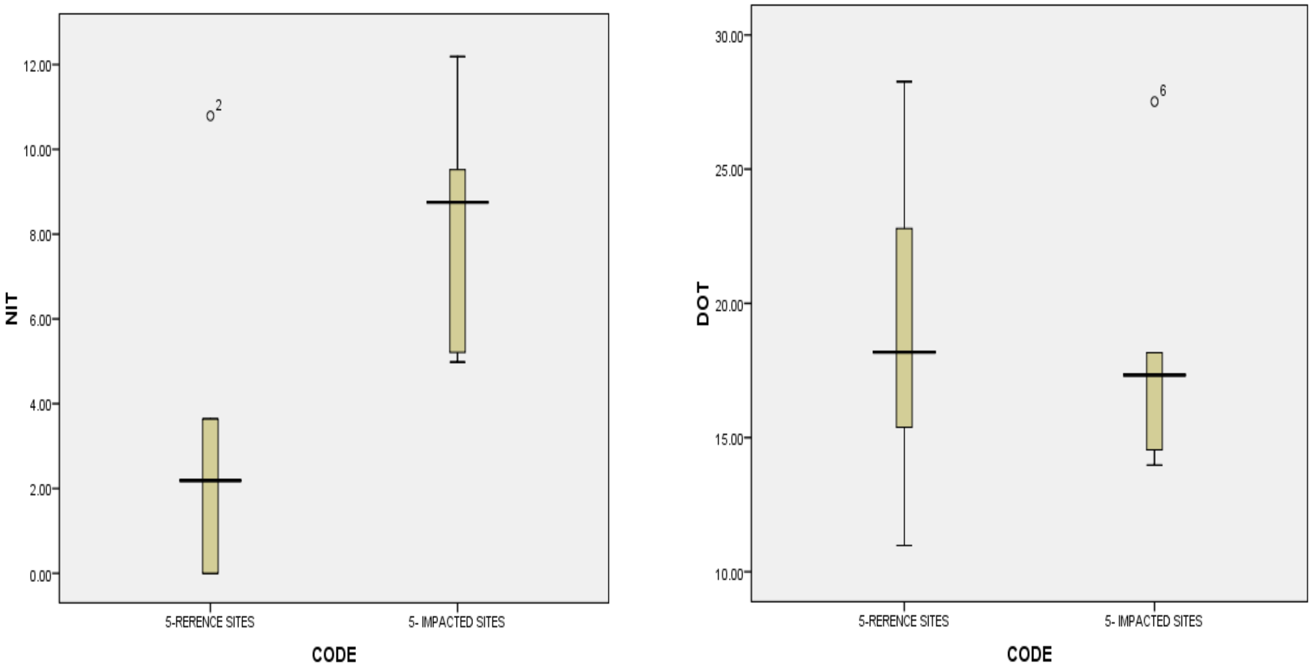


Figure 5 Discriminatory box plots of the candidate metrics considered for the MCTWR

Asterisks show =values outside the minimum and maximum, Open circles show =extreme values, HFBI= Hilsenhoff family level biotic index, T.R= Taxa richness, EPT= Ephemerophtera, Plecoptera, Tricoptera family, EPHE= % Ephemerophtera, Cole=%Coleoptera, Tricop =%Tricoptera, Pleco=% Plecoptera, Diptera = %Diptera, ETO=%ETO,REPTCH= Ratio of EPT to Chironomidae, BRCH= Chironomidae, OLIGO=% Oligochaetae, NIT=% non- insect taxa, DOT= % Dominant taxa & Sample sizes are= 5 for the reference and 5 impacted, respectively.

From figure 5 metrics such as %Ephemerophtera, %Diptera, %Tricoptera and %Dominant taxa are not show the difference in reference and the impacted sites. Their median values are existed in interquartile overlap and their sensitivity values assumed to be zero. So that metrics such as Shannon, Simpson, %Ephemerophtera, %Diptera, %Tricoptera and %Dominant were rejected from the core metrics that selected for final index development.

5.3. 2. Macroinvertebrate core metrics

Core metrics were normalized into unit less scores that potentially discriminate both the reference and impaired sites was given in the table 8.

Table 8 . Normalized score for core metrics in each study sites

Parameters	Sites									
	U1	U2	U3	U4	U5	D1	D2	D3	D4	D5
Family Biotic Index	3	3	5	5	5	1	1	3	3	3
%Taxa Richness	5	5	3	3	3	1	3	3	3	3
% EPT	3	3	5	5	5	3	3	3	3	3
%Ephemerophtera	3	5	3	5	3	1	1	3	3	3
%Coleopteran	5	5	3	3	3	3	1	1	3	3
%Plecoptera	5	5	3	5	3	1	1	1	3	3
Ratio of EPT and Chironomidae	1	3	3	1	3	1	1	1	3	3
%blood red Chironomidae	1	5	3	5	5	3	3	3	3	5
%Oligochaetae	5	5	5	5	5	3	3	5	5	5
%Non-Insect Taxa	5	5	5	5	5	1	3	1	3	3
Total out of 50%	36	44	38	42	40	18	20	24	32	34
Total out of 100%	72	88	76	84	80	36	40	48	64	68

The metrics values in each site was summed up and taken from hundred. The total values that taken from hundred was considered as the BMI (biotic multimetric index) value for each sites were compared with the standard values to show the site impairment levels. Sites D1 & D2 were categorized under sever to slight impairment levels, D3—D5 were categorized under moderate to less impairment levels and all the upstream study sites were categorized under very little to no impairment level based on the standard values from table 9.

Table 9. Categorization of sites into different impairment levels based on BMI

BMI Value (Source: Barbour et al., 1996)	Water Quality Characterization	Impairment	Sites at each impairment level
20-46	Very poor to Poor	Sever to Slight	D1 & D2
46-72	Fair to Good	Moderate to Less Impairment	D3, D4 & D5
72-100	Very good to Excellent	Very little to No impact	All upstream sites

CHAPTER SIX

DISCUSSION

The concentration of COD, BOD_5, TDS & TSS were higher at TFO. This is due to the nature of waste strength from the textile factory. According to Ahn et al., 1999 textile wastewater contributes to high suspended solids (SS), chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), acidity, basicity and other soluble substances.

