AN ASSESSMENT OF THE IMPACTS OF HUMAN ACTIVITIES ON RIVER'S WATER QUALITY: A CASE STUDY OF CHIMVU RIVER

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DECLARATION

I, Jaime Sabiti declare that this research project represents my own work and that it has never been submitted to this institution or any other for any academic purpose. All sources of information have been properly acknowledged.

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ABSTRACT

Human activities are recognized as major sources of environmental problems. Worldwide freshwater resources, which provide important ecosystem services to humans as well as aquatic organisms, are under threat from rapid population growth, urbanization, industrialization, agricultural activities as well as domestic activities. Therefore, there is a need to assess and monitor these resources so as to as how human activities are having an impact on them. In this context, the physical and chemical water quality of Chimvu River located in Thyolo district, close to Malawi University of science and Technology (MUST) was assessed with possible contamination from agriculture activities and sand mining. The chemical and physical parameters were assessed at seven sampling sites. In addition, a biomonitoring approach was used where by organism from the river were collected to estimate aquatic ecological condition of Chimvu River using South African Scoring System (SASS). The results showed that some of the measured parameters in some sampling stations did not conform to local as well as international standards of water quality. For example, concentration of dissolved oxygen (DO) in almost all sampling stations were below the recommended level of greater than 8mg/l. Turbidity was found to be at above an agreed value of 50 NTU at sampling point 2 where turbidity value was 63.5 NTU. This is attributed to agriculture activities and sand mining activities which happens along the river's stretch. Biomonitoring assessment revealed that the river is dominated by pollution tolerant as well as semi-tolerant organisms which indicates that the river is polluted hence not suitable for pollution - sensitive organisms

The study therefore proposes the need for further monitoring of the river where the sampling period should be increased in order to cover the whole stretch of the river

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ACRONYMS/ABBREVIATIONS

DO Dissolved oxygen

MBS Malawi Bureau of Standards

Mg/l Milligram per littre

NTU Nephelometric Turbidity Units

SASS South African Scoring System

WHO World Health Organization

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CHAPTER 1: INTRODUCTION

1.1. Introduction

Water quality is defined as the physical, chemical and biological nature of water and is applied in respect to its suitability for a designated water use (World Health Organization-WHO, 1996). The term water quality came due to the expansion of water requirements and ability to measure and interpret water characteristics. The definition of water quality depends on the factors that have an influence on it, and other variables that affect the physical, chemical and biological nature of water resource. The introduction of harmful substances in river water results in deterioration of water quality, and this interferes with any important water use (Bonzemo, 2013). Water quality status of rivers is affected by many physical, chemical and biological parameters introduced by natural forces and human activities. Limits on particular chemicals or conditions in a water body (water quality criteria), water quality standards and legislation are often used as the main means of administering management of water quality status in order to achieve user requirements. Standards on water quality for surface water vary significantly due to different environmental conditions, ecosystems and intended human uses. Different uses of water raise different concerns and therefore different standards must be considered (Bonzemo, 2013). The common standards on water quality used by many countries are those standards based on World Health Organization (WHO) guidelines on water quality

Water quality is an important factor influencing the distribution and abundance of stream fauna and flora. Species richness is when the ecological community has a population of organisms represented by different species and species composition is the relative abundance and availability of different species in a region. Streams and rivers that have high water quality status have the greatest species composition, richness and diversity. Many of the aquatic organisms are sensitive to pollutants and they are hardly found in polluted water bodies. When water bodies are highly polluted, the population of organisms with different species will be lower because few species will be able to adapt

highly polluted waters. Highly polluted rivers have less oxygen content, and the absence of this gas inhibits the survival of aquatic organisms. Land use has always had an effect on water quality and aquatic biota (Bonzemo, 2013).

