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FACULITY OF CIVIL AND ENVIROMENTAL ENGINEERING

ENVIROMENTAL ENGINEERING CHAIR

ANALYSIS OF SPATIAL VARIATION OF PHYSICO-CHEMICAL PARAMETERS AND MACRO INVERTEBRATE METRICS IN RELATION TO SHONGA RIVER WATER QUALITY STATUS IN MIZAN-AMAN TOWN, SNNPR, ETHIOPIA

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A Thesis Submitted To Faculty of Civil And Environmental Engineering, Jimma Institute of Technology, Jimma University in Partial Fulfillment for the Requirements of the Degree of Masters of Science in Environmental Engineering

MAY, 2018

JIMMA, ETHIOPIA

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DECLARATION

This thesis research is my original work and has not been presented for a degree in any other university.

This thesis entitled "Analysis of spatial variation of physico-chemical parameters and macro invertebrate metrics in relation to shonga river water quality status in Mizan-Aman Town Bench Maji zone south western, Ethiopia." has not been presented for a Masters or any other Degree in Jimma Institute of Technology (JIT) or any other university.

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DEDICATION

I dedicate this work to my family and friends. Thank you so much for your endless prayers and encouragement to hold firm to my dreams.

STATEMENT OF AUTHOR

First, I declare that this Thesis which entitled by "Analysis of spatial variation of physico-chemical parameters and macro invertebrate metrics in relation to shonga river water quality status in Mizan-Aman Town, SNNPR, Ethiopia" is my own work and that all sources of materials used for writing it have been duly acknowledged. This thesis has been submitted to school of graduate studies of Jimma University faculty of Civil and Environmental Engineering in partial fulfillment of the requirement for the degree of Master of Science and is deposited at the library of the University to be made available to borrowers under the rule and regulation of the library.

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ABSTRACT

Fresh water ecosystems are used to monitor and evaluate water quality and macro invertebrate as a key component. The Physico-chemical parameters and macro invertebrate fauna of Shonga River were studied from August 2016 to December 2016. Surface water and benthic macro invertebrate samples were collected from five sampling stations along the river. This covers the area lying between 1363 m.a.s.l at SR1 to 1326 m.a.s.l at SR5. The Shonga river crosses a wide area of farmlands and MTU, Mizan campus territory especially from SR2 to SR4 sampling sites and is mostly exposed to frequent runoff from Mizan to Aman highway and both the left and right side of MTU, point and non-point sources of waste to river. The samples were collected along the flow of the river from five sampling sites. SR1 sites were taken as the reference based on USEPA protocol. Benthic macro invertebrates were sampled from riffle or pool areas of the river and were identified to the family level following the standard methods in the laboratory. Physico-chemical parameters listed below were analyzed on site by employing were determined using in standard methods for examination of wastewater using multi parameters analyzer instrument. SPPSS version.16 and Excel software were employed for statistical analysis of samples. The range values of Surface water temperature was 19.32 to 22.12°C, Dissolved Oxygen 4.19 to 7.55mg/l, Biological Oxygen Demand 4.24 to 7.75mg/l, Electro Conductivity 55.07 to 71.44 us/cm and Alkalinity 32.32 to 35.60 mg/l. Generally of eight taxa comprising of 1063 individual species were recorded. The aquatic Diptera Chironomidae were the most abundant accounts 14 %, followed by Elmidae which accounted for 7.53% while Ephemerilidae was 7.15% of the percentage number. Finally, FBI value were classified water quality both of the upstream sites SR1 and downstream SR5 are Excellent and very good respectively, while it classified all the rest midstream sites were good to fair water quality.

Key words*:* Benthic macroinvertabrates, biotic index, physico-chemical, tolerance value, Shonga River.

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ACRONYMS

ANOVA	Analysis of Variance
APHA	American Public Health Association
BOD	Biologically Oxygen Demand
BI	Biotic Index
CCA	Canonical Correspondence Analysis
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
EC	Electrical conductivity
EPA	Environmental Protection Agency
EPT	Ephemeroptera (mayfly), Trichoptera (caddisfly) and Plecoptera (stonefly)
ERA	Ethiopian Road Authority
FBI	Family Biotic Index
FPOM	Fine Particulate Organic Matter
FR	Flow Rate
GPS	Global Positioning System
IBI	Integrated Biotic Index
JU	Jimma University
MI	Macro Invertebrates
MTU	Mizan-Teppi University
NTU	Nephelo metric Turbidity Unit
P	Phosphorus
pH	Hydrogen ion concentration
SD	Standard Deviation
SNNPR	South Nation Nationality and People Reign
SPSS	Statistical Package for Social Science
SR_1-SR_5	Site Reference for samples taken from Shonga River
TSS	Total Suspended Solid
UNEP	United Nation Environmental Protection
USEPA	United State Environmental Protection
WHO	World Health Organization
WQ	Water Quality
WQI	Water Quality Index
μ g/l	Microgram per liter
μ s/cm	Micro Siemens per centimeter
^{0}C	Degree Celsius

1. INTRODUCTION

1.1.Background of the Study

Fresh water ecosystem plays crucial role in the life of organisms on this planet directly or indirectly in different ways. Among this importance the most outstanding are domestic consumptions, industrial processes, generation of electric power, agricultural purposes, recreation values and habitat for aquatic organisms (Malmqvist and Rundle, 2002). As the habitat of organisms it is one of the most scheming factors for biodiversity of animals, plants, bacteria and their interrelated physical and chemical environments. The physical and chemical condition of these ecosystems can be changed; because of the sediment, nutrients and toxic substances they receive from their riparian area. As a result, an aquatic ecosystem is indicative of the conditions of the terrestrial habitat in its watershed or riparian area through its functional and structural components(Goldstein, 2003).

Therefore, community composition of the streams can be highly influenced agricultural activities, urbanization, forests and wetlands. These may be due to conversion of a catchment from that influence stream ecosystems via changes in nutrient loading, sediment inputs, organic matter inputs and decomposition rates (Roger*et al.,* 2008). Increased nutrient loads are associated highly with agricultural and urban land use in both freshwater and coastal watersheds compared to forested watersheds (Azyak & Urd, 2005). However, at smaller spatial scales, riparian forests and wetlands may improve the effects of agricultural and urban land uses.

Aquatic biotic communities associated with watersheds with high agricultural and urban land use are generally characterized by lower species diversity, less tropic complexity, altered food webs, altered community composition and reduced habitat diversity(Jackson & Fu, 2006).

It is to be expected that the criteria set for water quality in the first effort is based largely on physical and chemical conditions. The attempt to establish chemical criteria in terms of toxicity to aquatic organisms is fraught with difficulties and indeed, may prove to be impossible. The great host of potentially toxic compounds, the vast numbers of species of organisms, the innumerable inter-action effects among compounds and the wide range of effects produced by variations in temperature, dissolved solids, pH and other physical and chemical factors produce permutations which may exceed the capability of adequate testing (Jerry L, Wilhm and Troy C, Dorris, 2012).

An ecosystem is a natural unit composed of abiotic and biotic elements interacting to produce an exchange of materials. Actions of the abiotic environment and coactions between biotic components result in a characteristic assemblage of organisms. The complex of individuals belonging to the different species in the ecosystem is referred to as community structure (Jerry L, Wilhm and Troy C, Dorris, 2012).

The assumption that natural communities represent meaningful assemblages has prompted a diverse series of analyses. One of the simplest and most promising methods of analysis is the diversity index. Diversity indexes are mathematical expressions which de-scribe community structure and permit summarization of large amounts of in-formation about numbers and kinds of organisms (Jerry L, Wilhm and Troy C, Dorris, 2012). Ethiopia is one of the developing countries where only 52% the population have access to safe water and 28% of its population has access to sanitation coverage (MoWR, 2007).

1.2.Statement of the problem

The ecological integrity assessment method for fresh water by invertebrate community structure is used in worldwide. By using this parameter we can justify that changes in water quality affect the community structure of stream invertebrates. However, little is known about how mach changes in community structure translate into alteration in fresh water ecosystem function. Although the structure of biotic communities and ecosystem function do not always respond equally to anthropogenic stress the human induced changes can affects physical structure of stream or fresh water, concentrations of dissolved chemicals in water, living organisms and ecosystem function(Goldstein, 2003). Hence, in order to assess ecosystem situation in response to human stressors the measurements of both structural and functional parameters should be included. Different biological communities, like macro invertebrates have been used to assess the structural integrity and status of water quality (Cláudia P, Manuela P, 20013).

Both human activities and natural activities can change the physical, chemical and biological characteristics of water and was specific ramifications for human and ecosystem health. Water quality is affected by changes in nutrients, sedimentation, temperature, pH, heavy metals, non-metallic toxins, persistent organics and pesticides and biological factors, among many other factors (Carr and Neary, 2008). Freshwater ecosystems are among the most degraded on the planet, and have suffered proportionately greater species and habitat losses than terrestrial or marine ecosystems (Revenga *et al.*, 2000). However, relatively a small number of studies have assessed functional ecosystem aspects by examining factors which affects the quality of fresh water by using indicator ecological micro invertebrates. Existing evidences shows that microorganisms that are colonizing leaves improve the quality of food for shredders (GRAÇA, 2001).

Also study conducted in impacted temperate streams has shown that slower leaf break down and decomposition of substrates and the decrease the numbers of micro invertebrates (Gonçalves *et al.*, 2014). The ever increasing settlement of population around the river banks are going presume on the quality of the river water, whereas in Ethiopia this is seriously creating major health risk (Postel and Richter, 2003).

Using biological criteria to assess environmental impact was developed in the USA since the classical studies of S.A Forbes on Illinois River. Forbes immunological investigations began in the 1870s and demonstrated the indicator value of benthic fauna (Cairns and Pratt, 1993). The use of indicator organisms to help classify tropic status of rivers and streams is also developing in Europe (Davis, 1995).

The use of biological criteria to assess environmental impact assessment is developing in Ethiopia. Therefore, Tesfaye Berhe (1988) used some biological parameters in the evaluation of the degradation of Abo-Kebena River in Addis Ababa. Solomon Akalu (2006) also assessed the biological integrity of Great Akaki River using macroinvertabrates. Baye Sitotaw (2006) used various macroinvertabrates metrics and habitat scores in the assessment of environmental degradation in some rivers of Ethiopia.

Shonga River is one of the freshwater bodies under moderately pollution impact in Ethiopia. In study area, it is subjected to municipal, domestic and industrial sources of pollution. Like Coffee processing industry, MTU of Mizan campus and illegal car wash are established near the river for easy discharge of the effluent into the river. Among these no one has effluent treatment plant; all of them release untreated waste effluents into the river. Those activities are jointly posing series pollution problem on the Shonga river ecosystem and local communities. In addition to domestic and municipal wastes from MTU/Mizan campus, hotels and individual households together with toilet discharge join the river. Wastes generated from these all sources degrade the river ecosystem together with the physical alterations.

In Shonga River basin, huge amount of pesticides and fertilizers have been employed and there is no data about the physico-chemical and macroinvertabrates, which are the measure of total organic lode in river water. Thus, still now no strong water quality research is conduct on shonga river water quality. Therefore, there is a need to conduct study over suitability of Shonga River in Mizan-Aman town for washing clothe, shower, bathing, coffee processing, cattle drinking and irrigation purpose. Hence, current study provides valuable information on the quality of Shonga River. But, the increased pollution and multi-purpose of the river were no started monitoring actions. The present study is an assessment of the water quality and biological integrity of the river using physico-chemical data and macroinvertabrates community structures.

1.3. Objective

1.3.1. General Objective

- ☞ To analyze water quality and assess macroinvertabrates community assemblages of Shonga river.

1.3.2. Specific Objectives

- ☞ To assess the variation of physico-chemical water quality of Shonga River water along its flow.
- ☞ To assess macroinvertabrates community assemblage along the Shonga river water.
- ☞ To identification of families of benthic macroinvertabrates found in study area.
- ☞ To assess pollutant status on the river based on macroinvertabrates along its flow.
- ☞ To evaluate water quality status of the river water using biometrics.

1.4. Research Questions

- Is there a difference in benthic macroinvertabrates at references and study sites?
- Which parameters meet the standard guideline (EPA, WHO and National, if available)?
- Which source from point, non-point or other sources affect the river water quality?
- Which families of benthic macroinvertabrates are common in study area?

1.5. Significance of the study

In the contemporary world the main concerning problem is quality of fresh waters as they are used for domestic consumption, habitat for aquatic organisms and serve as indicator of land use system. Conducting study on the river water is significant to keep human health and to protect environment. Thus, they interlink ecosystems and show the condition of environmental health. Therefore, this study is important to determining the quality of Shonga River for different purpose and government as management tool, better handling, controlling parameters of fresh water ecosystem, conservation of organisms that are aquatic dwellers; forecast the future status of fresh water, environmental wealth and specific identification of point (site) of pollutant discharge to the river. It is also important to control the source of pollution activates around the watershed. It used determine nature of the river water. For implementation of better treatment activities for Shonga River by Mizan-Teppi University and other stake holders as the river is crossing in the middle of university and town. For non-governmental organization it will give clues about the reality of environmental and ecological integration to improve their productivity while they are investing and contribute their attribute on the environmental protection. Also this study aimed to be used by other researchers for further study and encourage Mizan-Teppi university academicians for further investigations and design of better management ways for the river.

1.6. Scope of the study

The number of population and urbanization increase from year to year and alsosome industries, poor sanitation, uncontrolled solid or liquid waste disposal, unmanageable deranges etc. causes severe quality degradation of both surface and groundwater in Mizan-Aman. A key to successful restoration and conservation efforts is having an objective way to measure the biological condition of sites and to compare those sites to an objectively defined benchmark condition (Karr, 2005).The overall goal of this study is to assess the biological integrity and physico-chemical parameter of the Shonga River with the intention of protecting and restoring the ecosystem so that the sustainability of the goods and services that the society gets from the river is ensured.

1.7. Limitation of the study

The study is conducted in one season; from August, 2016 to December, 2016. Therefore, due to time limit and budget constraint. Since it is difficult to study over all river bank and path therefore, it focuses only on selected site to collected water and macroinvertabrates samples.

2. LITERATURE REVIEW

2.1. Major sources of water pollution

Pollution may result from point sources or diffuse sources (non-point sources). An important difference between a point and a diffuse source is that a point source may be collected and treated or controlled (diffuse sources 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). Some agricultural activities such as animal husbandry are also point source pollution of freshwaters. Most other agricultural activities like pesticide spraying or fertilizer application are considered as diffuse sources.

Domestic wastes are those wastes generated from commercial establishments and residential activities. They are primary source of organic waste released in to freshwater (Tesfaye B, 1988). Pollution of rivers and lakes with organic matter results in depletion of dissolved oxygen, destruction of aquatic invertebrates and extensive fish kill. Industrial wastes polluting water bodies may contain inorganic nutrients, detergents, mineral compounds such as inorganic salts, heavy metals and natural organic compounds like carbohydrate and protein (UNEP, 1991). Water consisting of high DO is usually considered healthy and capable of maintaining stable ecosystem with many taxa of organisms. However, a fall in DO level is an indicator of organic pollution. Suspended solids and colloidal matter discharged with industrial wastes and sewage reduce water clarity and contribute to a decrease in photosynthesis in surface waters.

In addition, they bind with toxic compounds and heavy metals are rise water temperature by absorbing sunlight. They may also clog the gills of fishes and benthic organisms, the benthic macro invertebrate are more adversely affected than fishes because of their small sizes (Murphy, 2005; USGS, 2003).

2.2. The integrity of river ecosystem

The integrity of river ecosystem refers to its biotic integrity (also called biological integrity). Biotic integrity according to Karr and Dudley (1981) is “the ability of an aquatic ecosystem to support and maintain a balanced, adaptive community of organisms having species composition, diversity and functional organization comparable to that of natural habitats within a region."