Concentrations of the parameters at the point outlet from the lagoon such as COD (1008.1±15.10mg/l), BOD_5 (142.175±4.175mg/l) and TSS (1202.91±4.40Omg/l) & TDS (2115±35.00) were 7, 3, 26 & 40 times respectively higher than the acceptable ranges of the maximum discharge limits set by Ethiopian EPA, 2003. This indicates that the lagoon is not effectively treating the wastewater from textile factory. Similar studies in characterization of textile effluents, showed that both measured BOD_5, COD and TSS levels were in the range of (163-645mg/l), (1067-2430 mg/l) and (35-1200) varying from textile to textile respectively (Yusuff and Sonibare, 2004) when comparing the result of BOD_5 & COD found under the range. Similarly Sapci et al., 2003 reported COD value (3218mg/l) and TSS (250mg/l) in this finding COD concentration is 3 fold of the present study this is due to in textile manufacturing factory waste concentration different from factory to factory.

High COD levels imply toxic condition and the presence of biologically resistant organic substances (Sawyer and McCarty, 1978). The high levels of BOD_5 are indications of the pollution strength of the wastewaters and also indicate that there could be low oxygen available for living organisms in the wastewater when utilizing the organic matter present. According to Wynne et al., (2001) noted that textile effluents are highly colored and saline, contain non-biodegradable compounds, and are high in Biological and Chemical Oxygen Demand.

The result in this finding shows that the concentration of TSS (1202.91±4.40 mg/L) and TDS (2115±35.00 mg/L) were 40 & 26 times higher than the maximum discharge limit set by Ethiopian EPA, 2003. This is due to the application of heavy metals in textile factory finally being able to attribute to colored wastewater.

The concentration of Ammonia N (5.51±0.195mg/l) and Nitrate N (15.2±3.905mg/l) respectively at the lagoon effluent found to be lower than the standard discharge limit of orthophosphorus, ammonia nitrogen & nitrate nitrogen respectively as (30, 50) mg/L by EPA (2003). Their concentration is within the discharge limit so may cause less effect on aquatic life forms. Similar study by (Yusuff & Sonibare, 2004) from textile wastewater reported mean concentration of Ortho-phosphorus, Ammonia-N and Nitrate -N value which ranged (0.09 -3.42), (0.05- 2.72), (0.8-7.97 mg/l) the maximum values are less than the results in present findings. This is may be chemical application different from factory to factory. When compared with this result the concentration is much higher so it can cause eutrophication in the river water.

In downstream study sites the mean pH value ranged from (8.05—9.9) which did not meet the EPA (2003) standards for surface water (6.0—9.0). This indicates that the higher pH was the result of wastewater discharged from the lagoon was with higher pH. Similar studies on Lake Hawassa and its feeders (Desta**,** 1997) and (Seyoum *et al*., 2003) reported that high pH value could alter the toxicity of other pollutants in the river. This results in an unhealthy biological community dominated by a few tolerant taxa. pH can have a direct effect on the physiology of organisms (Kimmel, 1983).

The maximum value of TSS (1130±25.00 mg/L), TDS (1457.35±1.19 mg/L) and EC (2211.15±3.4 mg/L) in the downstream study sites which is higher than values in upstream sites. This could be wastewater from the lagoon was higher in both TSS & TDS from the lagoon and may adversely affect water quality and macroinvertebrates abundance in the river. Based on the standard permitted limit value, the suspended solids in the river may adversely affect the use of water for various purposes (Desta, 1997). Suspended solids create the dissolved oxygen problem by sedimentation and forming oxygen demanding sludge deposit, which cause turbidity in the receiving water and may alter the habitat of aquatic microorganisms (Gebre-Mariam and Desta*,* 2002; Shu *et al.,* 2003).

Concentrations of COD & BOD_5 in downstream were significantly higher than the upstream study sites. This is due to the discharge of untreated wastewater from the textile factory with higher BOD_5 & COD concentration. According to (Mammo, 2004) reported mean concentration of COD (38100± 6647 mg/l) and BOD (11064 ± 1080 mg/l) in Sebeta River when compared with this result the COD & BOD_5 (944.35±1.19 & 91.3±7.5) mg/L the result indicates there is great difference between the two results this due to in Tikur Wuha River waste only from the textile factory but in Sebeta river waste from alcohol and liquor factory so the waste composition concentration also different. The COD & BOD_5 concentration in downstream study sites decreased by 36.1% & 35.95% in a uniform manner and this due to the self dilution of river water.

The total nitrogen concentration was ranged (15.25±1.25- 49.55±1.75mg/l) which was lower than the EPA (2003) standard limit value 40 mg/l. Similar studies on Modjo and Sebeta Rivers, reported that the values of total nitrogen ranged from 8.7±1.97- 42.0±30 mg/l, (Seyoum *et al*., 2003) and 0.35±0.33-615±281mg/l, Mammo, (2004). High concentration of total nitrogen could indicate pollution of a water body that is rapidly converted to ammonia and become toxic to aquatic life. The concentration of NH_3-N and TN was higher at Site D3 than the other sites. Animal and human waste, decaying organic matter, can contribute to total nitrogen and ammonia enrichment of water and the downstream Sites (D3) is highly exposed to animal and human feces.

The levels of ammonia N in Tikur Wuha River was in the range of (1.8±.30–5.05±0.20mg/l) was below the standard discharge limit (EPA, 2003), 30 mg/l. Due to its toxicity to aquatic biota including fisheries, the European Union has set a safe limit of 0.005–0.025 mg NH3-N mg/L (Chapman, 1996). The study relies on ammonia, formed only at high pH values (pH>8.5), is extremely toxic to fish and other aquatic life at high concentration (>2mg/l) (Berenzen *et al*., 2001). Higher concentrations of NO_3-N at D1 (6.655±0.19 mg/L) might be due to discharge of nitrogen containing wastes from the textile industry in the river. Further downstream decline in nitrate-nitrogen could be attributed to denitrification process of the microbial communities.

Orthophosphate concentration was high in downstream sites could be to the point of source pollution from the factory. Mean values of $P\text{-}PO_4^{3-}$ at all upstream & downstream sites, exceeded the UK criterion (0.1 mg/L) for running freshwaters subject to eutrophication (Young *et al*., 1999). Too much phosphorus in surface waters, however, can contribute to nutrient enrichment, increasing aquatic plant growth, and changing the types of plants and animals that live in a stream. Sources of phosphorus include certain soils and bedrocks, wastewater and domestic phosphate based detergents, human and animal wastes, decomposing plants, and runoff from fertilized lawns and cropland (Morrison *et al*., 2001).

