JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

FACULITY OF CIVIL AND ENVIRONMENTAL ENGINEERING

ENVIRONMENTAL ENGINEERING CHAIR

ASSESSMENT of WATER QUALITY USING PHYSICO CHEMICAL AND MACROINVERTABRETE INDICES, IN CASE OF AWETU RIVER, JIMMA ETHIOPIA.

BY:-TEMAM HAMBISA

A thesis submitted to Jimma University, institute of technology, faculty of civil and environmental engineering, for school of graduate studies in partial fulfillment of the requirements for the degree of Master of Science in environmental engineering.

September, 2021

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Main advisor; - Prof. Dr. Eng Esayas Alemayehu (PhD)

Co-Advisor: - Mr. Adisu Befakadu (MSc)

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JIMMA, ETHIOPIA

DECLARATION

This thesis is my original work and has not been presented for a degree of Master of Science in Environmental Engineering in this university or any other universities.

Temam Hambisa   Signature ______________Date_____________

This Thesis has been submitted for examination with my approval as university supervisor.

Prof. Dr. Eng Esayas Alemayehu (PhD) Signature ___________Date________

Eng. Adisu Befekadu (MSc.) Signature _________________Date__________

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ABSTRACT

The quality of water resource of Ethiopia is declining as a resulting of severe environmental degradation and some human made problems. It is necessary that the quality of drinking water should be checked at regular time interval, due to use of contaminated drinking water, human population suffers from varied of water borne diseases. The aim of the study was to assess the Pollution status of Awetu River by physico chemical parameter and the extent of microbial with environmental matrices. In this study water samples were collected from six sample sites of Awetu River using sterilized bottles and have been analyzed for some physico-chemical parameters like pH, electrical conductivity (EC), total suspended solids (TSS), alkalinity (A), biological oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), Nitrates and phosphates. Analysis was done using complete randomized design (CRD) with three composite replicates in each sample stored in 4 ^{o}C and subjected to analysis with interval of 24 hours. Bottles and materials were sterilized and covered to protect contacts. Canonical correspondence analysis (CCA) was used for the identification of physicochemical parameters which was more affect the assemblage of macroinvertabretes. Shannon and Simpson diversity indices were performed for calculation of taxa, data analysis was performed by variance (ANOVA) using statistical analysis software (PAST-3) software. The result of physicochemical parameters such as pH, temp, Conductivity and Turbidity were determined (7.78, 23.86 ^{O}C, 94.46µs/cm,7.6 NTU) respectively at site, where as TSS, COD, BOD, Nitrate, Alkali and orthophosphate were (152.5mg/l, 957mg/l, 765.5mg/l, 2.02mg/l, 375.8mg/l, and 0.051mg/l) respectively identified in laboratory. From the result data PH and DO were in a permissible standard of WHO (6.5-8.5), (5-7) mg/l respectively. Turbidity, TSS, COD, BOD, and Alkali were not the standard of WHO. Macroinvertabrates result of the river was a total of 1142 individual, 8(eight) and (30) families were collected from upstream to downstream of the river. Results reveal that there is a highly significant difference between the 6 (six) selected sample site of the river. Ec, BOD, alkali and orthophosphates were more affect the benthos assemblage communities of the River. macroinverabretes indices value of the all sample site shows (Shannon and Simpson) diversity indices result (2.269-2.952)bit and (0.897-0.932)bit respectively, shows the river was lightly and very lightly polluted by solid and liquid waste disposed to the river. So that direct using of the river for drinking and washing of food causes healthy risk.to control the pollution risk, avoiding waste discharge to the river.

Key words: Bio-indicators, Macroinvertabretes, physicochemical, water quality index

TABLE OF CONTENT

LIST OF TABLE

LIST OF FIGURES

ACRONYMS

ANOVA----ANALYSIS OF VARIANCE

APHA-------AMERICANPUBLICHAELTHASSOCIATION

BOD---------BIOLOGICAL OXYGEN DEMAND

COD---------CHEMICAL OXYGEN DEMAND

CCA---------CANONICAL CORESPONDENCE ANALYSIS

DO-----------DISSOLVED OXYGEN

EC------------ELECTRIC CONDUCTIVETY

EPA----------ENVIRONMENTAL PROTECTION AUTHORITY

TDS----------TOTAL DISSOLVED SOLID

TSS----------TOTAL SUSPENDED SOLID

pH-----------POWER OF HYDROGEN

WHO--------WORELD HEALTHY ORGANIZATION

CHAPTER-ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Water is the most important natural resource in the world, since life cannot exist and industry cannot operate without water. Unlike many other raw materials there is no substitute for water in many of its uses. The health and wellbeing of a population is directly affected by the coverage of water supply and sanitation. On-site sanitation and sewerage systems, waste disposal, urban runoff, fuel storage and pesticide application for public health and vector control and Spills of many chemicals found in urban areas (including petroleum and fuel oils) are also a source of contamination of both ground waters and surface waters. In addition, problems associated with human settlements can carry risks for rivers, streams and other water reservoirs if insufficient care is taken and human habitation are sited near to the water bodies (Mengesha, 2004).

African countries are known for many problems, one of which is environmental degradation. Despite these problems, the region is still known for its nature reserves and many other vulnerable unique features. One of the vulnerable natural resources that need attention in Africa region is its surface water. This resource is badly needed by each nation of the region as one of the means to boost national economy by using the water for irrigation and power generation. However, in most cases, these nations have forgotten conservation of natural resources like surface water resources when designing development strategies, unless Political motivated. In many developed nations, natural resource conservation has to be carried out in different regions by following a variety of techniques. Bio monitoring is a popular monitoring method for surface water resources in developed nations than in African countries (Resh, 2007).

Many cities in Africa are disposing untreated liquid and solid wastes to nearby rivers. Addis Ababa, the capital of Ethiopia and the seat for African Union, is a very good example. The sewage system is not complete and the waste collection system is very poor. The sewage is hardly treated. As the result, the aquatic ecosystems are serving as final disposed. Factories, like tanneries, textile factories and food processing plants are located along the river side and the discharges coming out are poorly treated or raw, and disposed into the rivers (Mebratu, 1990).

Ethiopia is one of the water scarce countries in the world providing less than $1000m^3$ of safe fresh water/year/person. The Percapita per day safe fresh drinking water cannot even satisfy 50% of the minimum requirement of the WHO recommendation (Abera Kumie and Ahmed Ali, 2005). Moreover, it is also the poorest and the second most populous country in Sub-Saharan Africa, with high rates of infectious diseases. Illnesses associated with poor environmental conditions account for 75% of all morbidity in Ethiopia (Abera Kumie and Ahmed Ali, 2005; Warner *et al*., 2000).

Based on the 1995 population of Ethiopia, 56.4 million, the percapita safe fresh water consumption was 1,950 liters/year (POPLINE, 1998). This very low water consumption is because about 80% of the rural (majority) and 20% of the urban population do not have access to safe fresh water (MoH, 2004; Warner *et al*., 2000). Meanwhile, the overall access to clean water is estimated to be between 10 and 20% of the total Ethiopian population (Abera Kumie and Ahmed Ali, 2005; Warner *et al.*, 2000; MoH, 1997).

Accelerated pollution and eutrophication of rivers, streams, springs and other water reservoirs because of anthropogenic activity are a concern throughout the world including Africa particularly Ethiopia is a case since as developing counties lack and have not stringent regulations that have been implemented to restrict the discharge of untreated wastewater into rivers, streams and other water bodies (Kumie and Ahmed Ali, 2005). Ethiopia is weak and generally not adequately enforced into action to protect the water bodies and other environmental entities (Kumie and Kloos, 2006).

Most Ethiopian cities lack waste treatment systems, including Addis Ababa, the capital city of Ethiopia (pop, More than 4 million). About 90% of the industrial firms in Addis Ababa discharge their effluents directly into the nearby streams without any form of treatment. In addition, oil pollution to rivers from waste discharge from car wash and garages are very common situations of Awetu River. The study conducted on Awetu River revealed that physicochemical parameters like dissolved oxygen sharply depleted and biochemical oxygen demand is sharply increase downstream (Mebratu, 1990).

Besides to wastes discharged from aforementioned sources, the Awetu Rivers suffers from Diversion of its tributaries, pumping of water for irrigation, deforestation, erosion, and town settlement around the river side. This has made life difficult to the surrounding fringe as they depend on dwellers, wells rain water for drinking than Awetu River and to give its water to their cattle to drink. This highly polluted river is a tributary to the omo River, which pretty much dilutes these pollutants because of its large volume, but one should ask for how long? The omo River irrigates most of the large-scale farms, fruits and many more agricultural products. We should think of the loss of healthy vegetables due to the pollution at national scale as we throw our garbage into the rivers and streams passing our backyard (Weldegebriel *et al.*, 2012).

1.2. Statement of Problems

Awetu River is one of the Ethiopian river which had the above mentioned problem in jimma town. The Awetu river water supply satisfy three-fourth of the total population, the rest of the residents of Jimma town use water sources such as streams, springs, boreholes and hand-dug wells for drinking and other related purposes, (Bishaw Deboch and Kebede Faris, 1999).

For instance, Awetu stream is the primary source of water for a range of activities such as recreation, bathing, washing clothes and household utensils, livestock watering, small scale agricultural irrigation and car washing (Dejene Hailu, 1997).

Awetu River is which has small tributaries, in jimma town, runoff from different direction flow to this river, solid and liquid waste from hotels, restaurants, shops and market places were discharged to this river. Clothes and carwash, also public bath practices to this river by peoples around jimma town. A number of studies on rivers and streams indicate that poor farming practices and poor provision of sanitation facilities to the riparian communities (Mathooko, 2001; Mokaya *et al.,* 2004).

Rapid population growth, urbanization, uncontrolled waste disposal; plastic bags and packages, as well as leachate from open solid waste dumps which are usually located on edges of the rivers inflict serious water quality deterioration (Hamze *et al.,* 2005; Tamiru Alemayehu *et al.*, 2005; Koukal *et al*., 2004; Adane Bekele, 1999).

Water quality assessments on downstream pollution profiles of rivers and streams has been undertaken on different rivers and streams in Ethiopia such as; Kebena stream (Tesfaye Berhe, 1988), Great and Little Akaki rivers Modjo river (Seyoum Letaet *et al*., 2003), Sebeta river (Deshu Mamo, 2004), and Awash river (Adane Bekele,1999). Nevertheless, majority of these studies concentrate on rivers that are found near the capital, mostly in the Awash River basin. However, studies on the Omo-Ghibe river basin are lacking (Tamiru Alemayehu *et al.,* 2005; Tamiru Alemayehu, 2001).

Nevertheless, a comprehensive investigation of the quality of drinking waters sources particularly on pollution profiles of Awetu stream encompassing physicochemical parameters and macroinvertabrates is lacking. Therefore, this study aims to assess the quality of Awetu River used for drinking purposes and water supply to Jimma town based on physicochemical parameters and macroinvertabretes indices to figure out if there are environmental and health risk associated with the use of these water sources.

1.3 Scope of the study

This study was mainly carried out the water quality assessment by physicochemical and macroinvertabretes indices of Awetu river. The study was limited to Awetu River in Jimma town for analyzing physicochemical parameters standards of the river and macroinvertabrete loading rate. Similarly, the study was conducted in dry time due to the factors such as floods which can affect the physicochemical and macroinvertabrete behavior of the river water. The result and findings of the canonical correspondence analysis, Shannon and Simpson diversity index was the reflections of water quality standard of the study river.

1.4 Objectives of the Study

1.4.1 General Objective

- Assessment of water quality using physicochemical parameters and macroinvertabrate indices, in the case of Awetu River in jimma.

1.4.2 Specific Objectives

The specific objectives of this research is;-

- To determine the physicochemical parameters of the river water and compere with WHO standard.
- To evaluate bentic macroinvertebrate loading rate along the flow of the River.
- To identify quality standard of the river by (Shannon) and (Simpson) diversity indices
- To identify if physicochemical parameter affect the assemblage of macroinvertabretes in the river.

1.5 Research Questions

1-Is the physicochemical parameters of the study river in the limit standard of WHO?

2-What is the bentic macroinvertabrete loading rate along the flow of the river?

3-what will be the quality standard of (Shannon and Simpson) diversity index of the river?

4-Is the physico-chemical parameters of the river affect the aquatic macroinvertabretes community of the River?

1.6. Significance of the study

The study designed for determination of physicochemical parameters and macroinvertabrates standard of Awetu River for drinking purpose. The work will help to assess the pollution status of Awetu River and suitability of this river water for drinking purpose. Similarly, important for providing scientific evidences before someone using this river water especially for every drinking purpose that help them to take care from being infected by poisonous chemicals and microorganisms from different sources.

1.7. Limitations of Study

The study focus assessment of water quality by physicochemical and macroinvertabrete indecision the case of Awetu river, jimma town. The limitation of the study will be;

- Seasonal variation was not identified

CHAPTER TWO
LITERATURE REVIEW

2.1. General

Today River water pollution remains a global problem, with impacts on health of fresh water ecosystems and human communities that relay on them for water supply (Revenga and Mock, 2000).

River Water pollution is the direct or indirect alteration of the physical, chemical and/or biological properties of a water system in such a way as to create a hazard or potential hazard to health, safety or welfare of any living species (Macmillan dictionary, 1998; Chapman, 1996; Beeby; 1993, Holdgate; 1979).