It can be fully characterized by the three major components: hydrology, physico-chemistry and biology. DeBerry and Perry (2005) gave summary of five attributes of river ecosystem (Fig. 1).

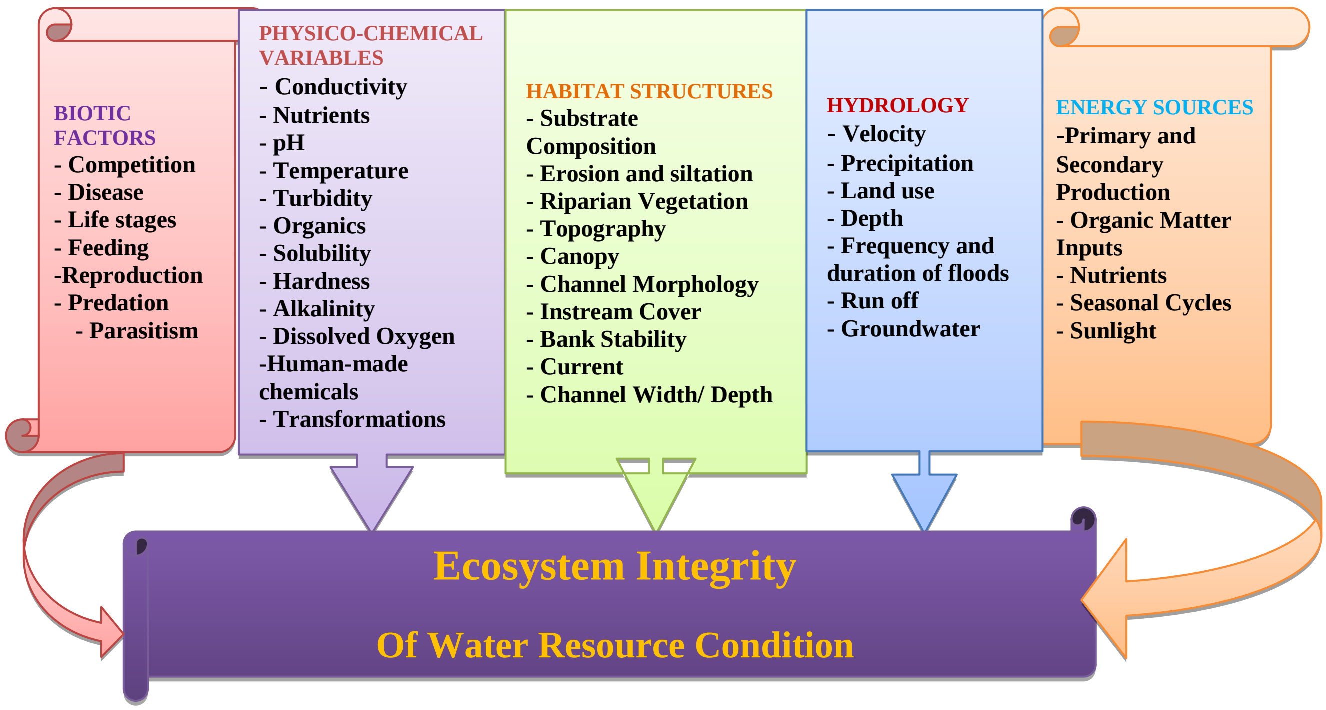

Figure 1The schematic illustration of components contributing to the integrity of water resources and aquatic ecosystem (modified from DeBerry and Perry, 2005).

2.2.1. Riparian land use

The recently proposed models reveals that response to anthropogenic stress is at slower threshold in biodiversity whereas biomass and function are constant or enhance under low to moderate stress and decrease only under high stress conditions. Conversely, the nature of the ecosystem response to pressure may differ for different stressors and further research is needed for better comprehending the ecological responses to multiple environmental stressors. High human densities in coastal zones with large urban and industrial settlements and intensive agriculture causes great pressure on surface water bodies and consequent deterioration of water quality and changes in riparian vegetation(Issues, 2001).

2.2.2. Urbanization

Catchment urbanization can alter physical, chemical, and biological attributes of stream ecosystems. Land-use, physical, chemical and biological variables were highly inter correlated. Principal-component analysis was used to reduce the variables into several orthogonal axes. Using stepwise regression, we found that flow regime, snail biomass, snail and total invertebrate richness and metal and nutrient content (which varied in a nonlinear manner with impervious surface area) were likely factors affecting litter breakdown rates in these streams(Chadwick *et al*. 2014).

2.2.3. Agricultural activities

As shown by many studies the expansion of agricultural land is related with modifications in the macro habitats and resulting to alteration in the macro invertebrates' community composition. The riparian vegetation near the streams or fresh water seems to help increasing EPT taxa, total richness and diversity as a whole.

The stream Nutrient concentration, temperature, sedimentation increased and dissolved O_2 decreased along the gradients agricultural land use. Macroinvertabrates richness and macroinvertabrates density are important tools and indicators of water quality. The researcher have concluded that leaf breakdown rates may not be a useful indicator of stream integrity because of the confounding effects that agricultural land use has on breakdown rates (Hagen *et al*. 2014). However, these may not be the case in all climatic conditions, geographical location and different types of land uses like urbanization, forest and wetland.

2.2.4. Forest Area

The main energy source for stream is riparian vegetation because they supply leaves for invertebrates. However, fresh water invertebrates are selective along with vegetation cover and they may be limited by food; it is reasonable that forest cover can influence the population of aquatic micro invertebrates. As it was shown by another study; Leaves entering low order streams were subjected to conditions like physical abrasion, microbial degradation and invertebrate fragmentation. Also the correlation of aquatic micro invertebrates and their densities with spatial and temporal accumulation of organic matter was investigated (Graca, 2001).

2.3. Physico- chemical conditions of streams

The physico-chemical features of surface water quality results into marked intersspecific variation in macroinvertabrates assemblage. Therefore, the relation of macroinvertabrates assemblage with physico-chemical conditions like temperature, pH, dissolved oxygen and electrical conductivity plays significant role in the water quality analysis.

A certain merit exists in this approach, since physical and chemical parameters generally are easily defined. In the case of micro invertebrate assemblage, the attempt to establish chemical criteria in terms of toxicity to aquatic organisms is fraught with difficulties and indeed may prove to be impossible.

The great host of potentially toxic compounds, the vast numbers of species of organisms, the innumerable inter-action effects among compounds and the wide range of effects produced by variations in temperature, dissolved solids, pH and other physical and chemical factors produce permutations which may exceed the capability of adequate testing (Jerry L, Wilhm and Troy C, Dorris, 2012).

2.3.1. River water temperature

All benthic micro invertebrates are exothermic. The fluctuation in river water usually depends on the season, geographic location, sampling time and temperature of effluents entering the stream (Ahipathy& Puttaiah, 2006). The standard value of temperature of river water is20^0C- 30^0C (ECR, 1997).Therefore, temperature plays an important role in their ecology and influence in their growth rate, life cycles and other behavioral and morphological attributes. Several studies demonstrate that microbial activity in streams are regulated by environmental factors such as temperature, concentration of dissolved nutrients and pH (Trivedi *et al*, 2009). In addition, temperature affects the growth and reproduction of aquatic organisms. If the temperature gets too high or too low, the local population of a species decreases. Temperature also affects water chemistry, which in turn then affects biological activity. A sudden change of temperature of river water can too higher rate of mortality of aquatic biota (Fakayoda, 2005).Therefore, temperature is one of the significant factors that can determine biological diversity in aquatic ecosystem of fresh water. Thus it needs to be determined to avoid confusion of what makes species diversity in aquatic ecosystem.

2.3.2. Biological oxygen demand

BOD is the amount of oxygen required by the aerobic bacteria to biochemically oxidize the organic matter present in the waste. More oxidize able organic matter present in water, more the BOD (Gupta, 2001). The biodegradation of organic materials exerts oxygen tension in the water and increases the biological oxygen demand (Abida and Harikrishna, 2008).Study done on polluted river for assessment of structural and functional conditions of ecosystem reveals that increase in organic and inorganic nutrients was associated with an increase in the density and a decrease in the richness of micro invertebrates.

2.3.3. Dissolved oxygen

Dissolved oxygen is a vitally important parameter of water that is required for aquatic organisms. In natural and waste water, DO levels depend on the physical, chemical and biological activities in the water body (Huq & Alam, 2005). Dissolved oxygen levels below 1.0 mg/l will not support fish; levels of 5 to 6 mg/l are usually required for most of the aquatic organisms. Water consisting of high DO is usually considered healthy and capable of maintaining stable ecosystem with many taxa of organisms. However, a fall in DO level is an indicator of organic pollution. Therefore, depletion of DO can cause major shifts in the composition and abundance of aquatic organisms. Families that cannot tolerate low levels of DO like Mayfly, stonefly and caddis fly will be replaced by few kinds of pollution tolerant taxa such as worms and fly larvae (Barbour et al., 1999; Delzer and McKenzie, 1999).Even though, some species like Diptera larvae and Oligochaeta have a certain tolerance to oxygen deficiency; the low oxygen concentrations can heavily impact most of the aquatic (Ward, 1992). The concentration of dissolved oxygen less than 50% is a signal of occurrence of dissolved organic matter that frequently comes from domestic fertilizer and agricultural wastes. For the streams located in the upper basin the concentrations of dissolved oxygen fluctuation is around 70% (Maldonado A, 2010).

2.3.4. River water pH

Both high and low pH poses adverse effect on stream biota. Ahmed &Rahman (2000) reported that in most raw water sources pH lies in the range of 6.5- 8.5. The standard value of surface water ranges from 6.5-8.5 (ECR, 1997). The pH of the water is important because affects the solubility and availability of nutrients and how they can be utilized by aquatic organisms. Aquatic organisms are very sensitive to the pH of the aquatic environment because most of metabolic activities are pH dependent.

2.3.5. Electrical conductivity (EC)

Electrical conductivity usually used for indicating the total concentration of ionized constituents of water (Huq & Alam, 2005). The standard value of electrical conductivity is 300µS/cm (De, 2007).The EPA standard for EC in surface waters is 1000μs/cm (EPA, 2003). EC in fresh waters range between 10 and 1000μs/cm, but it may exceed the maximum value of the range in polluted waters (Chapman and Kimstach, 1996).Conductivity is an indirect measure of the presence of dissolved solids and can be used as an indicator of water pollution. This is widely used to indicate the total ionized constituents of water.

2.3.6. Alkalinity

Alkalinity is a general term used to express the total quantity of base (Bhatnagar and De v, 2013).Generally water alkalinity is caused by basic species like bicarbonate ion, carbonate ion and hydroxide ion. Typically observed concentrations of bicarbonate are less than 10 mg/l in rain water and less than 200 mg/l in surface streams (Montgomery, 1985).

2.3.7. Turbidity

Turbidity is suspended particles absorb heat from the sun light and causes oxygen levels to fall and decreases photosynthesis as less light penetrates the water. Therefore, its loses water ability to support a diversity of aquatic organisms. Turbidity consists of suspended particles in water and is usually affected by factors such as clay particles, dispersion of plankton organism, particulate organic matters as well as pigments caused by decomposition of organic matter (Bhatnagar *et.al*, 1980-1993).

2.3.8. Total suspended solids

Total suspended solids are the sum of the dissolved solids and the suspended solids contained in water, which include anything from silt and plankton to wastes and sewage. Total suspended solids are made up of carbonates, bicarbonates, chlorides, phosphates and nitrates of metals such as calcium, magnesium, sodium, potassium, magnesium as well as other particles. TSS affects the turbidity of water bodies (M.R. *et al.*, 2010).

2.3.9. Nitrate

Nitrogen is essential for all living things as it is a component of protein.Nitrates represent the final product of the biochemical oxidation of ammonia. Nitrates represent the final product of the biochemical oxidation of ammonia. Monitoring of nitrates in drinking water supply is very important because of health effects on humans and animals (Salvato, 2003). In addition to fertilizer, nitrogen occurs naturally in the soil in organic forms from decaying plant and animal residues. An excessive amount of nitrate and phosphate in rivers can induce eutrophication of surface waters leading to change in aquatic algal and macrophyte species composition and consequent decrease in dissolved oxygen (GSWQMP, 2002; Murphy, 2005; USGS, 2004).The use of nitrogen fertilizers on farmlands on the watershed can also contribute to elevated NO3-N. Concentrations in excess of 5mg/L NO3-N usually indicate pollution by human or animal waste or fertilizer runoff (Chapman and Kimstach, 1996). The Environmental Protection Authority of Ethiopia set a standard of 10 mg/L nitrate-nitrogen for surface waters.

2.3.10. Phosphate

High phosphate concentration in rivers can lead to eutrophication. In most natural waters, phosphorus ranges from 0.005 to 0.02mg/L. Concentrations as low as 0.001mg/L may be found in some pristine waters and as high as 200mg/L in some enclosed saline waters (Chapman and Kimstach, 1996). Small amount of phosphate (to the level 0.01mg/L) can have measurable effect on aquatic communities (USEPA, 2006).

2.3.11. Hardness

Calcium and magnesium are the major elements, which make hardness of water. These elements contribute to hardness of water. Calcium and magnesium together comprise most natural water hardness.

2.4.Assessing river water quality using benthic macro invertebrate

Benthic macro invertebrates are animals without backbone inhabiting in or on the bottom substrate of an aquatic environment and are large enough to be seen with unaided eye (Beauchene, 2005).The concept of biodiversity (species richness and evenness) is a central theme in community/ ecosystem ecology and can be used to explain other ecosystem properties such as biological productivity, habitat heterogeneity, habitat complexity and disturbance (Pielou, 1984).Macro invertebrates communities of stream can differ along upstream and downstream in the same stream because ecological factors types of substrate drown into water, velocity of water, discharges to stream, riparian vegetation, altitude, latitude and land use(Roger G. Young *et al*, 2008). Species diversities are moderate in stable ecosystems highest in intermediate and low in severely degraded ecosystems (Connel, 1978). Several techniques, protocols and indices have been developed to monitor stream quality using changes in species compositions, diversity and functional organization of aquatic insects (Lenat, 1993). The distribution and composition of macro invertebrate’s taxa is related to the capacity to tolerate the environmental disturbances and stress usually linked to the change of land use. Therefore, the abundance and diversity of macro invertebrate’s community can be used to evaluate ecological changes and impacts that might occur due to the change in land use.

Thus, it recommends stream protection by maintaining and if it is possible minimizing the urban and agricultural land cover in the catchment (Cláudia P, Manuela P, 2013).

Table 1 Potential metrics and Description of effective bio assessments

Category	Metrics	Description	Predicted response
Richness measure	Total taxa richness	Total no of individual taxa	Decreases
	No. EPT taxa	No of taxa in the Ephemeptera, Plecoptera and Trichoptera	Decreases
	No. of Ephemeroptera taxa	Number of mayfly taxa	Decreases
	No. of Plecoptera taxa	Number of stonefly taxa	Decreases
	No. of Trichoptera taxa	Number of caddis fly taxa	Decreases
Composition measure	% EPT	% Composition of mayfly, stonefly and caddis fly larvae.	Decreases
Composition measures	% Ephemeroptera	% composition of my fly larvae	Decreases
	% Chironomidae	% composition of midge larvae	Increases
	% Plecoptera	5 composition of stonefly larvae	Decreases
	ShannonDiversity Index	Sample diversity that incorporates richness and evenness	Decreases
	Total No of individuals Collected	Abundance of the shredder to the abundance of all other functional groups	Decreases
Tolerance measure	% Tolerant organisms	% organisms that are highly tolerant to impairment	Increases
	% Intolerant Organisms	% organisms that are highly intolerant to impairment	Decreases
	% Dominant taxon	Dominance of the single most abundant taxon	Decreases
	% intolerant taxa	%organism that are highly tolerant to impairment	Decreases
	Hilsenhoff family-level biotic index (FBI)	Uses tolerance values to weight abundance in an estimate of overall pollution. Originally designed to evaluate organic polln.	Increases

2.5. Methods used for assessment of water quality

2.5.1. Biological monitoring

The assessment of water quality by using of aquatic organisms is a century-old approach (Cairns and Pratt, 1993). Biological monitoring can provide a “moving picture” of past and present conditions and thus, a more spatially and temporally integrated measure of ecosystem health, as it was described by (Hellawell, 1986). Even though, there are advantages to using macro invertebrates in water-quality monitoring, there are also several disadvantages. For example, they may not be sensitive to some perturbations, such as human pathogens and trace amounts of some pollutants; Factors other than water quality can affect distribution and abundance and Seasonal variation may complicate interpretations or comparisons of results.