The water quality of rivers is being increasingly adversely affected by human activities such as agriculture, industries as well as domestic activities (Ababio & Wyk, 2004). Malawi's river catchments, in spite of being beneficial for its population, have are being deteriorated in terms of health of the ecosystem and water quality due to human activities (Pullanikkatil, Palamuleni, & Ruhiiga, 2015). Most of the river's catchment in Malawi are affected by changes in land use caused by the increasing population and failure to follow catchment management and conservation practices. Deforestation, agriculture and degrading activities such as waste disposal, river bank cultivation and river sand mining are some of the activities causing damage to the water quality of rivers in Malawi (Chimphamba & Brummet, 2003)

Chimvu river which is found in Thyolo district, Southern region of Malawi is one of the river where people use it for different purposes, mostly the river is used by people for irrigation. However , even though the river is beneficial to the people there are human activities which takes place along this river which put threats on the water quality of the river .Sand mining is the one of the human activity that is having an impact on water quality of Chimvu River according to (Magwaza, 2020) who assessed the quality of water in the Chimvu River and found that the river is affected by sand mining activities. This study updates and expands that study, focusing on other human activities that cause changes in water quality, such as agriculture activities. Water quality parameters such as nitrates, dissolved oxygen, turbidity, temperature and pH were monitored and measured. Biomonitoring assessment was also used to establish the ecological condition of the river

1.2. Problem statement

An increase population growth, and expanding food production put pressure on water resources. Increased population causes people to cultivate along river banks hence increasing damages to water sources (Fagbayide & Abulude, 2018). Chimvu river is one

of the river with several human activities that may cause degradation and deterioration of the river. There is stream bank cultivation being practiced along the river (figure 1). The other human activity which contributes to the deterioration of the river is sand mining (figure 2). The river is also used by residents to wash their clothes as well bathing (figure 3). Against this background this study was conducted to examine how the human activities in the river's catchment affect water quality of the river'



Figure 1. 1:Stream bank cultivation along Chimvu river



Figure 2. 1 :People washing clothes along Chimvu river



Figure 3. 1 :People doing sand mining along Chimvu river

1.3. Research questions

- What is the water quality status of Chimvu River in relation to human activities happening along the river?
- What is the ecological condition of Chimvu River as indicated by Biomonitoring assessment?
- What actions are taken by communities along Chimvu River on the management of the river

1.4. Hypothesis

- There is a degradation of water quality in Chimvu River as result of human activities
- Communities around Chimvu river are not adhering to legislative framework on conservation, protection and management of rivers in Malawi

1.5. Objectives of the study

Main objective:

- Examine impacts of human activities on Chimvu River's water quality

Specific objectives

- To determine the water quality status of the river in relation to human activities which are happening along Chimvu River's water catchment
- To establish the ecological aquatic condition of Chimvu River by using biomonitoring assessment
- To assess public knowledge and awareness of the impacts of human activities on rivers
- To identify communities along Chimvu River's concerns and their actions towards management of the river

1.6. Significance of the study

This study will provide key information for taking appropriate action to improve the water quality of the Chimvu River. It will also provide information to educate communities and individuals about the links between their human activities and its impacts on Chimvu river. The research will also be beneficial to policymakers, and environmental organizations in water resource management

CHAPTER 2: LITERATURE REVIEW

2.1. General background

Rivers and streams are very important ecosystems for socio-economic development and sustainability of the environment since they provide a variety of functions of great value to the ecosystem, economies and on communities that depend on them for their different purposes. However, the systems are unable to provide basic functions to the rapidly growing population because they are threatened by human activities (Njiru, Gichana, Raburu, & Masese, 2014). There are various human activities that poses threat to rivers and streams. Some of these human activities are discussed below