The advent of industrialization and increase in human population both have resulted in greater demands of high quality water for range of activities (Chapman, 1996). In addition, the scale and diversity of human activities such as agriculture, urbanization, and industry have increased rapidly in recent times (UNEP/DFID; 2003; ESA, 1998; POPLINE, 1998)

For instance, worldwide the agricultural use of water takes the largest fraction-about 69%, while 23% goes to industries and the rest 8% for domestic use (personal, household and municipal) (Engleman and Leroy, 1993). In-line with this, water consumption has almost doubled in the last 50 years meanwhile; water quality continues to worsen due to pollution (UNPF, 2002).

The presence of pollutants such as pathogens, suspended particulate matter, decomposable organic matter, nitrate, salts, trace metals and organic micro pollutants in water bodies can induce marked impairment of water bodies from their use (drinking, habitat for aquatic wildlife, recreation), when they enter into them in excess amounts from different point (e.g industries) and non-point (e.g. agricultural runoff) sources (Manahan, 2000; Taylor and Smith 1997; Chapman, 1996; McEldowney *et al.*, 1993; Miller, 1987).

However, non-point source pollutants are more difficult to measure and regulate because of their dispersed origins and variation with seasons and weather than point source pollutants (ESA, 1998).

2.2. River water pollution In Ethiopia

The majority of the Ethiopian surface water resources have faced a serious quality deterioration that mainly resulted from increasing anthropogenic activities. The alarming human population growth has demanded intensified agricultural activities resulting in more forest clearings, irrigation, fertilizers and pesticides application and overgrazing, which are becoming major surface water pollution sources (EPAE, 2008).Industrialization and urbanization are other major threats in the deterioration of surface water quality. In fact, the deterioration of the water quality was already detected some time ago (Zinabu and Elias, 1989).

The few reports are showing that there is an increasing discharge of liquid and solid waste into the nearby rivers. Studies done on a limited number of sites of a few rivers have indicated that quality of rivers crossing urban environment are getting degraded due to municipal and industrial discharges. Generally pollution coming from point and diffuse sources are major threats resulting in a continuous decline of the water quality. Therefore imperative to have a decision support tool for monitoring and management of surface waters in Ethiopia (Hailu and Mulat, 1997; Beyene *et al.,* 2009a).

2.3 Water Quality parameters

Water quality monitoring is the sampling of the conditions of water including sediments, physico-chemical parameters, fish tissues and the macroinvertebrates in order to determine the pollution level of lotic and lenthic water systems. to characterize water and identify the changes in trends in water quality over time; identify specific existing or emerging water quality problems; gather information to design specific pollution prevention or remediation programs; determine whether programs, goals e.g. compliance of population implementation have been met; and to respond to emergencies for instance flash floods and spills. Thus, water monitoring is a fundamental tool in water quality resource management.

The principle of biological monitoring as a tool is that the incidence and intensity of environmental stressors is based on the degree to which the chosen endpoint organism association deviates from the expected natural diversity (Hynes, 1972). This approach helps to detect ecological changes which are indicative of the water quality though it does not specify the causes of the change making the physico-chemical approach a more viable technique. This method is often applied because it is cheaper in term of costs and since river sample are easy to collect and analyze for inferences of health status (Nixon *et al.,* 1996).

2.3.1 Physical Water Quality Parameters

Temperature is an important variable in water quality assessment since affects physic-chemical and biological processes in water bodies(Chapman,1996).increasing temperature of water changes the physical environment in terms of reduction in oxygen concentration of water bodies while increasing the metabolism of species such as fish that are very sensitive to changes in temperature (Harrison; 1990).

Suspended particulate matter in water systems reduce clarity and contribute to decrease in photosynthesis, act as binding sites for toxic substances and leads to increased water temperature through the absorption of sunlight (Manahan, 1991,2000). Furthermore, it provides surfaces for bacterial growth and decreases the depth of a water body while settling. Suspended particulate matter (SPM) regulates the transport of all types of water pollutants in dissolved and particulate phases in water bodies. It regulates the depth of photic zone and also regulates mineralization, oxygen consumption and oxygen concentration, to regulate sedimentation (Hakanson, 2005).

Total Dissolved Solids (TDS) includes inorganic salts, principally calcium, magnesium, potassium, sodium, bicarbonate, chlorides, sulfates, and small amounts of organic matter that are dissolved in water (WHO, 2004). TDS in water originate from natural sources, sewage, urban runoff, and industrial wastewater. Concentrations of TDS in water vary considerably in different geological regions owing to differences in the solubility's of minerals and the presence of high levels of TDS in drinking water may be objectionable (WHO, 2004).

The physical parameters such as temperature, turbidity, conductivity and Total Suspended Solids (TSS) were as physical water quality parameters to measure and identify the quality standard of Awetu River. Most physical water quality parameters were measured in situ (at site) using standard methods at sampling stations. In This study four physical parameters were tested.

2.3.2. Chemical Water Quality Parameters

There are different types of chemical water quality parameters. Among those parameters these study the pH was measured by the use a corning 105 pH probe meter. Conductivity was measured by use of the probe conductivity meter Dissolved Oxygen (DO) was measured by use of a calibrated portable DO meter

PH is a very important variable in water quality assessment as it influences biological and chemical processes (Chapman, 1996). Acids and base can affect the PH of a water body and may eliminate those aquatic organisms that are PH change intolerant (Manahan, 2000; Fifield and Haines, 1995). Besides, a reduction in PH will increase the mobility of trace metals and makes them bioavailable for organisms (Mc Eldowney *et al*. 1993).

Higher level organic matter, measured commonly as Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) discharged in to a water body deplete the oxygen present in them and cause gradual deterioration of the aquatic ecosystem as a whole (Harrison, 1990). Once the oxygen is depleted, anaerobic microorganisms will flourish in the water bodies and produce noxious and harmful substances which are aesthetically unpleasant, and make the water bodies virtually unfit for utility. The sources for these pollutants include effluents from sewage treatment plants, enter in to water bodies from urban and agricultural runoff industries such as breweries, dairies and food processing plants (Chapman, 1996).

On the other hand, dissolved nitrate can easily leach into surface and groundwater to become a significant pollutant (WHO, 2004). Now, there exists a considerable public concern over the possible health hazards linked with elevated levels of nitrate in drinking water such as its carcinogenic potential and methaemoglobinaemia (blue-baby syndrome) (WHO, 2004). For instance, positive association between nitrate in drinking water and non-Hodgkin lymphoma and colorectal cancer has been reported (Gulis *et al.*, 2002).

The level of nutrients such as nitrate and phosphate in freshwater ecosystems is a problem worldwide (Shiklomanov, 1997). Natural waters have very low concentrations of nitrate (a soluble form of nitrogen) and phosphate, because they exist in forms not readily available to the biota. However, excessive inputs of phosphorus (P) and nitrogen (N) into surface waters from various human activities made water bodies unsuitable for designated uses such as drinking, irrigation, industry, recreation, or fishing (McEldowney *et al.*, 1993).

However, a shortage in phosphorus limits the productivity of most freshwater systems due to its immobilization in the biota and insolubility of its compounds (Beeby, 1993).The bioavailability of phosphorus in water is largely PH dependent (McEldowney *et al*., 1993). At a lower PH, phosphorus is strongly bound to clay particles and is found at a lower concentration. Similarly, phosphorus is immobilized at higher PH too. Therefore, the concentration of dissolved phosphorus is higher at around PH 6-7 (McEldowney, 1993).

The problems associated with chemical constituents of water arise primarily from their ability to cause adverse health effects after prolonged periods of exposure. Of particular concern are; contaminants that have cumulative toxic properties, such as trace metals, and other substances that are carcinogenic (WHO, 1993). Metals in water may be present as ionic species, inorganic and organic complexes or associated with collides and suspended particulate matter (McEldowney, 1993). The sources of these metals into the environment could be natural processes such as weathering of rocks or volcanoes, and anthropogenic activities related to industrial effluents, mining activities, etc. (McEldowney *et al.,* 1993; Manahan, 1991). The main cause to increase various diseases including Asthma, birth abnormalities, impaired mental development, Cancer and Alzheimer's disease may be directly related to the ever-increasing trace metal pollution of water bodies (Fifield and Haines, 1995).

Worldwide the lack of sanitary waste disposal and of clean water for drinking, cooking, and washing is responsible for over 12 million deaths each year (USAID, 1990). The most common risks to human health related to water arises because of pathogens such as viruses, bacteria, and protozoa (Manahan, 1991). Most of the time these pathogens originate from water polluted with human excrement (Revenga and Mock, 2000; Chapman, 1996). Human feces can contain a variety of intestinal pathogens that may cause diseases such as ameboic dysentry, bacillary dysentry, diarrheal diseases, cholera, hepititis-A, parathyphoid and thyphoid and polio (POPLINE, 2000).

Pathogens associated with the discharge of sewage, agricultural and urban runoff and domestic wastewater when released into water bodies such as rivers may present a risk to downstream users (Chapman, 1996). In addition, they can percolate through the soil and contaminate groundwater. In fact, surface water bodies are recognized to be more vulnerable to contamination than groundwater (Kistemann *et al.,* 2002).

2.3.3 Microbiological and Bentic Water quality Parameters

Macroinvertebrates or more simply "*benthos*" are organisms in the aquatic environment without a backbone that can be seen with the naked eye. These animals can be found on rocks, logs, sediment, debris and aquatic plants during some period in their life. The *benthos* include crustaceans such as crayfish, mollusks such as clams and snails, aquatic worms and the immature forms of aquatic insects such as stonefly and mayfly nymphs. Among the aquatic insects, Ephemeroptera, Plecoptera and Trichoptera (EPT), comprise rich assemblages in low and medium order stony cobble streams. These organisms are sensitive to environmental perturbations and therefore occur in clean and well-oxygenated waters. Therefore, EPT assemblages are frequently considered to be good indicators of water quality (Rosenberg & Resh 1993).

Aquatic macroinvertebrates are an important component of the freshwater communities and a link to the aquatic food chain (Waters 1995). Its species diversity is controlled by productivity, habitat heterogeneity and biotic interactions (Townsend 1989 as cited by Moretti & Callisto 2005). They are widely used as water quality bio-indicators due to their long life period (Marques & Barbosa 2001) and they are also sensitive to changes in the ecosystem (Uyanik *et al* 2005). Moreover, they are serve as a tool to measure continuous and chronic effects of pollution, stream degradation from storm water runoff, point source discharges and are thus indicators of stream recovery (Yandora 1998).

Assessment of the water quality of aquatic ecosystem can be done using non-systematic units such as fish, macroinvertebrates, zooplankton, macrophytes, phytoplankton and diatoms. The most frequently used community to determine the water quality in the aquatic bodies is the benthic macroinvertebrates. They have been identified as organisms useful to biological monitoring for their measurable and variable sensitivity to in-stream disturbance over long life cycles, time and cost efficient compared to its rapidly changing physico-chemical assessments of water quality which provide little insight into temporal variation in conditions (Bode *et al*., 1996; Resh *et al*., 1996; Sharma, *et al*., 2008).

Many metrics have been developed using benthic macroinvertebrates as biological monitoring each biological metric is a mathematical expression of a different aspect of the benthic-macroinvertebrate community and how it relates to the river quality. They can be collected easily from most aquatic systems with inexpensive or homemade equipment (Uyanik *et al* 2005).

CHAPTER THREE
METHODS AND MATERIALS

3.1 Description of the Study Area

The study was conducted in Jimma town located on south west Addis Abeba, having a total area of 220 Km^2. It is located:07 ^{0}39'Lat and 36^0 50'Long, at an altitude of 1700-1750m above sea level and 335 km south west of the capital-city, Addis Ababa.

Jimma is an old town divided by 09 administrative Kebeles. Due to lack of systematic land-use classification, most people live in unstructured and scattered residential areas mixed with hotels, bars and restaurants, big shops, milling houses, medium and small clinics, small furniture manufacturing centers, garages, etc. Most of the area is occupied by private residential houses and small governmental and commercial buildings. A point worth noting is that, there are no big manufacturing industries. In the outskirts of the town, subsistence farming is prevalent. The central part of the town is highly congested and is characterized by active business transaction. A large number of people live in this central part of the congested area with poor sanitary facilities. The town has a poor sewerage system where, the runoff from roads and wastewater from different sources finally end-up into Awetu stream. Solid waste is found all along the streets, marketplaces, and riparian zone of Awetu River. The population of the town is increasing from year to year (56,278 in 1978 to 151,679 in 2005). This brings a big problem for the municipality which has limited budget to undertake the collection of solid waste in an integrated manner and cope-up with the growing population a significant factor for an increase in solid waste. The city has a population density of about 3521 person's per km in 2015 and an average population growth rate of 4.9% per year there are two major rivers flowing through the city: Awetu, which bisects the center of the city and Kito, which flows at the western end (Central Statistical Agency, 2015).

3.2 Geology and Hydrogeology of the area

The study area is located in the southwestern Ethiopia plateau in an area of moderate relief and is situated on a low hill to the north of the wide alluvial plain of the Gilgel Ghibe River (Nata Tadesse, 1994). It is also underlain by tertiary volcanic rocks, while the valleys bedrock is overlain by alluvial sediments. These alluvial sediments occupy the broad valleys of the study area. The thickness of the alluvial sediment beneath the surface ranges from 20m in the upper part to greater than 200m in the deeper part of the valleys. Based on topography, variation in hydraulic properties of the volcanic rocks and alluvial sediment, and their location the main hydrological basin the study area is classified into three sub-basins as the Kochi, seto, kito Awetu Bishishe Bridge and boye sub-basins (Nata Tadesse, 1994).

