Faculty of Public Health Institute of Health science Jimma University

Department of Environmental Health Sciences and Technology

Influence of Urban Pressure on the Ecological Status of Showunga River, Mizan-Aman Town, Bench Maji Zone, Southern Ethiopia

By Yewubdar Zewdie

A Thesis Submitted to the Department of Environmental Health Sciences and Technology, Faculty of Public Health, Institute of Health Science, Jimma University, in Partial Fulfillment for the Requirements of Master of Science in Environmental Science and Technology

November, 2019

Jimma, Ethiopia

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Advisor

Prof. Dr. Argaw Ambelu

November, 2019

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APPROVAL SHEET

As thesis research advisor, I hereby certify that i have read and evaluated this thesis prepared under me guidance by Yewubdar Zewdie: Influence of Urban Pressure on Ecological Status of Showunga River, Mizan-Aman Town, Bench Maji Zone, Southern Ethiopia. I recommended that it be submitted as fulfilling the thesis requirement.

Prof. Dr. Argaw Ambelu	______________	___________
	Signature	Date

As member of the board of examiners of the M.Sc. thesis open defense examination, we certify that we have read and evaluated the thesis prepared by Yewubdar Zewdie and examined the candidate. We recommend that the thesis be accepted as fulfilling the thesis requirement for the degree of Master of Science in Environmental Science and Technology.

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Abstract

Background: Urbanization is one of the main causes for ecological problems due to the introduction of pollutants into water bodies. Degradation of water resources with pollutant effluent occurs by altering attributes that influence ecological integrity of surface water resource such as water quality, habitat structure, energy source and biotic interactions. Showunga River crosses Mizan-Aman town and has long been used for a variety of purposes including source of public water supply, small scale irrigation, recreation, bathing, washing, animal watering, and sand and stone dredging.

Objective: The main objective of this study is to assess the influences of urban pressure on the ecological status of Showunga River.

Method: A total of eleven samples were collected along Showunga River by following the standard methods of American Public Health Association procedures in April 2019 using cross sectional study design. The assessment involved on-site measurements and collection of water samples, laboratory analysis of water samples and macroinvertebrates identification to the level of family using microscope. Kruskal-Wallis multiple comparison test, Pearson correlations, Excel, SPSS version 24, PAST version 3.18 and STATISTICA® software package were performed.

Results: The result clearly shows that upstream sites have oxygen level of 7 mgL^{-1}, while turbidity, BOD, nitrate, phosphate, and chloride concentrations was elevated at midstream sites where main human activity is undertaken. Macroinvertebrate assemblages were compromised in the mid-stream sites where diversity of sensitive taxa was diminished due to anthropogenic disturbances. However, downstream sites showed a gradient of recovery where the most downstream site, S11, was found to have better macroinvertebrate diversity with improved water quality than midstream sites.

Conclusion: Physicochemical and biological data revealed that much influence of urban pressure at the midstream sites (waste water discharge, coffee processing, sand and stone deranging are main ecological deteriorated), thus necessitated a need for mitigation measure to save the Showunga River.

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Above all I thank the almighty GOD for his generosity throughout my work from the beginning to the successful completion of the research. The next deep and sincere thanks go to my advisor Prof. Dr. Argaw Ambelu for giving me the opportunity to work with him and for all of his unreserved support, insightful guidance and comments in every moment throughout this research work. Indeed, Prof. Dr. Argaw is not only an effective guide but also a father of very positive personality towards successful completion of this thesis work.

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List of Abbreviations and Acronyms

APHA	American Public Health Association
AWWA	American Water Works Association
BMWP	Biological Monitoring Working Party
BMI	Benthic Macroinvertebrate Indices
BOD	Biological Oxygen Demand
CLI	Community Loss Index
DO	Dissolved Oxygen
EC	Electrical Conductivity
EEPA	Ethiopian Environmental Protection Authority
EPT	Ephemeroptera, Plecoptera, Trichoptera
FBI	Family Biotic Index
FAO	Food and agricultural Authority
H'	Shannon-Weiner Diversity index
GPS	Global Positioning System
MTU	Mizan Tepie University
NMS	None metric Multidimensional Scaling
RBP	Rapid Bioassessment Protocols
SNNPRS	Southern Nation Nationality people Regional State
TSS	Total Suspended Solids
UNEP	United Nations Environment Program
USEPA	United States Environmental Protection Agency
WCP	Wet Coffee Process
WHO	World Health Organization

Chapter 1: Introduction

1.1. Back ground of the study

Ecological deterioration is the disturbance of chemical, physical and biological integrity that influence the interdependence of living organism in the environment. When an ecosystem gets polluted, the natural balance in the system is disturbed and this affects the organisms in different ways (Karaouzas et al., 2018).Rivers are sources of substantial biodiversity and support numerous species from all of the major groups of organisms ranging from microbes to higher forms (Anna et al., 2018).

Over the past few decades, aquatic ecology has been subjected to a great number of anthropogenic impacts. So that degradation of water resources with pollutant 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. They are seriously threatening the ecological integrity of most aquatic ecosystems on earth and within this terrible and real scenario, water pollution and its ensuing habitat degradation is the most global challenge in river ecosystems (Desrosiers et al., 2019).

As dynamic systems rivers and cities have been in interaction under changing relations over time, and the morphology of many cities has risen through a long and steady struggle between the city functions and the river system flowing inside, this makes river cities an interesting case to study how the presence of geographical features interacts with spatial morphology in the formation of cities (Bostanmaneshrad et al., 2018).

Clean water is a fundamental resource for socio-economic development & transformation; it is essential for maintaining healthy environment and smooth function of ecosystems. There is a raising demand for fresh water resources as a result of increasing population. It has become difficult to treat the current context of growing pollution world-wide. Such problem requires urgent attention, since water is scarce and such an important resource needs detailed scientific research all over the world in order to sustain and protect the water resource from pollution and for its wise utilization (Fierro,et al., 2018).

Water resources provide valuable food through aquatic life cycle and irrigation for agriculture production, however, liquid and solid wastes produced by human settlements and industrial effluent disturb most of the water ecology throughout the world(Berger et al., 2017).

Human pressures on rivers are pollutants like organic residues and heavy metals, acidification and alterations of hydrology and morphology, modification of chemical parameters and variation in biological communities. Activities such as industrialization, urban effluents, deforestation, drainage of wetlands and diffuse sources linked to agriculture have been causing great impact on aquatic ecology in (Berger,et al., 2018).

Now a day freshwater ecosystems disturbance is the most threatening environmental effect on earth and its normal functionality, sustainability and their services is declining .Environmental pollution has become a key focus of concern all over the world and has many forms. The air we breathe, the water we drink, and the ground where we cultivate our food crops to health problems and lower quality of life. Among all the environmental pollutants, pollution of freshwater resources especially flowing waters is a matter of great concern. In Africa rapid growth of human populations and the attendant increase in domestic sewage, agricultural development and industrialization are the main causes for ecological deterioration of water (Damanik-ambarita et al., 2016).

In Ethiopia, there are many studies done to assess effects of urban pollution on rivers consequently, discharge of untreated effluent from industries, solid wastes and waste water from households and institutions, are the major sources of pollution of the rivers flowing through the city (Berihun, et al., 2017; Desalegne, 2018).

1.2. Statement of the problem

River water bodies are widely used as disposal sites of solid and liquid waste in the world (Society, 2015). Discharges of pollutants to the fresh water ecosystem results in a consequent reduction of aquatic life (Luo et al., 2017). Thus, the uncontrolled release of waste from urban, domestic, agricultural, and industrial facilities can affect the water quality of the receiving water body and this may leads to the severity of ecological disturbance across the river(Abdul-raouf et al., 2016).

The main sources of pollution that enters urban surface water bodies such as streams, rivers and reservoirs are discharge of untreated effluents , poor provision of sanitation facilities, rapid population growth, uncontrolled urbanization and improper waste disposal are the major sources of pollution of the rivers flowing through the town (Derso et al., 2017).

Water quality disturbance from human activities are likely continuing harming human and ecosystem health and verifies that excessive nutrient loads and organic pollutant are among the fresh water contaminants of primary concern(Hovhannisyan & Shahnazaryan, 2016).

Water pollution profiles of rivers and streams has been undertaken on different rivers and streams in Ethiopia such as; Kebena stream(Awoke et al., 2016), Great and Little Akaki rivers (Akalu et al., 2017), Sebeta river (Mamo, 2004), Awash river (Bekele,1999) and Alaltu Rivers (Prabu et al.,2011) and disturbance of the ecological quality of Awetu River as a result of discharge of municipal wastes and urban runoff has been indicated (Hailu, 1997).Nevertheless, majority of the studies focused on rivers that are found near city or town.

Mizan-Aman is the largest town there are encounter urban pressure such as:

- More than six coffee processing industries
- Nearly 119,000 town population
- Many hotels
- Different institutions
- Commercial center for coffee, fruits….etc.
- Sand and stone dredging
- Many human activity carried on there

1.3. Significance of the study

A supply of clean water is an essential requirement for the establishment and maintenance of ecological integrity. Water resources provide valuable food through aquatic life cycle, irrigation for agriculture productions and animal watering. Though, improper liquid waste discharge and solid wastes produced by human settlements and industrial activities leads to negative effect to surface water ecosystem and as pollution of river.

However, as far as we know there is no any study that has been conducted the ecological problem of this river when crossing the town. Under taking this study will have the following benefit:

- Point out the possible pollution sources that are causes for the observed ecological problem.
- To ensuring the rightness of the usability of Showunga Rivers by surrounding local community for different purposes.
- To provide better understanding of the current ecological status of this river.
- To generate the baseline data for the further studies.

Chapter 2: Literature review

2.1. Surface water resources

Surface water sources are rivers, lakes, oceans, etc. Water is the essential component of life. About 70% of the earth's surface is water, and 3% of this is fresh water. Yet, out of this 99% is found beneath the surface(Karikari, 1992).Water has become an essential commodity for the development of industrials and agricultures. Surface water is naturally replenished by precipitation and naturally lost through discharge to the oceans, evaporation, transpiration and ground water recharge (Karikari, 1992).

Surface water is the most accessible source of water, which hallows taking on large amount of water, despite of the seasonal variation of water flow. Surface water constitutes less than 0.02% of the global water inventory, but the myriad lake, river, and wetlands that Earth surface are what we commonly associate with the field of hydrology and with global water source. These water bodies are relatively easily tapped for drinking water usage, as well as offering traditional over land transportation pathways, for these reason, most of the world's settlements and urban areas were established adjacent to river or lakes(Kamble, 2015)

2.2. Surface water pollution and ecosystem disturbance

Surface water ecosystem can be disturbed by hazardous substances coming into contact with this surface water, dissolving or mixing physically, chemically or biologically with water can be called surface water disturbance (Zhang et al., 2014). Surface water is heavily affected by human impact and their pristine state is no more recognizable in many temperate regions, due to the long history of anthropogenic influence(Ambelu, 2017). Moreover, surface water is considered the most threatened ecosystems of the world .The discharge of effluent following sewage is one of the major factors affecting the biological quality of surface waters (Chapman, 1996).There are hundreds, perhaps thousands of pollutants whose effects are actual and potential concern. Pollutants have been classified according to their mode of occurrence into physical and chemical.

2.2.1. Chemical water pollution

Chemical surface water disturbance are generally atoms or molecules, which have been discharged into natural water bodies, usually by activities of humans. Common examples of such chemical surface water pollutants are mercury emanating from mining activity, certain nitrogen compounds used in agriculture, chlorinated organic molecules arising from sewage or water treatment plants or various acids which are the externalities of various manufacturing activities(Etissa et al., 2014).

2.2.2. Physical water pollution

The physical surface water disturbance are either much larger particles or physical factors such as temperature change, both of which while not typically toxic, cause a variety of harmful effects. The most obvious of physical disturbance are excessive sediment load, mostly arising from over-intense land use practices and rubbish discarded from human manufacturing activity (e.g. plastic bags, bottles). While these materials are not so harmful to human health as chemicals or pathogens, they comprise the majority of visual impact of water pollution. In the case of thermal disturbance, these point source discharges typically affect the metabolism of aquatic fauna in adverse ways(Berger et al., 2017) .

2.3. River ecological deterioration

Clean, safe, and adequate fresh water is vital to the survival of all living organisms and smooth functioning of ecology, food production and economic development. Evidently, fresh water is an essential natural resource for humankind and central to sustainable development as well as poverty alleviation. Consequently many journals describe it as oil of the 21st century while it is indeed life.