Macro invertebrates have been used to evaluate the effects of anthropogenic stressors at all levels of biological organization, from the molecular to the ecosystem. At the molecular level, the effects of pesticides have been examined by measuring depressions in acetyl cholinesterase levels. At the organism level, the changes in growth, reproduction and rates of morphological deformities and various physiological responses, such as changes in respiration and metabolism (Martinez *et al,* 2002). At population and community (assemblage) levels evaluation of long term effects of pollution are examined.

2.5.2. Physico-chemical monitoring

As it is shown by (Roger G, Young *et al,* 2008) physic-chemical conditions of stream is important parameter for water quality assessment. The chemicals of the streams can be changed from time to time across different catchment land uses. These may be due to conversion of a catchment land use from one land use to another that influence stream ecosystems via changes in nutrient loading, sediment inputs, organic matter inputs and decomposition rates. One problem in relying solely on chemical and physical measurements to evaluate water quality is that they provide data that primarily reflect conditions that exist when the sample is taken. In essence, a physico-chemical approach provides a "snapshot" of water-quality conditions.

2.6.Selection of reference and impaired sites

The designation of sites as reference and impaired may be based on a prior knowledge of pressures acting over different locations (e.g. presence of point source pollution, eutrophication, hydrological modification, etc.) (Barbour *et al*., 1996) or may involve a post classification based on measured/recorded abiotic and biotic variables. The development of a multimetric macroinvertabrates index as part of a bio assessment program requires establishing reference conditions (Barbour *et al*., 1996). The latter approach was applied in this study. The designated wetland sites was taken as reference and impaired based on land use patterns, the degree of habitat degradation as quantified by the USEPA protocol (USEPA, 2002), variables characterizing hydrological modification and the Prati index as a measure of chemical water quality. The basic Prati index is calculated based on the concentration of ammonium, chemical oxygen demand and oxygen saturation (Prati*et al.*, 1971). A Basic Prati index value of two or less was considered as good water quality and an index greater than two was considered as poor water quality. Land use, habitat alteration and hydrological modifications were quantified based on their intensity in the studied areas (Hruby, 2004). A score of 1 was awarded for no or minimal disturbance, 2 for moderate and 3 for high disturbance (Appendix 6). Based on these criteria, of the 5 samples used for the development of the index, 1 (54.47%) samples were categorized as reference and the remaining 4 (45.531%) samples as impaired.

3. MATERIALS AND METHODS

3.1. Description of the study area

This study was conducted in Shonga river of SNNPR Bench-Maji zone Mizan-Aman town which is located 592 Km away from Addis Ababa city, found at southwest of Ethiopia and with tropical climatic conditions with elevation of 1451m to 1753m from sea level. The study area is located between 7^0 0′ 0″ N and 35^0 35′ 0″ E (CSA, 2007). The Shonga River upon which the study is conducted drains in the center of Mizan-Teppi University. The riparian land uses surrounding the river are used for urbanization, agricultural practice and coffee processing activities that can affect biological, chemical and physical condition of streams (Table 2). The river crosses predominantly forest, urban places of the town, Mizan-Teppi University and farm land of the farmers along the way; it is exposed to intense institute effluents from coffee processing waste and municipal waste products. The framework of bioassessment consists of characterizing reference conditions upon which comparisons can be made and identifying appropriate biological attributes with which to measure the condition (Major *et al.*, 2001).

Table 2 Physical Characterization of the study area

Physical parameters		SR1	SR2	SR3	SR4	SR5
Watershed features	Land use	Forest area	Agricultural/ residential	University/ residential	University/ residential	Agricultural/ residential
	Watershed Erosion	None	Moderate	Slight	Slight	Moderate
Riparian vegetation	Vegetation structure	Tree, Shrubs & grass	Shrubs& grass	Tree, Shrubs	Tree, Shrubs & grass,	& grass,
		trees dominant	shrubs dominant	Grass dominant	trees dominant	Shrubs dominant
IN stream features	Canopy	High cover	None	None	partly	partly
	Physical Alteration	None	None	None	None	None
	Stream width(m)	2.5	3.2	5.4	4	4.6
Water quality	Odor	None	None	Sewage	None	None
	Color	Slight Sediment	Slight Sediment turbid	Ashy turbid	Slight Sediment turbid	Slight Sediment turbid

Five sample stations including reference site (SR1) are selected along the flow of the river to take water samples for physico-chemical data and macro invertebrates sample forbioassessments. Selection criteria were based on minimally degraded physical habitat, the distribution of human activities, pollution sources and the flow regimes.

References (SR1) were selected as reference site to compare the induced change in other sites due to different activities. Reference condition was established using best professional judgment and based on guide lines established by Hughes (1995). A reference site represents a standard for what the macro invertebrate assemblage would look like in the absence of human influence (Hughes, 1995).

The remaining four sites (SR_2 to SR_5) were selected on the basis of prominent land use in the stream catchment, discharge of point and non-point pollutants. Site SR_1 were located in upper part of the stream where the riparian zone vegetation was dominated by locale name kereru and in lower stream side dominated by eucalyptus and coffee trees. On this study, since reference conditions are the expectations on the state of aquatic biological communities (in this case macroinvertabrates) in the absence of human disturbance and pollution, the reference sites selected are those which are anthropogenically undisturbed or minimally disturbed aquatic systems. The water was used for washing clothes, bathing and coffee processing purpose. Coffee waste effluent was found in the stream side and waste from Mizan campus of Mizan-Teppi University was also released in to river at the point when the river reaches the campus territory.

SR_2 were located near Mizan-Aman highway or before entering Mizan-Teppi University. Above the sampling point of SR2 and bellow SR1 there is ahighway of Mizan-Aman and illegal car wash which discharges its waste include grease and car fuel in to the river.

SR_3 were located at the middle of Mizan-Teppi University, where the river crosses the Mizan campus. The waste from university directly discharged on both side of river bank. Solid and liquids waste of the student cafeteria were very common to dispose around the river bank.

SR_4 were located at on the down side of Mizan-Teppi University border line before out from university territory. SR4 was crosses between farm land or agricultural activities and university area.

SR_5 was the last sample site of the river which not in side of Mizan-Teppi University. SR_5 were located at the middle of farm land, tyre tree (goma zafe) and one coffee processing industry. SR5 sampling site is near to the main road leading to Mizan-Aman.

Generally, five sampling points' uses and chosen based on our objectives of study. All sampling points were delineated and located by using GARMIN 72 GPS instrument. Latitude, longitude and elevation points are measured by the above instrument.

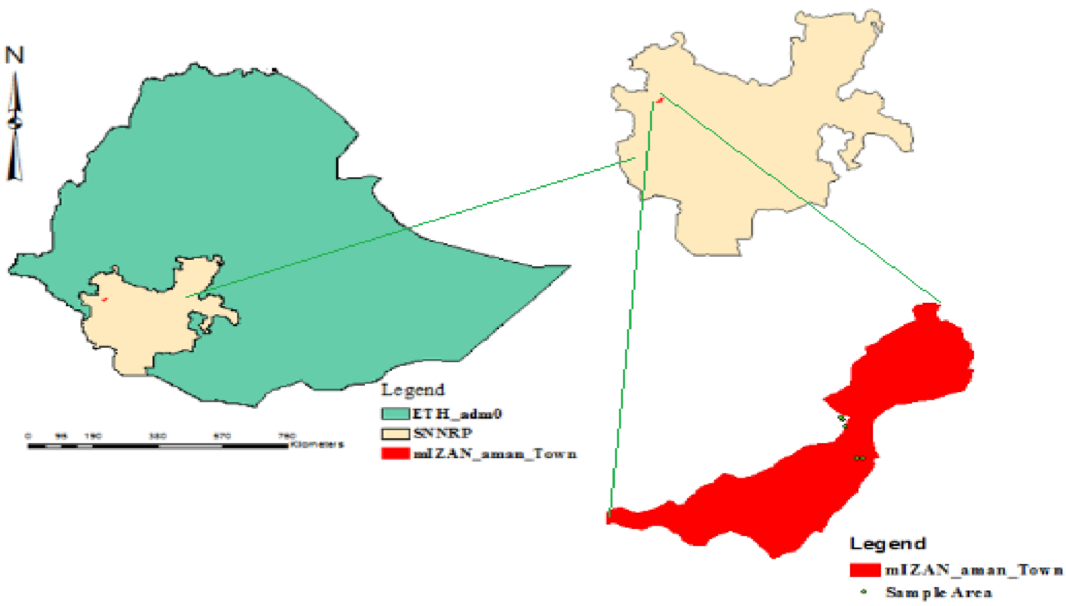

Figure 2 Map of study area

Table 3 Sampling sites, local names, location and altitude

Code	Site Name	Coordination		Altitude (m.a.s.l.)
		X	Y	
SR1	Gare-nance	0784110	0770531	1363
SR2	Shonga deledi	0783883	0770769	1359
SR3	Nuhamin café	0783688	0770915	1348
SR4	Goma zaffe	0783505	0771903	1325
SR5	Meles park	0783474	0771980	1326

3.2. Sampling and laboratory analysis of physic-chemical parameters

Beginning from August, 2016 to December, 2016, samples were collected at all sites of study area. Benthic macroinvertabrates were collected, also water samples were taken together with biological sampling in a one-liter clean polypropylene bottles that have been pre-washed and thoroughly rinsed with deionizer water. Other measuring kit's taken from Jimma University Environmental health, science and technology laboratory and Mizan-Teppi university chemistry laboratory were calibrated their reliability, especially prior to reaching the laboratory. The collected water samples were transported to laboratory for analysis of physico-chemical parameters. The samples were kept in a refrigerator at 4^{o}C until analyzed for the parameters. pH, temperature, electrical Conductivity (EC), DO, Flow rate (FR) were measured at the time of sampling in the field using Portable water quality measuring equipment (Model H9024, HANNA Instruments). The pH sample was measured with a portable pH meter that has been previously calibrated with standard buffer solutions of pH 4 and pH 7. Temperature was also measured in situ, using a handheld degree Celsius digital thermometer. (EC) was measured with Conductivity meter that has been calibrated with standard conductivity buffer solution. (DO) was measured at site with a portable DO meter. Flow rate was measured at site where macroinvertatbrates and water samples were collected with a handheld standard mechanical flow meter as the number of counts per 10 seconds. While the remaining parameters like Nitrate, Phosphate, Alkalinity and Sulfate were analyzed using (HACH DR/2010, USA) according to HACH instructions which were determined by titrimetric method following the instructions with them. BOD5 and TSS were determined using methods outlined in standard methods for examination of wastewater manual (APHA, 1998). All the reagents and chemicals used for the analysis are used based on analytical Laboratory grade. Specimen vials is grouped by sites and data are placed in jar with small amount of alcohol (97%) and tightly capped.

3.3. Macroinvertatbrates field sampling

Macroinvertatbrates sampling was conducted bimonthly together with water sampling based on the Rapid Bio assessment Protocols for use in streams and wadeable rivers (Barbour *et al*., 1999).

Invertebrate samples were collected from shallow riffle areas of Shonga river using surber sampler frame net (Mesh size = 500µm, Sampling area = 0.9 m2). At each sampling site, three samples were usually taken and the water was then strongly disturbed with kicks so that the dislodged invertebrates are carried into the net by the current. Six kicks per reach for 10 minutes each were done. Individual stones were also picked up and then scraped to dislodge attached invertebrates. At each of the riffle sites, benthic samples were collected by placing the surber sampler frame net with its mouth facing upstream. The square foot frame of the sampler was lowered onto the substrate and held in place. Four sweep samples were taken over the length of the reach of a pool. Scoop net was used to collect invertebrates in pools. Samples from riffles and pools were composited on site were sorted in white trays, identified and counted using dissecting microscope and the collected macroinvertabrates samples were transferred to glass jars to be preserved with 97% alcohol and transported to laboratory.

In the laboratory, each sample was washed through a 500μm sieve. Taxonomic identification was made to family level using standard keys (Macan, 1979; Edington and Hildrew, 1981; Bouchard, 2004).

Figure 3 Collecting samples of macroinvertabrates from the first sampling station

3.3.1. Sorting and identifying macro invertebrates laboratory analysis

Samples of macro invertebrate were taken once in the time interval from beginning of August 2016 to end of December 2016 from five different sample site of Shonga River. The relationships between environmental variables and benthic macro invertebrate assemblages were explored using Shannon index evenness and richness formulas .The Shannon–Wiener diversity (Shannon and Weaver 1949), the Pielou (1966) evenness and taxa richness were calculated.

On return to the laboratory, samples containers were rinsed through a 500 µm mesh sieve and identified to the family level under a dissect compound microscope, enumerated and assigned a pollution tolerance value level (range 0-10) as given in Bode, *et al.* (1996).

Taxa richness, EPA index, percent dominant taxon, diversity index, Family Tolerance Scores of Hilsenhoff (1988) were calculate for each site. Water quality of the sites was identified by comparing the calculated values to the reference water quality conditions according to Hilsenhoff (1987), Weber (1973) and Plafkin, *et al*. (1989). Identification of macro invertebrates was done with the help of keys from literature for Tropical Africa (Durand, 1981). Each taxon found in a sample was enumerated and record in a data book prepared for this purpose. The identity and number of organisms were record on the data book using a tally counter to keep track of cumulative count.

3.4. Study period

Experimental study design is conducted from August, 2016 to December, 2016 in Mizan-Aman town, Shonga River. This study design was preferred in order to assess macro invertebrates' community assemblages and river water quality along different sample sites.

3.5. Study population

Water samples and macroinvertabrates' taxa from different sample sites were taken as study population.

3.6. Statistical data analysis

Spearman bivariate correlation analysis is used to relate macro invertebrates' metrics to physico-chemical parameters. To determine if significant differences exist between reference and study sites with regard to physico-chemical parameters, one-way ANOVA was performed. This analysis was performed on all physicochemical data. All statistical analyses were done using the Microsoft excel (Version 13 Inc., 2007) and SPSS statistical software

(Version 20, SPSS Inc., 2013). Principal components analysis (PCA) based on environmental variables using past software.

3.7. Ethical consideration

Ethical clearance to carry out the study was obtained from Jimma university Environmental Engineering ethical review committee. Data and sample collection was conducted after obtaining informed consent from the concerned offices such as Zonal, woreda and town water supply offices including Mizan-Teppi University. Study objectives can be clearly explained to administration offices, water supply offices, Mizan-Teppi University and municipalities.

3.8.Data quality assurance

Proper quality assurance procedures and precautions were taken to ensure the reliability of the results. Samples were handled carefully and analyzed within holding time to avoid physical, chemical and biological changes occur to them. For the sake of data quality assurance data is assessed carefully and triple entry of data is performed to assure quality of data.