The Kochi sub basin is drained by the Kochi stream which joins Awetu River at Boye. On the other hand, the Kitto sub-basin drains by the Kitto stream finally joins Awetu stream at the dado bridge. Awetu River originate from north of the town and flows along the middle of the valley in the south direction. Groundwater occurs in many types of geologic formations; those known as aquifer are of most importance. An aquifer is a formation that contains sufficiently saturated permeable material to yield significant quantities of water to wells and springs (Todd, 1980). Probably 90% of all developed aquifers consist of unconsolidated rocks or alluvial sediments (Todd, 1980).

The prevailing types of rainfalls that occur in the study area are orographic and convective. Yet, a cyclonic type of rainfall prevails in June, July, and August. The moisture for the rain originates from gulf of Guinea. However, the rainy periods extend from March to October since the rainfall coefficient (RC) is greater than or equal to 0.6. On the other hand, from November to February is a dry period with rainfall coefficient less than 0.6 (Warner *et al.*, 2000)

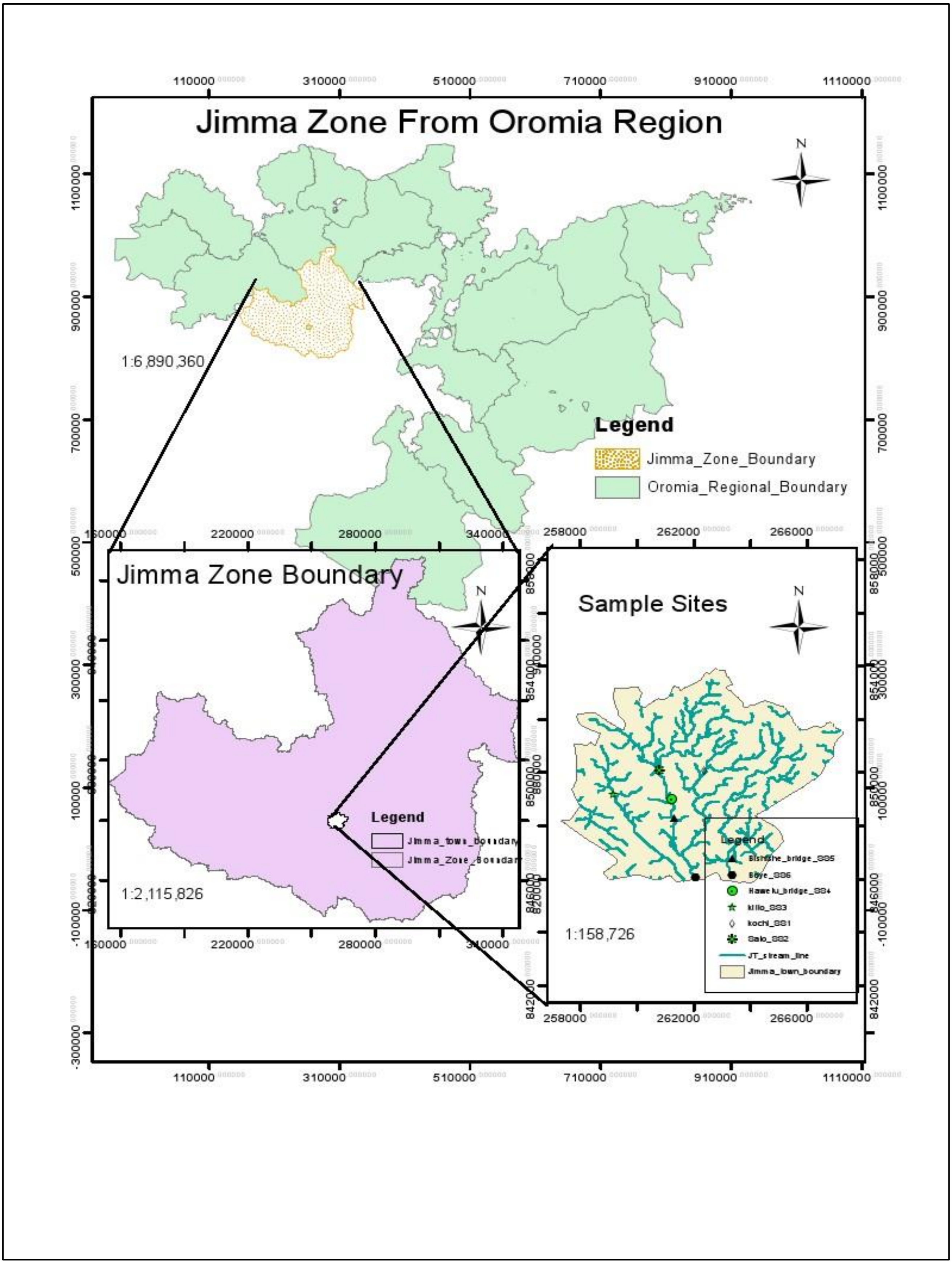


Figure-3.1 Map of the study area (sample site)

3.3 Materials

Digital conductometer was used to measure Electrical Conductivity. PH of the river water sample was measured by pH meter (pH 600Milwaukee (Mauritius) on the field. An ice bag was used for sample preservation. Uv-vis Spectrophotometer (ELICO SL 160, INDIA) was used for the determination of Nitrate and Phosphate. Generally different sized volumetric flask, pipettes, measuring cylinders, burettes, drying ovens mechanical shakers desiccators and analytical measuring balances were used as required. Turbidity of water samples was measured by digital Turbidimetrc 2100A instrument. Total dissolved solids (TDS) were measured by Digital Conduct meter.

Table-3.1: Physico-chemical parameters selected for the study site measurement and unit

Tl	Physicochemical parameters	Measurement	Unit
1	PH	Probes multi parameter methods (pH meter)	
2	Turbidity	Turbidity meter	NTU
3	EC	Probes multi parameter methods (EC meter)	µS/cm
4	TDS	Gravimetric Method, dried at 180°C	mg/L
5	BOD5	The Azide Modification of the Winkler Method	mg/L
6	COD	Kit (Hachlange cuvette test, LCk 614 &114)	mg/L
7	TSS	Gravimetric Method, dried at 103-105°C	mg/L
8	DO	Probes multi parameter methods (DO meter)	mg/L
9	NO3	Phenol sulfonic Acid Method (Uv-vis Spectrophotometer)	mg/L
10	Phosphate	Stannous Chloride Method (Uv-vis Spectrophotometer)	mg/L
11	Temp.	Probes multi parameter methods (thermometer)	°C

3.4 sample site selection

Study area has divided into upstream, midstream, downstream. Sampling sites were selected based on accessibility and the presence of point sources and diffuse sources of pollution. A total of 6 samples sites were selected around Jimma Town of Awetu River. Of which 2 were located in upstream, 3 in midstream, 1 downstream, of the river.

The upstream areas of the rivers KOCI (SS1), SETO (SS2), were mainly characterized by small-scaled agriculture and cattle grazing. Runoff from land was therefore expected to be the major source of pollution. Additionally, solid and liquid wastes from different houses, hotels and the newly built slaughter house were investigated as potential point sources of pollution.

The midstream reaches were subjected to high anthropogenic impacts, as these were situated in the urban area. KITO (SS3), Awetu Bridge (SS4) And Bishishe Bridge (SS5) Untreated wastewater and solid waste were in discrimately discharged on land and in Awetu River water ways. The main campus of Jimma University (JU), which mainly discharged its waste in the river Aramaic Hotel, Dolollo Hotel and Central Hotels and dry coffee processing plant (CP), were considered to have a negative effect on the water quality of Awetu River

Figure-3.2 Image while sampling

Finally, The Rivers from upstream and mid-stream merge together in downstream, where the main source of pollution was solid waste from shop, restaurant and bishishe market areas were discharged. Small agricultural actives around the area of Boye (SS6) sample site.

3.5. Sampling Methods

3.5.1. Physicochemical parameters

Purposive sampling method was employed. Water Samples were collected from six (6) sample sites in sterilized PVC bottle and glass bottles, which are pre cleaned thoroughly with nonionic detergent, to maintain accuracy or minimize contamination of physicochemical changes that can occur between time of collection and analysis as indicated in standard method (APHA, 2005). The water samples were collected by inserting the plastic and glass bottles to the opposite direction of the river flow and capped tightly immediately after filling to the tip of the mouth of this bottle by using depth-integrated sampling technique. Water samples were put in $4^{O}C$ by adding a preservative (of 70% HNO_3) alcohol. Determinations of TDS, pH, EC, temperature, turbidity and DO fixing were carried out in-situ as (APHA, 2005). Whereas total alkalinity, nitrate and orthophosphate concentrations were analyzed by using Uv-Vis Spectrophotometer (Shimadzu UV-1800) according to (APHA, 1996). The water samples used for DO and BOD determinations were collected directly into dark DO bottles, and some drops of manga nous sulphate solution were added to fix dissolve oxygen. After collection, they were stored at room temperature. These samples were properly and carefully labeled, sealed and transported to Jimma University Department of Environmental Health Sciences and Technology laboratory. Cold storage was maintained throughout the process till analysis.

3.5.2 macro-invertebrates (benthos)

Macro invertebrat**es** were collected using a triangular D-frame Dip-Net (mesh size = 500 µm, sampled area = 100 m^2) was used to collect benthos by kick sampling method. In this method, the river bed was disturbed for a distance of about 100 m^2 for 3-5 min. multihabitat approach to dislodge macro invertebrates attached to any substrates at each sampling point (Gabriels *et al.* 2010).samples were collected during the dry season . The gravel, sand, and mud biotopes were disturbed by kicking whilst holding the hand net in opposite direction to the water current and continuously sweeping the net over the disturbed area to catch the free organisms for 2-5 minutes (Bwalya, 2015). The collected samples were washed down to the bottom of the net using clear water and the contents were tipped into a white sorting tray for on-site identification. The taxa were identified up to the lowest taxonomic level and recorded on the score sheet (Appendix 1). After completing the identification process, the identified taxa were returned into the river. Identification was done using the macroinvertebrate guide book for SASS (Appendix 2) and has been performed in the laboratory using identification key (Durand and Levêque (1991), Tachet *et al.* (2006) and (Moisan, 2006; Moisan, 2010) were used. and a microscope. Identification has been performed in the laboratory using identification key and a microscope.

Benthos sample was conducted three times from each riffle and run sample site. These samples were properly and carefully labeled, sealed and transported to the laboratory of

Jimma University Department of Environmental Health Sciences and Technology. Cold storage was maintained throughout the process till analysis. Identification to a family level and macroinvertebrate in species level was done using a compound light microscope and assisted by a standard identification key (Bouchard 2004; Kobingi *et al.*, 2009).

3.6 Sample Analysis

3.6.1. Physic-Chemical Analysis

The water samples were analyzed for various physico-chemical parameters using standard methods recommended by (APHA, 1998). Physicochemical parameters such as temperature, pH, electrical conductivity, turbidity, total dissolved solids, total suspended solids, dissolved oxygen, biological oxygen demand, chemical oxygen demand, alkalinity, nitrate (NO_3), and orthophosphate were analyzed using the standard analytical methods. The temperature, pH, EC and turbidity were determined on site using Multimeter, turbidity also determined on site using nephelometric turbidity meter. BOD was measured based on oxygen consumed in a 5-d test period (5-d BOD or BOD_5) after arrival of sample to the laboratory. Standard laboratory methods as described by the APHA for the examination of water samples was employed for the analysis of TDS, DO, COD, NO_3.

3.6.2. Macro invertebrate Diversity Metrics

Benthic macroinvertebrate metrics measure different components of the community structure and have different ranges of sensitivity to stress. Therefore, it is recommendable to use several metrics because an integrated approach provides more assurance of a valid assessment (Klemm *et al.*, 1990). In the present study, the Total number of taxa (Family level Richness), Percentage Dominant taxa, Shannon Diversity Index (SDI), Simpson index were applied.

Figure-3.3 Image while laboratory analysis

3.6.2.1. Taxonomic Richness (TR)

Number of different species represented in an ecological community.TR is the number of taxa present in each station. It is the measure of community's diversity, number of different families found in samples of each site. Reductions in community diversity have been positively associated with various forms of environmental pollution, including nutrient richness increases with increasing water quality, habitat diversity and habitat suitability (Barbour MT, R, Mc Carron E, *et al.* 1996).

3.6.2.2. Abundance (N)

Abundances is a number of individuals from a taxonomic group in each station. Relative abundance (Nr) = ratio as a percentage of the number of taxon individuals in a station to the total number of individuals of all species of all stations. Frequency of family observation (FO) = $(Fi \times 100)/ Ft$. In such, Fi = number of stations containing the family and Ft = total number of stations studied. Three families were thus distinguished as (Abahi *et al.* 2018), as previously demonstrated. We have "very frequent families'' ($F \geq 50\%$), "frequent families'' ($25\% \leq F \leq 50\%$) and "rare families'' ($F \geq 25\%$)

3.6.2.3. The Shannon-Wiener Diversity Index (H′)

Shannon-Wiener diversity index is a mathematical measure of species diversity in a community accounting for both abundance and evenness. Or diversity index that incorporates richness and evenness. A high H′ value indicates a good water quality. H′ was calculated as follows:

$$H' = - \sum (P_i \ln [P_i]) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equ-1}$$

Where: P_i is the relative abundance of i species in the sample. The Shannon index is expressed in bits. It was determined by station. Shannon index values obtained were used to assess water quality, ranging from 0 for a community with a single family, to over 7 for a very diverse community. An H' value of less than 1 indicates highly polluted, 1-3 moderately polluted, and greater than 4 unpolluted water bodies (Wilhm and Dorris, 1968).