2.2. Human activities that affect River's water quality

2.2.1. Use of inorganic fertilizers

Inorganic fertilizers are commonly used to increase yield in crops. The major inorganic fertilizers used in agriculture are those that contains nitrogen and phosphorus compounds. If insufficiently absorbed by plants and soil or washed away by heavy rains, these fertilizers end up in rivers possibly causing eutrophication (Ullberg, 2015).Eutrophication is the process by which waterbodies becomes enriched with nutrients and becomes more productive such that aquatic plants such as algae will be able to grow in it. Eutrophication has many negative effects on water bodies such as oxygen depletion which may then affect the availability of aquatic organisms which depend on oxygen for their survival. Eutrophication also interferes with use of water for industry, recreation, agriculture and drinking (Holm, 2004). Apart from causing eutrophication in water bodies the components contained in fertilizers such as nitrate can have an effect on health of young animals and human infants. High level of nitrate in water especially drinking water may cause methaemoglobinaemia which decreases the ability of blood to carry oxygen (Chambers, et al., 2001)

2.2.2. Waste disposal

One of the most critical problem of developing countries is improper management of vast number of wastes generated by various human activities (Boakiye, 2012). Open and

indiscriminate dumping of solid wastes in the riverbanks is among the problems of improper management of waste in the developing countries of the world (Omoleke, 2004). Water bodies, especially fresh water resources which are the major sources of drinking water, are now major receptacles of treated and untreated or partially treated wastes both from households, industrial as well as agricultural wastes (Boakiye, 2012). Wastewater contains elevated levels of nutrients, such as different forms of nitrogen, phosphorous, Sulphur and potassium (Ullberg, 2015). When the wastewater gets released into the water bodies they change the water quality of the receiving water body and then make the water not to be suitable for its important uses such as drinking, recreation and also make the water body not suitable for the aquatic life. Major sources of wastes in water bodies are industrial activities, domestic activities and agricultural activities.

2.2.3. Sand mining

Sand mining is the action of removing sand from a riverbed for further use in construction and related purposes. The most common sources are river channel deposits, floodplain alluvial deposits and residual soil deposits (Ullberg, 2015). (Magwaza, 2020)reported effects such as increased turbidity of Chimvu river which was largely attributed to the sand mining activities in the river. Sand and smaller particles stirred up by sand mining activities can be transported along way, depending on the on the nature of the stream and size of the particles, causing high turbidity and deposition of sediments downstream (Ullberg, 2015). This may affect the conditions of the aquatic life

2.2.4. Stream bank cultivation

Stream bank cultivation is a practice that involves growing crops along banks of streams (Mlowoka, 2008). Farmers use these streams to spread risk of crop failure from hazards such as droughts and dry spell (Kadyampakeni, 2004). Siltation of rivers and streams is one of the main effects of river and stream bank cultivation. Mostly siltation causes the water to become turbid which makes the water not suitable for drinking, washing clothes and bathing. Stream bank cultivation was observed in the area where this study was done

2.2.5. Deforestation

This is the clearing of vegetation and cutting down of tress and making the ground bare. Agricultural activities are the major source of deforestation. The ground is then exposed to the impacts of rainfall and wind; this leads to soil particles being loosened and washed away by runoff water when it is raining (Nyasulu, 2010). This fast moving rain water enhances soil erosion, a process through which soil and sediments are transported into surface water bodies. Deforestation along river catchments also robs the ground of its natural cover hence direct sunlight reaches the soil. This increases the evaporation of water from the soil, thereby affecting the amount of water available in the river (Newson, 1992). Where most of the tree covers and vegetation has been removed, the temperature of river water tends to rise, while under good cover, temperature would remain constant for most of the time. This has a direct influence on the biochemical dynamics that can affect the chemical composition of water and aquatic life in the ecosystem (Moss, 2001).

2.2.6. Human Settlements

The rapid increase in population that Malawi is undergoing has resulted in an increase in the demand for shelter and housing. There are an increasing number of unauthorized constructions of dwelling structures in unplanned areas using environmentally unsuitable materials. This has led to uncontrolled brick moulding and cutting down of trees for curing the bricks and other constructions, thus creating a great disturbance to the natural environment (Nyasulu, 2010). An increase in human settlement means an increased need for sanitation facilities for waste disposal for the population (Chindah, 2004). The habit of defaecating in the bush by some people contaminates surface water through run off. Sanitation facilities such as pit latrine soak ways, poorly constructed rubbish pits and broken sewer lines, are a source of pollutants into the rivers when wastes are washed away by rain water runoff (WHO and UNICEF, 2000).