Habitat qualities such as bank stability, sediment deposition, pool substrate characterization, riparian vegetative zone protection, grazing and all human impacts were not significantly different in both upstream and downstream study sites. In habitat assessment the result was compared with percent comparability ≥ 95 % as excellent, ≥ 85% as very good, ≥ 75 % as good, ≥ 60 % as fair, ≥ 50 % as poor, and ≤ 49 as very poor (Barbour et al. (1999). Based on percent comparability level the result showed that sites such as U1, U3, U4, & U5 categorized under ≥ 75% as good habitat condition while U2 was categorized ≥ 60% as fair habitat condition in upstream and those D1, D3, D4, & D5 categorized under ≥ 75% as good habitat condition while D2 was categorized≥ 60% as fair habitat condition in downstream sites. This is due to there was no compounding factors such as floriculture and other mechanized agriculture activities are not present in the area. Human activities in both the upstream and the downstream sites are most similar.

Concentration physicochemical parameters were significantly varied in both upstream and downstream study sites. This is due to the strong wastewater discharge from the textile factory lagoon.

The result in this study showed that taxonomic richness is a metrics that reflects the diversity of aquatic organisms and is higher in upstream than the downstream study sites. Maximum taxa richness at D1 (13) while at U2 (27) from appendix 3. This is mainly could be due to the wastewater discharge from the lagoon was not effectively treated. Taxonomic richness is a metrics that reflects the diversity of aquatic organisms that indicate the health of the aquatic ecosystems (Baptisita et al., 2007). Ecosystems with elevated taxonomic richness contain diversified physical habitats, physicochemical conditions of water quality, and available food resources for the maintenance of many species (Barbour et al., 1996).

The sites in both upstream and downstream were characterized by taking the sum of each normalized core metric values and compared with the reference value (BMI= 20-46, 46-72 & 72-100) sever to slight, moderate to less and very little to no impairment level respectively(Barbour et al., 1996) .

Percent (%EPT) was showed strongly negative correlation with the TDS, Electrical conductivity, COD, BOD & pH, this showed that the increased concentration of these parameters especially COD, BOD & TSS in water may causes lower DO concentration in the river, that decrease directly the water quality and the abundance & distribution of macroinvertebrates community. The decreased count of most sensitive Ephemerophtera taxa and other EPT taxa (Plecoptera, Tricoptera), at the impacted sites indicates that excessive pollutant loading, increased concentration of chemicals from industrial wastes are harmful to these organisms. According to Berhe (1988), Legesse *et al.,* (2000) and Sitotaw (2006) the %EPT taxa was highly reduced at the perturbed sites in different rivers and streams in Ethiopia.

The metrics, %EPT was lower in downstream sites. This is due to its pollution sensitive nature and the downstream sites were impacted since untreated waste discharge from the factory. Ephemerophtera, Plecoptera, Tricoptera, which has sensitive to the anthropogenic impacts such as the discharge of raw sewage (Baptisita et al., 2007).

The metrics %Chironomidae, %Oligochaetae & %non-insect taxa were higher in the downstream sites than upstream sites due to their higher pollution tolerant nature. The importance of the presence of %Chironomidae & %Oligochaetae group of organisms used to characterize the impacted sites (Callisto and Mereno, 2005).

The percent coleopteran taxa was showed a strong negative correlation with pH (at $p<0.05$), moderately negative correlation with COD & BOD & low negatively correlated with ortho phosphorous, TDS & Electrical conductivity. For example %Chironomidae showed positive correlation with orthophosphate ($r=0.659$). Miltner and Rankin (1998) noted that, rivers and stream the number of EPT taxa (belonging to Ephemerophtera, Plecoptera and Trichoptera) and the relative abundance of Tanytarsini midges decreased relative to increasing nutrient concentration while other dipterans and non-insects were positively associated with increasing nutrient concentration.

CHAPTER SEVEN

CONCLUSION AND RECOMMENDATIONS

7.1. CONCLUSIONS

From the multi metric scores downstream sites such as (D1 & D2) categorized under sever to slight impairment level, sites (D3—D5) categorized under moderate to less impairment level and all the reference sites (U1—U5) categorized under very little to no impairment level. The two downstream sites D1 & D2 categorized under sever impairment level this indicates that these sites are highly impacted by poorly treated wastewater from the textile factory lagoon.

From Bivariate spearman correlation analysis at $p < 0.05$, metrics expected to decrease with perturbation had a strong negative relationship with pH, orthophosphate, COD, BOD_5, TDS & Electrical Conductivity. The metrics include: Percent taxa Richness, %Ephemerophtera, % Trichoptera, % Plecoptera, % EPT, %ETO. On the other hand the metrics that expected to increase with perturbation are % Chironomidae, % Oligochaetae, % Non insect taxa; Ratio of EPT to Chironomidae has strong positive relationship with pH, COD, and BOD_5, orthophosphorus and Electrical conductivity.

In generally the result of this study was showed that the water qualities of Tikur Wuha River were adversely affected and its aquatic conditions were impaired due to the untreated wastewater discharged from the textile factory.

7.2. RECOMMENDATIONS

The river was impacted in the downstream sites some communities use this water directly for their domestic purpose such as bathing, washing their clothes, recreational and animal watering without prior treatment. For sustainable management of this water resource, regional environmental protection agencies in cooperation with the factory manager should take technical measures to alleviate the problem. The environmentalist in the factory should continuously monitor the textile effluents and take necessary actions to change wastewater to environmentally friendly form before discharging it. The factory manager should improve the performance of existing treatment systems through modifications and technological upgrades. The newly establishing industries near the area should also take wastewater treatment practices as the major issues.

References

Ahn, Kyu-Hong, Song, Kyung-Gen, Cha, Ho-Young, and Yeom, Ick-Tae. 1999. Removal of ions in nickel electroplating rinse water using low-pressure nanofiltration. *Desalination* 122: 77-84.

American Public Health Association (APHA). (1998), Standard methods for the examination of water and wastewater. 20th edition Washington, D.C.