4. RESULTS AND DISCUSSIONS

4.1.Physico-chemical parameters

Physicochemical data supplemented with bioassessment are critical for evaluating the health of a river and in turn their results are essential to provide the information of disturbed systems to be restored (Ramakrishna, 2003). According to (Kudesia, 1980) water is soul of nature and if polluted will perish the world. Water pollution is any chemical biological or physical change in water quality that has a harmful effect on living organisms or makes water unsuitable for desired uses (Miller, 2002). Physico-chemical parameters was measured the assessment of Shonga River water pollution level.

4.2. Physical parameters

4.2.1. River water temperature

Surface water temperature is an indispensable ecological factor that regulates the physiologica l behavior and distribution of aquatic organisms. Lower temperatures are reported to likely re duced metabolism and growth (Abowei, 2010). Therefore, the standard value of temperature of river water is 20^0C- 30^0C (ECR, 1997). The temperature values for surface water recorded were under the stipulated range of 25-30°C for aquatic organism (WHO, 1984). Temperature of water samples in all study sites increased across the sampling point. Minimum temperature was recorded on the reference site (SR1) with value of 19.32 °c (Figure 4). Maximum temperature (22.12 °c) was recorded on the downstream sample point (SR5). The average temperature of the sample water is 20.85 °c. The increasing water temperature towards down steam side of the river may be due to increase in concentration of suspended solid and accumulation of dissolved solids within the river.

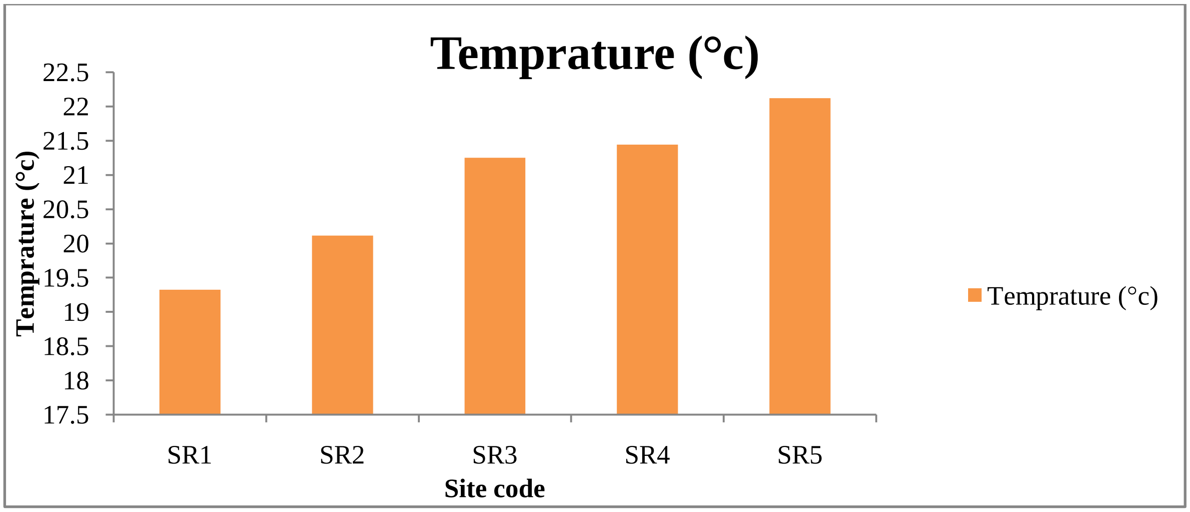

Figure 4 Temperature of river water on different sample sites

4.2.2. pH of river water

The term pH indicates the alkalinity or acidity of a solution on a scale of 1-14. pH affects many chemical and biological processes in water (Vyas and Bhawsar,2013). The standard value of surface water ranges from 6.5-8.5 (ECR, 1997)**.** Ahmed &Rahman (2000) reported that in most raw water sources pH lies in the range of 6.5to8.5. Also the recommended range of 6.5 - 8.5 set by the WHO standard water quality in (WHO, 2004) They also meet the EPA (2003) standards for surface water (6.0-9.0).Minimum pH (7.3) of the river water sample was recorded on SR1 which is the reference site of the river. Maximum (7.8) pH value was recorded on SR4. The average pH of water sample is 7.67. This result agrees with the findings of this study as the pH obtained in river Shonga during the study at most of the sample sites is suitable for the growth of the fish community. From the result (Figure 5) it was possible to say the water ranges lies between standard values of surface water ranges. Therefore, that is suitable for aquatic life.

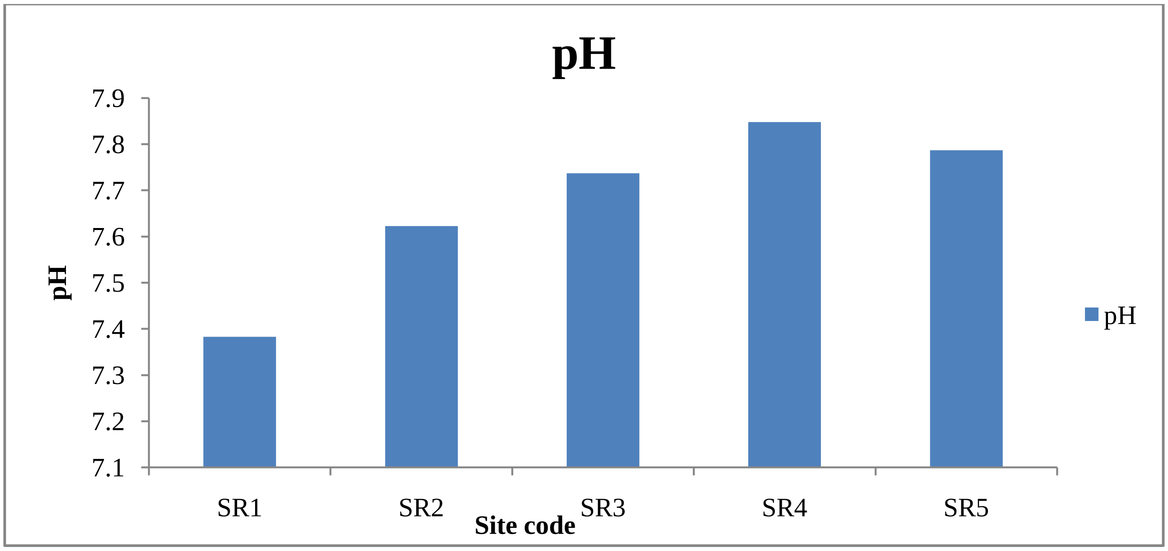

Figure 5 pH of river water on different sample sites

4.2.3. Turbidity

Turbidity consists of suspended particles in water and usually affected by factors such as clay particles, dispersion of plankton organism and particulate organic matters as well as pigments caused by decomposition of organic matter (Bhatnagar*et.al,* 1980-1993). In study area turbidity values were 76.63, 100.66, 107.60, 144.12 and 200.38 NTU recorded on SR1, SR2, SR3, SR4 and SR5 respectively. Minimum turbidity (76.63 NTU) was recorded on reference sample site (SR1) and maximum turbidity was 200.38 NTU (SR5). Average turbidity of river water sample is 125.88 NTU. This result exceeds the recommended standard value for turbidity of 5.00NTU (WHO, 2004). Higher levels of turbidity, water loses its ability to support a diversity of aquatic organisms because suspended particles absorb heat from the sun light, causes oxygen levels to fall and decreases photosynthesis as less light penetrates the water.

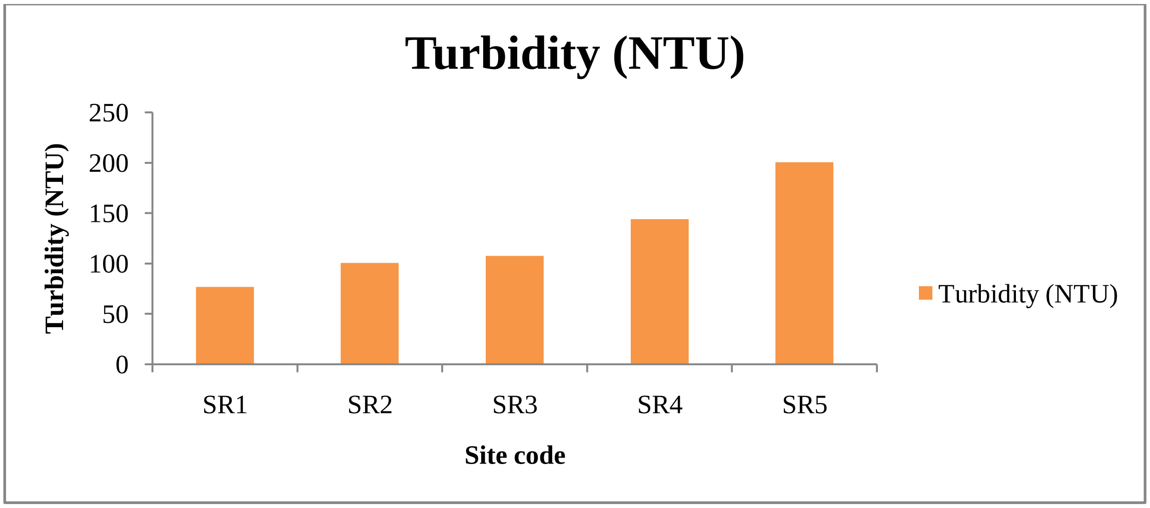

Figure 6Turbidity of river water samples

Figure 7Physico-Chemical parameter of water on site

4.2.4. Total suspended solids (TSS)

Bilotta and Brazier (2008) reported that TSS in excess 8.00mg/L increased the rate of drift of benthic fauna in surface water. Based on this study the levels of TSS recorded In SR2, SR3, SR4 and SR5 downstream, the value of TSS is 128.29, 132.45, 149.34 and 157.46 mg/l respectively. The average TSS is 138.56 mg/l. The largest TSS concentration is 157.46 mg/l which was recorded on out let down stream sample point (SR5). The least TSS is recorded in reference sample site (SR1) is 125.26mg/l. However, this result disagrees with the earlier study in Nigeria River Benue that reported mean TSS of 18.3 ± 14.00 mg/L (Eneji et al., 2012). These values were found to be greater than the acceptable limits of surface waters (<

50mg/l) especially the downstream that has the largest value. The increase in TSS concentration of river water across downstream sample site will be due to load of wastes from surrounding area while route of river.

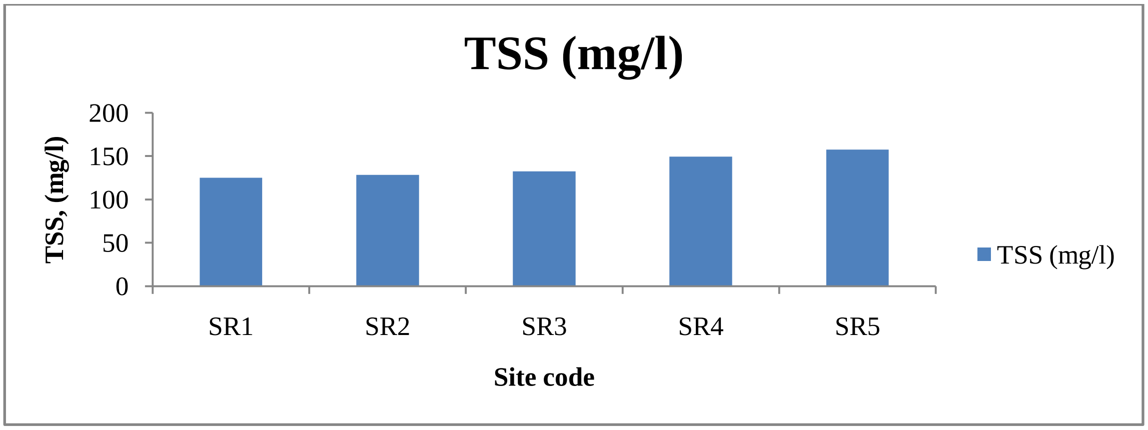

Figure 8 Total Suspended Solid (TSS)

4.2.5. Electrical conductivity (EC)

Electrical conductivity usually used for indicating the total concentration of ionized constituents of water Huq & Alam (2005). EPA standard for EC in surface waters is 1000µs/cm (EPA, 2003).In this study area the EC value of river water sample was 55.07, 63.47, 64.29, and 67.08, 71.44µS/cm in SR1, SR2, SR3, SR4 and SR5 respectively. Minimum (55.07µS/cm) EC was recorded on reference site (SR1) while maximum (71.44µS/cm) EC was recorded on SR5 which is on the outlet of river. The average EC value of river water is 64.27µS/cm. This result was below the maximum limit of 1000.00µS/cm specified by World Health Organization (WHO, 2004). But, in this study area the increment of EC value towards downstream side of the river will be due to increase in salinity content of river water across the flow direction. The salinity increment will be resulted from entry of waste from surrounding of river bank.

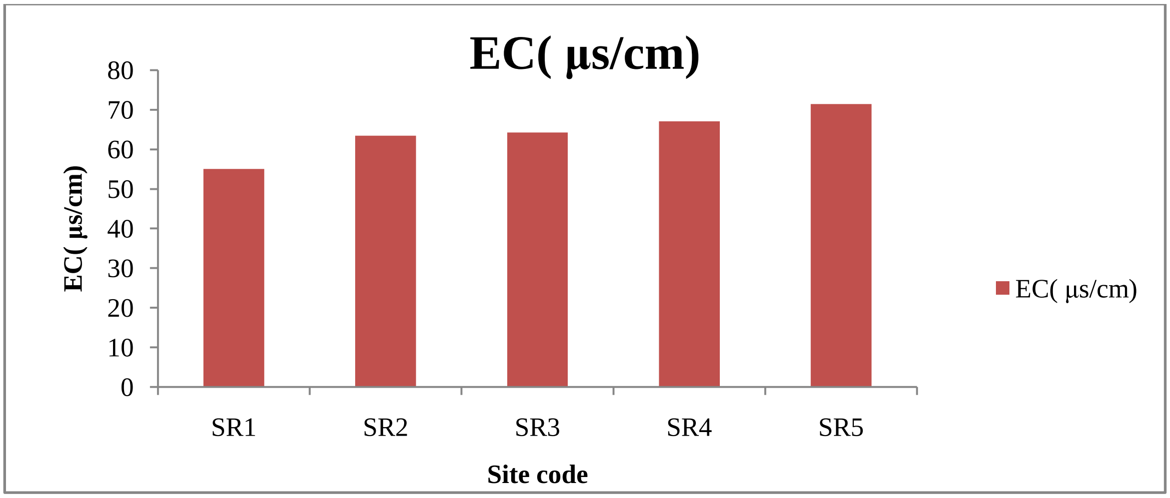

Figure 9 Electro conductivity (EC)

4.2.6. Flow rate

Flow directly affects the amount o f oxygen dissolved in the water. Higher volumes of faster moving water increases the turbulent diffusion of atmospheric oxygen in to the water (McMahon and Finlayson, 1992). The river flow velocity was measured and the recorded values are 0.772, 0.64, 0.117, 0.25 and 0.097 m/s on SR1, SR2, SR3, SR4 and SR5 respectively. Minimum (0.097 m/s) river flow was recorded on downstream sample site (SR5). Maximum (0.772 m/s) river water flow was recorded on reference site (SR1). Average river flow velocity was 0.375m/s. The decrease in flow velocity of river water across flow direction will be due to accumulation of sediment load and morphology of river.