3.6.2.4. Simpson index (D)

Mathematical measurement of species diversity in a community accounting for the number of species present, as well as the abundance of each species. Simpson index (D) = 1 – $\sum_{i=1}^{s}(pi)$^2, with S standing for the total number of individuals and pi = meaning the relative abundance.

Spearman's rank correlation coefficients were used to determine the relationships between physico-chemical parameters, biotic indices and macro-invertebrate metrics.

3.7. Statistical Analysis

The taxonomic richness, the taxonomic abundance, the average values of the physico-chemical parameters were calculated per each site. Parametric and non-parametric tests (test t student and test of Kruskal-Wallis) were used to evaluate the variability of the taxonomic richness of the abundances and diversity indices at the 5% threshold with the PAST software. Moreover, the factorial correspondence analysis (FCA) was used for grouping the stations according to the similarity association of macroinvertebrate families. In addition, a canonical correspondence analysis (CCA) was performed using PAST statistical package (ter Braak, 1986).

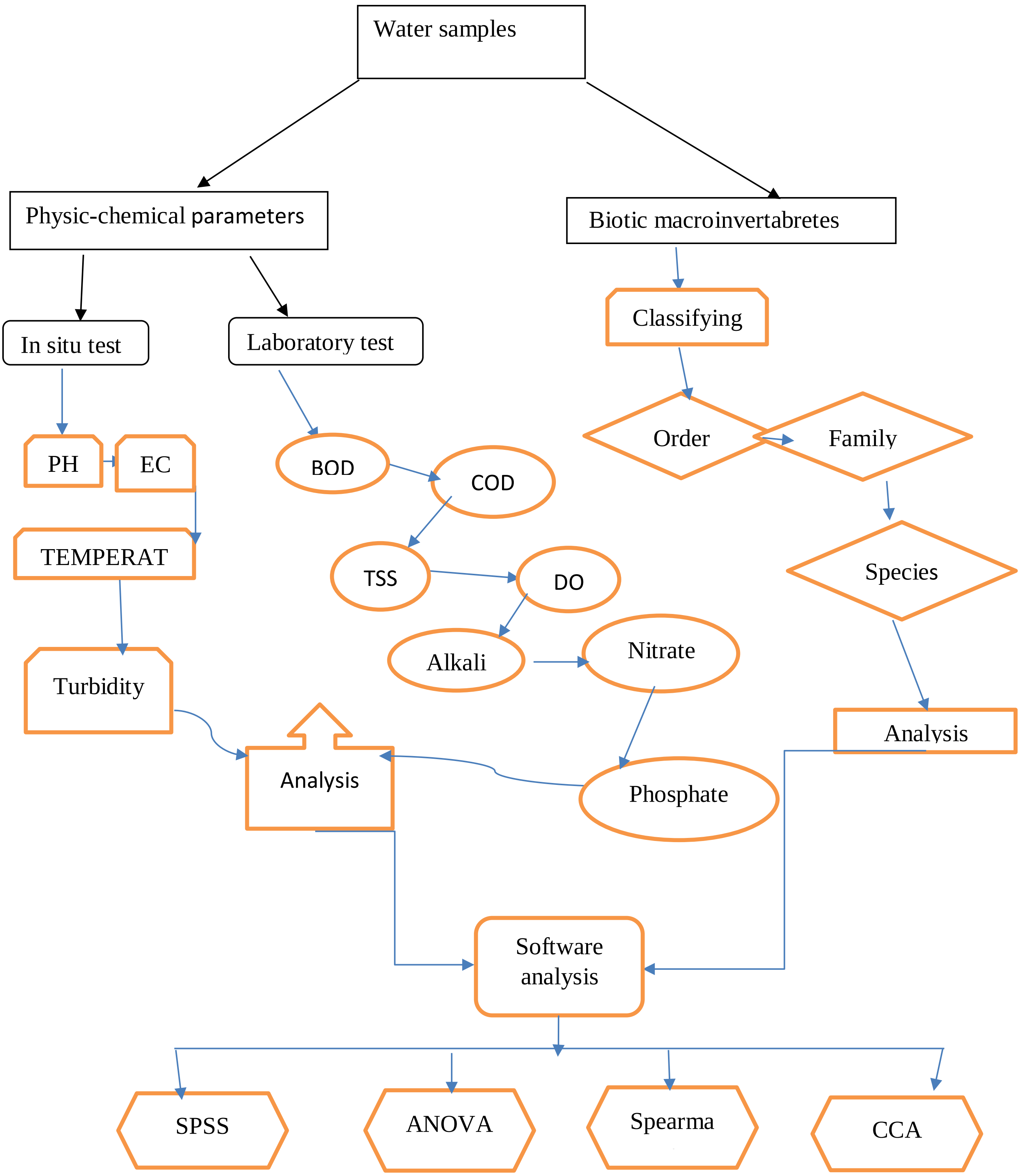
One-way ANOVA was computed to see significant difference between each sample site for the physicochemical parameters and benthos assemblages as biological indicators. Pearson correlation matrix analysis was used to reveal the magnitude and direction of relationship between different physic-chemical parameters within and among benthos assemblages as biological indicators of river water quality. Benthos assemblages as biological indicators of Eco hydrological river water quality samples were determined by using benthos assemblages multimetric indices mentioned above.

The physicochemical and macroinvertebrate were analyzed by canonical correspondence analysis (CCA) software to identify the relationship between physic chemical and biotic indices and influencing parameters on both communities of the river (ter Braak, 1986). The result of physico-chemical parameters were compared with set standards of WHO guidelines for drinking water on each site and to identify the pollution loading rate of each site.

3.8. Quality control and quality assurance

Blanks were run for every analysis to correct measurements. Calibration of the Uv-cis Spectrophotometer was made using standard solutions. For sets of ten samples, a procedure blank and a spiked sample containing all reagents were read to check contamination and triplicate measurements were taken for each sample. For the sake of quality assurance data were assessed carefully using standard operating procedures and Double entry of data were performed to assure the quality of data.

Flow charts of methodology throughout the study.



CHAPTER-FOUR

RESULT AND DISCUSTION

4.1 physicochemical water quality restrictions

The result of physic chemical parameters of Awetu River identified from selected 6 sample site was list in table 4.1.

Table 4.1: physic chemical parameters of Awetu river water recorded on each samples site.

No	Parameters	Units	Sample code						Aver.	WHO
			SS1	SS2	SS3	SS4	SS5	SS6		
1	Temperature	^0C	25.4	26.0	24.1	22.3	22.1	23.3	23.86	40
2	PH	Log units	9.40	7.26	7.28	7.50	7.84	7.41	7.78	6.5-8.5
3	EC	µS/cm	58.2	77.4	96.4	111.5	111.6	111.7	94.46	750
4	DO	Mg/L	5.98	6.05	6.01	5.41	3.40	4.23	5.18	5.0-7.0
5	BOD	Mg/l	999	745	734	710	705	700	765.5	2.0-5.0
6	COD	Mg/l	1230	942	936	910	875	849	957	1000
7	Turbidity	Mg/l	5.12	5.97	6.42	10.12	9.67	8.30	7.6	5.0
8	ALKALI	Mg/l	300	378	423	514	342	298	375.83	120
9	TSS	Mg/l	180	160	155	140	130	150	152.5	50
10	NITRATE	Mg/l	2.43	2.21	2.01	1.86	1.54	2.12	2.03	45
11	ORTOPHOS.	Mg/l	0.023	0.052	0.049	0.055	0.063	0.065	0.051	0.35

4..1 Physical water quality parameter

4.1.1.1 Temperature

There is a variation of temperature along the river for all sample sites. The highest temperature is being at site (SS2) and the lowest at site (SS5). This is because there are different small and big trees around the river on these station. Generally, the result of Awetu river water temperature ranged from 22.1 ^{0} C to 26.0 ^{0}C with an average value of 23.86 ^{0} C and is not found within the permissible limit of (WHO, 2008) or less than the standard of WHO. The maximum temperature determined at upstream SS1 and SS2 (25.1˚C and 26.0^{0}C). At this sites there were no coverage of canopy and the river was directly exposed to the solar energy, which can attribute to the increase temperature. Lower temperature was recorded at SS4 and SS5 sample sites (22.3^{0}C and 22.1 ^{0}C) respectively. These sites might be explained by the highest upland plantation cast canopy cover (90%) and high altitude. This may slightly lower the temperature. The highest (26.00 °C) and lowest (22.10 °C) temperature from Awetu river water, were related to the 28 °C reported from different water source of Nigeria (J Appl Biosci. 2010) but higher than the study conducted in Bahir Dar town (15–20 °C) (Ethiop J Health Sci. 2011). Almost all the recorded water temperatures were above the WHO recommended level (<15 °C).

4.1.1.2. Electrical conductivity

Electrical conductivity values recorded varied between 58.2 and 111.7 μS/cm. It was seen that the EC was maximum at the downstream station and minimum at the upstream station. EC of the river at all sites was lower than the permissible limit by WHO for drinking irrigation purposes. Thus, the result indicated that the river receives low amount of dissolved inorganic substances in ionized form from their surface catchments. Electrical conductivity is related to provide a measure of the total dissolved solids. The rises and/or falls of electric conductivity are attributed to the dissolved solids in water (Colin *et al.*, 2017). These is true for this study high discharge of dissolved solid was caused for increasing EC at down stream

4.1.1.3. Turbidity

Turbidity is measured by the amount of light that is scattered by the sample. Result obtained from the study showed that, the lowest turbidity value is recoded (5.12) NTU. The value range from 5.12 to10.12 NTU, was recorded at the Upstream to downstream Sites. The maximum turbidity was recorded at the SS4 Site with value of 10.12 NTU. The average turbidity value of sampled water was 8.325 NTU. The values obtained for the river were above the permissible limit set by WHO for drinking. The maximum turbidity recorded attributed to highest sediment lodes through surface runoff from agricultural and urban land uses.

4..2 Chemical water quality parameters

4.1.2.1 PH

On-site measurement, of the sampled water PH value varied from 7.26 to 9.40 with average value of 7.78. The highest value of pH reading was observed at the upstream and the lowest value at the second sample site (SS2) of water. According to (WHO, 2004) and Ethiopian guide line the permissible limit of pH is from 6.5 (lowest value) to 8.5 (highest value). It is known that pH of water (6.5 to 8.5) does not has direct effect but, lower value produce sore taste and higher value above 8.5 has alkaline taste. The pH values of the present investigation were within the standards set for drinking and irrigation purposes, at five sites and above the standard at one site (SS1). The highest pH was recorded at SS1 (9.40) might be explained due to waste discharge, cloth washing and open bathing.

4.1.2.4 Orthophosphates

Orthophosphate (reactive) is analyzed directly on an unpreserved sample within 48 hours of sampling. The results obtained for this study were maximum and minimum of 0.065 and 0.023 mg/L. phosphate is decreasing from upstream to downstream of the river.this is also associated with fertilizer from the upstream agriculture.

Alkalinity is a measure of water capacity to neutralize acids, and is important during softening. In the present investigation, the alkalinity ranged between 298 mg/L and 300 mg/L. Alkalinity at all sites was above the desirable limit of WHO standard guideline. The high values of alkalinity may also be due to increase in free bicarbonate and soap from clothes wash in the river which ultimately result in the increase in alkalinity. (Napacho and Manyele, 2010) found that pH values in shallow tube wells varied between 6.7 and 8.3 due to dissolved minerals from the soil and rocks. They further explained higher alkalinity by the presence of two common minerals, calcium and magnesium, affecting the hardness of the water. On the other hand, water with low pH values is meant to be acidic, soft, and corrosive. These study identify that urban construction of road and buildings around the river and washing closes soap (increase hardness of water) to the river make increasing of alkalinity.

4.3 Biological parameters

4.3.1. Dissolved Oxygen

DO was recorded as 6.05 mg/L and minimum value of 3.41 mg/L. Concentration levels of DO below 5.0 mg/L adversely affect aquatic life. Thus in this study, DO ranged from (3.41 to 6.05 mg/L). A minimum value was recorded in Site (SS5) and (SS6) indicated that the studied Site SS4 was susceptible to pollution due to the nearby market and a maximum value was recorded in Site SS2 and SS3 which may be due to self-purification of the water along the course of the river. DO levels are important in the natural self-purification capacity of the river. A good level of DO in sampling sites of the river indicated a high re-aeration rate and rapid aerobic oxidation of biological substances. In general the average values (5.18mg/l) DO was recorded in all sites which were acceptable compared with WHO standard.

4.3.2 BOD

BOD is a measure of the amount of oxygen used by biological and chemical processes in a stream of water over a 5-day. BOD5 in the present study ranges from 700 to 999 mg/L. The BOD values of the studied river were above the recommended values of WHO. The BOD values of the present study were not suitable for fish culture or irrigation. BOD values ranged from 109 mg/L to 163 mg/L in Buriganga River and 102 mg/L to 149 mg/L in Balu River, which is lower than the present study (Adesalu, *et al.* 2010). Increasing value of BOD is excessive solid and liquid waste discharged and car wash nearer the river.

High concentrations of total suspended solids (TSS) can cause many problems for stream health and aquatic life. Water is filtered, and then the residue is dried and weighed then compared to the original sample. The total suspended solids of this study values ranges from 180 to 130 mg/L. while this amount should not be greater than 500 mg/L as recommended by EPA for drinking water. The variability or range in the recoded TSS data was significantly high as compared to the earlier report (10–32.4 mg/l) made from Southern Rajasthan, India (Sharma BK, 2008).and low compared to hand pump water sources and the value (210.0 ± 127.7 mg/l) from untreated water of Jimma town, Ethiopia (Israel D, 2007). This study, TSS in water samples was higher than 200 mg/L, which was considered harmful for the environment (Ogidiaka *et al.* (2012). These values of TSS were also higher than DoE effluent standard (150 mg/L) and Indian effluent standards (100 mg/l) (Adesalu, *et al.* 2010) is less than the present study.