Badalians Gholikandi G.et al., Int. J. Sus. Dev. *Plann. Vol. 5, No. 3 (2010) 299–312* Impact of Wastewater Discharge on Water Quality of Karoon River in Iran

Baptista and NESSIMIAN, JL., 2007. A multimetric index based on benthic macroinvertebrates for evaluation of Atlantic Forest streams at Rio de Janeiro State, Brazil. *Hydrobiologia*, vol. 575, no. 1, p. 83-94.

Barbour, M.T., Gerristen, J., Griffith, G.E., Frydenborg, R., McCarron, E., White, J.S, and Bastian, M.L. (1996). A framework for biological criteria for Florida streams using benthicmacroinvertebrates. *Journal of the North America Benthological Society. 15(2): 185-211.*

Barbour, M.T., Gerristen, J., Snyder, B. D. and Stribling, J. B. (1999). *Rapid Bioassessment Protocol for Use in Streams and Wadeable Rivers: Periphyton, BenthicMacroinvertebrates, and Fish*, 2nd ed. US Environmental Protection Agency, Washington DC.

Barbour, M.T., Gerristen, J., Snyder, B.D., and Stribling, J.B. (1999).Rapid bioassessment protoclos for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates and fish, second edition.EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water, Washington, D.C.

Barbour, M.T., J. Gerritsen, G.E. Griffith, R. Frydenborg, E. McCarron, J.S. White, and M.L. Bastian. 1996. A framework for biological criteria for Florida streams using benthic macroinvertebrates. Journal of the North American Benthological Society 15(2):185-211.

Barbour, M.T., J.B. Stribling, and J.R. Karr. 1995. The multimetric approach for establishing biocriteria and measuring biological condition. pp. 69-80 IN: W.S. Davis and T.P. Simon (eds.) Biological Assessment and Criteria: Tools for Water Resource Planning and Decision-making. Lewis Publishers, Chelsea, Michigan.

Berenzen, N., Schulz, R., and Lies, M. (2001). Effects of chronic ammonium and nitrite contamination on the macroinvertebrate community in running water microcosms.*Wat. Res*. 35(14): 3478-3482.

Berenzen, N., Schulz, R., and Lies, M. (2001). Effects of chronic ammonium and nitrite contamination on the macroinvertebrate community in running water microcosms. *at. Res*. 35(14): 3478-3482.

Berhe T. (1988). The Degradation of the Abo- Kebena River in Addis Ababa. Ethiopia. MSc thesis, School of Graduates Studies, Addis Ababa University.

Bode, R.W. and Novak, M.A. (1995). Development and application of biological Impairment criteria for rivers and streams in New York State. In Biological assessment and criteria. Tools for water resource planning and decision making, pp 97-107. (Davis, W.S. and Simon, T.P., eds.) CRC LLC Press. Boca Raton, Florida.

Bode, R.W., Novak, and M.A., and Abele, L.E. (1996) .Quality Assurance Work plan for Biological Stream Monitoring in New York State. NYS Department of Environmental Conservation, Albany, NY.

Bouchard, R. W., Jr. (2004). *Guide to Aquatic Macroinvertebrates of the Upper Midwest,* 208 pp., Water Resources Center, University of Minnesota, St. Paul.

Braccia, A. and Voshell, J. R. (2006). *Benthic Macroinvertebrate Fauna in Small Streams*

Brno, Czech *(*2003*).* Republic in *bacterial nitrification* and gentrification of trout hepatocytes to *oxidizes nitrite* to *nitrate* Mortality in seawater *occurred* at ni Jensen F.B. *Nitrite* disrupts multiple physiological book

Buchholz R. A., (1998). Principles of environmental management. The Greening of Business, 2^{nd}. Prentice- Hall, London, UK.

Callisto, m., and Mereno P., 2005. Invertebrados aquáticos Como bioindicators. In GOULART, EMA. (Ed.). *Navegando o Rio das Velhas das Minas aos Gerais*. Belo Horizonte: Rona Editora, vol. 2, p. 555-566.

Chapman, D. (Ed.) (1996). Water Quality Assessment: A guide to the Use of Biotic, Sediments and Water in Environmental Monitoring.2nd ed., Chapman and Hall, London.

Davis, W.S. (1995). Biological assessment and criteria: Building on the past. *In:* Biological assessment and criteria. Tools for water Resource planning and decision making, pp 15-29 (Davis, W.S. and Simon, T.P., eds.). CRC press LLC. Boca

Diaz F., Raimbault P., Boudjellal B., Garcia N. and Moutin T., (2001), Early spring phosphorus limitation of primary productivity in a NW Mediterranean coastal zone (Gulf of Lions), *Marine Ecology Progress Series,* 211, 51-62.

Dierig, S. (1999).Urban environmental management in Addis Ababa: problems, perspectives, and the role of NGOs. Original paper.

Environmental Protection Agency. 1996. Revision to Rapid Bioassessment Protocols For use in Streams and Rivers: Periphyton, Benthic Macroinvertebrate, and Fish. Assessment and Watershed Protection Division, *Washington, D.C. EPA/444/4-89-001*.

Environmental Protection Authority (EPA) (2003). Provisional Standards for Industrial Pollution Control in Ethiopia. Prepared under the ecologically sustainable industrial development (ESID) project – US/ETH/99/068/Ethiopia, EPA/UNIDO, Addis Ababa.

EPA (United States Environmental Protection Agency). 1978. Environmental pollution control: Textile processing industry. Washington, D.C. (EPA-625/7-78- 002).

Fore, L.S., Karr, J.R. and Wisseman, R.W. (1996). Assessing invertebrate responses to human activities: Evaluating alternative approaches. *Journal of the North American Benthological Society. 15(2): 212-231.*

Gallardo, A.C., Garrish, J.E., Hill, C.R. and Stribling, J.B. (2006). *Biological Assessment of the Cattail Creek and Brighton Dam Watershed,* 61 pp. Tetra Tech Inc., Howard County, Maryland.

Gebre-Mariam Z. and Desta Z. (2002).The chemical composition of the effluent from Hawassa Textile Factory and its effects on aquatic biota. *SINET: Ethiop.J. Sci., 25(2)*. 263-274.

Government of Ethiopia (GOE, 2002). Environmental pollution control proclamation. Nagarit Gazeta of the federal democratic republic of Ethiopia, Proclamation No. 300/2002, Addis Ababa.