2.3. Chemical and physical parameters of aquatic ecosystems/water

2.3.1. pH

The pH is a measurement of hydrogen and hydroxyl ions in a solution, using a logarithmic scale. The measure indicates if the solution under consideration is alkaline (pH > 7) or acidic (pH < 7). Fresh water pH normally ranges between pH 6 and pH 8. The pH affects the availability and solubility of nutrients that are needed by aquatic organisms for utilization (Chapman, 1996). Increased pH in a stream or other body of water is caused by carbonates rich soils such as limestone as well as presence of nitrate-based fertilizers while low pH is caused by the presence of phosphoric acid in phosphorous fertilizers (Bell. M, 2019). Decomposing matter from domestic wastes produces carbonic acid which can lower pH in a river. Wastes from maize fields also can cause a decrease in the pH. Maize cobs and maize stems in the study area was observed being thrown into the river

2.3.2. Temperature

The temperature of surface waters is influenced by latitude, altitude, season, time of day, air circulation, cloud cover and the flow and depth of the water body. Many of the physical, chemical and biological processes in water are affected by temperature and this makes the temperature to be a general variable that concentration of other variables depends on. As water temperature increases, the rate of chemical reactions generally increases together with the evaporation and volatilization of substances from the water. Increased temperature also decreases the solubility of gases in water, such as oxygen, carbon dioxide, nitrogen, methane and others. Aquatic organisms also depend on temperature for the functioning of their body processes such as metabolic rate and respirations rates, for example in warm water respiration rate is high which increase oxygen consumption and then causes an increase in decomposition of organic matter. Growth rates of organisms also increase and this is most noticeable bacteria and phytoplankton whose population double in very short time periods hence leading to an increase in water turbidity and algal blooms, when nutrients conditions are suitable (Chapman, 1996)

2.3.3. Dissolved Oxygen

Dissolved oxygen is the amount of oxygen that is dissolved in a surface water body and is available for the sustenance of aquatic life. Dissolved oxygen is vital for the survival of aquatic organisms, including macroinvertebrates and fish, without which they would suffocate and die (Chapman, 1996). Dissolved oxygen is normally influenced by available nutrients with excess nutrients leading to eutrophication. Low dissolved oxygen in streams or rivers can be attributed to increase in temperatures, aerobic metabolism and sediment loads (Dickens & Graham, 2002). Communities, whose livelihood is supported by fishing, are negatively affected where dissolved oxygen concentrations are low, due to the decline of fish populations (Chapman, 1996). Littering of wastes into rivers causes decrease in dissolved oxygen concentration. This is because wastes such as domestic wastes contain suspended particulate organic matter such as steadily decomposing plant litter and animal faeces. Organic matter from these sources require oxygen for decomposition and often depletes oxygen upon entering surface waters thereby decreasing dissolved oxygen concentration in that system (Dallas H. a., 1994). Inorganic fertilizers also cause decrease in dissolved oxygen in surface waters. This because when the fertilizers get washed into the surface water bodies by running water, they cause an excessive growth of aquatic algae which over time they get decomposed by bacteria which then will require the use of oxygen available hence making dissolved oxygen unavailable for some of the aquatic organisms present in water (Chimuriwo, 2016). Farmers in the study area of this study also uses fertilizers that they apply in their crops to increase yield and also to improve fertility of the soil

2.3.4. Turbidity

Turbidity is a measure of water clarity. Turbidity in water is caused by fine suspended matter such as clay and silt along with small grains of organic and inorganic matter. Also plankton and other microscopic organisms can increase turbidity (Ullberg, 2015). Apart from these causes turbidity is also caused by agriculture activities mostly siltation as a result of cultivating along river banks. Sand mining also causes an increase in turbidity (Ullberg, 2015). Sand mining is one of the activity that occurs in the area this study was

done. When the level of turbidity is high the availability of macroinvertebrates will be low. This is because increased turbidity may alter prey-predator relationship since some of the aquatic organisms depend on other organisms as their food so when the water is more turbid it will make it difficult for other organisms to see their preys