Many parts of the world fresh water availability is severely limited and its quality is increasingly undergoing deterioration(Chughtai, 2014).The same source further points out that shortage of fresh water and deterioration of its quality which are already serious issues in most parts of the world . These imply that the challenge of fresh water in the 21st century is one of both quantity and quality(UNEPA, 2010).

Predicts by (Hopkins,1998) Ethiopia will face water scarcity by 2025 exactly when the country plans to become a middle income country. Wastes are also directly discharged with little or no treatment to many streams and rivers in the country crossing towns or cities as if they are open sewers. These imply that the challenge with fresh water in Ethiopia may also be of both quantity and quality if the available resource is not properly managed in an integrated way.

About 46% of mortality in children of less than five years is due to water-related disease to unsafe drinking water (Sorlini et al., 2013) and the poor are often forced to live near degraded waterways and unable to afford clean water(Wakuma & Fita, 2017). Streams and rivers are under various changes due to anthropogenic activities in their catchment areas (Sirisinthuwanich, 2016). Often, poor water quality is the result of the combined effects of a variety of activities in catchments. Some wastes are direct discharge from factory. However, many of the pollutants which enter fresh water ecosystems come from a wide area, for example fertilizers used throughout a farming area, or on parks and gardens. These are "non- point" (diffuse) sources and harder to manage(Cheng et al.,2019).

Increasing population, urbanization, industrialization and strong agriculture, the volume of wastewater generated is steadily growing and must be assimilated into the environment without impairing the health (Wu et al., 2017).

2.3.1. Nutrient enrichment

Nutrient enrichment has become the planet's most widespread water quality problem (Negero et al., 2017). Nutrients most responsible for ecological degradation via eutrophication are nitrogen, phosphorus and ammonia which are found in the aquatic environment as dissolved inorganic or organic forms (Wang et al., 2018). Land uses are usually associated with nutrient enrichment and most of the external sources of nutrients flow into rivers directly from streams or from shorelines. Human sewage, animal waste, and plant residue contain organic material which aquatic bacteria decompose and produce additional nutrients for plant growth. Associated with nitrogen and phosphorus from agricultural runoff as well as human and industrial waste, nutrient enrichment can increase rates of primary productivity (the production of plant matter through photosynthesis) to excessive levels, leading to overgrowth of algal blooms, and the depletion of dissolved oxygen (increased BOD) in the water column, which can stress or kill aquatic organisms and nitrate in drinking water has been linked to human health problems such as methaemoglobinaemia (blue-baby syndrome), stomach cancer and negative reproductive outcomes (Oketola et al., 2013).

2. 4. River water quality monitoring

2.4.1. Physicochemical method

Water quality monitoring was based mainly on physicochemical parameters, which indicate the quality of water at the time of sampling, and still the commonest method in developing countries(Barbour et al, 1999).

Physicochemical parameters are precise, discriminatory and quantitative for the variables to be determined at the moment of sample collection. But there are thousands of chemicals that may be discharged to streams and only few chemicals are selected for routine chemical analysis and the concentrations of pollutants vary with time leaving their effect for many weeks or months. Moreover, chemical analysis is costly, time consuming, and may not always give an accurate reflection of general water quality; only regular measurements can provide an integrated overview of general water quality. Thus, in running waters, where changes in hydrology are rapid and difficult to estimate, they cannot reflect the integration of numerous environmental factors and long-term sustainability of river ecosystems for their instantaneous nature with the increasing amount and variety of pollution of surface and other waters in the modern world, there is growing need for simple, rapid and reliable methods for assessing the degree of purity or contamination of water(Misganaw & Studies, 2015). In recent decades, a significant effort has been put forth all over the world to evaluate water quality attending to not only to chemical parameters (nutrients, metals, pesticides, etc.), which are important, but also to biological indicators.

2.4.2. Biomonitoring

Human activities may alter the physical, chemical, or biological processes related to water resources. Moreover, rivers are considered the most threatened ecosystems of the world and thus modify the resident biological community (Karr, 1991). One of the undesirable consequences of pollutants is their effect on biota. In this case, the direct study of the impact of pollution on biota is great interest. Because they focus on living organisms whose very existence represents the integration of conditions around them biological evaluations can diagnose chemical, physical, and biological impacts as well as their cumulative effects (Ogendie et al, 2015).

The use of biological methods or Biomonitoring is now recognized as one of the most valuable tools (Berger et al., 2017).Various biological monitoring methods that provide a direct measure of ecological integrity by using the response of biota to environmental changes have been developed to monitor the ecological status of water environments.

Organisms may be affected by their natural cycles, such as life cycle stage and reproductive condition due to ecological disturbance. Thus, like other techniques, biological monitoring methods should be developed and interpreted with care (Bartram and Balance, 1996; Giller and Malmqvist, 1998).

Moreover, biological monitoring should not be seen as an alternative to physical and chemical monitoring but as a useful complementary approach (Karr, 1991). Evaluation of impacts some of the advantages of biological monitoring include:

- Biological communities reflect overall ecological integrity (i.e., chemical, physical, and biological integrity).
- Biological communities integrate the effects of different stressors and thus provide a broad measure of their aggregate impact.
- Communities integrate the stresses over time and provide an ecological measure of fluctuating environmental conditions,
- The status of biological communities is direct interest to the public as a measure of a pollution free environment, and
- Where criteria for specific ambient impacts do not exist (e.g., nonpoint-source impacts that degrade habitat), biological communities may be the only practical means of evaluation.

2.4.3. Bioindicators for ecological water quality

Biomonitoring is based on the straight forward premise that living organisms are the ultimate indicators of environmental quality (Karr, 1991). Biological indicators are particularly important for monitoring ecological water quality because they show the cumulative effects of present and past conditions.

2.4.3.1. Macroinvertebrates

According to (Barbour et al 1999) macroinvertebrate assemblages are good indicators of localized conditions. Because many benthic macroinvertebrate have limited migration patterns or a sessile mode of life, they are particularly well-suited for assessing site-specific impacts (upstream- downstream studies).Benthic macroinvertebrate assemblages are made up of species that constitute a broad range of trophic levels and pollution tolerances, thus providing strong information for interpreting cumulative effects. Macroinvertebrates are ubiquitous and abundant in aquatic ecosystems and relatively easy to collect and identify (at least to family level) (Barbour et al., 1999). No expensive equipment is necessary for their collection. These organisms are usually relatively immobile, there by indicating local conditions, and since many have life spans covering a year or more, they are also good integrators of environmental conditions. Mmacroinvertebrates are bioindicators of river health because,

- Spend up to one year in the stream.
- Have little mobility
- Generally abundant
- Primary food source for many fish
- Good indicators of localized conditions

According to(Bartram and Balance, 1996) some macroinvertebrates are tolerant of degraded water quality conditions, while others are pollution sensitive. Many snails, worms and midge larvae belong to the former group, while the most widely recognized members of the latter group are the Ephemeroptera, Plecoptera and Trichoptera. The use of macroinvertebrates as indicators of environmental change in Ethiopia (Gezie et al., 2017).

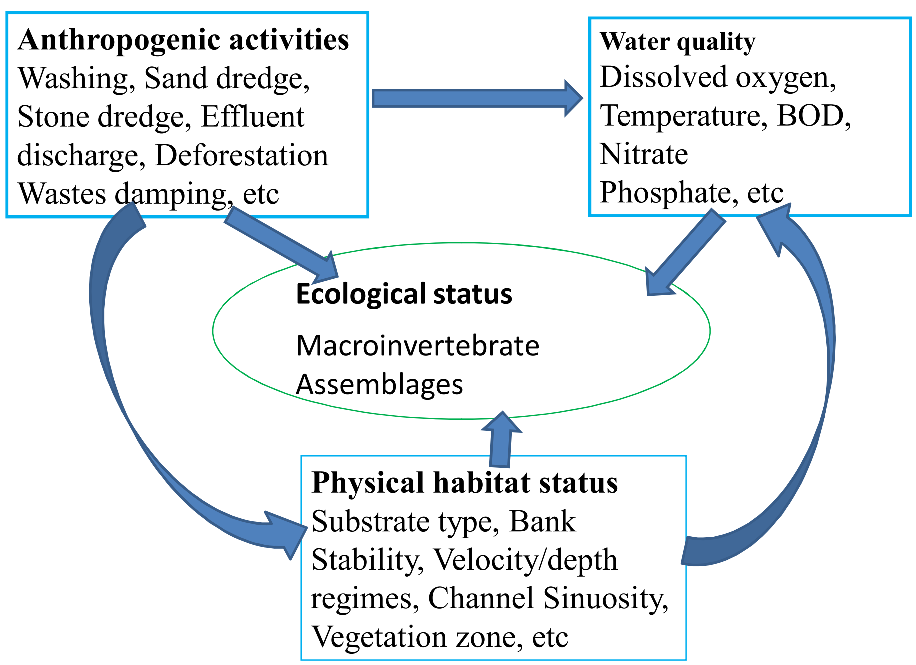
Table 1.Definitions of macroinvertebrate metrics and predicted direction of index response to increasing perturbation (Barbour et al., 1999)

Category	Metric	Definition(Description)	Predicted response to increasing perturbation
Richness measures	Total No. taxa	Measures the overall variety of the macroinvertebrate assemblages	Decrease
	No. Ephemeroptera taxa	Number of mayfly taxa (usually genes or species level)	Decrease
	No. Trichoptera taxa	Number of caddis fly taxa	Decrease
	No. Plecoptera taxa	Number of stone fly taxa adult	Decrease
Composition measure	%EPT	% of composite mayfly, stonefly Canddis fly larva	Decrease
	% Ephemeroptera	% of mayfly nymph	Decrease
Tolerance/Intolerance Measures	No of Intolerant taxa	Taxa richness of those organisms Considered to be sensitive to perturbation	Decrease
	% of Tolerant organism	% of macro benthos considered to be tolerant of various types of perturbation	Increase
	% of Dominant taxon	Measure the dominance of the single most abundant taxon	Increase
Habitat measure	Number Clinger Taxa	Number of taxa of insect	Decrease
	% Clinger	% of insects having fixed adaptation for attachment to surfaces in flowing water	Decrease
Feeding measures	% Filterers	Filter food from either the column and sediment	Variable
	% Grazers and scrapers	Percent of the macro benthos that scrape or graze upon periphyton	Decrease
	% Gatherers and filterers	% of collector feeders	Variable
	% Predators	%predator functional feeding group	Variable

2.4.4. Benthic macroinvertebrate indices

Many different indices have been used in the evaluation of benthic macroinvertebrate communities in order to summarize information and assess pollution effects on aquatic organism. Three basic types of indices (diversity, composition and biotic diversity) are mostly employed to assess rive health (Rosenberg and Resh, 1993).

2.5. Conceptual framework



Chapter 3: Objectives

3.1. General objective

- To assess the influence of urban pressure on ecological status of Showunga River in Mizan-Aman town.

3.2. Specific objectives

- To characterize the physicochemical conditions of Showunga River in the upstream, midstream and downstream from Mizan-Aman town.
- To determine the abundance of macroinvertebrate assemblage of the Showunga River in the upstream, midstream and downstream from Mizan-Aman town.
- To identify major anthropogenic activities causing ecological disturbance of Showunga River while crossing Mizan-Aman town.
- To assess the physical habitats status and physiographic condition at the sampling sites along the river.

3.3. Hypothesis

- Mizan-Aman town is affecting the ecological status of Showunga River in terms of water quality and macroinvertebrate assemblages.

Chapter 4: Materials and Methods

4.1. Description of the study area

The study area is located 233 km away from Jimma town. Showunga River is crossing Mizan-Aman town, southern Ethiopia (Fig.1).The administrative center of Bench Maji Zone of the Southern Nations, Nationalities, and Peoples Regional State. The estimated annual-rainfall is nearly1800 mm and annual mean temperature ranged between 20 and 31˚C. The town is located at altitude of 1000-1700 m.

Showunga River is a tributary to Akobo River basin. This river originates from Garenance Mountain and the topography is slopes down from north to the south with a number of steep-sided valleys. Besides administrative function the town serves as a commercial center of coffee, fruits like banana, mango, and food crops like teffe, rise, and corn. There are diverse economic activity around Showunga River such as wet coffee processing, car washing, sand and stone dragging, intensive agriculture activity, and commerce service.