Hilsenhoff, W.L. (1988). Rapid field assessment of organic pollution with a family level biotic index. *J. North Am. Benthol. Soc. 7(1): 65-68.*

Jaya Paul a/l arumai dhas, 2008.removal of cod and colour from textile wastewater using limestone and activated carbon, MSc thesis.

Karr, J. R. and Chu, E. W. (1997). Biological Monitoring: Essential Foundation for Ecological Risk Assessment. *Human and Ecological Risk Assessment* 3: 993-1004.

Karr, J.R. (1996). Aquatic invertebrates: sentinels of watershed condition. Wings 19(2): Jim Karr is a professor of fisheries, zoology, environmental health, and public affairs at the University of Washington in Seattle. His research, which includes ecology of tropical forest birds, stream ecology, and landscape management, aims to protect ecological health by guiding improvements in environmental policy. Tuesday, 16-Jul-2002 PDT.

Karr, J.R., Fausch, K.D., Angermeier, P.L., Yant, P.R. and Schlosser, I.J. (1986). Assessment of biological integrity in running water: a method and its rationale. Illinois natural history survey special publication, Number 5, Champaign, Illinois.

Kimmel, W.G., 1983. The Impact of Acid Mine Drainage on the Stream Ecosystem. In: Pennsylvania Coal: Resources, Technology and Utilization, (S.K. Majumdar and W.W. Miller, eds.), the Pennsylvania Academy of Science Publication. pp. 424-437.

Kumar V. and Kiran Karande (2000), "The Effect of Retail Environment on Retailer Performance," Journal of Business Research, Vol. 49 (2), pp. 167 – 181.

Legesse M. and Kaba T. (2004).Application of Cleaner Production Option in Hawassa Textile wet Processing. *The Ethiopian society of Chemical Engineering. 8(1):42-58.*

Mamo D., (2004). An Assessment of Downstream Pollution Profile of Sebeta River and its Surrounding. MSc. Thesis, School of Graduate Studies, Addis Ababa University.

Masud M., Baig, M., Hassan, I., Qazi, A., and Malik, M. (2001). Textile wastewater characterization and reduction of its COD& BOD by oxidation. *Electronic Journal of Environment, Agriculture and Food chemistry. Melbourne, Victoria, Australia.*

Mathur N, Bhatnagar P, Bakre P. Assessing mutagenicity of textile dyes from Palii (Rajasthan) using Ames bioassay. Applied Ecology and Environmental Research 2005; 4: 111-18.

Meybeck M and Helmer, R. (1996). An Introduction to Water Quality. In: *Water Quality Assessments. A guide to the use of biota, sediments and water in environmental monitoring*, pp. 1-22 2nd ed. (Chapman, D. ed.), Cambridge.

Miltner R. J. and Rankin E. T. 1998. Primary nutrients and the biotic integrity of rivers and streams. Freshwater Biology 40: 145-158.

Morrison, G., Fatoki, O S., Person, L. and Ekberg, A. (2001). Assessment of the Impact of Point Source Pollution from the Keiskam mahoek Sewage Treatment plant on the Keiskamma River- pH, Electrical Conductivity, Oxygen -Demanding Substance (COD) and Nutrients. *Water SA* **27(4)**: 475-480.

Plafkin J.L., Barbour M.T. and Hughes, R.M. (1989). Rapid bioassessment protocols for use in streams and rivers. Benthic macroinvertebrates and fish. EPA 440-4-89-00). U.S. Environmental Protection Agency; Office of water regulations and standards, Washington, D.C.

Pollution Research Group (PRG) (1998), Waste Minimization Guide for the Textile Industry – A Step towards Cleaner Production, University of Natal, Draft Volumes 1 and 2.

Pollution Research Group (PRG). (1998). Waste Minimization Guide for the Textile Industry – A Step towards Cleaner Production, University of Natal, Draft Volumes 1& 2.

Pond G. J., Call, S. M., Brumley, J. F. and Compton, M. C. (2003). *The Kentucky Macroinvertebrate Bioassessment Index: Derivation of Regional Narrative Ratings for*

Assessing Wadeable and Headwater Streams, 46 pp. Kentucky Department for Environmental Protection, Frankfort.

Ramesh B., Parande A.K., Raghu S., and Prem Kumar T. Cotton Textile Processing: Waste Generation and Effluent Treatment. *The Journal of Cotton Science 11:141–153 (2007)*

Rao M. Narayana, and Amal, K. Datta. (1987).Wastewater treatment-Rational methods of design and Industrial practices., Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, 2nd edition. Raton, Florida. Richard A. Smith, Richard B. Alexander, and Kenneth J. Lanfear .Stream Water Quality in the Conterminous United States -- Status and Trends of Selected Indicators During the 1980's. *National Water Summary 1990-91 -- Stream Water Quality, U.S. Geological Survey Water-Supply Paper 2400)*

Reynolds B., Hughes S., May L. and Gannon B., (2002), the phosphorus budget of the Thames catchment, Oxfordshire, UK: 2 Modelling, *Science of the Total Environment,* 282/283, 435-457.

Rosenberg, D.M. and Resh, V.H. (1993).Introduction to freshwater biomonitoring and benthic macro invertebrates. *In*: Freshwater biomonitoring and benthic macro invertebrates, pp1-9 (Rosenberg, D.M. and Resh, V.H., Eds). Chapman and Hall, Inc, New York.

Royer T.V and Minshall G.W. (2001). Development of Macroinvertebrate-based index for bioassessment of Idaho Rivers. *Environmental Management 27(4): 627-636.*

Sapci Z. Stun B. (2003).The Removal of Color and Cod from Textile Wastewater by Using Waste Pumice. *Electronic Journal of Environment, Agriculture and Food chemistr. 2(2):1579-4377.*

Shearer, J. (2006). *Macroinvertebrate Bioassessment of Black Hills Streams*, 23 pp., South Dakota Game, Fish & Parks Rapid City, South Dakota.

Sheng H. Lin and Ming L. Chen (1998). Purification of textile wastewater effluents by a combined Fenton process and ion exchange Department of Chemical Engineering, Yuan Ze Institute of Technology, Neili, Taoyuan

Shu L., Wait, T.D., Bliss, P.J., Fane, A., and Jegathessan.V. (2005) .Nanofiltration for the possible reuse of water and recovery of Sodium chloride salt from textile effluent, Desalination, 172.235 243.www.elsevier.com/locate/desal.