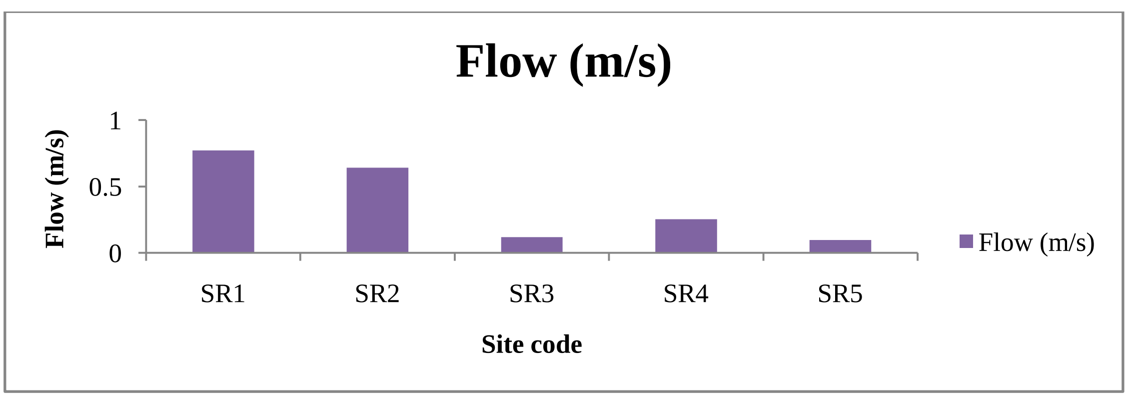

Figure 10 River flow velocity

4.2.7. Ambient temperature

Ambient temperature on the surrounding of each sample sites were 16.37, 19.54, 22.66, 26.29 and 25.62 °c on SR1, SR2, SR3, SR4 and SR5 respectively (Figure 11). Minimum ambient temperature is 16.37 °c which was recorded on SR1 while maximum was recorded on SR4 and SR5 each sites having 26.29, 25.62 °c respectively. Average ambient temperature is 22.1 °c.

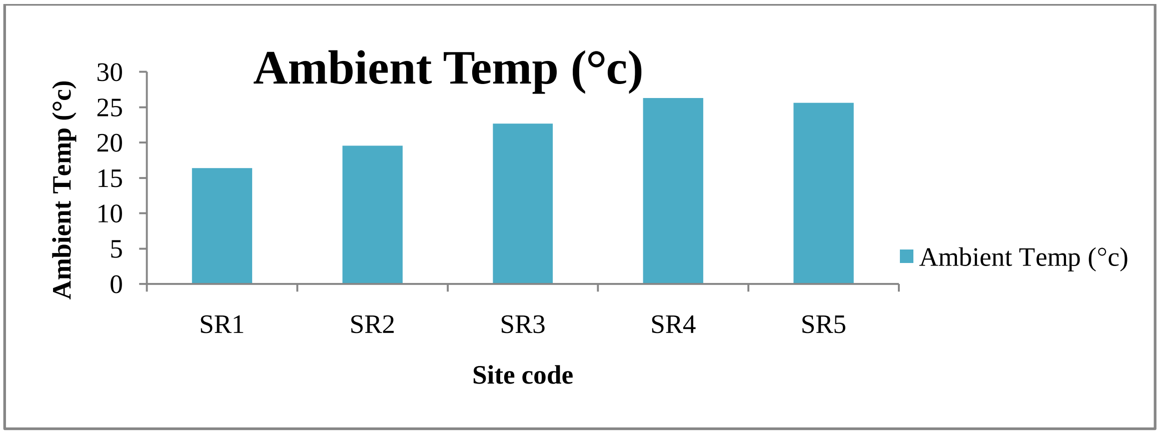

Figure 11 Ambient temperature

4.3.Chemical parameters

4.3.1. Dissolved oxygen of water sample (DO)

One of the important parameter, which shows the river water quality is the concentration of dissolved oxygen. Aquatic organisms which live in natural and waste water critically need dissolved oxygen. The level of DO levels depend on the physical, chemical and biological activities experienced in the water body (Huq & Alam, 2005). High organic and nutrient load reduces DO concentrations as a result of increased decomposer activities. Dissolved oxygen levels below 1.0 mg/l will not support fish, levels of 5 to 6 mg/l are usually required for most of the aquatic organisms.

Dissolved oxygen content of the river water sample was minimum (4.19 mg/l) on the middle sample site (SR3). Maximum DO (7.55 mg/l) was recorded on referee sample site (SR1). Average DO concentration in the river water sample was 5.75 mg/l. The river has DO concentration of 5.31, 5.14 and 6.58 mg/l on SR2, SR4 and SR5 sample sites respectively. Usually decrease of DO along river flow direction will be due to organic matter discharged from Mizan-Aman high way and MTU of Mizan campus. Therefore, low flow, high TSS and also higher temperature in downstream. Higher microbial load and pollution of the river water will also result decrease DO (Hoque *et al.*, 2012). The decrease (Figure 12) in concentration of DO along the river flow direction will be due to discharge of waste from Mizan-Teppi University, Mizan campus, discharge of waste from coffee processing industry and entering of agricultural waste containing sediment forced by flood.

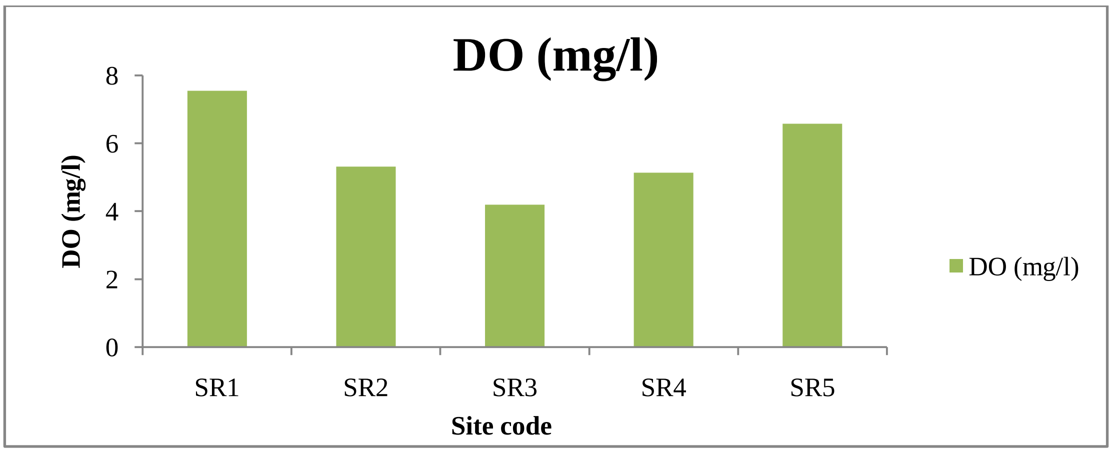

Figure 12Dissolved Oxygen (DO) of river water on different sample sites

4.3.2. Ammonia

The ecological impact of ammonia in aquatic ecosystems is likely to occur through chronic toxicity of fish and benthic invertebrate populations because of reduced reproductive capacity and reduced growth of young (Environment C, 2001). Result of measured ammonia from the study area shows that 0.86, 14.31, 16.43, 14.45 and 14.43 mg/l on SR1, SR2, SR3, SR4 and SR5 respectively. Minimum (0.86 mg/l) ammonia was recorded on SR1 and maximum was recorded on SR3 with value of 16.43 mg/l. The result showed decline after SR4 sample site towards flow direction (Figure 13). Average ammonia is 12.10 mg/l. The decline of ammonia concentration starting from SR4 to SR5 will be due to the dilution factor of the river water which will reduce concentration of different parameters.

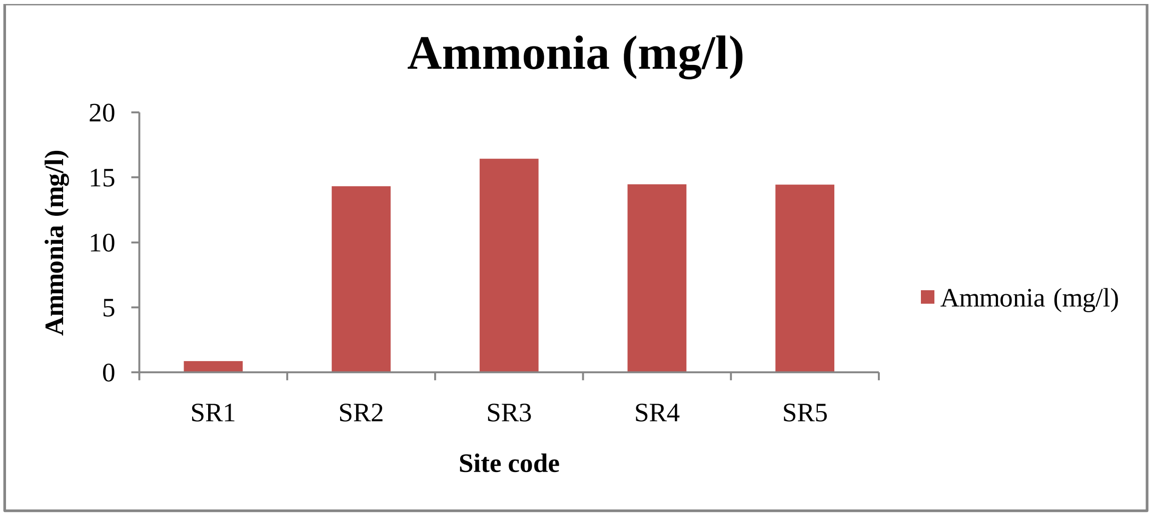

Figure 13 Ammonia

4.3.3. Nitrate

Nitrates represent the final product of the biochemical oxidation of ammonia (Salvato 2003). Nitrogen is essential for all living things as it is a component of protein. Monitoring of nitrates in drinking water supply is very important because of health effects on humans and animals (Salvato, 2003).

Nitrate concentration in the study area ranges from 0.79 to 2.05 mg/l. Minimum concentration of nitrate are 0.79 mg/l recorded on SR1 while maximum concentration of nitrate is recorded on SR3 with value of 2.05 mg/l. The average nitrate concentration is 1.57mg/l. The records of all the sites were also in the permissible limit of EPA (2003) standard of 10mg/L. Similar trends of nitrate were reported in surface waters. The concentration started declining at SR4 having value of 1.72 mg/l (Figure 14). The decline in nitrate concentration at this site will be due to the dilution factor of water.

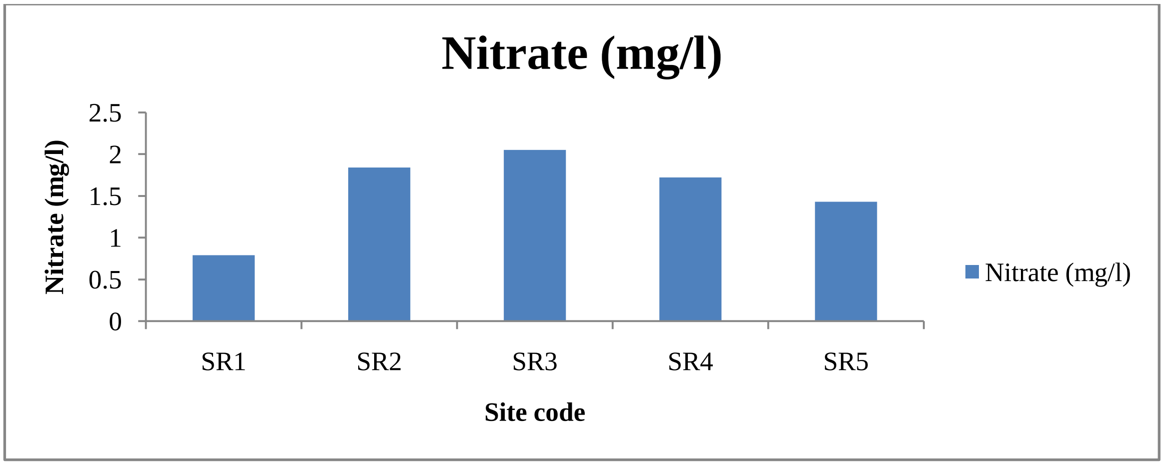

Figure 14 Nitrate

4.3.4. Phosphate

There is no legal water quality standard for the determination of phosphate in river water, but it is generally accepted that total phosphorus levels must be below about 0.10mg/l to prevent downstream eutrophication (U.S. EPA, 2006). Small amount of phosphate (to the level 0.01mg/L) can have measurable effect on aquatic communities (USEPA, 2006). High phosphate concentration in rivers can lead to eutrophication. The consequent depletion of DO can alter aquatic fauna.

Phosphate concentration in study area shows 0.005, 0.048, 0.086, 0.067 and 0.013 mg/l on SR1, SR2, SR3, SR4 and SR5 respectively. The higher levels of phosphorus observed on SR3(0.086mg/l) was most certainly due to the incorporation of different fertilizer and detergents incorporated by both the local widespread farming activities while minimum concentration was recorded on reference sample site (SR1) with value of 0.005mg/l. Average phosphate concentration is 0.044 mg/l. After SR4 sample site the concentration of phosphate started to decline (Figure 15). The possible reason will be more dilution of the entered phosphate with river water.

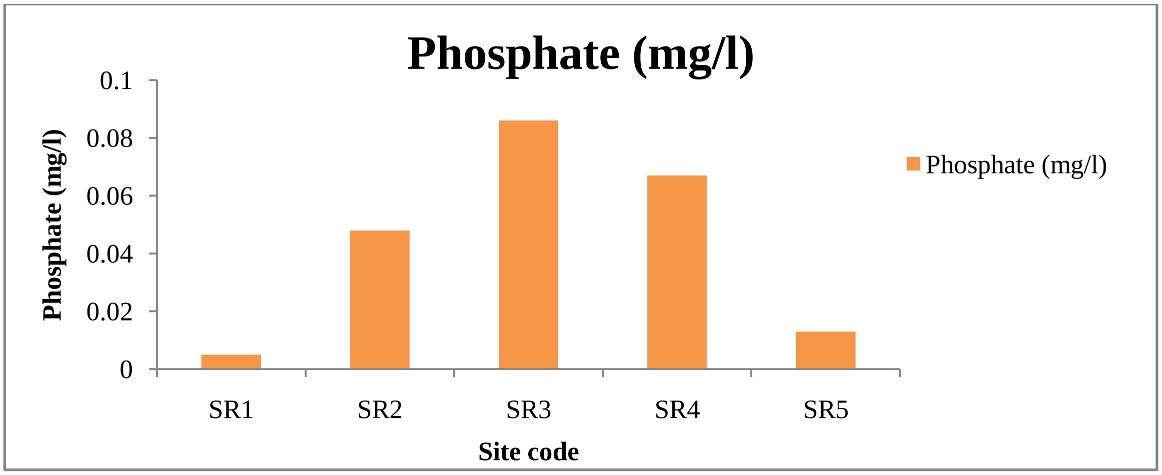

Figure 15 Phosphate

4.3.5. Sulfate

The concentration of sulfate did not show significant changes up to station SR2, but increasing at the station SR3. Sulfate concentration in study area is 0.057, 0.065, 0.074, 0.067 and 0.054 mg/l on SR1, SR2, SR3, SR4 and SR5 respectively. While the permissible standards for this anion is 250 mg/l (desirable < 50 mg/l) (Hammer, 2003). Low flow of the river water and discharge of agricultural wastewater are the main reasons for these changes.