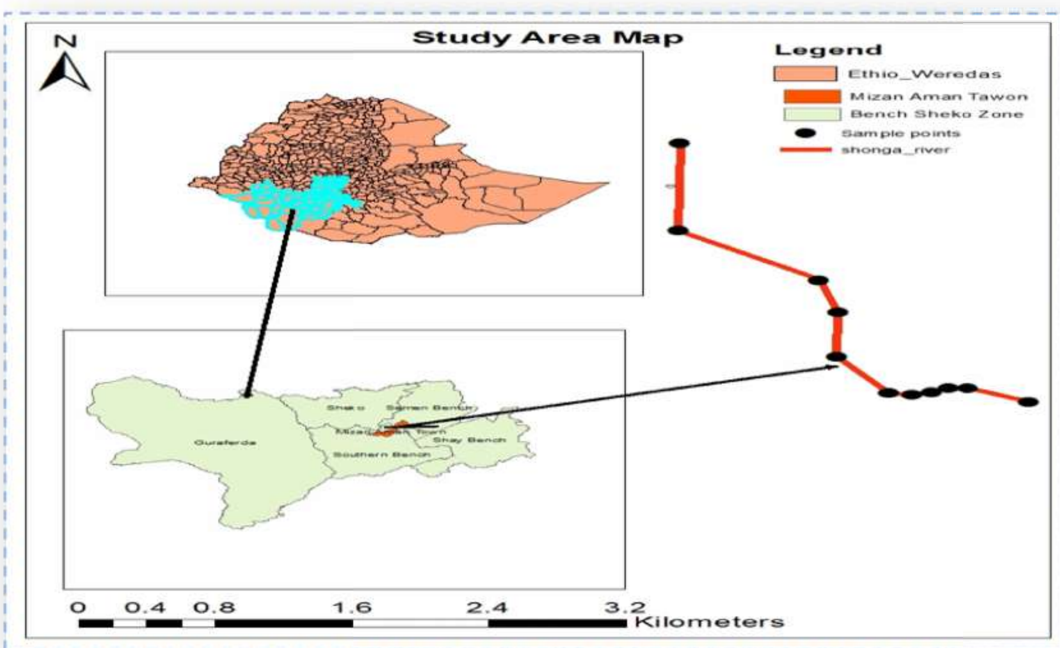


Figure 1.Map showing sampling sites along Showunga River.

4.1.1. Sampling site selection

A total of 11 sampling site coded from S1 to S11 (Fig. 1) were chosen along Showunga River course from source (Garnce Mountain) to the point where it join with Denbi dam and the sampling criteria were leveled of human impact on the river, the study considering processes affecting ecological integrity and their influences, accessibility and evaluate the environmental impact of wastes on Showunga River.

Sites (S1, S2, and S3) were selected as reference sites before entering the town; using as benchmark to compare changes in other sites .These sites (S1, S2, and S3) were located in the upper part of the river where the riparian vegetation was dominated by eucalyptus tree. The other five sites (S4 to S10) were selected on the basis of the prominent land use in the river where as S11 is far from the town. Site (S4, S5, S6, S7and S8) urban landscape were midstream and there were extensive human settlement, waste effluent discharge, car washing, commercial activity, open bathing, cloth washing, sand and stone deranged, various solid and liquid waste damping from the town. Here, the water and environment had obnoxious odor when walk across the road. Site (S9, S10and S11) were downstream, S9 and S10 located in the town, however less human settlement than midstream. At S11 no urbanization seen, this site is far from the town and relatively, low anthropogenic activity to compare the other two downstream sites.

4.2. Study design and period

A cross-sectional study design was used to assess urban pressure on Showunga River while crossing Mizan-Aman town in April, 2019.

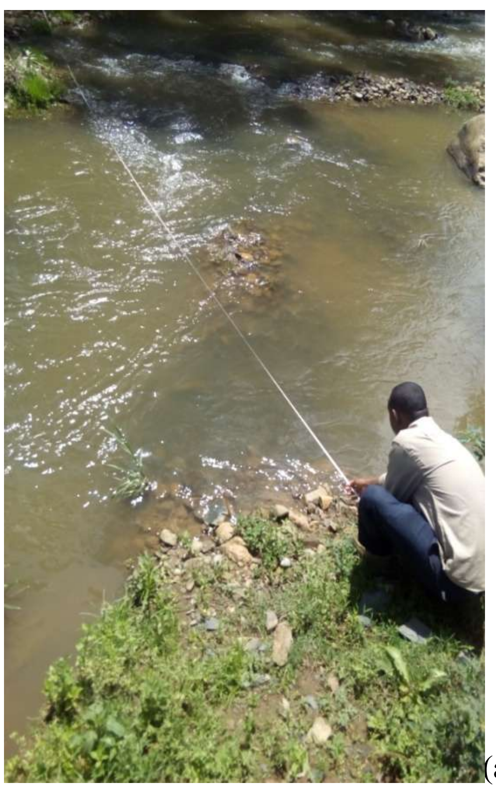
4.2.1. On- site measurements

4.2.1.1. Water quality

DO, Water pH, conductivity, turbidity, and water temperature were measured at each sampling site with Portable multi meter hand-held probe during the sampling periods (Table 2). Altitude, longitude and latitude were measured using global positioning system (GPS).

4.2.1.2. Habitat and physiographic assessment

Habitat conditions information at each site were collected with measured of the physicochemical parameters and recorded for each monitoring reach during collection of macroinvertebrate samples. Physical habitat were scored with the USEPA"s rapid bio assessment protocol the procedure given in(Barbour et al., 1999). Habitat assessment involved rating 10 habitat parameters (epifaunal substrate/available cover, embeddedness, velocity/depth regime, sediment deposition, channel flow status, channel alteration, frequency of riffles, bank stability, vegetative protection and riparian vegetative zone having habitat score classifying each sampling site as optimal (160-200), suboptimal(100-159), marginal(60-99) and poor(<60). All the parameters were evaluated and rating on a numerical scale from 0-20 for each sampling reach at each site. Water depth, river velocity were measured using dip stick and flotation methods, respectively. Then the rating total expressed as score to provide the final habitat quality ranking. Physiographic conditions were measured at each sampling site with meter, whereas canopy cover value used visual estimated and presented by percent.


(a)

(b)

Figure 2.Wetted width (a) and on site measurements of water quality along Showunga River

4.2.1.3. Anthropogenic activity assessment

The assessment of human activity were used by observed and recorded each activity including the portion of the sampling site 100m surrounding station(Barbour et al.,1999) and considering based on the major human activities in the area.

4.2.2. Sampling collection and protocol

4.2.2.1. Water samples

Composite water sample were collected by 2-L polyethylene sampling bottles and10 cm below the surface as indicated in(ÃPHA et al., 1999). At each sampling site, the bottles were rinsed at least three times before sampling.

4.2.2.2. Macroinvertebrate samples

Macroinvertebrate samples from the sampling sites concurrently were collected with the water sampling. According to international standardized protocol using a D-frame kick hand net with a 250 µm mesh size in all the available habitat types (multi habitat sampling procedure), such as riffles, macrophytes, pools and bedrock collectively. At each sampling site, macroinvertebrates were taken by submerging the hand net in the river at different depths , sweeping and kicking at each location, covered both vegetation and open-water areas to incorporated habitat heterogeneity and benthic substratum were dislodge to any attached macroinvertebrates (Berger et al., 2017).


(a)

(b)

Figure 3.Kick sampling (a) and on-site sorting of macroinvertebrate in the Showunga River (b).

After the macroinvertebrate samples were collected and transferred into a bowel and washed with sufficient amount of water were added and the supernatant was poured onto a sieve to retain the macroinvertebrates while removed the mud .This was repeated until all the macroinvertebrates separated from mud. The macroinvertebrate samples collected were then pooled to form single composite samples and preserved with 70% ethanol.

After all samples collected then placed in an insulating ice packs cooled boxes and transported to Jimma university Environmental Sciences and Technology laboratories with due care for chemical and biological analyses and water samples stored in a refrigerator at 4˚C until analysis.

4.2.3. Laboratory analyses

4.2.3.1. Nutrient analysis

From each water sample nitrate, phosphate, chloride, TSS, and BOD_5 were analyzed by following the procedures outlined in (APHA et al., 1999) to determined level of ecological status of nutrient. The methods were presented in Table 2.

Figure 4.During analyses of physicochemical parameters in the laboratory.

Table 2.Methods used for water quality analysis

Physicochemical parameters	Units	Methods of analysis
pH	Log units	Portable multi meter hand-held probe
Water Temperature	ºC	
Electrical Conductivity	μscm^{-1}	
Dissolved Oxygen	mgL^{-1}	
Turbidity	NTU	
Phosphate	mgL^{-1}	Stannous Chloride method (UV-Vis spectrophotometer at 690nm)
Chloride	mgL^{-1}	Argentometric method (titrating by Ag No_3 using K2 Cr O4 as indicator)
Nitrate	mgL^{-1}	Phenol disulphonic Acid Method (UV-Vis spectrophotometer at 410nm)
Total suspended Solids	mgL^{-1}	TSS dried at 103 ˚C (drying at oven)
Biological Oxygen Demand	mgL^{-1}	Whinkler method

4.2.3.2. Macroinvertebrate identification

All macroinvertebrate samples were transferred in to Petri dish by their each site in order to easily observed and peaked up the organisms with forceps then sorted and identified the specimen to the level of family by using a stereo dissecting microscope given in(Gerber & Gabriel, 2002)then based on by their specific category of all specimens counting and putting in one vial.

Figure 5.Macroinvertabrates specimens identifying by family level in the laboratory.

4.2.4. Study Variables

Macroinvertebrate assemblages (Dependent variables)

- Diversity, composition and biotic

Physicochemical parameters (Independent variables)

- pH
- Water Temperature °C
- Electrical Conductivity (µscm^{-1})
- Dissolved Oxygen (mgL^{-1})
- Turbidity (NTU)
- Phosphate(mgL^{-1})
- Chloride (mgL^{-1})
- Nitrate (mgL^{-1})
- Total suspended Solids (mgL^{-1})
- Biological Oxygen Demand (mgL^{-1})

Habitat and physiographic conditions (Independent variables)

- Canopy cover (%)
- Habitat status (%)
- River bank width (m)
- Average water width (m)
- Average water depth(m)
- Average velocity (m/s)

Anthropogenic activity (by observation)

4.2.5. Data analysis

Physicochemical parameters, habitat survey, biotic indices and multivariate analytical tools (cluster analysis, canonical correspondence analysis and non-metric multidimensional scaling) were used in assessing ecological status at Showunga River. Significances of variability of the water quality parameters and biological attributes determined were tested using Kruskal-Wallis multiple comparison test and Pearson correlations were performed between bio-assessment indices and physicochemical variables to determine the sensitivity of each index. A statistical analysis was performed using Excel and statistical package for social sciences (SPSS) version 24 software. Cluster analysis and canonical correspondence analysis were done using paleontological statistics software package for education (PAST 3) version 3.18.In addition, to compare the three streams post-hoc comparisons and non-metric multidimensional scaling to discriminate irrelevant macroinvertebrate metrics for detection of human impact were performed using the STATISTICA® software package version 7.1.

4.2.5.1. Shannon Diversity Index

Shannon diversity index(Shannon, 1948) is the most used metric which measure different aspects of diversity for macroinvertebrates to describing the species abundance of individuals within the eleven sites were calculated based on(Shannon,1948). Shannon index values greater than three indicate unpolluted water, while less than one values indicate severe pollution and intermediate values are characteristic of moderately polluted conditions (Shannon,1948).

$$H' = -\sum_{i}^{s} pi \log (pi)$$ Eq.1

Where,

H´ is the standard symbol for the maximum Shannon index, and pi is the proportion of i'th species.

i = an index number for each species present in a sample.

4.2.5.2. Evenness

Evenness was measured of the relative abundance of the different species making up the richness of an area. Evenness was calculated for macroinvertebrates as the ratio of diversity with the maximum possible diversity for the number of species found as, then the number closer to 1 the more even the populations that form the community.

$$E = \frac{H'}{H'max}$$ …………………………………………Eq. 2

Where, H' is Shannon index and H 'max= maximum possible Shannon's diversity

4.2.5.3. Community loss index

Community loss index measures the loss of benthic tax in a study site with respect to a reference site. Value range from 0 to "infinity" and increase as degree of dissimilarity between the sites increase (Mandville,2002). The index was calculated based on the following formula.

$$CLI = \frac{d-a}{e}$$ ……………………………………..Eq.3

Where ″a" is the number of taxa common to both sites, ″d" is the total number of taxa present in the reference site, and "e" is the total number of taxa present in the study site.