Sitotaw B., 2006. Assessment of Benthic-Macroinvertebrate structures in relation to environmental degradation in some Ethiopian rivers. MSc thesis, School of Graduate Studies, Addis Ababa University.

United Nations Environmental Programme (UNEP) (1991). Tanneries and the United States Environmental Protection Agency (US EPA). (1978). Environmental pollution control: Textile processing industry. Washington, D.C. (EPA-625/7-78-002).

USEPA. (2005). Use of biological Information to better define designated aquatic life uses in state and tribal water quality standards. EPA 822-R-05 001. Office of water, U.S. Environmental Protection Agency, Washington, D.C.

WHO, 2003. The World Health Report 2003: Shaping the Future, World Health Organization, 1211 Geneva 27, and Switzerland.

Wynne G., Maharaj D. and Buckley C. (2001), Cleaner Production in the Textile Industry – Lessons from the Danish Experience, School of Chemical Engineering, University of Natal, Durban, South Africa, pp3.

Young R.A., Morse G.K., Scrimshaw M.D., Kinniburgh J.H., Mac-Leod C.L. and Lester J.N., (1999), the relation between phosphorus and eutrophication in the Thames catchment, UK, *Science of the Total Environment*, 157-183.

Yusuff, R .O. and Sonibare, J.A. (2004) .Characterization of textile industries' effluents in Kaduna, Nigeria and pollution implications. *Global nest: the International Journal, 6(3). pp 212-221.*

Appendices

Appendix 1. Kruskal Wallis Test of physicochemical parameters along the sites.

Parameters	**Chi-square**	**df**	**Asymp. Sig**
pH	**6.82**	**1**	**.009**
Tempe.	**.011**	**1**	**.917**
Flow	**5.77**	**1**	**.016**
Discharge	**.011**	**1**	**.917**
COD	**6.818**	**1**	**.009**
BOD5	**6.818**	**1**	**.009**
NH3-N	**6.818**	**1**	**.009**
NO3-N	**.535**	**1**	**.465**
TN	**.54**	**1**	**.46**
OP	**1.84**	**1**	**.175**
TP	**3.15**	**1**	**.076**
SO4	**1.3**	**1**	**.25**
TDS	**5.80**	**1**	**.016**
EC	**2.45**	**1**	**.017**
TSS	**.098**	**1**	**.035**
Turbidity	**6.81**	**1**	**.009**

Simpson	1.320	1	.251
Shannon	3.153	1	.076
HFBI	2.151	1	.142
TAR	6.902	1	.009
EPT	5.771	1	.016
EPHE	1.855	1	.173
COLE	3.153	1	.076
TRICO	.405	1	.525
PLECO	3.153	1	.076
DIPTE	.884	1	.347
ETO	6.818	1	.009
REPTCH	6.818	1	.009
BRCH	3.231	1	.072
OLIGO	.222	1	.638
NIT	3.172	1	.075
DOT	.273	1	.602

Appendix 2. Bivariate spearman correlation among physicochemical and biological parameters

	pH	Temp.	COD	BOD5	NH3-N	NO3-N	T.N	O.P	SO4	TDS	E.C	TSS	NTU
D	-.729*	-.214	-.699*	-.697*	-.419	-.611	-.254	-.632	-.523	-.668*	-.525	-.007	-.534
	.017	.552	.025	.025	.228	.061	.480	.050	.121	.035	.120	.985	.112
H	-.857**	-.240	-.846**	-.840**	-.569	-.551	-.332	-.711*	-.341	-.793**	-.659*	-.117	-.703*
	.002	.504	.002	.002	.086	.099	.349	.021	.335	.006	.038	.748	.023
HFBI	.616	.046	.618*	.636*	.521	.525	.198	.347	-.037	.566	.479	.169	.530
	.058	.899	.047	.048	.123	.119	.583	.326	.920	.088	.161	.640	.115
%TAR	-.839**	-.170	-.889**	-.876**	-.739*	-.322	-.483	-.722*	.040	-.790**	-.709*	-.107	-.868**
	.002	.638	.001	.001	.015	.364	.158	.018	.912	.007	.022	.769	.001
%EPT	-.818**	-.190	-.845**	-.853**	-.627	-.411	-.234	-.550	.138	-.766**	-.646*	-.326	-.742*
	.004	.600	.002	.002	.052	.239	.516	.100	.705	.010	.044	.358	.014
%EPHE	-.516	-.282	-.543	-.539	-.409	-.755*	-.202	-.181	-.278	-.496	-.437	.160	-.562
	.127	.430	.105	.108	.241	.012	.576	.616	.436	.145	.207	.658	.091
%COLE	-.601*	.132	-.493	-.472	-.397	-.042	-.240	-.177	.297	-.399	-.312	-.266	-.408
	.056	.717	.147	.169	.256	.909	.504	.626	.405	.254	.380	.457	.242
%TRIC	-.516	.232	-.403	-.395	-.366	-.567	-.065	-.295	-.359	-.382	-.321	-.014	-.235
	.196	.258	.262	.273	.145	.693	.865	.451	.173	.497	.656	.757	.323
	.196	.258	.262	.273	.145	.693	.865	.451	.173	.497	.656	.757	.323
%DIPT	-.446	-.037	-.535	-.537	-.479	-.150	-.191	-.818**	-.207	-.552	-.565	-.191	-.446
	.196	.919	.111	.109	.161	.678	.597	.004	.565	.098	.089	.597	.196

%ETO	-.727*	-.375	-.815**	-.794**	-.627	-.286	-.349	-.370	.301	-.697*	-.639*	-.143	-.901**
	.017	.286	.004	.006	.052	.423	.324	.292	.397	.025	.047	.694	.000
%REPT	-.600*	-.145	-.671*	-.667*	-.628	.039	-.289	-.331	.650*	-.575	-.562	-.423	-.718*
	.046	.689	.034	.035	.052	.915	.418	.351	.042	.082	.031	.223	.019
%BRC	.809**	.267	.795**	.769**	.327	.133	.135	.497	-.084	.672*	.459	.252	.676*
	.005	.456	.006	.009	.357	.713	.711	.144	.818	.033	.182	.482	.032
%OLI	.625	.462	.686*	.683*	.208	.354	.204	.745*	.429	.740*	.646*	.361	.508
	.053	.179	.029	.030	.565	.315	.572	.013	.217	.014	.043	.305	.134
%NIT	.503	.242	.537	.582	.494	.288	.483	.291	-.305	.552	.527	.446	.481
	.138	.501	.109	.078	.147	.420	.158	.415	.391	.098	.118	.196	.159
%DOT	.263	.367	.220	.252	-.127	.704*	.098	.267	.862**	.287	.121	-.149	.021
	.463	.296	.541	.483	.726	.023	.789	.456	.001	.421	.739	.680	.953