In the present study water samples from different sampling point stations (SS1 to SS6) showed low concentrations of nitrate (1.54 to 2.43 mg/L) well below permissible levels as per the standards. According to this study the minimum nitrate concentration is 1.54 mg/L recorded Midstream (SS5) and the maximum nitrate concentration is recorded at the upstream station with value of 2.43 mg/L. the average value recorded on all site is (2.02Mg/L). Nitrate is a form of nitrogen and a vital nutrient for growth, reproduction, and the survival of organisms. High nitrate levels (>1 mg /L) are not good for aquatic life (Johnson *et al.*, 2009). This is because the upstream of the river has covered by small scale agriculture. Fertilizer from this agriculture area discharged to this river. This fertilizer increase nitrate content of the river.

In general in these study 11 physico-chemicals parameters were selected to study the quality of Awetu River. The variables PH and DO met the proposed standard of WHO. But TEMP, EC, BOD, nitrate and orthophosphate were below the standard of WHO guide lines, Indicating high organic loads and poor chemical water quality conditions. The amount of turbidity and alkali in the assessed river was too high compared with WHO Gide lines and approximately 50% of all sampled sites to ensure a healthy ecosystem.

The below graph shows detail information on physicochemical parameters results of Awetu river and the WHO Standard guide lines in comparison.

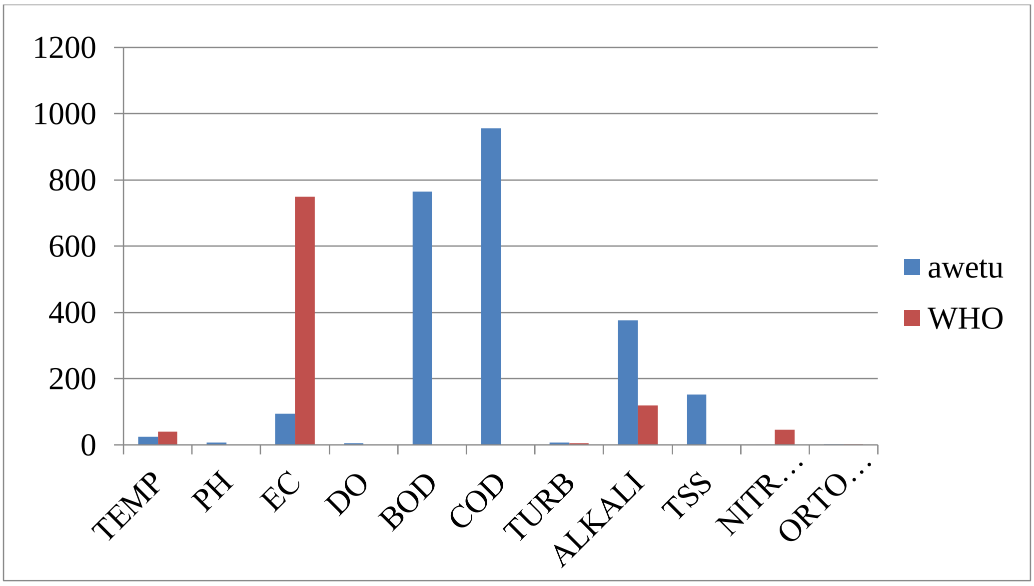


Figure-4.1: Physic chemical parameter of Awetu River with WHO standard guide lines

COD can be related empirically to BOD, organic carbon or organic matter. In this study the maximum COD was minimum value recorded 849mg/L and maximum value of 1230 mg/L. the average value recorded was 975mg/l. Higher BOD values record reveals clearly that midstream was experiencing a higher level of pollution than upstream and downstream. The higher level of BOD and lower DO occur at midstream sites might be due the introduction of solid and liquid wastes from the town. Also Higher BOD reported in this study can be attributed to the low flow rate of the river and in such a way it is able to recover from organic load from external sources. Water with biochemical oxygen demand less than 4 mg/l are termed reasonably clean and unpolluted, while water with level greater than 10 mg/l are considered polluted since they contain large amount of degradable organic materials (Ohimain *et al*., 2008). COD values ranged from 185 mg/L to 381 mg/L in Buriganga River and 204.8 mg/L to 307.2 mg/L in Balu River (Ohimain *et al*., 2008) were recorded. The result were low compared to the present study.

Minimum allowable concentration of phosphate in irrigation water is 2 mg/l in all most all sites except upstream and SS1 and this may be due to jimma town domestic waste discharges, and phosphates detergent to the sites through point and non-point source in addition to fertilizers run from the catchment. It has been reported that rapid urbanization, waste discharge, and other anthropogenic activities are known causes of nutrient enrichment and threat river deterioration (Luo *et al*., 2017).

4.2 Bentic macroinvertebrate loading rate

4.2.1. Macroinvertebrate Order

For all sites sampled site the following metrics were calculated for macroinvertabrte study: (i) taxonomic richness (i.e. number of taxa); (ii) abundance (i.e. numbers of individuals per site); (iii) Shannon-Wiener Diversity Index (H') (Nurhafizah-Azwa, S. and Ahmad, A.K. 2018) and, (iv) the Simpson Diversity Index (1 – D) (Micha, J.-C. 2014). The water quality assessment for a range (Shannon and Simpson) index values were presented in appendex-3.

Table 4.2: Order of Macro-invertebrate Load Collected from Selected Site of Awetu River

Order	Sample code						Aver	%	Sum
	SS1	SS2	SS3	SS4	SS5	SS6			
Odonata	98	68	56	44	39	38	57.2	29%	343
Himeptera	31	28	24	20	17	16	23.5	11%	136
Coleptera	32	27	22	13	10	4	18	8%	108
Tricoptera	64	50	40	23	16	16	34.8	18%	209
Dipteral	2	5	10	33	57	95	33.6	17%	202
Ephemeroptera	31	23	16	12	4	6	18.5	9%	100
Plecoptera	17	8	5	4	1	1	9	5%	36
Hirudinea	0	0	1	1	2	4	2	1%	8
total	275	209	174	150	146	180	24.58	100	1142

Macroinvertabretes result of the river indicates, a total of 1142 individual macroinvertebrate which belongs to eight (8) orders and 30 Family were collected from 6(six) sampling sites of Awetu Rivers (appendex-1). The most abundant orders were Odonata 343 (29%), tricopetra 209(18%) and Diptera 202(17%). The most dominant orders were plecoptera which was

38(5%) and Hirudinea which is 2(1%). But among the orders Himeptera and ephemoptera are moderately abundant taxon with 136(11%) and 100(9%) respectively.

The macro-invertebrate communities composition were lowest when compared to related findings e.g. 10 orders and 37 families in the spring and stream sites of the upper Awash River (Negero *et al.,* 2017), 10 orders and 34 families in Cheffa wetland from Borkena Valley (Getachew *et al.*, 2012), 9 orders and 34 families in Wedech River in Debrezeit (Tamiru *et al*., 2017), 12 orders 33 families in highland stream of Northern Ethiopia (Teferi *et al*., 2017). Moreover, the present finding not agrees with (Hirpa, 2012) in the same study area where 8 orders and 21 families of macro-invertebrates were investigated. The differences of macro-invertebrates composition in the present study might be attributes that which was conducted at the downstream.

From table 4.2 the total of 343 families of Odonata 98 families are collected from (SS1), which is the highest percentage. But on SS6 the list or small number of Odonata families are collected. Hemoptera is also abundant on SS1 and less on SS6 of Awetu River. From the total of (108) coleopteran, 32 families were on (SS1) and less number of the families were on site (SS6). Tricoptera, plecoptera and ephemeroptera families where highly accumulated on site SS1 and less number of families were on (SS6) from the total number of their families.

Ephemeroptera, Plecoptera and Trichoptera are restricted to cool, clean streams and rivers with high dissolved oxygen content, these groups of macroinvertebrates serve as bio-indicators of pollution in the aquatic ecosystem (Victor and Ogbeibu, 1985; Olomukoro and Ezemonye, 2006). Numerically, the species of Ephemeroptera and Trichoptera identified at all stations were decreasing from upstream to downstream, while Plecoptera was virtually absent in downstream site. According to Stewart and Stark (1993), plecopterans are the most sensitive order of aquatic insects and many species are restricted to habitats with high levels of dissolved oxygen. The dissolved oxygen concentration may not be the possible explanation for absence of plecopterans in this study, because concentrations above 5.0 mg/l (Table 4.2) were recorded at all stations during the study period except site SS5. Their absence can be attributed to pollution by organic substances which were discharged into the river and the various human activities on the bank of the river.

Generally Odonata, Tricoptera, Coleptera, Himiptera and Ephemeroptera were mostly abundant on the upstream of Awetu River. But less number of these orders were recorded on the downstream of the river. On the hand Diptera, Plecoptera and Huridinea were the most dominant species on upstream to downstream, except Diptera that highly abundant on downstream of Awetu river.

Moreover, low macroinvertebrate counts were also observed in the downstream area of the Awetu River (except sampling sites SS6 which has high macroinverabrete). This could be attributed to the high values of alkali. These results correspond with the study of Duran (2006) in the Behzat stream in Turkey. Macroinvertebrates have also been identified and the highest species number was recorded near tributaries due to the availability of food while the lowest are in the impacted areas where there are pollution discharges (Beqiraj et al 2006).

2.2.2. Taxa richness

The highest taxa richness at SS6, the probable reason might be explained due to the sites have been good physical habitat quality (i.e. substrate composition protected riparian vegetation, bank stability, vegetation and canopy cover) water quality as well as good ecological integrity.

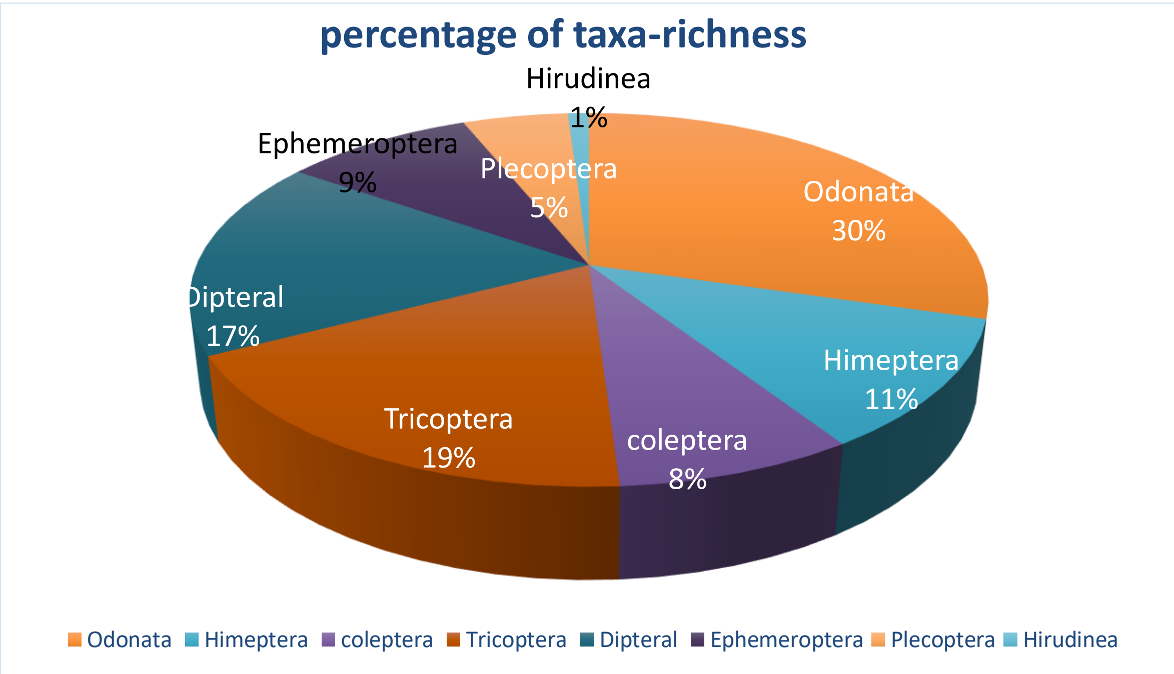


Figure -4.3: percentage composition of invertebrate's taxa on each sample site

Figure -4.3 clearly indicate odonata, Diptera and Tricoptera has higher number of species (9, 5, 6) respectively. Himeptera, Ephemeroptera and Coleptera are moderately distributed. But Plecoptera and Hirudinea has small distribution in Awetu river sample sites.

4.3 macro invertebrate indices (Shannon and Simpson)

4.3.1 Abundance

The number of individual macro invertebrates per benthic site ranged from 0 to 338. The changes of dominant species at 6 sites expressed clearly the habitat characteristics of the Awetu River and its tributaries.