4.2.5.4. EPT richness

EPT index displays the taxa richness within the insect groups which are considered to be sensitive to pollution, and therefore should increase with increasing ecological water quality. The EPT index is equal to the total number of families represented within these three orders in the sample(Jun et al., 2012)**.**

4.2.5.5. Family biotic index

Family biotic index is an average of tolerance values of all the macroinvertebrates families in a sample (Hilsenhoff, 1988). FBI was calculated by multiplying the number in each family by the tolerance value for that family, summing the products, and dividing by the total macroinvertebrate in the sample. The family-level tolerance values range from 0(very intolerant) to 10(highly tolerant) based on their tolerance to organic pollution. The FBI was then used to evaluate the pollution stats of the water for each sampling sites and the three streams by comparing with the standard used to rate the ecological water status (Annex 6). The index is calculated based on the following formula.

$$\mathrm{FBI} = \frac{\sum(\mathbf{xi} * \mathbf{ti})}{\mathbf{n}}$$ ……………………………………………Eq.4

Where ***xi*** is abundance of taxon ***i*****,** ***ti*** is the tolerance value of taxon ***i*** and ***n*** is abundance in the sample.

4.2.5.6. Biological monitoring working party

Biological monitoring working party score is an index for measuring the biological quality of rivers using species of macroinvertebrates as biological indicators at the family level score which is representative of the family's tolerance to water pollution(Walley and Hawkes, 1997). Each family is then given a score between 1 and 10.Tolerant (1) and intolerant (10).The overall BMWP Score for a site is the sum of all of the scores of each family present at that site. Then compare with the standard (Annex. 5).If the value greater than 100 is associated with clean rivers, whilst heavily polluted rivers score less than 10.

4.2.5.7. Cluster analysis

Cluster analysis one which is an exploratory multivariate data analysis tool that sorts different objects into groups in a way that the degree of association between two objects is maximal if they belong to the same group and minimal otherwise. This helps to arrange the data into a meaningful structure (Goethals et al., 2011). Different clustering algorithms like single linkage, complete linkage, Ward's method, etc. can be applied. In this thesis, hierarchical clustering of macroinvertebrate and physicochemical data were performed using Bray-Curtis distance and Ward's clustering algorithm to assessing their effectiveness in classifying sample sites based on pollution load and sources of pollution. The Paleontological Statistics software package for education (PAST 3) version 3.18 was used to undertake this cluster analysis.

4.2.5.8. Non-metric multidimensional scaling

Non-metric multidimensional scaling was performed to the similarity between samples and macroinvertebrate metrics from the reference condition. This method is vital for the development of bio-monitoring metrics for one region(Ambelu, 2009). NMS is not an Eigen value-eigenvector technique like principal component analysis or correspondence analysis. Because of this, an NMS ordination can be rotated, inverted, or centered to any desired configuration. NMS makes no assumption of linear relationship, so it is well suited for a wide variety of data.NMS allows the use of any distance measure of the samples. This makes NMS suitable for analysis of samples and variables and for choosing appropriate variables during the metric development. To discriminate irrelevant macroinvertebrate metrics for detection of human impact was performed using the STATISTICA® software package version 7.1.

4.2.5.9. Canonical correspondence analysis

The analysis of environmental and biological data, canonical correspondence analysis is used to assess the relationship between the two groups of variables (Ambelu et al., 2013). CCA can be applied to detect both species-environment relations, and for investigating the response of species to environmental variables. CCA constructs linear combinations of environmental variables, along which the distributions of the species are maximally separated by Eigen values produced which are measured by CCA. In this case, CCA is one of the most used ordination technique in ecology. The PAST for Windows Version 3.8 software package was used to undertake the CCA analysis.

4.2.6. Limitation of the study

Environmental measurements are highly prone to variation in time and space change. But in this study the sample collection was conducted in April which is considered as dry season. The sample was not collected in wet season in which the effect may be reduced due to the presence of runoff and rainfall which may lead to the occurrence of dilution.

4.2.7. Ethical consideration

Ethical clearance was obtained from institutional Review Board (IRB), Institute of Health, and Jimma University. Formal letter of cooperation was written to Mizan-Aman town administrative office about the objective of the research clearly. Necessary permission for sampling collection was taken from the authority Mizan-Aman town administrative office.

4.2.8. Plan for dissemination and ensuring utilization of finding

The finding will be presented to Jimma University scientific community in a defense and it was submitted to the Jimma University Institute of Health science, faculty of public health, department of Environmental Health Science and Technology. The findings will be also communicated to Mizan-Aman town administrative center, Environmental Protection Agency, municipal and water office to enable them to know the overall status of Showunga River to take appropriate measure.

Chapter 5: Results

5.1. Physicochemical parameters

The physicochemical parameters of Showunga River were summarized into mean, standard deviation, minimum and maximum values among upstream, midstream and downstream sites (Table 3). From the upstream sites, the oxygen level was greater than 7 mgL^{-1}, while turbidity was increasing in the downstream direction where the maximum was at midstream sites. Likewise, BOD was higher in the midstream sites which showed recovery in the downstream sites. Table 3 shows the detail values of physicochemical parameters.

Table 3.Physicochemical parameter results along Showunga River.

Physicochemical parameters	Upstream (n=3)			Midstream (n=5)					Downstream (n=3)		
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
DO(mgL^{-1})	7.92	7.8	7.21	4.47	2.57	3.13	1.28	1.11	3.39	2.12	5.11
pH	7.21	7.27	8.1	6.4	6.28	6.48	9.2	5.4	7.5	6.2	7.2
EC(μscm^{-1})	30.8	32	38	72.4	165.5	160.3	167.7	188.2	145.3	197.1	43.8
Turbidity (NTU)	5.7	6.8	6.3	27	195.3	192.6	174.3	280.6	135	160	45.2
Water T(˚C)	22.4	22.6	22.8	24	27	26	28	29.3	24.5	28.1	23.7
Nitrate (mgL^{-1})	0.74	0.75	0.8	2.94	4.55	5.39	9.64	13.56	8.12	10.7	1.63
Phosphate (mgL^{-1})	0.64	0.73	0.88	1.71	6.75	4.14	8.5	11.1	7.57	8.7	0.97
BOD (mgL^{-1})	6.1	6.6	6.95	31.4	66.7	52.6	86.2	109.35	61.65	60.4	36.7
Chloride (mgL^{-1})	3.3	6.6	8.3	9.9	46	41	46	50.8	38	43.3	7.8
TSS (mgL^{-1})	6	8.4	15.3	73.6	196.6	167.5	642	790.6	419.3	430	131

Kruskal-Wallis test indicated that the mean values of dissolved oxygen, electrical conductivity, turbidity, phosphate, nitrate, chloride, BOD and TSS significantly differed among upstream, midstream and downstream ($p<0.05$),whereas pH, and temperature were not significantly ($p>0.05$) differed among upstream, midstream and downstream water level.

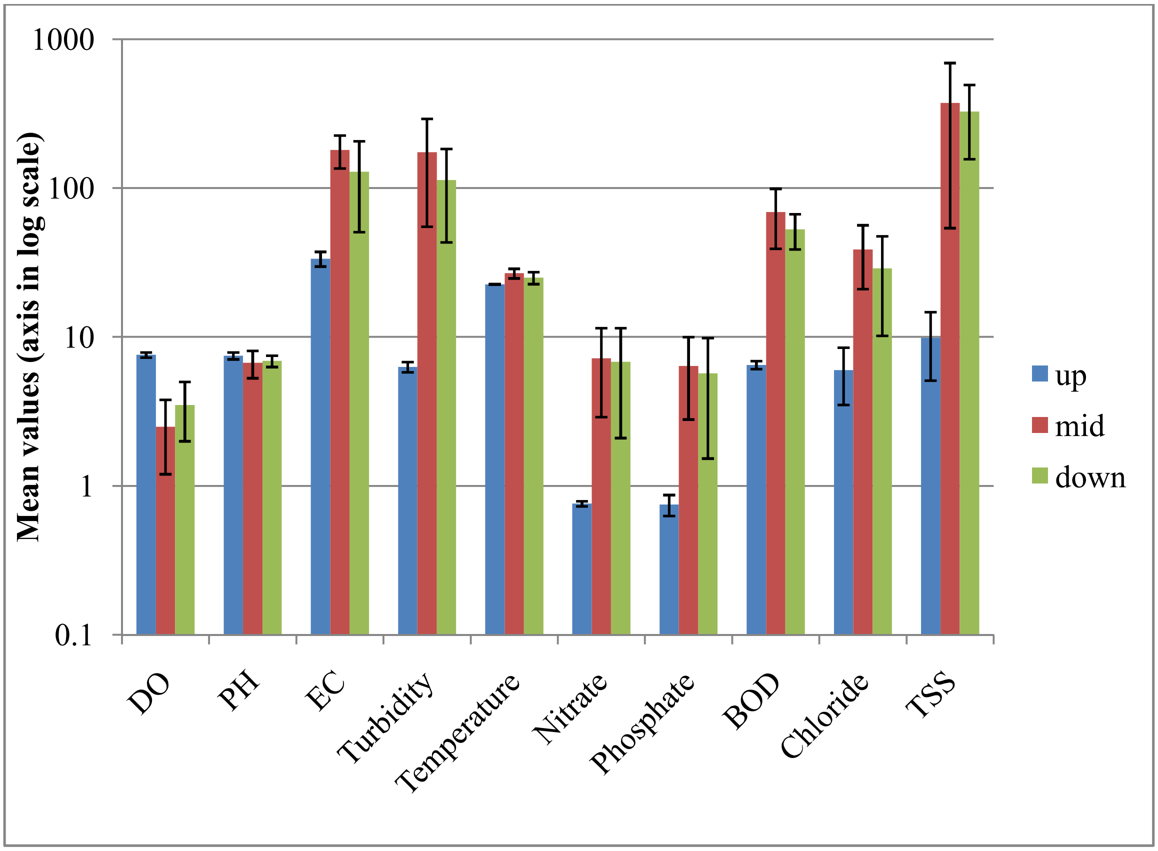


Figure 6:- Mean concentrations of physicochemical parameters at the three different streams (Up-Upstream, Mid-Midstream and Down-Downstream) along Showunga River.

5.2. Physical habitat status and physiographic condition

The habitat evaluation scores at the sampling sites ranged from 43 at S8 to 183 at S1.From the upstream sites except S3, optimal score was recorded (160-200).Likewise, and canopy cover was higher in upstream sites. Based on the Kruskal-Wallis test, habitat score, canopy cover and river discharge significantly differed among upstream, midstream and downstream sites ($p<0.05$).

Table 4.Physical habitat and physiographic conditions of Showunga River.

Habitat condition	Upstream (n=3)			Midstream (n=5)					Downstream (n=3)		
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
Average velocity (m/s)	1.25	1.3	1.1	0.9	0.71	0.41	0.53	0.5	0.61	0.58	0.75
Average water depth (m)	0.95	0.92	0.85	0.75	0.45	0.5	0.35	0.35	0.55	0.61	0.8
Average water width(m)	11.5	10	9.2	8.8	5.35	6.6	5.1	4.55	6.8	6.9	9
River bank width(m)	12.65	12.6	11	10.2	8.6	9.4	6.3	6	7.9	8.1	9.7
Canopy cover (%)	90	70	65	10	0	0	0	0	0	0	50
Habitat score	183	172	116	136	47	53	61	43	73	64	116

Note: habitat score, as optimal (160-200), suboptimal (100-159), marginal (60-99) and poor (<60).

5.3. Macroinvertebrate assemblages

A total of 30 taxa (macroinvertebrate families) with 746 individuals of macroinvertebrate were collected from all sampling sites in which the highest (19 families comprising 172 individuals) and the lowest (3 families comprising 20 individuals) taxa richness was collected at S1 and S5, respectively (Appendix. 3). Upstream have significantly better macroinvertebrate assemblages (23 taxa) than midstream (13 taxa) and downstream (19 taxa).