Correlation is sign* at 0.05
Correlation is sign** at 0.01

Appendix 3. Macroinvertebrate abundance on Tikur Wuha River study sites

	Site code & number of families in each site										
Taxa list	**U1**	**U2**	**U3**	**U4**	**U5**	**D1**	**D2**	**D3**	**D4**	**D5**	**Total**
Ephemerophtera (Mayflies)											
Baetidae (Small Minnow Mayflies)	2	1	3	3	1	0	0	0	0	0	10
Caenidae (small square –gill Mayflies)	1	1	0	6	0	0	0	3	10	5	26
Leptophlebiidae (Prong-gilled Mayflies)	2	1	3	0	6	0	0	5	0	0	17
Ephemerellidae (Spiny-crawler mayfly)	2	2	1	4	0	0	0	0	0	7	16
Siphlonuridae	3	0	2	0	0	0	0	37	17	20	79
Odonata (Damselflies &Dragonflies)											
Coenagrionidae(Narrow-Winged Damselflies)	3	3	20	26	1	11	11	30	23	17	145
Aeshnidae (Darner Dragonflies)	0	2	0	1	1	0	0	0	1	0	5
Gomphidae (Club-Tail Dragonflies)	5	0	3	0	12	0	1	0	0	0	21
Libellulidae (Skimmers & Perchers)	6	1	3	3	0	0	0	7	5	7	32
Macromidae	8	3	1	0	0	7	0	0	0	0	19

Plecoptera (Stoneflies)											
Perlidae (Common Stoneflies)	**1**	**1**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**1**	**5**
Chloroperlidae (Green stonefly)	**2**	**3**	**0**	**1**	**10**	**0**	**32**	**12**	**2**	**0**	**62**
Periodidae (Platterned stonefly	**0**	**0**	**2**	**3**	**1**	**0**	**0**	**0**	**1**	**0**	**7**
Hemiptera (Water or true bugs)											
Belostomatidae (Giant water Bugs)	**10**	**0**	**10**	**4**	**13**	**50**	**87**	**38**	**45**	**58**	**315**
Nepidae(Waterscorpion)	**4**	**7**	**15**	**2**	**3**	**0**	**1**	**1**	**0**	**0**	**33**
Notonectidae (back swimmers)	**0**	**1**	**1**	**2**	**3**	**21**	**52**	**65**	**87**	**1**	**16**
Trichoptera (Caddisflies)											
Hydropsychidae (common netspinning caddisfly	**5**	**1**	**0**	**0**	**6**	**0**	**5**	**7**	**3**	**6**	**33**
Coleoptera (Beetles)											
Dytiscidae (Predaceous Diving Beetles)	**8**	**1**	**8**	**2**	**15**	**0**	**6**	**12**	**0**	**8**	**60**
Haliplidae(Crawling Water Beetles)	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**3**
Hydrophilidae (Water Scavenger Beetles)	**8**	**2**	**17**	**15**	**31**	**31**	**80**	**75**	**34**	**35**	**328**
Scirtidae	**7**	**3**	**1**	**3**	**5**	**0**	**0**	**6**	**0**	**12**	**37**
Diptera (Two winged or' True flies")											
Ceratopogonidae (Biting Midges)	**3**	**10**	**2**	**0**	**4**	**0**	**1**	**0**	**1**	**0**	**21**
Ephydridae - Shore Flies	**2**	**2**	**3**	**5**	**3**	**0**	**0**	**12**	**56**	**23**	**106**
Chironomidae (Non-Biting)											
Chironomidae (Blood-red)	**1**	**1**	**0**	**1**	**0**	**23**	**27**	**0**	**33**	**12**	**98**
Psychodidae (Moth Flies)	**0**	**0**	**1**	**0**	**2**	**4**	**0**	**44**	**0**	**0**	**51**
Stratiomyidae(Soldier Flies)	**2**	**1**	**2**	**0**	**3**	**79**	**23**	**0**	**58**	**23**	**191**
Syrphidae *(*Rat-Tailed Maggots,Flower flyies	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**2**
Simulidae (Black Flies)	**1**	**0**	**0**	**1**	**0**	**0**	**0**	**68**	**75**	**27**	**172**
Culicidae (mosquitoes)	**2**	**5**	**2**	**0**	**2**	**3**	**32**	**0**	**2**	**0**	**48**
Mollusks(Snails)											
Physidae	**0**	**1**	**3**	**0**	**3**	**0**	**2**	**0**	**2**	**35**	**46**
Planoribidae	**0**	**1**	**1**	**3**	**8**	**2**	**8**	**45**	**20**	**28**	**116**
Lymnaeidae	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
Chelicerta,Arachnida											
Hydracarina(water mites)	**0**	**2**	**1**	**2**	**1**	**0**	**33**	**23**	**0**	**36**	**98**
Hirudinae(Leeches)	**2**	**7**	**4**	**0**	**0**	**35**	**25**	**47**	**25**	**38**	**183**
Oligochaetae (Aquatic Earth worms)	**0**	**0**	**0**	**3**	**2**	**21**	**53**	**0**	**0**	**0**	**79**
Total	**91**	**65**	**110**	**92**	**136**	**287**	**479**	**537**	**502**	**399**	**2698**
Taxa richness	**24**	**27**	**25**	**23**	**23**	**13**	**18**	**18**	**21**	**17**	**37**