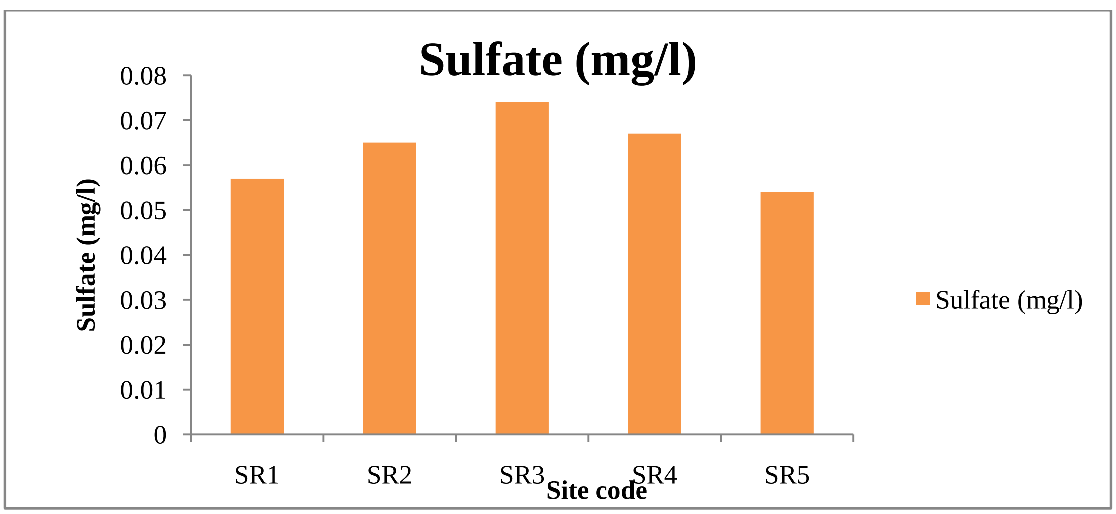

Figure 16 Sulfate

4.3.6. Alkalinity

Alkalinity is a general term used to express the total quantity of base (Bhatnagar and Dev, 2013). Water with high alkalinity is said to be "hard." The most prevalent mineral compound causing alkalinity is calcium carbonate, which can comefromrockssuchaslimestone or can be l eached from dolomite and calcite in the soil (www.ehow.com/about). Alkalinity in water comes from a high concentration of carbon-based mineral molecules suspended in the solution. Typically observed concentrations of bicarbonate are less than 10 mg/l in rainwater and less than 200 mg/l in surface streams (Montgomery, 1985). Generally, water alkalinity is caused by basic species like bicarbonate ion, carbonate ion and hydroxide ion. Alkalinity concentration in the study area ranges from 32.32 to 35.60 mg/l. Minimum concentration of alkalinity are 32.32 mg/l recorded on SR1 while maximum concentration of alkalinity is recorded on SR3 with value of 35.6 mg/l. The average alkalinity concentration is 34.70 mg/l. The concentration started declining at SR4 having value of 35.41 mg/l (Figure 17). The decline in alkalinity concentration at this site will be due to the dilution factor of water. Alkalinity of natural water is due to bicarbonate. Low alkalinity is for low production, medium alkalinity for medium production and high alkalinity is for high production (Olopado, 2013).

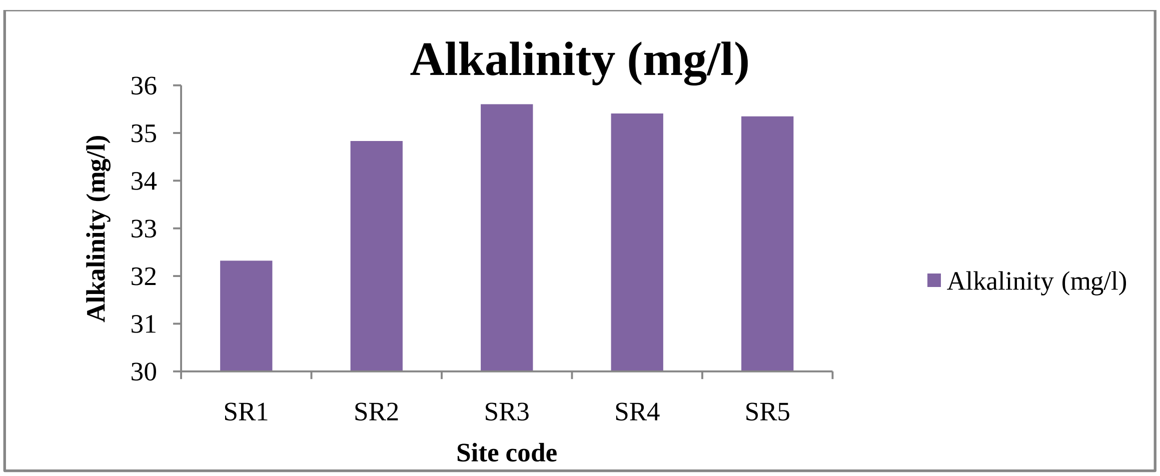

Figure 17 Alkalinityof river water

4.3.7. Magnesium hardness

Magnesium and other alkali earth metals are responsible for water hardness. Water containing large amounts of alkali earth ions is called hard water and water containing low amounts of these ions is called soft water (http://www.lenntech.com/element-and-water/magnesium-and-water.htm).The magnesium hardness of a sample is calculated as the difference between the total harness and calcium hardness values obtained from analysis of the sample. Magnesium ion concentrations of all the sources of water were within the WHO acceptable guideline value of 150mg/l. The concentration ranged from 4.50 to 15.28mg/l. The least concentration was observed in SR1 (4.5mg/l), followed by SR2 (9.6mg/l), SR3 (14.4mg/l), SR4 (15.2mg/l) and SR5 (14.3mg/l). The highest level was observed in SR4 (15.28mg/l). The average magnesium concentration is 11.65 mg/l. The concentration started declining at SR5 having value of 14.31 mg/l (Figure 18). The decline in magnesium concentration at this site will be due to the dilution factor of water.

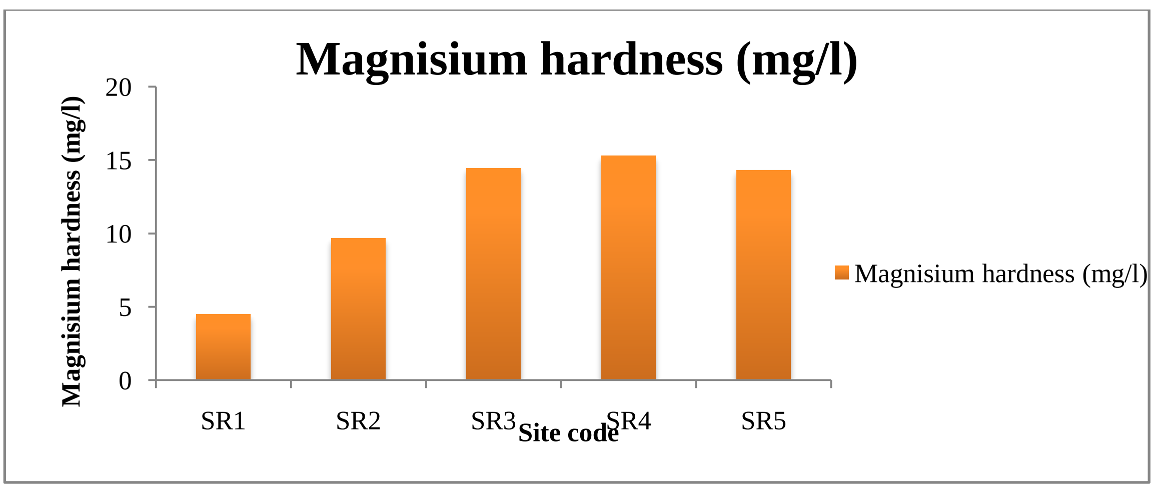

Figure 18 Magnesium hardness of river water

4.3.8. Calcium hardness

Calcium occurs in water naturally. One of the main reasons for the abundance of calcium in water is its natural occurrence in the earth's crust. Calcium is also a constituent of coral. Rivers generally contain 1-2 ppm calcium, But river in lime area may contains calcium concentrations as high as 100 ppm. Calcium is essential to human health (http:www.lenntech. com/Periodic-chart-elements/Ca-en.htm). Calcium is an important determinant of water hardness and it also functions as a pH stabilizer, because of its buffering qualities. Calcium also gives water a better taste. Hard water may assist in strengthening bones and teeth because of its high calcium concentration. (Fig.19) shows the average of calcium concentration of the Shonga River was 15.49 mg/l. Minor changes were observed from SR4 up to SR5 Station. At the station SR1 (12.78mg/l) calcium was increase to downstream compare with the 14.30, 17.66, 16.69 and 15.99mg/l recorded on SR2, SR3, SR4 and SR5 respectively. The concentration increased from SR2 (14.30mg/l) up to SR3 (17.66 mg/l) and decline at the station 16.69 and 15.99mg/l recorded minor changes were observed from SR4 up to SR5 respectively. Therefore, due to the dilution factor of surface water.

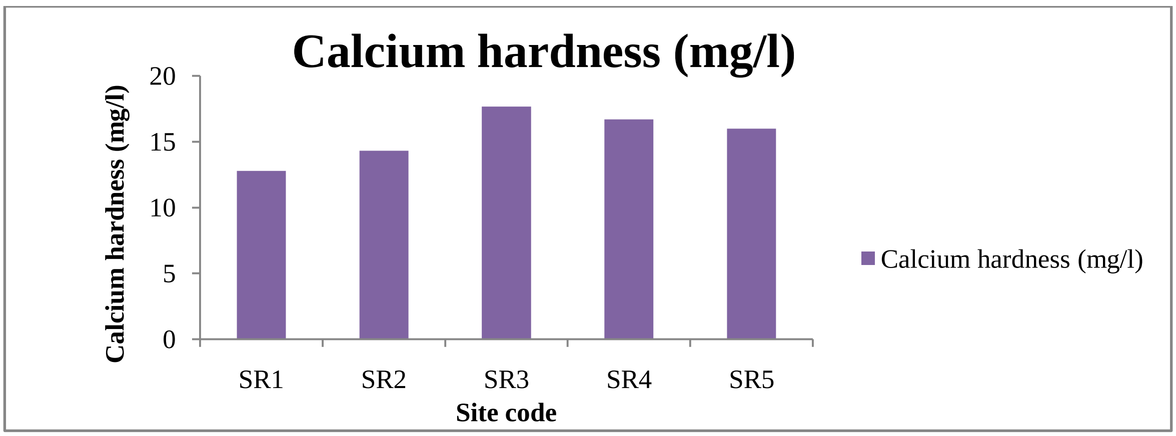

Figure 19 Calcium hardness of river water

4.3.9. Total hardness

Hardness is a natural feature of water reflecting calcium and magnesium, as carbonates, bicarbonates and sulphates. Water hardness in this study varied widely with values ranging from 17.29 to 32.12 mg/l. These values were, however, within WHO maximum contaminant value of 500mg/l.

Titration was repeated until a consistent titer was obtained. The value of the average titre was recorded (APHA, 1998). (Figure 20) shows the average of 27.14 mg/l of total hardness along the river. Total hardness was observed (from 17.29, 23.98, 32.12, 31.98 and 30.30 mg/l) recorded on SR1, SR2, SR3, SR4 and SR5 respectively.

The maximum hardness recorded on SR3 (32.12mg/l) and minimum hardness recorded on SR1 (17.29mg/l). The total hardness of a sample is calculated as addition of magnesium harness and calcium hardness values obtained from analysis of the sample.

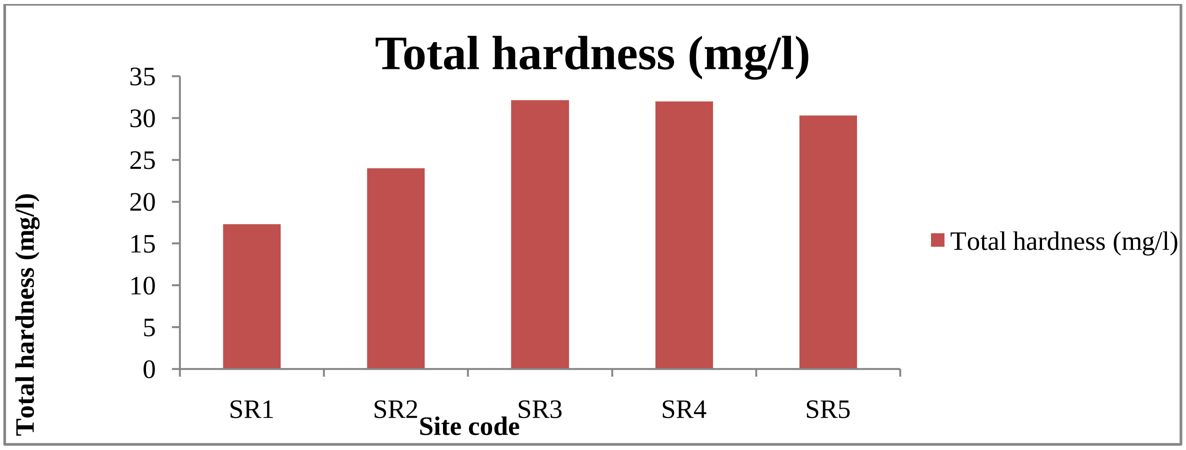

Figure 20 Total hardness

Table 4 Average physicochemical analysis results (Mean± SE) of Shonga River. n= 3

Parameter	SR1	SR2	SR3	SR4	SR5
T^o	19.323±0.145	20.113±0.245	21.250±0.272	21.445±0.454	22.123±0446
pH	7.383±0.099	7.623±0.207	7.737±0.273	7.848±0.127	7.787±0.200
NH_3-N	0.863±0.367	14.317±0.517	16.437±0.405	14.453±0.376	14.432±0.357
NO_3-N	0.79±0.11	1.84±0.43	2.05±0.40	1.72±0.32	1.43±0.12
$PO_4$3-	0.005±0.001	0.048±0.007	0.086±0.0.005	0.067±0.007	0.013±0.004
S_2^{2-}	0.057±0.009	0.065±0.008	0.074±0.009	0.067±0.009	0.054±0.013
BOD	4.247±0.554	6.250±0.592	7.75±0.417	5.44±0.758	4.32±0.710
TSS	125.267±0.730	128.297±0.483	132.453±0.595	149.343±0.673	157.460±0.469
DO	7.55±0.31	5.31±0.42	4.19±0.58	5.14±0.21	6.58±0.76
EC, µs/cm	55.073±0.521	63.475±0.545	64.290±0.469	67.082±0.829	71.443±0.313

The mean and standard error of the physicochemical parameters measured in Shonga River are shown in (Table 4). The lowest temperature was recorded on SR1 (19.323±0.145) which is reference site and highest temperature was reported in Sample site SR5 (22.123±0.446). Higher pH was recorded at SR4 (7.848±0.127) which is immediately downstream from MTU, while the lowest was in SR1 (7.383±0.099) which is at reference site. The river crosses different farm land places before reaching the (SR2) sample site. The lowest DO was recorded in last sample station SR3 (4.19±0.58) while the highest value was recorded on reference station SR1 (7.55±0.31).

Lowest mean BOD was recorded in the reference sample station (SR1) (4.247±0.554) while highest mean value was recorded in middle stream sample station (SR3) (7.75±0.417), the place where almost the river gets more perturbation from the middle stream. The lowest (0.79±0.11) nitrate recorded in (SR1) which is reference site while the highest value (2.05±0.40) was in Station 3 (SR3) which is at the middle of MTU.

The lowest Sulfide value was recorded in SR5 (0.054±0.013) while the highest value was recorded at (0.074±0.009) SR3. Few total suspended solid was recorded on reference sample site (125.267±0.730) SR1 and maximum total suspended solid was recorded (157.460±0.469) at bottom of the river on SR5 or last sample site. The mean Phosphate (0.005±0.029) and ammonia (0.863±0.367) respectively were recorded at upstream sites (SR1) while the highest mean and SE value were recorded Phosphate (0.086±0.005) and ammonia (16.437±0.405) respectively at middle of sample site (SR3). The maximum EC was recorded at SR5 (71.443±0.313µs/cm) which is at last sample site. The lowest EC was recorded at SR1 (55.073±0.521 µs/cm) at upstream.