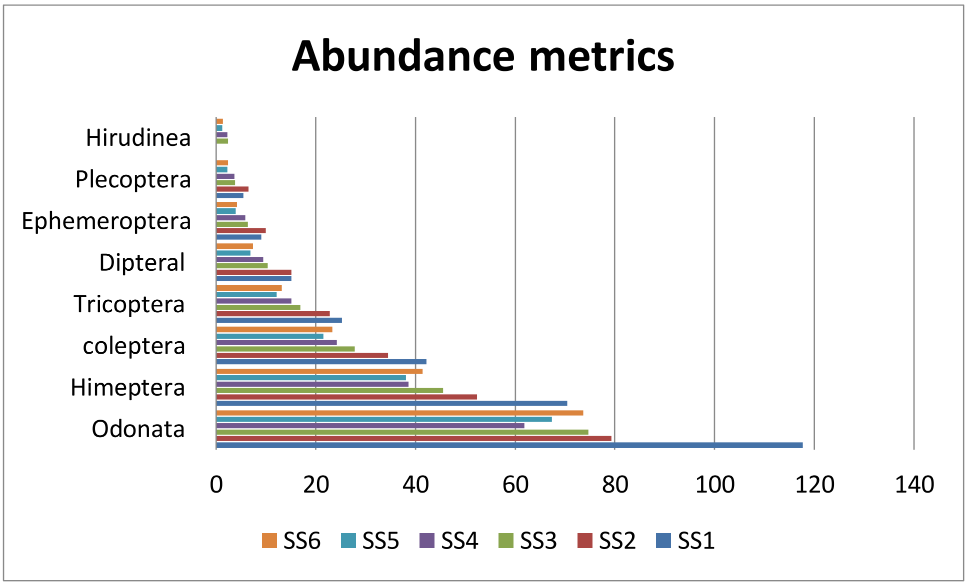


Figure -4.4: abundance metrics of macro invertebrate order in Awetu River.

Abundance metrics is the number of individual in each site. The above figure 3 indicate Odonata has the largest abundance on sample site SS1 and Himiptera, coleptera and tricoptera also has large number of abundance on upstream of the study river. Hirudinea and plecoptera were dominated taxon. Dipteran is lower on upstream but it increase throughout the site.

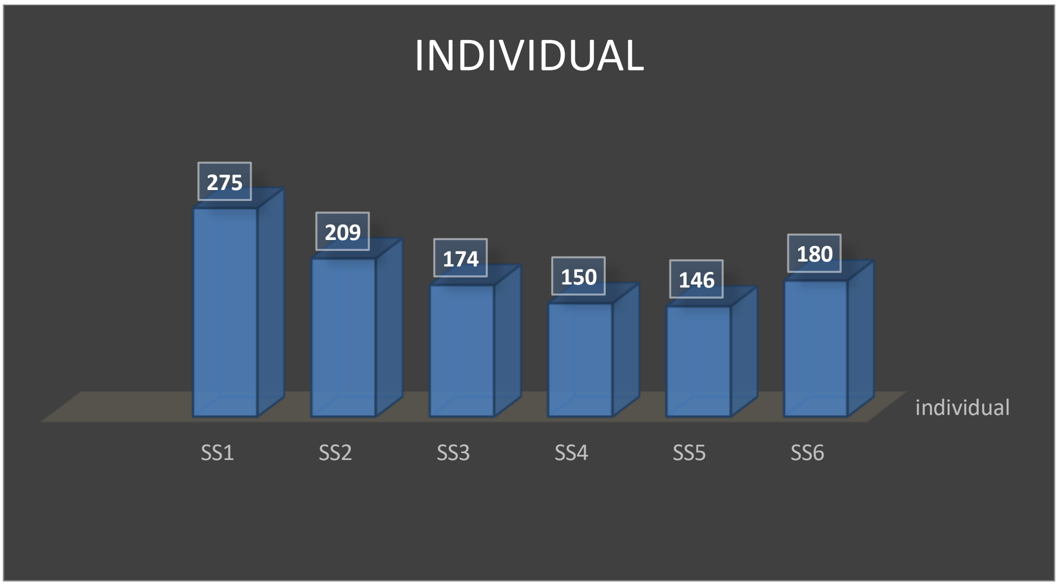


Figure-4.5: Taxa accumulation curve

Figure 4.5 indicate taxonmic richiness the numbr of individuals is greater than 275 on SS1 and SS5 has the least taxonomic individuls were recorded. this means the number of taxa richiness dicrease from SS1-SS5. Decraesing taxa richeness also called water quality become dicraesing from upstteam to down stream of the river.distribution of macroinvertabrte taxa in awetu river sample sites were not equal.

4.3.2 .bio-index analysis

In present study to indices, Shannon diversity indices and Simpson diversity Indices were selected for calculation of taxon.

Table-4.4: Result of bio-indices of Awetu River and its site.

Indices	Sample code					
	SS1	SS2	SS3	SS4	SS5	SS6
Taxa_S	13	21	27	29	28	27
Individuals	275	211	174	150	146	180
Dominance_D	0.1106	0.1022	0.08535	0.06756	0.08754	0.1112
Simpson_1-D	0.8894	0.8978	0.9147	0.9324	0.9125	0.8888
Shannon_H	2.269	2.434	2.694	2.952	2.809	2.641
Evenness_e^H/S	0.7437	0.5428	0.5477	0.6603	0.5925	0.5193

The result of (table 4.4) indicate that taxonomic richness has increasing from up to downstream of the river. Number of individual show decreasing trend. Shannon and Simpson diversity indices show different results throughout the site.

4.3.4. Shannon diversity index

The Shannon diversity index of macro invertebrate communities was significantly lower at all sampling sites, where macro invertebrate was found with range from 2.269-2.952 at all sites of the river.

The Shannon diversity index value is relatively higher in midstream sites relative to the selected site of the river, namely (SS3, SS4, SS5), and lower at site (SS1, SS2) namely koci and seto. Most values measured using the Shannon diversity index (Turkmen and Kazanci, 2010) range from 1.5 to 3.5, rarely exceeding 4.5. Values above 3.0 indicate that habitat structure is stable and balanced and values under or less than 1.0 indicate the presence of pollution and degradation of habitat structure. Based on these criteria, all of sampling sites of Awetu river fallen below 3 with value (2.952) level of the Shannon diversity index in all site (Table 6).when the value is compared with the standards of Shannon diversity indices It further indicating that the presence of lightly pollution level and degradation of habitat structure in the studied area.

The below graph shows the Shannon index value highest on sample site SS4,on mid-stream with the value of 3.on site SS1,SS2,SS3,SS5 and site SS6 the value of Shannon diversity indices show increasing. Shannon-Wiener diversity index values among stations were different probably due to the presence of livestock grazing around and other anthropogenic activities have direct impacts on the macro-invertebrate communities in streams (Hynes, 1970; Nedeau, 2003; Azrina et al., 2006; Hamilton, 2008).

The result of Shannon diversity index was:-on sample site one (SS1)

Species	Pi=sample/sum	Ln (Pi)	Pi*Ln (Pi)
98	=0.356	=-1.03	-0.966
31	=0.112	=-2.189	-0.545
32	=0.116	=-2.154	-0.559
64	=0.232	=-1.461	-0.365
2	=0.007	=-4.961	-0.234
31	=0.112	=-2.189	-0.245
17	=0.061	=-2.796	-0.170
0	=0	=0	0
			H= 2.245

Table-4.5: Ranking of bio-index values using benthic macro invertebrates [(Restello, R.M. 2010), (Edia, E.O. 2009)]

Sample code	H` Value	1-D Value	Ranking
SS1	2.269	0.889	Light pollution
SS2	2.434	0.897	Light pollution
SS3	2.694	0.914	Light and very light pollution
SS4	2.952	0.932	Light and very light pollution
SS5	2.809	0.912	Light and very light pollution
SS6	2.641	0.888	Light pollution

Notes: H' (Shannon-Wiener Diversity Index); Ds (Simpson Dominance Index

The Shannon and Simpson diversity indices result value of Awetu river shows, at sample site SS1 and SS2 there was a light pollution type of the river but Simpson diversity indices result on sample site SS3, SS4,SS5 and SS6 indicate very light pollution of Awetu river.

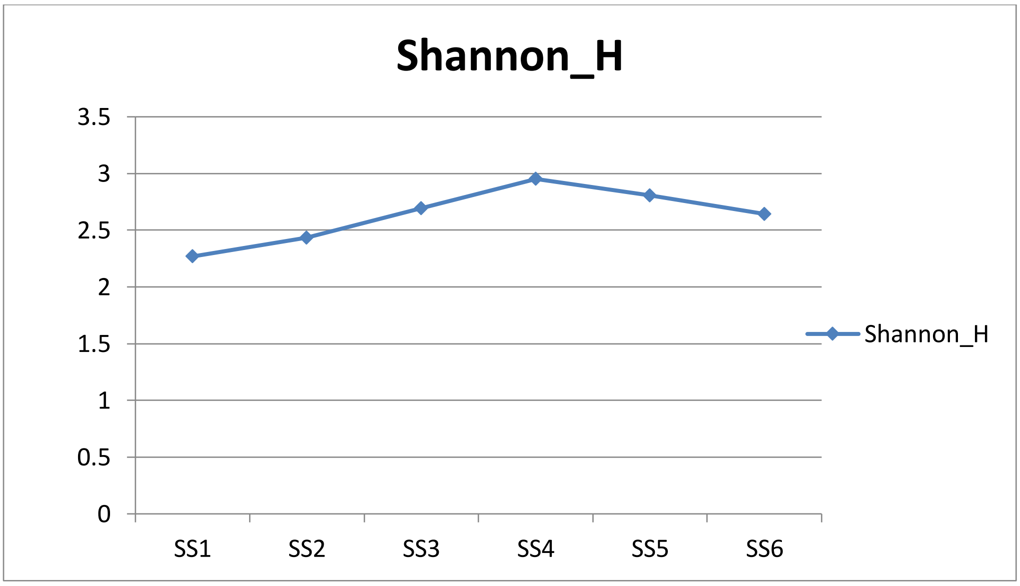


Figure 4.6: Shannon Diversity Index result of Awetu River

The Shannon diversity indices result of Awetu river of figure 4 indicate that, sample site SS4 (2.95) which is nearer to three (3).these indicate the site have highly polluted than other site. This is because the site is located near market place and different solid and liquid wastes are discharged around this site of the river from market, shops, restaurant and hotels.

4.3.5. Simpson diversity index

The Simpson diversity index of macro invertebrates communities were also significantly lower at all sampling sites.

Species/family, 98, 31, 32, 64, 2, 31, 17, 0

Pi= (sample/sum)^2= $\left(\frac{98}{275}\right)2 + \left(\frac{31}{275}\right)2 + \left(\frac{32}{275}\right)2 + \left(\frac{64}{275}\right)2 + \left(\frac{2}{275}\right)2 + \left(\frac{31}{275}\right)2 + \left(\frac{17}{275}\right)2 +$ 0=0.055+0.031+0.003+0.140+0.14+0.003+0.031+0.003

=0.154

D=1-0.154=0.864

From the result of macro invertebrate data collected from awetu river sample site the Simpson diversity index was found ranging from 0.897 - 0.932. According to (Smith and Wilson, 1996), values measuring using Simpson diversity index range between zero and one. Zero represents minimum evenness and one for the maximum. Based on this fact, all the sites fallen nearly zero and indicated the presence of light pollution in all sites of the Awetu river from upstream to downstream. Based on rank criteria of Simpson diversity indices value of all sites' selected for test were fall in light pollution level. and this indicate that the river was deteriorated by anthropogenic activities, including open defecation, linkage of toilets from nearby dwellers, washing and other hotels and restaurants influents. Graphical description of the Simpson diversity index was analyzed in (Figure -5) below.

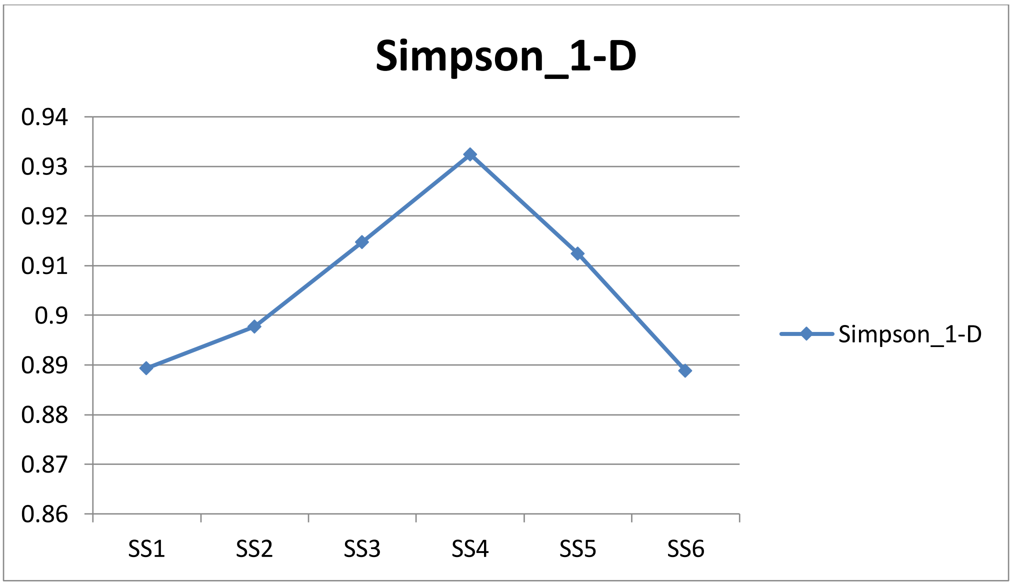


Figure 4.7: Simpson biotic index of Awetu River

Simpson diversity index result of Awetu River (figure 4.4) indicate that there are difference pollution type among all sites, that means SS1, SS2 and SS6 ,were lightly polluted and SS3,SS4 and SS5 failed under very lightly polluted sites. These indicate that, the midstream of the river highly polluted than upper stream. The midstream of the river was site at which untreated liquid waste water and solid wastes are discharged from big hotels like dollolo, markato market and runoff from different direction of jimma town was discharged to the river. Additionally people wash clothes and cars at these site of the river.