Appendix 4. Bivariate spearman correlation matrixes of selected physicochemical and macroinvertebrates metrics

	pH	COD	BOD5	O.P	TDS	TSS
%taxa richness	-0.839	-0.888	-0.887	-0.723	-0.790	-0.876
%EPT	-0.817	-0.845	-0.853	-0.550	-0.765	-0.765
%Coleoptera	-0.612	-0.493	-0.472	-0.675	-0.597	-0.833
% ETO	-0.726	-0.815	-0.794	-0.765	-0.695	-0.762
% Chironomidae	0.809	0.795	0.769	0.659	0.672	0.789
%Oligochaetae	0.625	0.685	0.683	0.745	0.734	0.845
%Non-insect taxa	0.503	0.537	0.582	0.802	0.755	0.674

Appendix 5. Bivariate person correlation matrix of all macroinvertebrate metrics

	SIMPSON	SHANNON	HFBI	%TAXA RICHNES	%EPT	%EPHE	%COLE
SIMPSON							
SHANNON	0.9699						
HFBI	-0.4748	-0.5719					
%TAR	0.7259	0.829	-0.6521				
%EPT	0.603	0.7478	-0.8814	0.7616			
%EPHE	0.6147	0.6476	-0.7246	0.5406	0.6587		
%COLE	0.1704	0.2953	-0.7246	0.3753	0.6644	0.3033	
%TRICO	0.6001	0.5822	-0.7769	0.4046	0.5941	0.6558	0.6082
PLECO	0.23	0.3278	-0.57	0.5055	0.599	0.0016	0.6116
%DIPTE	0.5916	0.6047	-0.0701	0.6324	0.2673	0.1003	-0.3015
%ETO	0.4096	0.5904	-0.6347	0.702	0.8136	0.7084	0.445
REPTCH	0.0425	0.2767	-0.6162	0.5192	0.776	0.3208	0.6236
%CHIRO	-0.6027	-0.7172	0.5782	-0.6517	-0.8044	-0.416	-0.6593
%OLIGO	-0.6375	-0.6727	0.2529	-0.5372	-0.4369	-0.4185	-0.0907
%NIT	-0.0755	-0.2341	0.8051	-0.5214	-0.703	-0.3901	-0.7413
%DOT	-0.7974	-0.6475	0.1832	-0.309	-0.1643	-0.4476	0.1057

%TRICO	%PLECO	%DIPTE	%ETO	%REPTCH	%CHIRO	%OLIGO	%NIT	%DOT
0.3554								
0.0664	0.1444							
0.2426	0.2389	0.186						
0.1294	0.5281	0.0339	0.8189					
-0.3951	-0.4472	-0.1695	-0.6852	-0.5864				
-0.2819	0.217	-0.5634	-0.4543	-0.1518	0.5972			
-0.38	-0.5162	0.1104	-0.5863	-0.764	0.4469	0.0941		
-0.4415	0.1431	-0.2949	0.0202	0.4454	0.276	0.4749	-0.1682	

Appendix 6. The habitat assessment of selected sites on Tikur Wuha River, Hawassa, 2011.

	Site code									
Parameters	U1	U2	U3	U4	U5	D1	D2	D3	D4	D5
epifaunal substrate	18	18	15	15	15	16	15	12	16	16
Pool substrate characterizations	16	16	15	18	19	18	15	18	18	19
velocity/depth regimes	5	5	5	5	5	5	5	5	5	5
Stream bank stability	15	14	18	18	16	16	16	15	18	16
bank vegetation protection	19	10	14	16	18	14	18	16	16	18
Riparian Vegetative Zone Width	16	16	15	18	19	18	14	16	16	19
Sediment deposition	18	15	18	14	16	16	18	18	16	18
Channel Flow Status	18	15	20	20	20	18	20	19	20	18
Channel alteration	19	20	20	20	19	16	12	14	14	20
Grazing	16	18	15	16	18	18	18	18	15	18
Channel sinuosity	18	16	18	16	18	18	16	16	16	16
Total habitat score	165	146	162	152	161	163	147	164	156	176
Scores (from100%)	82.5	73	81	76	80.5	78,5	73.5	79.5	75.3	80
Comparability			Fair to good				Fair to good			

Appendix-6 plates that shows sample sites some important practices

Plate 1. Hawassa textile factory Biological lagoon Hawassa, 2011.

Plate 2. Tikur Wuha River Downstream site 1, Hawassa, 2011.

Plate 3. Tikur Wuha River Downstream site 2, Hawassa, 2011.

Plate 4. Tikur Wuha River Downstream 3, Hawassa, 2011.

Plate 5. Tikur Wuha River Downstream 4, Hawassa, 2011.

Plate 6. Tikur Wuha River Downstream 5, Hawassa, 2011.

Plate 7. Tikur Wuha River Upstream site 1, Hawassa, 2011.

Plate 8. Tikur Wuha River Upstream site 2, Hawassa, 2011.

Plate 9. Tikur Wuha River Upstream site 3, Hawassa, 2011.

Plate 10. Tikur Wuha River Upstream site 4, Hawassa, 2011.

Plate 11. Tikur Wuha River Upstream site 5, Hawassa, 2011.

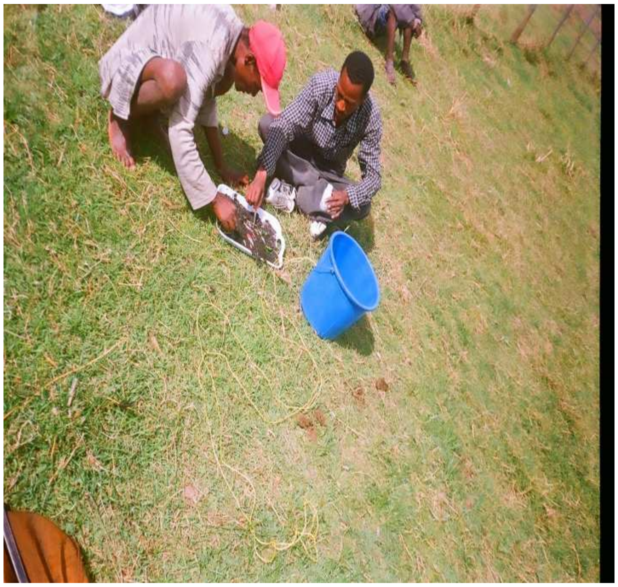


Plate 12. Macroinvertebrate sampling Plate 13. GPS Data taking from each site

Plate 14. Water Chemistry sampling from the site Plate 15. Wastewater sample from the point, Hawassa, 2001.