Figure 21 Physic-Chemical parameters analyze in laboratory

4.4.Biological parameters

4.4.1. Biological oxygen demand (BOD_5)

In this study, BOD_5 is used as an index of organic pollution in water. The biodegradation of organic materials exerts oxygen tension in the water and increases the biological oxygen demand (Abida and Harikrishna, 2008). The result showed increased in SR3 and decline after SR4 sample site towards flow direction (Figure 22).The average value of BOD was recorded (5.60 mg/l).The lowest value was registered (4.24mg/l) at sampling stations SR1, which is the indication of fairly clean water. The highest value of BOD (7.75 mg/l) was observed at middle station SR3. This sharp increase is because of effluent discharge into the river from MTU and farmers around the riverbank/catchment exercise agricultural activities using synthe tic fertilizers. In SR1, SR5 sampling sites BOD is under the standard value set for surface water (5mg/l).

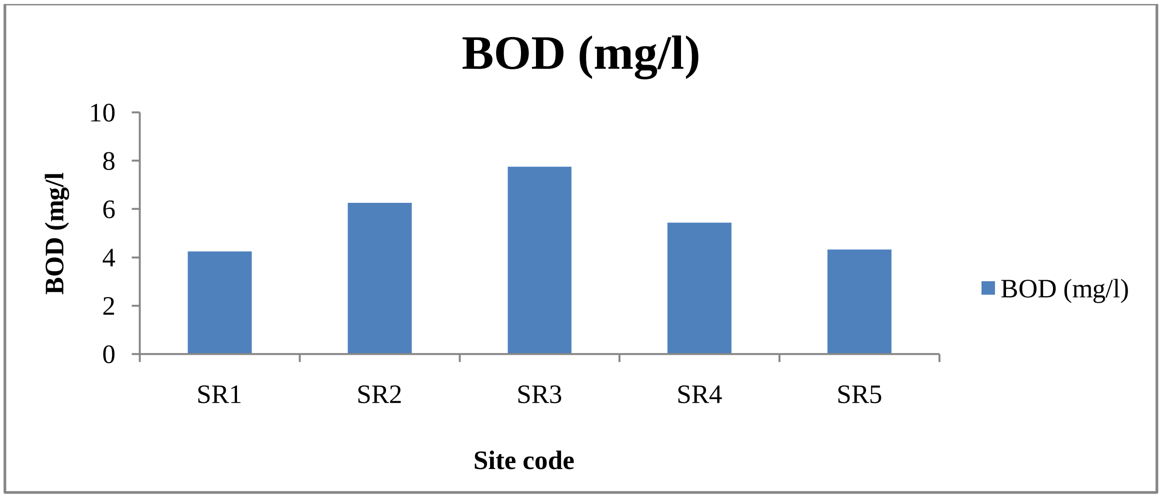

Figure 22 Mean value of BOD5 in shonga Rive

4.5. Benthic macroinvertabrates

A total of 1063 macroinvertabrates representing , 34 families and 5 higher order taxa were collected from five study areas of different sampling points, SR1, SR2, SR3, SR4 and SR5. The minimum and maximum number of macroinvertabrates and type of the invertebrate fetched are Oligochaeta (6) and Chironomidae (150) respectively. Chironomidae (14%) the most abundant and Oligochaeta (0.56%) are the smaller proportion of macroinvertabrates tallied among all the impacted sites. Even though, the abundance and richness of macro invertebrates are different, all of 34 species were found in five different sample sites. Macro invertebrates of diptera family are more abundant in study area having 333 individuals. Chironomids are most abundant species of diptera taxa with value of 150. This species is most commonly present in sample sites of SR2, SR3 and SR4 in which the sample sites are known by holding different types of wastes and organic loads from the surrounding area. Chironomids are much tolerant for pollution with having tolerance value of eight. They can even stay longer in highly polluted areas. Higher tolerance of the blood red chironomidae is due to its pigment that helps the organism to get oxygen from the atmosphere hence the name “blood red” (Barbour *et al*., 1999; Bouchard, 2004).

The second most abundant (223) taxa found in study area was Coleoptera. Elmidae is a species which is sensitive to pollution with a tolerance value of four .This species (Elmidae) was dominantly present on reference sample site was found to be larger species of Coleoptera taxa with 201 individuals. Among total of eighteen individuals seventy four of them were recorded from reference (SR1) sample site while the remaining species were found on SR2, SR3, SR4 and SR5. Few species only one species is present on each SR2 and SR4 sample sites. These places are known by holding waste from Mizan-Teppi University, Mizan campus students' cafeteria waste, flood holding waste from surrounding farm lands and waste discharge from households of communities. This indicates that, sample site two and three (SR2 and SR3) are most probably polluted site. Oligochaetes which are pollution tolerant taxa were few to present in five sample sites. A total of only six species of Oligochaetes family were present in samples.

Two individual species were found on second sample site (SR1) and only single species were found in remaining sample sites of SR1, SR3, SR4 and SR5.Gastropoda by separating species on the basis of those found only in brackish water and those found in freshwater habitats (Elliott & Mann, 1979). Gastropoda which are pollution tolerant taxa were to present in five sample site. Large number of gastropoda species found on SR2 (9) and SR3 (7) the remaining SR1, SR4 and SR5 are recorded 1, 3 and 1 respectively. (Fig 23) show results of the Principal components analysis (PCA) use past software based on the invertebrates assemblages with respect to environmental variables. PCA axis 2 explained 18.1% and PCA axis 1 explained 23.4% of the variability among sites. Among the sorted and identified families the following are the common species found in all the five sampling sites. Baetidae, Culicidae, Leptophlebiidae, Ephemerilidae and Lymnephiliidae

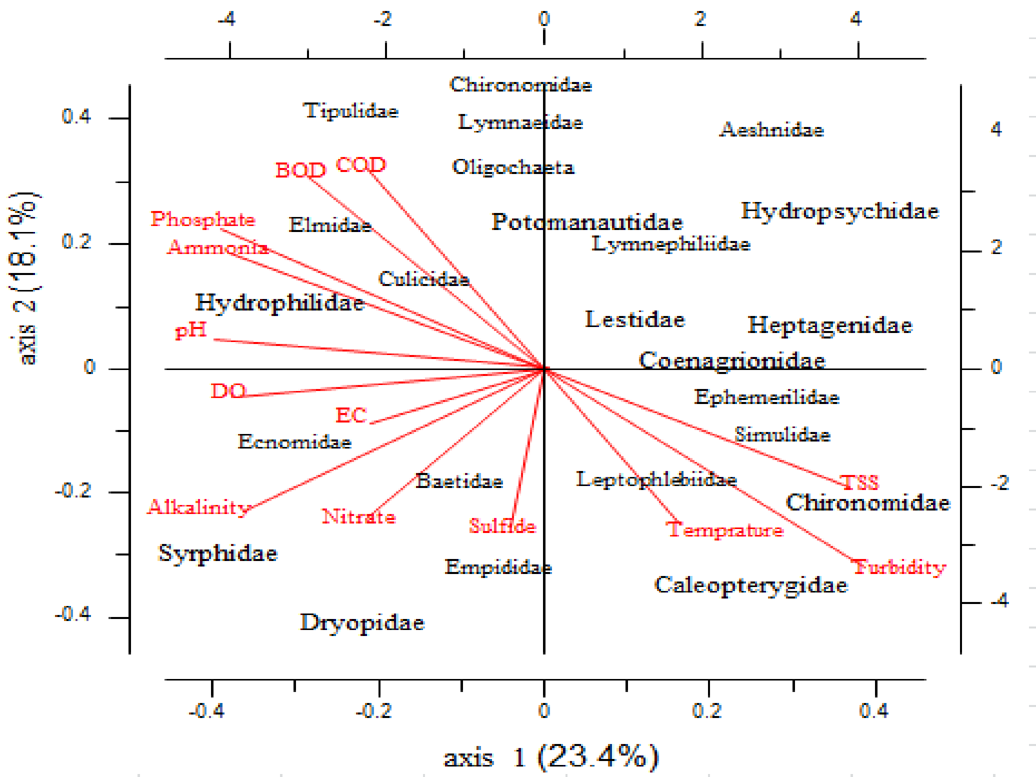

Figure 23 Principal components analysis (PCA) based on the invertebrates assemblages with respect to environmental variables using past software

Therefore, the figure above at axis one Ephemerilidae, Simulidae, Leptophlebiidae, Chironomidae, coenagrionidae, heptagenidae, Lestidae and Caleopterygidae are positively correlated with the ingredient of TSS, Turbidity and Temperature. Whereas, Phosphate, hardness, EC, pH, BOD and nitrite are negatively correlated with axis one. Axis one has a great correlation with the environment.

4.5.1. Diversity indices

A diversity index is a mathematical measure of species diversity in a community. Diversity indices provide more information about community composition than simply species richness (i.e., the number of species present); they also take the relative abundances of different species into account. By considering relative abundances, a diversity index depends not only on species richness but also on the evenness, or equitability, with which individuals are distributed among the different species. Its importance is, Diversity indices provide important information about rarity and commonness of species in a community (Weber, 1973). The ability to quantify diversity in this way is an important tool for biologists trying to understand community structure. Based on the species richness (the number of species present) and species abundance (the number of individuals per species), the more species you have the more diverse area.

Commonly used community indices were considered as composition measures, among which “Shannon’s diversity index” was found to be the most suitable. This index generally decreases with increasing degradation of habitat quality and at a very low level, represents a stressed community that tends to be unstable. The value of this index ranges from 0 to 5 and is maximal when all species are evenly distributed in the most desirable environments Rosenberg *et al.,* (1993).

A total of 1063 macro invertebrate species of 34 families were recorded from five sample site of Shonga River. On the reference site (SR1) a total of 579 macro invertebrate species were recorded. SR2, SR3, SR4 and SR5 have 206, 121, 82 and 75 species respectively. Shannon Diversity (H) value of macro invertebrate in the study area were 2.9, 2.3, 2.7, 2.7 and 3.4 on SR1, SR2, SR3, SR4 and SR5 respectively.

Maximum Shannon diversity value (3.4) was observed on SR5 which is the out let side of Shonga River. The higher diversity value on this area will be due to the preferably of the site for the species of tolerating moderate perturbation of environment and for those which can still live on safe water areas. The lower diversity value (2.3) was recorded on second sample site (SR2) next to reference sampling point (Table 5). This site (SR2) found below high way from Mizan to Aman and this site is suffering from different organic and inorganic wastes including entrance of sediments resulted from flood. The reason for the lowering of diversity index value will be due to the waste accumulation and in on the site that will make intolerant macro invertebrates to move to upper or to the lower diluted site.

Macro invertebrates of reference site (SR1) are more likely dominated by different species with Dominance (D) = 0.5 which can also represent good water quality and safe environment. But on the rest sites relatively similar macroinvertabrates are dominating the place. The Simpson Dominance value of the sample site which shows the dominance of macro invertebrates indicate that 0.5, 0.2, 0.3, 0.4 and 0.4 for SR1, SR2, SR3, SR4 and SR5 respectively. SR4 and SR5 have moderate water quality with having 0.4 species dominance value at both sample sites. SR2 has relatively poor water quality which has only 0.2 species dominance (D) value.

A high degree of dominance by few tolerant taxa implies lowered diversity and increased disturbance Klemm*et al., (*2002). The places with little value of dominance values will be due to disturbances and perturbation of the site which make the environment unsuitable and discomfort able for non-tolerant species.

The concept of biodiversity (species richness and evenness) is a central theme in community/ ecosystem ecology and can be used to explain other ecosystem properties such as biological productivity, habitat heterogeneity, habitat complexity and disturbance Pielou (1984).

Species evenness values of macroinvertabrates in study area shows 0.8, 0.6, 0.8, 0.8 and 1.0 on SR1, SR2, SR3, SR4 and SR4 respectively. The highest evenness (1.0) was observed on the last sample site while the least value (0.6) was recorded on second sample site (SR2). Diversity indices generally quantify either taxon richness or the proportional representation of the taxa present Derksen*et al.,* (1995), also known as evenness or equitability Peet (1975). Evenness has been defined as the ratio between the number of abundant taxa and total taxon richness (Alatalo, 1981; Smale*et al*., 2003). Evenness measures can be expected to show a response to a change in community composition even when there is no change in taxon richness (Johnston & Roberts, 2009).The place with largest evenness value indicate that species are more equally abundant in all sample sites while least number of macro invertebrate indicates that the species are not equally abundant on all sites. The last sample site is characterized by equally abundant macroinvertabrates species and the second sample site is known little abundance (Appendix 6).

Table 5 Diversity index values of macro invertebrates on each sample sites

Sample site	SR1	SR2	SR3	SR4	SR5
Individuals species on each sites	579	206	121	82	75
Richness	34	34	34	34	34
Simpson Diversity Index (D)	0.5	0.2	03	0.4	0.4
Shannon Diversity Index (H)	2.9	2.3	2.7	2.7	3.4
Evenness (E)	0.8	0.6	0.8	0.8	1.0
Total species on study area	**1063**				

4.5.1.1. Simpson diversity index (D)

Diversity within the benthic macroinvertabrates community was described using the

Simpson's diversity index ("D"), which was calculated as:

$$D = 1 - \sum_{i=1}^{S} (ri)^2 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. \text{Equation } 1$$

Where "pi" is the proportion of individuals in the "ith" taxon of the community and "s" is the total number of taxa in the community. This index places relatively little weight on rare species and more weight on common species (Krebs, 1994). Its values range from 0 indicating a low level of diversity and to a maximum of 1-1/s.

Table 6 Diversity indices of the Benthos macroinvertabrates

Biological Indices	Sampling sites				
	SR1	SR2	SR3	SR4	SR5
Simpson's diversity, D	0.5	0.2	0.3	0.4	0.4

From Simpson's diversity index, the finding of the study indicates that since the values for the index ranges between 0 and 1, study area (SR1) have good diversity, hence the river has good water quality.

4.5.1.2. Shannon diversity index (H)

The Shannon-Weiner Species Diversity Index (H) = -Σ i = 1, S (pi ln pi). This index is calculated here as was originally expressed using log_2. Elsewhere, however, it is often calculated using natural logs (ln) or occasionally using decimal logs (log_{10}). Used by the Gerritsen*et a*l (1998), the Shannon-Wiener Diversity index (H) is commonly used to calculate aquatic and terrestrial biodiversity. This index was calculated as:

$$H = -\sum_{i=1}^{S} (pi)\left(log_{2^{pi}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \text{Equation 2}$$

Where "pi" is the proportion of individuals in the "i^{th}" taxon of the community and "s" is the total number of taxa in the community. As the number and distribution of taxa (biotic diversity) within the community increases, so does the value of "H" (Gerritsen*et al*., 1998).

Table 7 Diversity indices of the Benthos macroinvertabrates

	Sampling sites				
Biological Indices	SR1	SR2	SR3	SR4	SR5
Shannon Diversity Index (H)	2.9	2.3	2.7	2.7	3.4

The Shannon-wienner diversity index (H) takes a number greater than one (between one and ten). The higher score were better water quality and hence good diversity. In general, good diversity is coupled with good water quality. Therefore, all the values are under the standard value for good water quality. The site SR1 and SR5 has relatively good diversity with respect to other study sites. Hence, only the stated study sites got good water quality that showed us that it could support or accommodate both pollution tolerant and sensitive macroinvertabrates.

4.5.2. Metrics selection

High richness has been equated with high water quality. That is number of taxa decreases with decreasing water quality (Resh and Jackson, 1993). Candidate Metrics (Table 8) representing Number of taxa, % Dominat taxa and total number of EPT taxa were considered for the index development for Shonga River. The number of taxa is relatively high in the reference sites, especially at SR1. This is consistent with the expectation as the sites are found in areas where human influence is limited and good coverage of vegetation. In the remaining sites, the number of taxa showed a dramatic decrease and lower stretch is characterized by few taxa. Similar trends have been observed in other areas (Thorne and Williams, 1997; Ndarugaet *al*., 2004).