Figure-4.8. while people wash clothes and waste discharged to the river and near the river.

4.4. Multivariate analysis of macroinvertabretes and physicochemical

4.4.1. Canonical correspondence analysis of macro invertebrates and Physic-Chemical Parameters

Redundancy analysis among metrics has tested using Spearman rank order correlation analysis in PAST-3 software. Metrics were considered redundant if the spearman correlation coefficient was higher than 0.05 and the p-value was smaller than 0.05 (Whittier *et al*., 2007).

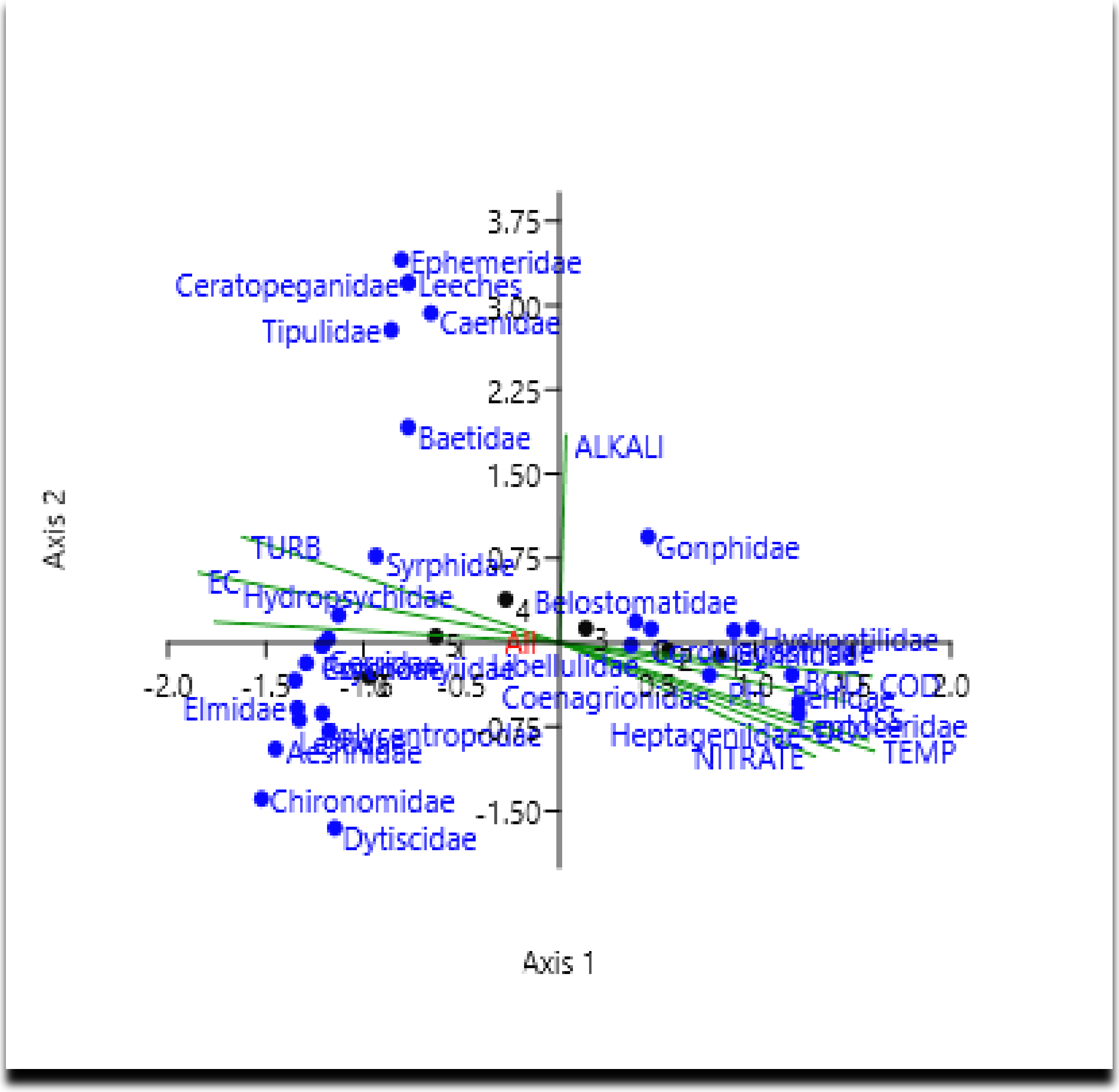


Figure-4.9: CCA of macroinvertebrates, physiochemical and samples sit of Awetu River.

Canonical Correspondence Analysis (CCA) is used to determine which physico-chemical parameters would influence the assemblage of macroinvertbrete, and was performed to correlate with physiochemical parameters and macroinvertabrate indices. The trip-lot of CCA indicates 86.54% of the variables were controlled by the system of axis1. The projection points, the origin (0, 0) indicates the global average of the variable. (ter Braak and Smilauer, 2002). Therefore, COD, Temperature and EC did not change much (short arrow length) and hence their influence were minimal as compared to BOD, TSS, NO_3, pH, and DO environmental lines which displayed the maximum rate of change across the diagram. Therefore, variations in macroinvertebrate composition were strongly correlated with these environmental variables.

PH, DO, BOD, COD, TSS and Nitrate were positively correlated with macroinvertabrete identified in the study river. On the other hand, EC, turbidity and phosphate had strong negative correlation with odonata, himeptera and coleptera at $P<0.05$. Also odonata, himeptera, colleptera, tricoptera, diptera, ephemeroptera, plecoptera and hirudinea had strong positive correlation with alkali at $P>0.05$. Simpson and Shannon diversity index were strongly correlated with EC, Turbidity, Alkali and orthophosphate on axis 2, Leeches, tripulidae, canidae, baelidae, syrphidae, hydropsiychidae and Ephemeridae were positively correlated with EC, Turbidity and alkali, but Aeshenidae, Pycentropodea, Chronomide, Dytiscidae, Elmidae had strong and negatively associated on axis1 those parametres. Whereas Gonophidae and belostomalidae have strong positive correlation. Leptophlebiidae, Hydrophilidae, Nemouridae, Dytiscidae, bellulidae and TSS, DO, PH, Temp and Nitrate are negatively associated on axis2. Additionally, Gonophidae and belollulidae are negatively associated with TSS, DO, PH, Temp and Nitrate with axis 2. Ephemeroptera, Trichoptera and Plecoptera are considered to be abundant in oxygen rich water very sensitive for pollution and used as a water quality monitoring index in Ethiopia (Worku Legesse, 2000).

The same is true in these study, Ephemeroptera, Trichoptera and Plecoptera are highly accumulated on upstream of the river where oxygen is high, especially on SS1, SS2 and SS3.But on midstream of the river the number of their family become decreasing because of poor oxygen at that site (SS4 and SS5) than other site.

On the contrary organically polluted sites were found to be dominated by pollution tolerant (Tripulidae and Ceratopogenidae) species of Diptera family, Baetidae, Ephemeridae and Caemidae species of (Ephemeroptera), leeches (Hurinidae) families were strongly affected by alkali. Odonata, Hemiptera, collateral and Tricoptera were strongly affected by EC, Turbidity and orthophosphate. Therefore the species sites CCA tri-plot diagram clearly discriminated physico chemical parameters that affect the assemblage of macroinvertabrates

Table 7: Spearman rank-order correlation of physicochemical and macroinvertebrate indices.

	Taxa	Indivi	Domin	Simpson	Shanno	TEM	PH	EC	DO	BO	CO	TU	AL	TSS	NITR	ORTO
Taxa_S																
Individu	-0.9															
Domin	-0.6	0.657														
Simpson	0.666	-0.6	-1													
Shanno	0.985	-0.9	-0.77	0.77143												
TEMP	-0.9	0.828	0.48571	-0.48	-0.8											
PH	-0.0	-0.0	-0.08	0.08571	-0.0	-0.1										
EC	0.753	-0.6	-0.08	0.08571	0.6571	-0.7	-0.3									
DO	-0.7	0.657	0.31429	-0.31	-0.7	0.942	-0.2	-0.6								
BOD	-0.6	0.657	-0.02	0.02857	-0.6	0.714	0.257	-0.9	0.6							
COD	-0.6	0.657	-0.02	0.02857	-0.6	0.714	0.257	-0.9	0.6	1						
TURB	0.985	-0.8	-0.54	0.54286	0.9428	-0.9	-0.1	0.828	-0.8	-0.7	-0.7					
ALKA	0.492	-0.4	-0.94	0.94286	0.6	-0.2	-0.1	-0.0	-0.0	0.2	0.2	0.371				
TSS	-0.9	0.942	0.42857	-0.42	-0.8	0.885	0.028	-0.7	0.771	0.828	0.828	-0.9	-0.2			
NITRA	-0.9	1	0.65714	-0.65	-0.9	0.828	-0.0	-0.6	0.657	0.657	0.657	-0.8	-0.4	0.942		
ORTOP	0.701	-0.5	0.02942	-0.02	0.5884	-0.7	-0.4	0.971	-0.6	-0.9	-0.9	0.794	-0.1	-0.7	-0.5	

4.5. Ecological quality of Awetu River

The calculated Shannon-Weaver index is less than 2.95 indicating that the waters of the Awetu River have lightly polluted indicated in (table-3) above. Shannon diversity indices results also reflect unpaired distribution of biological diversity in the studied stations. The values of the Shannon diversity index recorded are lower than the values obtained by (Foto et al. 2013) in the Nga streams in Cameroon and by (Koudenoukpo *et al*. 2017) in the So River in southern Benin. But the low obtained values are consistent with the results of the river reported by (Ibezuteet al 2016) on the Ikpoba River in Nigeria. The maximum obtained values of Simpson's index 0.963.

These results showed that macroinvertebrates are significantly distributed from upstream to downstream of the Awetu River. The low values of these indices at some stations show that they have minimal diversity and that the distribution of macroinvertebrates is less balanced poorly organized and dominated by a single species. Overall, the waters of the Awetu River have deteriorated. Similar findings have already been reported in several studies (B. Mekassa, Ethiopia, 2010)

4.6. Composition and distribution of macro invertebrates

A total of 1136 individual macro invertebrate which belongs to eight (8) orders and 30 Family were collected from 6(six) sampling sites of Awetu Rivers. The most abundant orders were Odonata 343 (26%), tricopetra 209 (18%) and Diptera 202(17%). The most dominant orders were plecoptera which is 38(5%) and Hirudinea which is 2(1%). But among the orders Himeptera and ephemoptera are moderately abundant taxon with 136(11%) and 100(9%) respectively

The observed taxonomic abundance is very low compared with the one reported by (Agblonon Houelome *et al*. 2017) at the Alibori River 39,718 individuals. On the other hand, it is higher than that of the upper Oueme River, where there were 1057 individuals of macro invertebrates (Fulk F and Lazorchak JM 1990).

CCA analyses indicate that macroinvertabrates data clearly separated all sites with disturbances water quality or ecology. The trip-lots for macroinvertabrates assemblage separated SS1, SS2 and SS3 from other sampling sites (SS4, SS5 and SS6).The direction proportional influences of EC, BOD AND turbidity was pointing towards the midstream and some downstream SS6.The figures above farther revealed that the direction proportional influence of BOD, DO, PH, Temp, Nitrate and

TSS pointing towards upstream. The arrow of environmental variables points in the direction of maximum change in the values of associated variable, and the arrow length is proportional to this maximum rate of change.

Taxa richness increase with increasing habitat diversity, suitability, water quality and ecological integrity (Oi, Atano, Egishi, & Anada, 2013). This might also be attributed to differences in eco-regions comprising the upstream, midstream and downstream sites.

As reported by (Whiles, Illinois, & David, 2007) anthropogenic impacts and urban activities have long been negative affect aquatic habitat this is true for this study. All most all midstream and some downstream have gotten poor habitat might be due to under pressure from poor waste management from the town administration such as untreated waste discharge, and intensive anthropogenic practices like deforestation, sand and stone dredging, vegetation clearance, grazing and river bank trampling were the most common cause of catchment degradations of the river.

Odonates such as Coenagriionidae prefer permanent habitats with high vegetation cover. (Muller *et al.* 2003) indicated that removal of vegetation from littoral zone resulted in the decline of odonate taxa richness. The occurrence of odonates, particularly Coenagriionidae showed strong association with wetland vegetation cover. Odonates use vegetation as ovi position sites (Muller *et al.* 2003).
According to Tesfay *et al.* (2017), Ephemeropterans, Plecoptera and Trichopterans (EPT) are very important in assessing water quality as they show low tolerance toward water pollutants. These organisms are sensitive to environmental changes that may occur in clean and well oxygenated waters. Therefore, EPT assemblages are frequently considered as good indicators for water quality. However, in the present study Plecoptera and Ephemeropterans were small number has recorded at downstream, this might be revealed that water quality changes at the study area. The insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies) and Tricoptera (caddies flies) are collectively known as EPT which means that they are generally pollution-sensitive (Rosenberg & Resh 1993), they are also good indicators of water quality. They are thus good for evaluating the balance in the community. These groups are present in all sample sites of the river showed decreasing in number from upstream to downstream of the river. Diptera are macroinvertebrates that represented by chironomids. Swarms of adult midges (Chironomidae), for example, are conspicuous and troublesome; but the adult midge lives just long enough, usually less than a day, to mate and lay

eggs. Thus, most of the life cycle happens under water of the larval stage that is wormlike in appearance; some have adapted to oxygen poor situations (www.britannica.com).