Beatidae was common taxa in the three stream while Physidae and Planorbidae were collected only in the midstream and downstream exclusively S11. However Perlidae, Caenidae, Athericidae, Psychomyiidae, Chloroperlidae, Libellulidae, Heptageniidae as well as Calopterygidae were found only in the upstream sites. From the eleven sites Physidae was the most dominant (136 individuals) which were mostly collected at midstream, whereas no one snail collected at upstream sites. Generally, taxa richness was tended to declining in the downstream direction where the minimum was at midstream sites (Table 5).

.Based on Kruskal-Wallis multiple comparison test, the total taxa richness significantly differed (p-value <0.05) among upstream, midstream and downstream. The metric negatively correlated with nitrate, phosphate, BOD_5, and chloride.

Table 5.Relative abundance of macroinvertebrate assemblages among the three stream category

Family	**Stream Category**		
	Upstream	**Midstream**	**Downstream**
Gomphidae	39	7	0
Aeshnidae	48	6	0
Coenagriidae	7	4	2
Velidae	12	4	5
Perlidae	2	0	0
Beatidae	4	2	3
Gyrinidae	8	0	2
Notonectidae	7	0	5
Corixidae	3	2	8
Chironomidae	6	35	18
Belostomatidae	8	8	4
Heptageniidae	8	0	0
Caenidae	14	0	0
Hydrophilidae	6	0	6
Hydropsychidae	11	0	2
Physidae	0	136	37
Libellulidae	11	0	0
Elmidae	7	0	8
Naucoridae	8	8	9
Chloroperlidae	9	0	0
Calopterygidae	13	0	0
Planorbidae	0	30	30
Lymnaeidae	0	17	16
Calopterygidae	13	0	0
Tipulidae	0	0	3
Oligochaeta	0	0	6
Culicidae	0	6	4
Tabanidae	0	0	3
Psychomyiidae	14	0	0
Athericidae	11	0	0
Total taxa	23	13	19

5.3.1. Macroinvertebrate indices

The Shannon diversity index varied among the sampling sites. The lowest value (0.8) was at S7, while the highest value (2.6) determined at S1, and Evenness exceeded at S5. When species composition was compared, diversity was highest at upstream with slight difference from downstream and lowest at midstream. Although midstream sites are least diverse, its evenness is comparable with upstream. Though in downstream sites are more diverse than midstream and less diverse than upstream sites. EPT richness was zero at S5, S6.S7, S8, S9 and S10. Relatively dominance by EPT at upstream, whiles except Beatidae no one EPT collected at midstream sites (Table 6).The EPT richness negatively correlated with nitrate, phosphate, chloride, and BOD_5 (Annex.9).

Table 6.Ecological quality in the indices analysis results from the sampling sites along Showunga River.

	Sampling sites										
Indices	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
Taxa richness	19	12	10	7	3	5	4	4	5	6	13
Individuals	172	63	41	23	20	24	83	145	41	74	60
Shannon_H'	2.62	2.16	1.71	1.97	1.04	1.39	0.89	1.09	1.27	1.66	2.46
Dominance_D	0.09	0.15	0.17	0.2	0.36	0.29	0.52	0.39	0.35	0.2	0.09
Evenness-E	0.77	0.72	0.72	0.79	0.95	0.8	0.61	0.74	0.71	0.88	0.9
EPT richness	51	10	3	1	0	0	0	0	0	0	5
FBI	2.8	3.2	5.39	4.56	8.5	6.48	7.72	6.96	5.65	6.64	5.03
BMWP	89	84	48	45	13	23	11	11	16	17	67
% Diptera	11.1	16.6	22	14.2	66.6	40	25	30	20	33.3	15.3
CLI	0.73	1.16	1.4	2	4.6	2.8	3.5	3.5	2.8	2.3	1

The three streams are compared with respect to family richness, dominance, H', BMWP, FBI, and EPT richness using standard err and 95% confidence interval plots of macroinvertebrate in upstream, midstream and downstream sites. The result presented in the following Figure Fig.7).

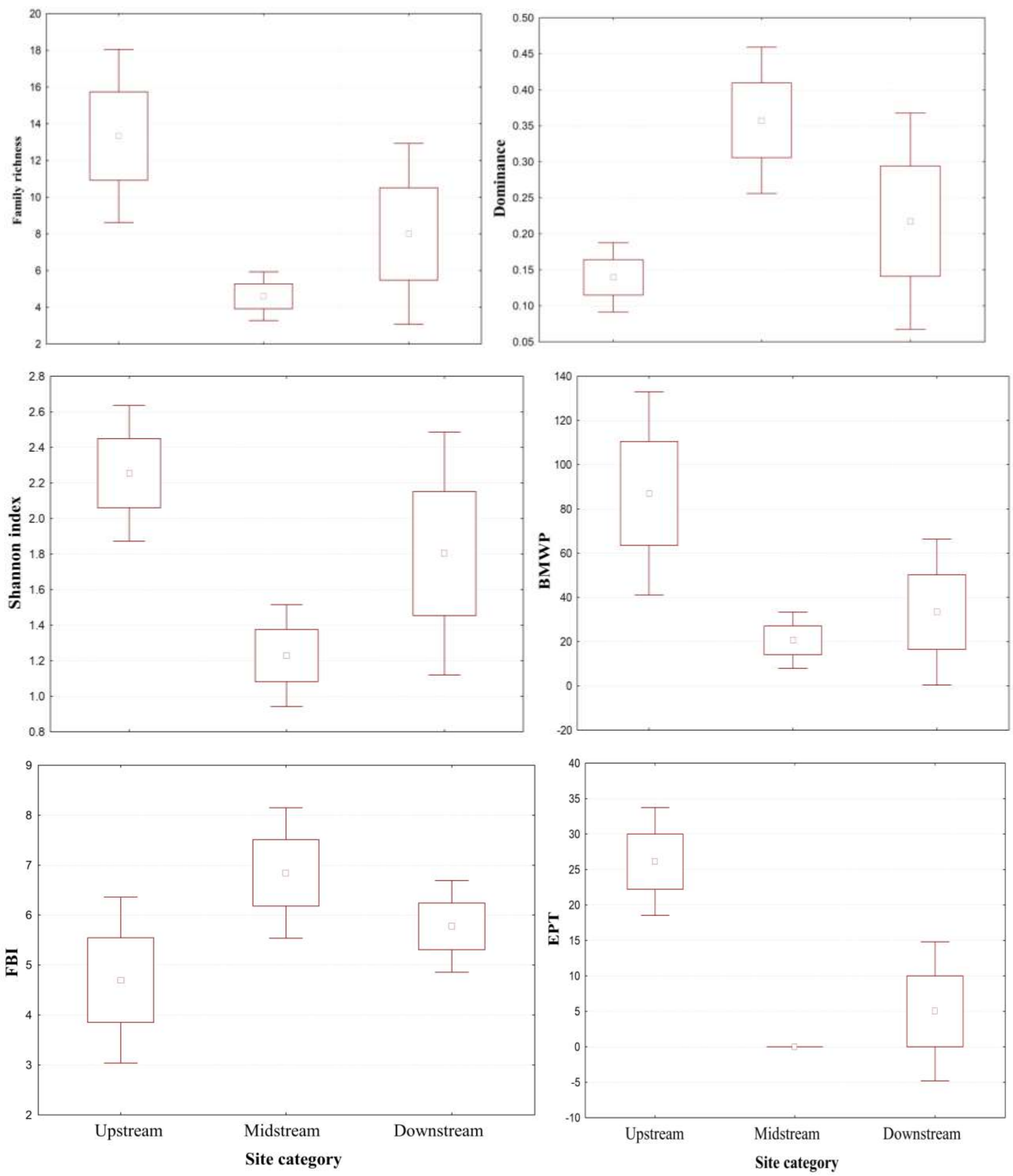


Figure 7: Box (standard err) and whisker (95%) confidence interval) plots of macroinvertebrate indices in upstream, midstream and downstream sites from the town

Family Biotic Index was used to assess the pollution status of the river using macroinvertebrate data, and the result is presented in Table 6. FBI varied from 2.8 at S1 to 8.5 at S5 among the sites where specimens were collected and relatively the highest value recorded at midstream sites. When the three stream categories are compared with respects to their FBI mean values, upstream value (3.7), followed by downstream (5.7) and midstream (6.8). The index was positively correlated with BOD_5, nitrate, phosphate, and chloride (Annex.9)

Biological monitoring working party score ranged from 11at S8 to 89 at S1 from the sites (Table 6). The BMWP score in stream category was measured mean values of 73.6, 20.6 and 43.3 for upstream, midstream and downstream, respectively. The score was negatively correlated with nitrate, BOD_5, phosphate, and chloride (Annex.9).

Diptera was collected at S5, S6, S8 and S10 whereas no specimen at S1 and S2. Diptera comprising mainly Chironomidae and Culicidae was abundant group in urban sites. Low %EPT and high %Diptera was collected at midstream sites (Fig.8).

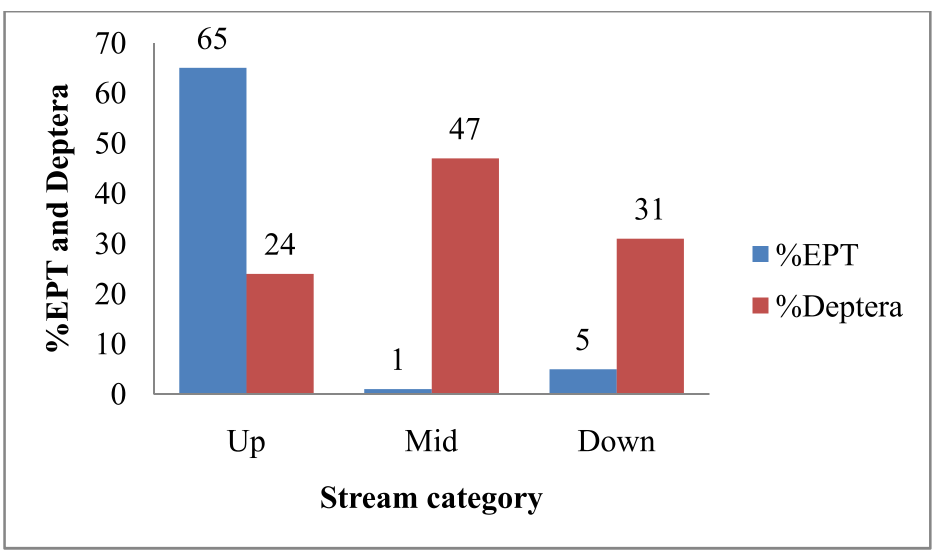


Figure 8:- .Both %EPT and %Diptera in the three different streams (Up-Upstream, Mid-Midstream and Down-Downstream) along Showunga River

Macroinvertebrate community loss index was measured the loss of taxa in the study site respect to the reference condition. Relatively higher at S8 and lowest at S1 (Table 6). A CLI value, at midstream is the highest 3.28; followed by downstream with 2 and upstream with 1 (Fig.9).

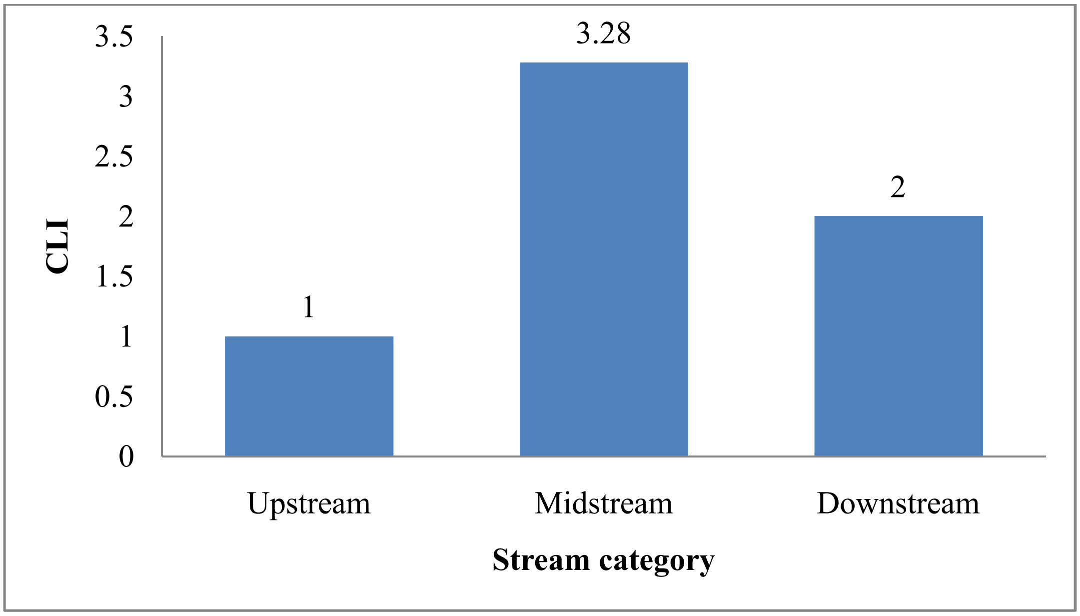


Figure 9.Ecological quality variations in community loss index was at upstream, midstream and downstream along Showunga River

Based on Kruskal-Wallis multiple comparison test, the total family richness, BMWP and EPT indices significantly differed (p-value <0.05) from the midstream sites but not from the downstream sites.