Table 8 Observed metric values for each site

Metrics	**Site**				
	SR1	**SR2**	**SR3**	**SR4**	**SR5**
Number of taxa	7.00	5.00	4.00	4.00	6.00
Ephemeroptera taxa	111	8	8	8	19
Trichoptera taxa	113	7	7	7	9
Coleoptera taxa	176	5	5	5	10
Diptera taxa	52	166	83	50	12
Peliocoptera taxa	19	3	4	2	7
Oligochate	1	2	1	1	1
Odonet taxa	106	6	6	6	16
Gastropoda taxa	1	9	7	3	1
EPT taxa	243	18	19	17	35
% Oligochate	0.83	1.65	0.83	0.83	13.22
% Gastropoda	0.83	7.44	5.79	2.48	0.83
% Diptera	42.98	137.19	68.60	41.32	9.92
% EPT	200.83	14.88	15.70	14.05	28.93
% Dominat taxa	145.45	137.19	68.60	41.32	15.70

4.5.3. Family biotic index (FBI) statistical analysis

Aquatic macro invertebrate tolerance values of species range from 0 to 10 for families and increase as water quality decreases. The index was developed by Hilsenhoff (Hilsenhoff, 1988) to summarize the various tolerances of the benthic arthropod community with a single value. The Modified Family Biotic Index (FBI) was developed to detect organic pollution and is based on the original species-level index (BI) of Hilsenhoff. Tolerance values for each family were developed by weighting species according to their relative abundance. Zero taxa are extremely intolerant of low dissolved oxygen; taxa with scores of 2 through 9 are tolerant to varying degrees; taxa which can survive great amounts of pollution are scored 10 (Hilsenhoff, 1987)

In 1988, Hilsenhoff proposed a family-level biotic index (FBI). The purpose of the FBI is to provide a rapid, but less critical evaluation of streams and is not intended as a substitute for the BI when detailed taxonomic information is available. The FBI values for macro invertebrate species can also indicate the degree of water quality. Water samples with FBI value ranging from 0.00 to 3.75 did not have organic pollution and the water is decided to be excellent while water samples with FBI value ranging from 7.26 to 10.00 is severely polluted by organic waste and the water quality is very poor (Table 9).

Table 9 Family Biotic Index (FBI) value of water quality standard

Family Biotic Index	**Water Quality/**	**Degree of Organic Pollution**
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very good	Slight organic pollution
4.26-5.00	Good	Organic pollution probable
5.01-5.75	Fair	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

Shonga River indicates that; the water quality is ranging from 3.45 on SR1 to 5.81 on SR2. Water on reference sample site (SR1) is not polluted by organic waste and it is suitable for survival of macroinvertabrates species. Among all sample sites maximum macroinvertabrates species (579) individuals were recorded on SR1 (Appendix 6) and FBI (Table 10) value of the water also shows the site is suitable for macro invertebrates survival. It is confirmed that the water at this point is suitable for organisms. The first sample site (SR1) is safe environment.
The second sample site (SR2) and the third sample site (SR3) have FBI value of 5.81and 5.17 respectively. This indicates that the water degree of water pollution is on likely substantial pollution status and the water quality is fair on both sites. These both sites are more

dominated by pollution tolerant macroinvertabrates species. The four sample site (SR4) has obtained FBI value of 4.54 and the degree of organic pollution of the water is on probable pollution status with good water quality status (Table 10). This site is characterized by both tolerant and intolerant macroinvertabrates species assemblage (Appendix 6). The last sample site (SR5) has obtained FBI value of 3.77 and the degree of organic pollution of the water is on Slight organic pollution status with very good water quality status

Table 10 Family Biotic Index (FBI) values of water quality on Shonga River sample sites

Site	**Obtained FBI result**	**Water Quality/**	**Degree of Organic Pollution**
SR1	3.45	Excellent	Organic pollution unlikely
SR2	5.81	Fair	Substantial pollution likely
SR3	5.17	Fair	Substantial pollution likely
SR4	4.54	Good	Organic pollution probable
SR5	3.77	Very good	Slight organic pollution

4.5.4. Macro invertebrate composition and abundance

The relative abundance of benthic macro invertebrate encountered in Shonga River during the study period is shown in (Appendix 6). Thirty four families of a total one thousand sixty three individual's species were recorded. The Diptera Chironomidae was the most abundant accounting for about 14%, followed by Elmidae which accounted for 7.53% while Ephemerilidae was 7.15% of the percentage number.

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

From the results of this study shown that, the water qualities of Shonga River were varied from excellent to fair on the downstream direction due to increase in the pollution levels as evidenced by high water turbidity, low species richness, composition and diversity of the benthic macroinvertabrates fauna. This was a result of natural forces and an increase on anthropogenic activities affected and its biological systems were impaired due to various human impacts. Measures of most of the physico-chemical parameters, biotic index and benthic macro invertebrate community index all indicated severe water pollution and associated ecological impairment in the impacted sites. The reported values refer to the mean value of water samples collected in different sites at different areas along the stretch of Shonga River. The results indicate that the quality of water varies from station to station. A conclusion of the findings is given below. The water temperature of Shonga River ranged between 19.32 ºC to 22.12 ºC.. The electrical conductivity (EC) of water is affected by the suspended impurities and the amount of ions in the water. The highest conductivity 71.44µs/cm of the river water was observed in the last sampling station SR5. The minimum conductivity 55.07µs/cm was observed at SR1 sampling station; this could be due to the reduction of suspended impurities. The turbidity in river was lowest at the reference sampling site SR1, which is 76.63 NTU. Moreover, the maximum turbidity observed in the river was on the SR5 sampling station, which is 200.38 NTU. Total suspended solids (TSS) may affect water quality. Water with high TSS was generally poorer portability. TSS was observed maximum 157.46 mg/l in SR5 and minimum 125.26 mg/l in SR1. Shonga river water contained higher dissolved oxygen (DO) at SR1; followed by a gradual decrease to downstream its lowest values in the middle sampling station SR3. B.O.D. was maximum 7.75 mg/l in SR3 sampling station and minimum 4.24 mg/l in SR1. Alkalinity throughout the study period ranges from 32.32 mg/l to 35.60 mg/l in river water. Maximum calcium 17.66 mg/l was found in SR3. Minimum calcium 12.78mg/l was found in SR1. Similarly, maximum magnesium 15.28mg/l was found in SR4 and minimum magnesium 4.5 mg/l in SR1. Concentration of Calcium was always greater than that of magnesium. The total hardness was higher in the SR3 (32.12mg/l) and lower in SR1 (17.29mg/l).

Calcium ions make major contribution to the hardness of river water. Phosphate was highest in SR3 (0.086 mg/l) and lowest in SR1 (0.005mg/l). The mean concentrations of ammonia, nitrate, Phosphate, BOD5 and Sulfate were more elevated at middle stream of SR3 sites. Moreover, TSS, conductivity and turbidity were more elevated at downstream of sites SR5 when compared with the standard values set by WHO and EPA. Turbidity was raised across to downstream sampling station of SR5. Additionally, Evaluation of the water quality using the FBI, the collected data was found to be on varied values (Table 10). SR4 get a score, which is good water quality, but probability of organic pollution. Whereas SR2 and SR3 which is on the range of Fair and substantial pollution was expected. SR1 and SR5 there is very likely substantial water pollution.

5.2. Recommendation

Shonga River was mainly across at upstream forest area, middle of Mizan-Teppi University and agricultural farm land. On the other hand, the river water was used for a variety of purposes such as, cattle drinking, car washing and domestic purposes without prior treatment. For sustainable management of this water resource, environmental protection agencies at different levels and other concerned administrative and/or non-governmental bodies should take strict as well as technical measures. Continuous monitoring using parameters such as those used in this study should be employed to assess timely status of the system.

Following measures can be put forward to prevent further deterioration of water quality of Shonga River;

- People should make aware about the importance of clean and pure water body and community mobilization should be encouraged to prevent direct waste disposal into the stream.
- Solid waste disposal in and around the stream course should be discouraged.
- Wastes from MTU, Mizan campus should be treated before releasing it into the stream.
- Detail study should be done on the ecological and other ongoing natural as well as anthropogenic processes in the stream course.

It is recommended that proper management of the river should be put in place to prevent water quality and bio diversity of the river for sustainable development.

Finally, an integrated study that involves index development for different assemblages, Physico-chemical analysis and thorough habitat assessment should be considered as this will give a complete representation of the factors affecting the Shonga River.

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APPENDIXES

Appendix 1: Sampling sites, local names, location and altitude.

Code	**Site Name**	**Coordination**		**Altitude (m a.s.l.)**
		X	**Y**	
SR1	GareNance	0784110	0770531	1363
SR2	Deledi	0783935	0770539	1360
SR3	Nuhamin cafe	0783607	0771674	1328
SR4	GomaZaffe	0783505	0771903	1325
SR5	Melesi park	0783474	0771980	1326

Appendix2: Family Biotic Index (FBI) value of water quality standard.

Family Biotic Index	**Water Quality/**	**Degree of Organic Pollution**
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very good	Slight organic pollution
4.26-5.00	Good	Organic pollution probable
5.01-5.75	Fair	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

Appendix 3: Family biotic index (FBI)

Site	**Obtained FBI result**	**Water Quality/**	**Degree of Organic Pollution**
SR1	3.45	Excellent	Organic pollution unlikely
SR2	5.81	Fair	Substantial pollution likely
SR3	5.17	Fair	Substantial pollution likely
SR4	4.54	Good	Organic pollution probable
SR5	3.77	Very good	Slight organic pollution

Appendix 4: Values of physico-chemical parameters on different sampling site of study area.

Parameter	SR1	SR2	SR3	SR4	SR5
T^o	19.323±0.145	20.113±0.245	21.250±0.272	21.445±0.454	22.123±0446
pH	7.383±0.099	7.623±0.207	7.737±0.273	7.848±0.127	7.787±0.200
NH_3-N	0.863±0.367	14.317±0.517	16.437±0.405	14.453±0.376	14.432±0.357
NO_3-N	0.79±0.11	1.84±0.43	2.05±0.40	1.72±0.32	1.43±0.12
$PO_4$3-	0.005±0.001	0.048±0.007	0.086±0.0.005	0.067±0.007	0.013±0.004
S_2^{2-}	0.057±0.009	0.065±0.008	0.074±0.009	0.067±0.009	0.054±0.013
BOD	4.247±0.554	6.250±0.592	7.75±0.417	5.44±0.758	4.32±0.710
TSS	125.267±0.730	128.297±0.483	132.453±0.595	149.343±0.673	157.460±0.469
DO	7.55±0.31	5.31±0.42	4.19±0.58	5.14±0.21	6.58±0.76
EC, µs/cm	55.073±0.521	63.475±0.545	64.290±0.469	67.082±0.829	71.443±0.313

Appendix 5: Diversity index values of macro invertebrates on each sample sites.

S. No	Macro invertebrates Species	SR1	SR2	SR3	SR4	SR5
Individuals species on each sites		579	206	121	82	75
Richness		34	34	34	34	34
Simpson Diversity Index (D)		0.5	0.2	03	0.4	0.4
Shannon Diversity Index (H)		2.9	2.3	2.7	2.7	3.4
Evenness (E)		0.8	0.6	0.8	0.8	1.0
Total species on study area		1063				

Appendix 6: Macro invertebrate species abundance and tolerance value.

Taxon	Family Species	Individual species						Tolerance value				
		SR1	SR2	SR3	SR4	SR5	Total	SR1	SR2	SR3	SR4	SR5
Odoneta	Aeshnidae	12	1	1	1	2	17	3	0	0	0	3
	Caleopterygidae	48	2	1	1	4	56	3	0	0	0	3
	Coenagrionidae	18	1	1	1	6	27	9	0	0	0	9
	Gomphidae	15	1	2	1	3	22	1	0	0	0	1
	Lestidae	13	1	1	2	1	18	9	0	0	0	9
Ephemeroptera	Baetidae	2	2	1	1	2	8	4	0	0	0	4
	Caenidae	9	1	2	1	3	16	7	0	0	0	7
	Ephemerilidae	68	1	1	2	4	76	1	0	0	0	1
	Heptagenidae	12	1	1	2	4	20	4	0	0	2	4
	Leptophlebiidae	11	2	1	1	3	18	2	0	0	0	2
	Potomanautidae	9	1	2	1	3	16	4	0	0	0	4
Diptera	Ceratopogonidae	1	47	12	6	1	67	0	6	6	6	0
	Chironomidae	1	78	42	27	2	150	0	8	8	8	8
	Empididae	38	7	4	3	1	53	0	6	6	6	0
	Culicidae	2	3	1	2	1	9	0	5	5	5	0
	Dolichopodidae	3	7	1	3	2	16	0	4	4	4	0
	Leptoceridae	1	5	4	1	1	12	0	4	4	4	0
	Simulidae	2	7	9	2	1	21	0	6	6	6	0
	Syrphidae	1	2	4	2	1	10	0	10	10	10	0
	Tabanidae	1	3	2	2	1	9	0	6	6	6	6
	Tipulidae	2	7	4	2	1	16	0	3	3	3	0
Coleoptera	Dryopidae	12	1	1	1	2	17	5	5	0	0	5
	Dytiscidae	73	1	1	1	1	77	5	0	0	0	5
	Hydrophilidae	17	2	2	1	5	27	5	5	0	0	5
	Elmidae	74	1	1	2	2	80	4	0	0	0	4
Peleocoptera	Perlodidae	6	2	2	1	3	14	2	0	0	0	2
	Gyrinidae	13	1	2	1	4	21	4	0	0	4	4
Tricoptera	Lymnephiliidae	2	1	1	2	1	7	4	0	0	0	4
	Philopotamidae	3	2	2	1	1	9	3	0	0	0	3
	Hydroptilidae	14	1	1	1	3	20	4	0	0	0	4
	Hydropsychidae	52	1	1	2	3	59	4	0	0	0	4
	Ecnomidae	42	2	2	1	1	48	3	0	0	0	3
Gastropod	Lymnaeidae	1	9	7	3	1	21	0	6	6	6	6
Oligochaeta	Oligochaeta	1	2	1	1	1	6	0	8	8	0	0
Total		**579**	**206**	**121**	**82**	**75**	**1063**					

Appendix 7:Bivariate Pearson correlation matrix of selected metrics

	NO of taxa	NOEphe	NOTrich	NOColeo	NODipte	NOOligochate	NOOdonet	NO Gastropod	% Oligochate	% Gastropoda	% Diptera	% Dominat taxa
NO of taxa												
NOEphe	0.826											
NOTrich	0.782	0.996										
NOColeo	0.787	0.997	1.000									
NODipte	-0.296	-0.267	-0.211	-0.217								
NOOligochat	-0.086	-0.283	-0.256	-0.259	0.901							
NOOdonet	0.823	1.000	0.997	0.998	-0.262	-0.281						
NOGastropo	-0.591	-0.557	-0.504	-0.510	0.907	0.739	-0.553					
%Oligoch	0.342	-0.167	-0.253	-0.243	-0.533	-0.187	-0.174	-0.450				
%Gastrop	-0.591	-0.557	-0.504	-0.510	0.907	0.738	-0.553	1.000	-0.450			
% Dipter	-0.296	-0.267	-0.211	-0.217	1.000	0.901	-0.262	0.907	-0.533	0.907		
% Dominat taxa	0.382	0.562	0.609	0.604	0.647	0.538	0.566	0.340	-0.613	0.340	0.647	