Ecological status of Awetu River using physicochemical parameters, biotic indices/metrics, and multivariate analyses indicated ecological deterioration with lightly polluted. Untreated or poorly treated waste effluent discharge, institutions, commercial center, crop productions as well as sand and stone dredging, cloth washing, open bathing, and waste water discharge from the town land uses all along the length of the river were the major environment stresses that affect ecological integrity of Awetu River. This is in agreement with reports from studies conducted in other rivers in the county (Desalegne, 2018; Hailu and Legesse, 1997; Legesse, 2000).

CHAPTER-FIVE

CONCLUSION AND RECOMENDATION

5.1. CONCLUSION

Awetu River was assessed based on its physicochemical and macroinvertabrate composition properties. The result of physicochemical parameter indicate only the average value of PH and DO were in a limit standard of WHO guide lines. But On one site (SS1) the PH was above the standard. Whereas EC, BOD, Nitrate and Orthophosphate were below the limited of standard of WHO guide lines. The average value of Turbidity and alkali of Awetu River sample data were above the limit standard of WHO guide lines. Unlimited value of BOD, COD, EC, TSS, Nitrate and Orthophosphates are responsible for the deterioration of the river quality cause for pollution. They exceed all the guidelines for human use whether for personal drinking, or washing of food.

Macrinvertabretes loading rate of the river result indicates a total of 1142 individual 8 order and 30 families. The number was decreasing from upstream to downstream of the river except on SS6. Reducing the species and family of macroinvertabretes has positive relationship with water quality. Therefore, quality of the studied river was decreasing at midstream. These is because liquid waste pollutants were discharged to the river from hotels, car and public wash near the river at mid-stream.

Canonical correspondence analysis (CCA) result of the river identifies that all physicochemical parameters affect the assemblage of macroinvertabretes of the river. But EC, turbidity, alkali and BOD were more affect than other studied physicochemical parameters in the river. Shannon and Simpson diversity indices calculation result of macrinvertabretes was (2.269-2.952) bit and (0.897 - 0.932) bit respectively at all sample sites. These indicates quality of the studied river was with in the interval of light and moderate light pollution standard at all sites.

Generally, Assessment of Awetu River from different sampling stations indicated that solid and liquid wastes disposal, distraction of riparian forest, car and cloth washing, open bathing sewage were the major environmental stressors responsible for ecological deterioration of the River.

5.2. RECOMMENDATION

The following recommendation has forwarded for different stakeholder and further researchers on the Awetu River.

- To preserve the remaining river segments with optimal habitat conditions and restore the degraded rivers, avoiding clearance of riparian vegetation, establishing vegetation buffer zone and taking other habitat restoration measures may be vital.
- Attempts to protect further deterioration and restore water quality of the river should involve regulating the waste water discharged to the river without treatment, promoting effective watershed management and introducing integrated solid waste management.
- Prepare Local area to wash clothes, bathing and carwash which is far away from the river bank.
- Further studies should be conducted in different seasons considering other water quality parameters such as biological water quality parameters and other water quality parameters.

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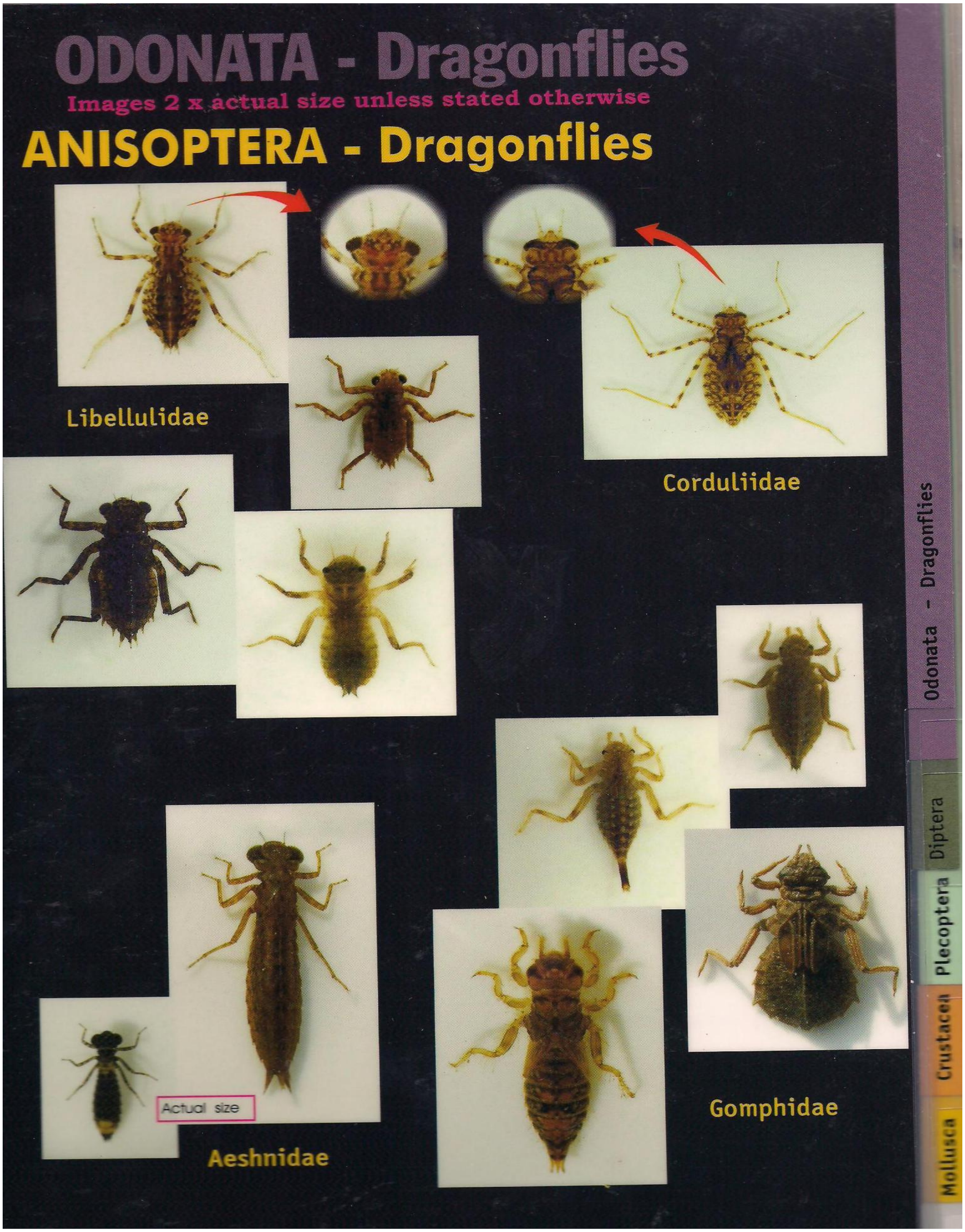
APENDEX-1

Tables-1. Macroinvertabrate results collected from sample site of Awetu River

TAXA	SAMPLE SITE						
	SS1	SS2	SS3	SS4	SS5	SS6	Sum
Odonata							
Coenagrionidae	39	25	19	11	8	6	108
Gonphidae	3	1	2	2	1	1	10
Libellulidae	27	21	17	13	12	10	100
Aeshnidae	0	1	1	2	2	2	8
Lestidae	0	0	0	2	3	9	14
Cordulegastridae	29	22	17	14	13	10	105
Hemiptera							0
Belostomatidae	30	25	21	16	13	11	116
Gerridae	0	1	1	2	2	2	8
Corixidae	1	2	2	2	2	3	12
Coleoptera							0
Gyrinidae	32	27	19	10	7	1	96
Dytiscidae	0	0	1	1	1	0	3
Elmidae	0	0	2	2	2	3	9
Trichoptera							0
Hydropsychidae	0	1	2	2	2	3	10
Hydroptilidae	25	21	17	8	4	1	76
Leptoceridae	39	26	17	8	3	1	94
Brachycentridae	0	1	1	0	2	2	6
Polycentropodae	0	1	2	4	4	9	20
Psychomyiidae	0	0	1	1	1	0	3
Diptera							0
Ceratopeganidae	0	1	1	1	2	0	5
Chironomidae	2	3	6	19	28	43	101
Pschodidae	0	0	0	1	3	9	13
Simuliidae	0	0	2	9	19	31	61
Tipulidae	0	0	0	1	1	1	3
Syrphidae	0	1	1	2	5	11	20
Ephemeroptera							0
Baetidae	0	1	1	2	1	2	6
Ephemeridae	1	1	1	3	2	1	9
Heptageniidae	30	21	13	4	0	2	70
Caenidae	0	0	1	3	1	1	6
Plecoptera							0
Perlidae	17	8	5	4	1	1	36

Hirudinea							0
Leeches		0	0	1	1	2	4	8
	Total	275	212	174	150	146	180	1136

APPENDEX-2 Example of the Macroinvertebrate identification guide



APENDEX-3

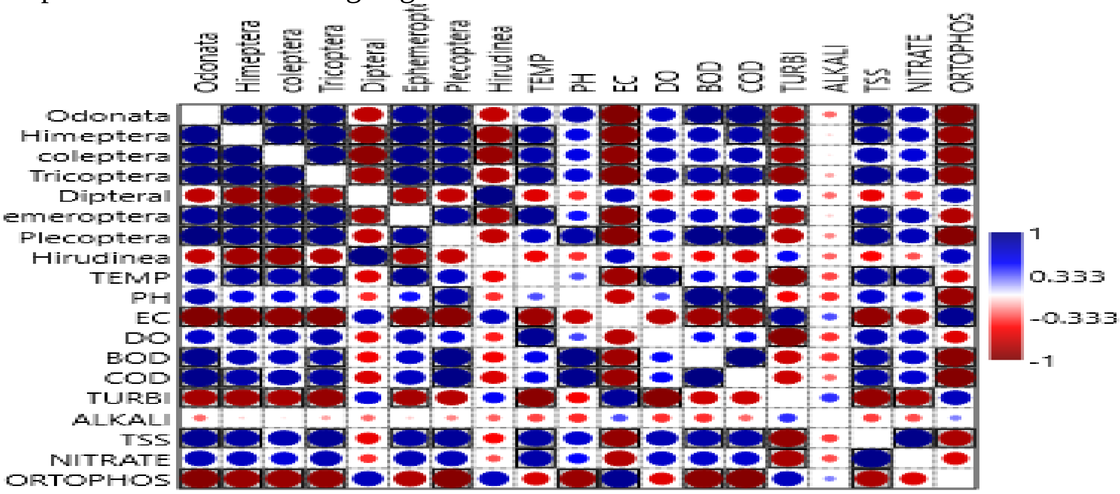
Table-2 of Ranking bio-index values using benthic macro invertebrates [(Restello, R.M. 2010), (Edia, E.O. 2009)]

NO	H’	1 – D	Ranking
1	> 3.25	> 0.90	Very light pollution
2	2.20 – 3.25	0.65 – 0.90	Light pollution
3	1.40 – 2.20	0.40 – 0.65	Low moderate pollution
4	0.80 – 1.40	0.25 – 0.40	High moderate pollution
5	0.10 – 0.80	0.10 – 0.25	Heavy pollution
6	< 0.10	< 0.10	Very heavy pollution

APENDEX-4

Significant correlation of physic chemical and micro invertabrete indices

At p<0.05. Boxes are strong negative correlation



Significant correlation of physic chemical and micro invertabrete indeses

At p>0.05. Cross point on correlation show they are positively correlated.

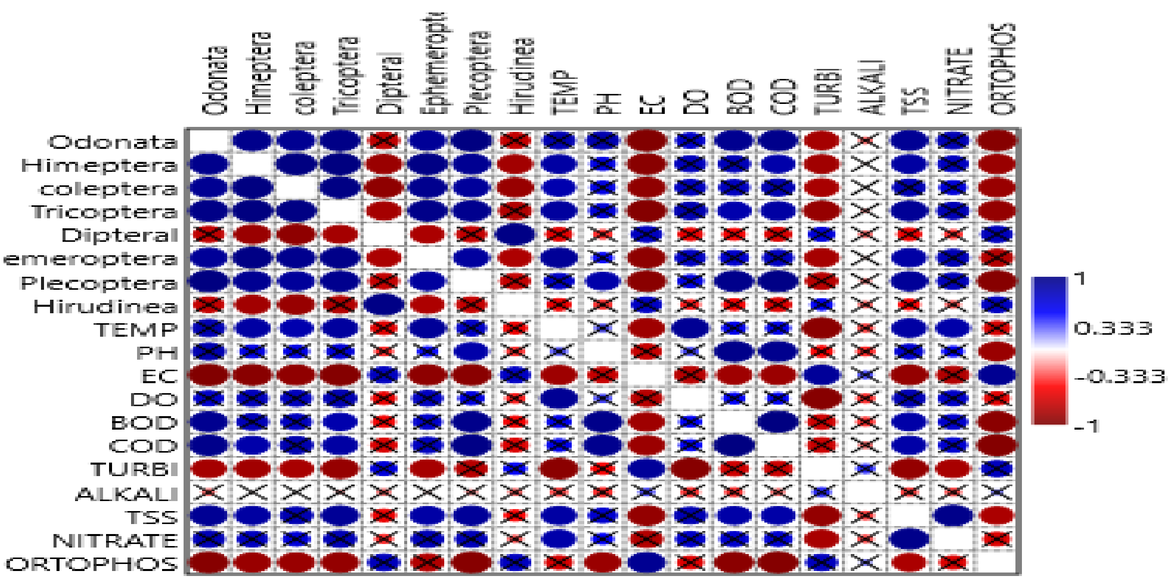


Figure: - Image of solid and liquid waste disposed to Awetu River

Figure:-image while open bath and solid waste disposed near the river (SS4)