5.4. Multivariate analysis

Cluster analysis using benthic macroinvertebrate data groped S1 and S2, S3 and S11, S5 and S6 where sampling resulted in low taxa collected (i.e. S7 and S8) in separate clusters but placed S4, S9 andS10 in their own groped (Fig.10)

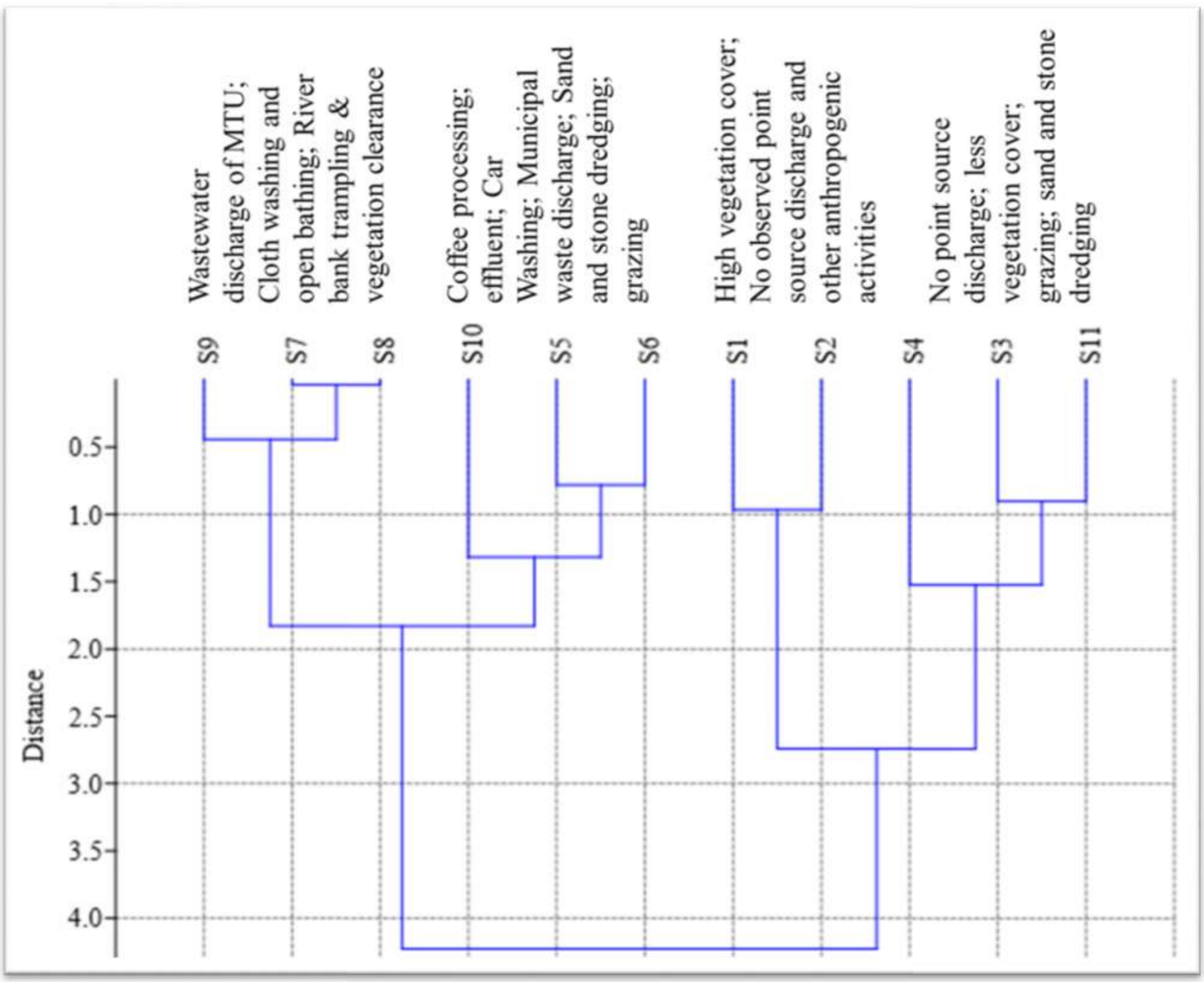


Figure 10.Hierarchical clustering macroinvertebrates data using Ward's clustering algorithm and human activities within the sites of Showunga River.

Cluster analyses using physicochemical data groped S2 and S3, S5and S6, S8 and S10 as well as S4 and S11in four different clusters while S1, S7 and S9 were placed separately in their own groups (Fig. 11)

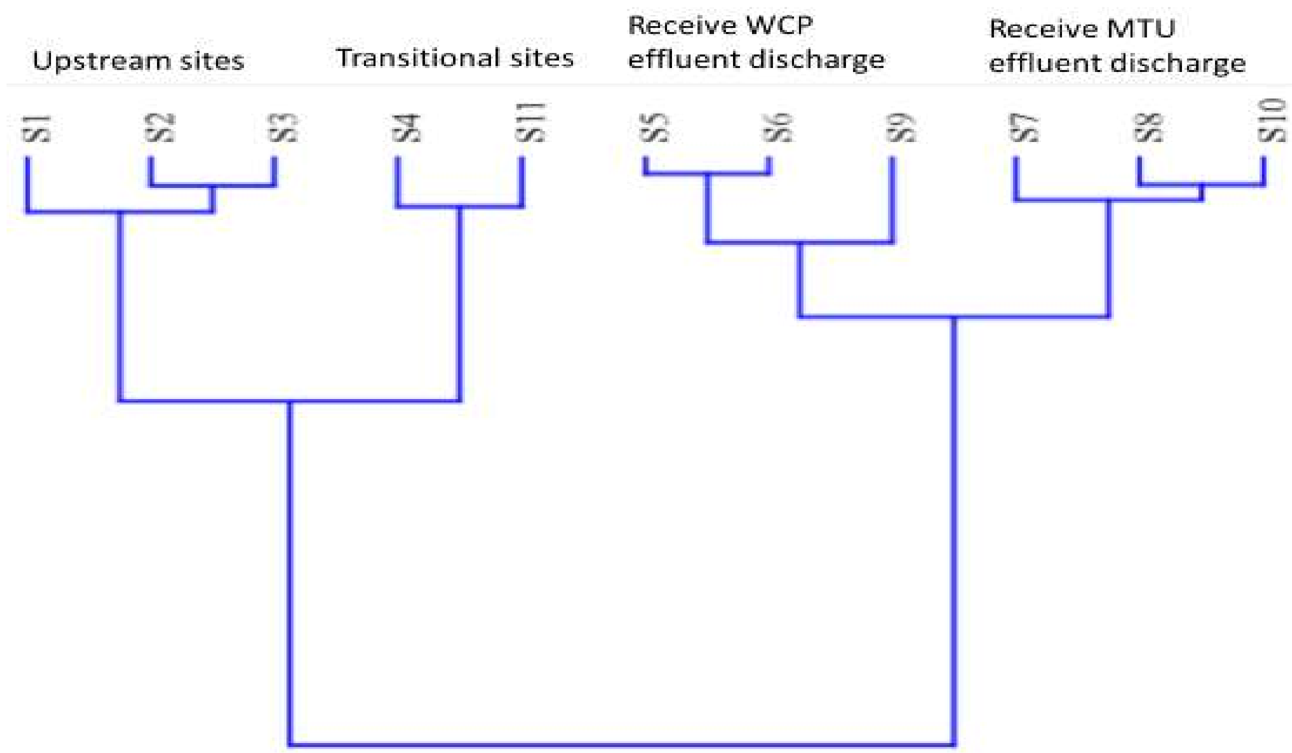


Figure 11:- . Hierarchical clustering of physicochemical data using Ward's clustering algorithm along Showunga River.

None metric multidimensional scaling plots using macroinvertebrate data. Three major groupings, where sites circled in green (S1, S2, S3, S4 and S11) are with better macroinvertebrates assemblage, in red (S5andS6) are impacted sites, and while in blue circle (S7, S8 andS10) are those receiving point source discharges (Fig. 12)

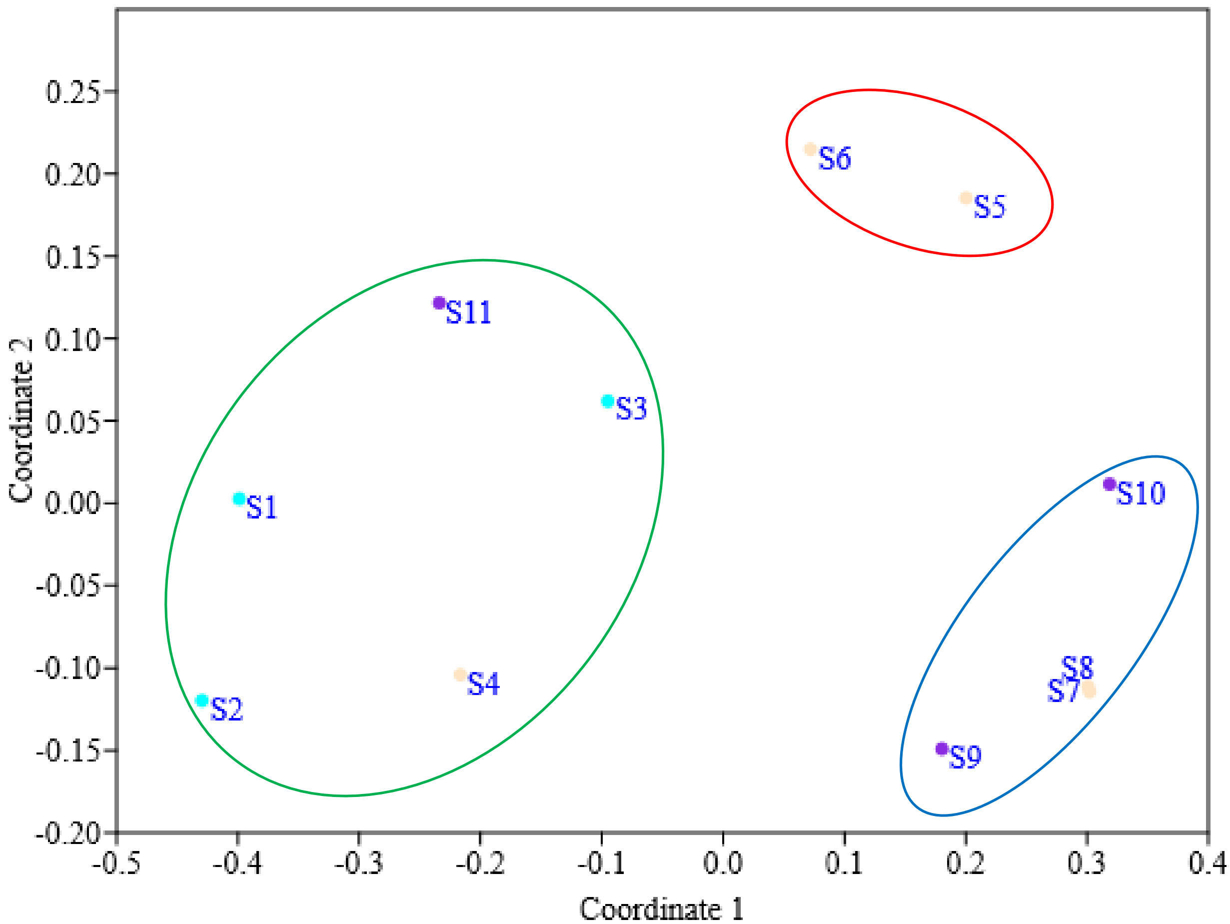


Figure 12.None metric multidimensional scaling plots using macroinvertebrate data along Showunga River

CCA tri plot for benthic macroinvertebrates (Fig. 13) indicated similarity between S1 and S2, S7 and S8, as well as among S3, S4 and S11 where as strong similarity between S5 and S6.

Axis 1 CCA tri plot macroinvertebrate data clearly separated S1, S2, S3 and S11 from the other sampling points while Axis 3 separated S5and S6, S7and S8 from other indicating that the sampling sites were different from other sampling sites in terms of water quality. The direction proportional influence of BOD_5, EC, TSS, nitrate, chloride and turbidity pointing S5, S6, S7, S8, S9 andS10.The directions proportional influence of DO were pointing S1, S2 S3 S4 and S11.

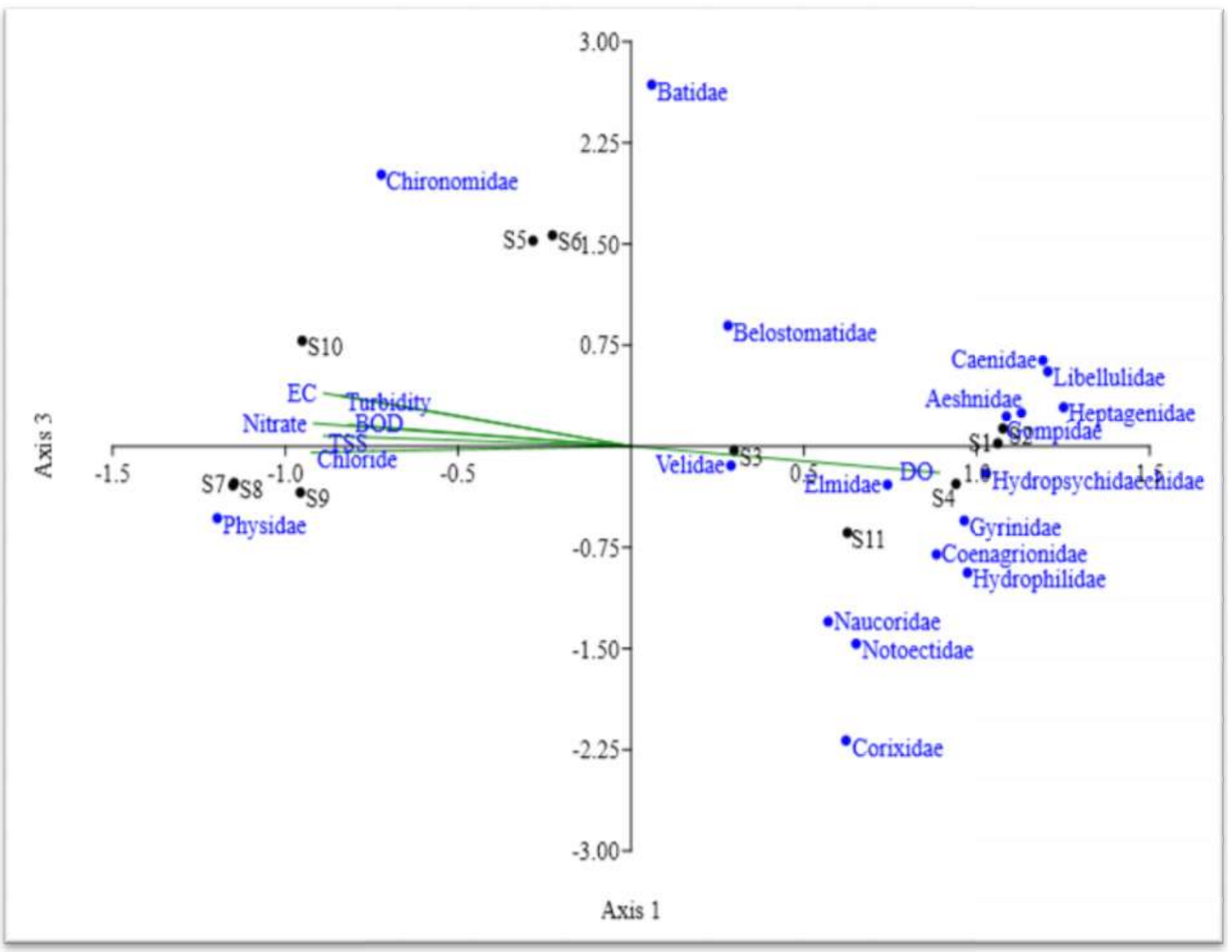


Figure 13. CCA tri plot constructed from the 1st and 3rd axis of benthic macroinvertebrates taxa with environmental variables and the corresponding sampling sites at Showunga River.

Chapter 6: Discussion

Clean water is an essential requirement for the establishment and maintenance of ecological integrity(Berger et al., 2017). Water resources provide valuable food through aquatic life cycle, irrigation for agriculture productions and animal watering(Bostanmaneshrad et al., 2018). However, improper liquid waste discharge and solid wastes produced by human settlements and industrial activities leads to negative effect to human health and environment as pollution to river water source(Ambelu et al., 2013).

This study has tried to identify major stressors of the Showunga River posed by the Mizan-Aman town. For example, BOD_5, which is a known indicator of organic pollution, was found to be greater in all midstream sites, where the highest concentration (109..3 mgL^{-1}) is recorded at S8 .This high BOD_5 might be due to the waste discharge from MTU, coffee effluent, animal waste from the catchment and disposal of solid and liquid wastes from Mizan town. It is quite interesting to note that the DO is less than 3 mgL^{-1} in all the midstream sites except S4, which is a transitional site to the stress. However, in the downstream sites, the BOD_5 values started to decline as it is evident in site S11.

Similar studies done in a fast growing east African city (Troyer et al., 2016) and disturbance of the ecological quality of Awetu River as a result of discharge of municipal wastes, and urban runoff (Hailu, 1997) also indicated that cities were found to be major ecologicl distruptors due to the twon discharges.

Specifically, at the point where the river crosses the town DO value fallen below $3mgL^{-1}$. This is very critical for normal ecological function of surface-water ecosystems. As implicated by U.S. Environmental Agency, $DO>5mgL^{-1}$ is considered favorable for growth and activity of most aquatic organisms; $DO<3mgL^{-1}$ is stressful to most aquatic organisms, while the standard for surface water of Ethiopia $\geq 4mgL^{-1}$.

All the sampling stations at the point where the river crosses the town showed higher BOD_5 values compared to before the river cross the town and after the river cross the town. This reveals clearly that midstream was experiencing a higher level of pollutions problem than upstream and downstream. This might be due to effluent discharged from various sources from

Mizan-Aman town, receive sewage discharge from the surrounding community and coffee effluent through point and non point source.

The relatively higher load of pollution correlated closely with decreased pollution sensitive species diversity (like EPT) and increased abundance of number certain pollution tolerant macroinvertebrates like Chironomidae , Physidae, Planorbidae, in the midstream sites of Showunga River.

The result of the current study were quite concurrent with a few earlier studies(Berger et al, 2018; Troyer et al., 2016;Arimoro & Muller, 2010), which reported that diversity or richness of tolerant species increased and sensitive species dominance decreased considerably a result of anthropogenic activity such as waste discharge ,unplanned urbanization, sand and stone derange ,coffee effluent and other interrelated activity.

The concentration of nitrate was grater the critical values in the entire sampling site except upstream sites and from downstream at S11.Nitrate concentration of unpolluted surface water seldom exceeds 0.1 mgL^{-1}, and whenever it has above $0.2mgL^{-1}$ enhances eutrophication(Ambelu et al., 2013). However, The required amount of nitrate in water for animal drinking use is set as $100mgL^{-1}$ and for irrigation water, FAO recommended maximum concentration of $30mgL^{-1}$ and a standard set concentration below $5mgL^{-1}$ poses either in plant or soil (Wang et al, 2017), whereas the ambient standard for Ethiopia surface water quality guide lines (< 50 mgL^{-1}). The intense coffee waste process, damping of various solid wastes and waste water discharge from the town in midstream sites could have been the major source of nutrients.

Diversity indices like Shannon were used in order to estimate the level of ecological disturbance along Showunga River. These indices can be used in order to show relative differences from one sampling sites to the other sites with the same aquatic system (Shannon,1948). Shannon index values greater than three indicate unpolluted water, while less than one values indicate severe pollution and intermediate values are characteristic of moderately polluted conditions (Shannon,1948).Consequently, upper and down sites are moderately polluted ,while midstream ,which is severely polluted according to (Shannon,1948),because values in upper segment sites were in between 3 and 1 where the urban land of the sites are less than one. The highest level of diversity was found at upstream, compared to midstream and downstream along this river. This might be attributed to better physical habitat and water quality condition supported by (Berger et al., 2017) which states that taxa richness increasing with habitat diversity, suitability, and water quality. This might also be attributed to different in ecoregions comprising the upstream, midstream and downstream sites. It shows that the greater diversity indices reflect the good quality of the river. This directly indicates that upstream of the river was less polluted than midstream and downstream regarding the diversity indices. In addition to biotic indices providing an overall clear assessment the benthic community, the examination of single groups of organisms and their relative abundance is seen to be a sensitive approach for detection of community changes in river ecosystems (Berger et al., 2017).

In this study abundance of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddis flies) taxa showed a general decline downstream direction, where the lowest were at midstream sites and might indicate to the decline physical habitat and water quality(Ambelu et al., 2013). At midstream sites only Physidae, Planorbidae and Chironomidae predominant taxon, though in upstream, taxa other than EPT and Chironomidae were present abundantly. This indicated that the river ecosystem showed impairment, possibly due to pollutants released into the midstream of Showunga River from Mizan-Aman Town. This might have caused the sharp decline of the most sensitive macroinvertebrate groups such as Ephemeroptera, Plecoptera, and Tricopterans due to incapability to tolerate higher load of pollution. This indicates that midstream of the river is relatively polluted more than upstream and downstream due to various solid and liquid waste discharge from Mizan-Aman town .

Pollutions are not the only cause for disappearance of macroinvertebrates, but physical habitat quality such as substrate composition, and vegetation protections (Shi et al., 2017).Thus, the poor physical habitat and water quality condition might be responsible for failure in collected benthic macroinvertebrates taxa from midstream. As reported by (David et al., 2007) anthropogenic impacts and urban activities have long been negative affect aquatic habitat this is true for this study. The dramatic impacts that humans have had on water ecosystem is exemplified in the midstream, the degree of which varied on values of BMWP and FBI (Berger et al., 2017 ; Ambelu et al., 2013). The change of the hydrological regime has therefore increased the human impact such as untreated waste discharge, and intensive anthropogenic practices like deforestation, sand and stone dredging, vegetation clearance, grazing and river bank trampling were the most common cause of catchment degradations of the river in the midstream part of the watercourse, which could have also contributed to a lower diversity of sensitive taxa like EPT.

Caenidae was confined to S1andS2 associated with vegetations and found to be more sensitive to water quality compared to Beatidae. A previous study investigating the relationship between macroinvertebrates and environmental factors by (Mereta, 2013) suggested that Caenidae were highly correlated with vegetation and mainly found at sites with good water quality.

The macroinvertebrates community structure and function change naturally along a river according to the stream order, which controls food supply, light and temperature as pointed out in the river continuum concept (Statzner & Higler, 1985).Nevertheless, the changes observed at midstream sites, in the present study at Showunga River may not be natural, because of the total disappearance of the sensitive taxa and some other taxa and, the dominance of the few more tolerant taxa.

The finding of the present investigation clearly shows that upstream better ecological integrity than midstream. However most downstream sites especially S11, there is enrichment macroinvertebrate diversity, water quality and habitat status compared with the midstream sites. This might be explained the river self purification, dilution and decrease human impact further down the pollutant loads(Gupta et al., 2011).

Chapter 7: Conclusions and Recommendations

7.1 Conclusion

Showunga river ecological status assessment based on physicochemical and biological data revealed that the higher level of BOD, nitrate, phosphate and lower DO as well as lower macroinvertebrate assemblages occur at the midstream, where much influence of urban pressure, due to solid and liquid wastes disposal, Coffee processing effluents, sand and stone dredging, poor farming method, distraction of riparian forest, car and cloth washing, and open bathing were the major environmental stressors responsible for ecological deterioration. Poorly or untreated waste water discharge from MTU was found to be one important point source of pollutions to the river whose effluent can negatively affected at midstream users and ecosystem. This correlates with higher values of pollution indicating nutrients (nitrate and phosphate) .Generally this study shows that at midstream was relatively more polluted due to the influence of urban pressure mentions above has directly caused the considerable reduction of macroinvertebrate diversity.

7.2. Recommendations

- Direct wastewater discharge into the river is one of the major problems we observed. Hence, the Mizan-Aman town administration needs to have treatment plant and treat the wastes before direct discharge.
- Attempts to improve ecological status of the Showunga River should be regulate point source loading such as waste water discharge, coffee effluent from the town and effective water shaded management which includes riparian forest improvement to minimize non-point source loadings.
- Similar study considering season variability is highly recommended to have the seasonal trends of the ecological situations of the River.
- Reducing directly piped drainage connection using infiltration and retention as well as proper solid waste management might be a logical step in the mitigation of the impacts of Mizan-Aman town on Showunga River ecological status quality.

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Annex I

Physicochemical analysis results with minimum (Min) maximum (Max), mean and standard deviation (STDV) at upstream, midstream and downstream sites along Showunga River

Physicochemical parameters	Upstream (n=3)				Midstream (n=5)				Downstream (n=3)			
	Min	Max	Mean	STDV	Min.	Max	Mean	STDV	Min	Max	Mean	STDV
DO (mgL^{-1})	7.2	7.9	7.6	0.3	1.1	4.4	2.5	1.3	1.1	5.1	3.2	2
pH	7.2	8.1	7.5	0.4	5.4	9.2	6.7	1.4	6.2	7.5	6.9	0.6
EC (μscm^{-1})	30.8	38	33.6	3.8	72	188.2	180.8	45.1	43.8	197.1	128.7	77.9
Turbidity (NTU)	5.7	6.8	6.3	0.5	27	280.6	173.9	118.7	45.2	160	113.4	70.1
Temperature (˚C)	22.4	22.8	22.6	0.1	24	29.3	26.8	2	23.7	28.1	25	2.3
Nitrate (mgL^{-1})	0.7	0.8	0.76	0.03	2.9	13.5	7.2	4.3	1.6	10.7	6.8	4.7
Phosphate (mgL^{-1})	0.6	0.8	0.75	0.12	1.7	11	6.4	3.6	0.9	8.7	5.7	4.17
BOD (mgL^{-1})	6.1	6.9	6.5	0.4	31.4	109.3	69.2	30	36.7	61.65	52.9	14
Chloride (mgL^{-1})	3.3	8.3	6	2.5	9.9	50.8	38.7	17.7	7.8	43.3	28.9	18.7
TSS (mgL^{-1})	6	15.3	9.9	4.8	73.6	790.6	374	320	131	430	326	169

Annex. II

Longitude, latitude and altitude along the sampling sites of Showunga River

Coordination	Sampling sites										
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
Longitude (N)	6° 57'5.1	6° 57'59	6° 57'58	6° 57'56	7° 57'57	7° 58'0.9	7° 58'5	7° 58'5	7° 58'30	7° 58'54	7° 58'62
Latitude(E)	35° 34'28	35° 34'23	35° 34'20	35° 34'17	35° 34'11	35° 34'05	35° 34'22	35° 34'02	35° 33'57	35° 33'37	35° 33'09
Altitude(m)	1416	1375	1668	1363	1356	1368	1332	1304	1278	1225	1271

Annex. III

Qualitative habitat conditions category and scale values result along Showunga River

Habitat status	Sampling sites										
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
Epifaunal substrate	18	17	10	14	3	6	8	5	8	7	12
Embeddeddness	17	S16	14	16	2	12	4	4	7	5	15
Velocity/Depth regime	19	17	15	12	6	7	5	7	8	7	14
Sediment deposition	19	18	13	12	7	2	7	2	10	7	13
Channel flow status	18	17	9	10	6	4	2	2	6	5	8
Channel Alteration	19	18	9	12	5	5	3	5	8	4	9
Frequency of riffle	19	17	10	12	8	4	5	2	8	7	11
Bank Stability	18	18	12	10	4	1)	2	2	5	7	14
Vegetative protection	18	18	14	11	2	3	2	2	9	6	16
Riparian vegetative	18	16	11	12	2	2	6	2	7	8	14
Total Habitat Score	183	172	116	136	47	53	61	43	73	64	111

Annex. IV

Relative abundance of benthic macroinvertebrates assemblage collected from the sampling sites along Showunga River.

Family	Stream Category											BMWP Score	TS
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11		
Gompidae	22	17	0	7	0	0	0	0	0	0	0	8	3
Aeshnidae	23	15	0	6	0	0	0	0	0	0	0	8	3
Coenagrionidae	4	3	1	4	0	0	0	0	0	0	2	8	8
Velidae	0	0	12	0	0	4	0	0	0	0	5	6	5
Perlidae	2	0	0	0	0	0	0	0	0	0	0	10	2
Beatidae	4	0	0	0	5	0	0	0	0	0	3	4	5
Gyrinidae	6	0	2	0	0	0	0	0	0	0	2	5	4
Notonectidae	2	0	5	0	0	0	0	0	0	0	5	5	5
Corixidae	0	0	3	2	0	0	0	0	0	0	8	5	5
Chironomidae	0	0	6	0	9	11	6	9	2	16	0	2	8
Belostomatidae	0	0	8	1	7	0	0	0	0	0	4	6	10
Heptageniidae	8	0	0	0	0	0	0	0	0	0	0	10	3
Caenidae	9	5	0	0	0	0	0	0	0	0	0	7	6
Hydrophilidae	4	2	0	0	0	0	0	0	0	0	6	5	5
Hydropsychidae	7	3	1	0	0	0	0	0	0	0	2	5	4
Physidae	0	0	0	0	0	0	57	79	22	15	0	3	8
Libellulidae	8	3	0	0	0	0	0	0	0	0	0	8	2
Elmidae	3	3	1	0	0	0	0	0	0	0	8	5	4
Naucoridae	6	0	2	2	0	0	0	0	3	0	6	5	5
Chloroperlidae	9	0	0	0	0	0	0	0	0	0	0	10	1
Calopterygidae	9	4	0	0	0	0	0	0	0	0	0	8	6
Planorbidae	0	0	0	0	0	0	17	43	9	21	0	3	7
Lymnaeidae	0	0	0	0	0	0	3	14	4	12	0	3	6
Ceratopogonidae	16	3	0	0	0	0	0	0	0	0	0	6	6
Tipulidae	0	0	0	0	0	0	0	0	0	0	3	3	3
Oligochaeta	0	0	0	0	0	0	0	0	0	6	0	1	8
Culicidae	0	0	0	0	4	2	0	0	0	4	0	5	8
Tabanidae	0	0	0	0	0	0	0	0	0	0	3	5	5
Psychomyiidae	12	2	0	0	0	0	0	0	0	0	0	5	2
Athericidae	8	3	0	0	0	0	0	0	0	0	0	8	4

Note: BMWP = Biological Monitoring Working Party (sensitivity) score. TS= tolerance score

Annex. V

Evaluation of water quality using the macroinvertebrates BMWP scoring system (Walley and Hawkes, 1997)

BMWP score	Category	Interpretation
0-10	Very poor	Heavily polluted
11-40	Poor	Polluted or impacted
41-70	Moderate	Moderately impacted
71-100	Good	Clean but slightly impacted
>100	Very good	Unpolluted, un-impacted

Annex. VI

Evaluation of water quality using the macroinvertebrates FBI (Hilsenhoff, 1988)

FBI	Water quality	Degree of Organic Pollution
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	very good	Possible slight organic pollution
4.26-5.00	Good	Some organic pollution probable
5.01-5.75	Fair	Fairly substantial pollution likely
5.76-6.50	Fairly poor	Substantial pollution likely
6.51-7.25	Poor	Very substantial pollution likely
7.26-10.00	Very poor	Severe organic pollution likely

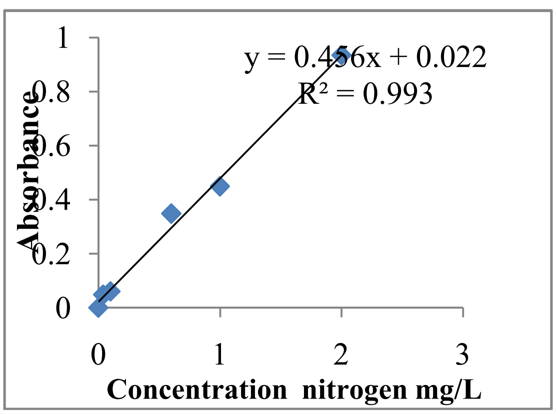
Annex VII

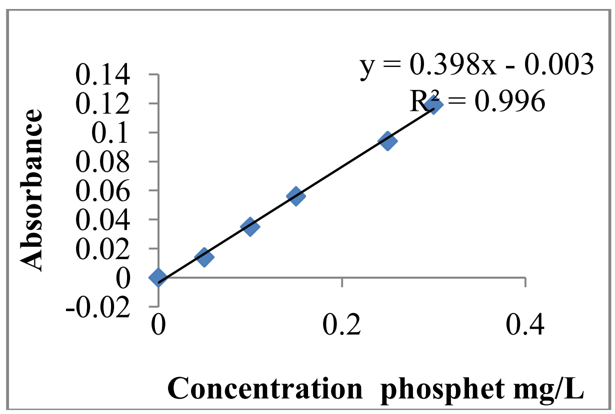
Interpretation of proportion of counts composed of taxa tolerant to organic -pollution at the sampling sites (Kelly and Whitten, 1995).

Proportion of count	Interpretation
<20% total valves belonging to tolerant taxa	Free of significantly organic pollution
21-40% total valves belonging to tolerant taxa	Some evidence of organic pollution
41-60% total valves belonging to tolerant taxa	Organic pollution likely to contribute significantly to eutrophication of site
>61% total valves belonging to tolerant taxa	heavy organic pollution at the site

Annex VIII

Determination of calibration curve for nutrient





Annex. IX

Correlations among physicochemical, habitat condition and indices

Correlations										
	Taxa richness	Individuals	H'	Dominance	Evenness	EPT	FBI	BMWP	Diptera%	CLI
DO	0.967	0.992	0.881	-0.851	-0.843	.997*	-0.974	0.951	-0.836	-0.893
pH	0.99	0.971	0.929	-0.906	-0.775	0.982	-0.993	0.98	-0.894	-0.939
EC	-1.000*	-0.937	-0.965	0.948	0.698	-0.954	1.000**	-0.996	0.939	0.972
Turbidity	-1.000*	-0.934	-0.967	0.951	0.693	-0.952	1.000**	-.997*	0.942	0.974
Temp	-.998*	-0.904	-0.984	0.972	0.635	-0.925	0.996	-1.000**	0.965	0.988
Nitrate	-0.947	-.998*	-0.844	0.811	0.879	-1.000**	0.955	-0.927	0.795	0.858
Phosphate	-0.964	-0.994	-0.874	0.844	0.85	-.998*	0.97	-0.947	0.829	0.887
BOD	-0.992	-0.968	-0.933	0.91	0.768	-0.98	0.995	-0.982	0.898	0.942
Chloride	-0.996	-0.956	-0.948	0.927	0.74	-0.97	.998*	-0.99	0.917	0.956
TSS	-0.966	-0.993	-0.878	0.848	0.846	-.998*	0.972	-0.949	0.833	0.89
AV	0.858	0.988	0.713	-0.67	-0.96	0.978	-0.871	0.827	-0.649	-0.731
RD	1.000*	0.918	0.978	-0.963	-0.66	0.937	-.999*	.999*	-0.956	-0.983
AWW	1.000**	0.924	0.974	-0.959	-0.673	0.943	-.999*	.999*	-0.95	-0.979
RWB	0.964	0.993	0.875	-0.845	-0.849	.998*	-0.971	0.947	-0.829	-0.887
CC	0.98	0.984	0.905	-0.878	-0.812	0.992	-0.985	0.967	-0.865	-0.916
HS	0.991	0.869	0.995	-0.987	-0.575	0.894	-0.987	.997*	-0.982	-.997*

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Note: AV= Average velocity, RD= river depth, AWD=Average water depth, AWW=Average water width, RWB = river water bank, CC =canopy cover, HS= habitat status

Annex. X

Photo showing anthropogenic activities that impacted part of Showunga River