2.3. 5.Nitrogen

Nitrogen is a critical nutrient that is generally used by plants within natural ecosystem. When nitrogen containing compounds is applied to the land in amounts greater than those that can be absorbed crops or lost to the atmosphere through volatization or denitrification, however nitrogen concentrations in streams can increase (United States Environmental Protection Agency). The major source of nitrogen is inorganic fertilizers and animal wastes; other sources include septic systems and atmospheric deposition. Excess nitrogen can result in the over production of planktons which when they die they may decompose and consume oxygen causing other organisms that depend on oxygen to be stressed (Matowanyika, 2010). Anthropogenic activities can accelerate the process of eutrophication by increasing the rate at which nutrients find their way into water bodies. Nutrient enrichment (nitrates) in aquatic ecosystem stimulates algae blooms. Sources of nitrates mostly include discharge of partially treated and untreated sewage and fertilizers that are applied in the fields close to the water sources. Surface runoff will carry the nitrates to the water bodies. Lowering levels of nitrates in soil using good agricultural practices results in less nitrates reaching and polluting water sources (Chimuriwo, 2016). Eutrophication causes an increase in water turbidity, reduced concentration of oxygen and change in the availability of aquatic. Algal blooms bring about changes that upset the natural balance of plant and animal life in an aquatic setup (Utete, 2013). When algal blooms decay, they cause an offensive smell and the process of decay uses up most of the oxygen effectively suffocating other aquatic life (Ndebele – Murisa, 2012).

2.4. Legislative frameworks for River conservation, protection and management in Malawi

Part VIII of the Environment Management Act of 2017 deals with the management of the environment and natural resources. Section 45 of the act provides for the regulation of use and management of rivers and lakes where it states that no any person shall deposit any substance in a river or lake or in, on or under its bed, if that substance would or is likely to have adverse effects on the environment, excavate, drill, tunnel, or disturb the river bed or otherwise, introduce or plant any part of a plant whether alien or indigenous in a lake or river. The act also specifically states that any person who contravenes this section or any guideline issued under this section commits an offence. The Act also places an obligation to every person to cooperate with state organs and other persons to protect and conserve the environment and ensure ecologically sustainable development and use of natural resources (Government of Malawi, 2017)

Section 61 of the Environmental Management Act (EMA) also provides for pollution control and specifically states that person shall not discharge or emit effluent into the aquatic environment except under a license issued by the Authority and subject to such conditions as the Authority shall determine. Any person to dump or discharge effluent into the aquatic environment in contravention of water pollution control standards shall be guilty of an offence and liable to conviction to a fine of ten million Kwacha (K10,000,000) and to imprisonment for ten (10) years. (Government of Malawi, 2017)

Section 25 of the Water Resource Act of 2013 provides for the establishment of Catchment management committees in areas which are close to rivers. These committees comprise of farmers within the catchment areas concerned, representatives of the non-governmental organizations engaged in water resources management programmes within the catchment area concerned, representatives of any regional development authorities and local authorities whose areas of jurisdiction or any part thereof fall within the

catchment area concerned and representatives of the business community operating within the catchment area concerned. These committees are responsible for conservation and proper management of water resources such as rivers in the area concerned (Governement of Malawi, 2013).

Section 45 and 61 of the EMA are of particular importance in the management and conservation of water bodies within Malawi. The provisions prohibit water pollution and imposes a hefty penalty to any person who discharges any pollutant. Section 25 of WRA also encourage the establishment of catchment management committees in areas for river management.

2.5. Summary

The literature discussed above have discussed so many activities that may have an effect on degradation of water quality on a worldwide scale. The literatures have indicated that human activities such as sand mining, agriculture, human settlements and deforestation can damage the water quality. Of the human activities discussed sand mining and agriculture activities are the main human activities of specific interest in this study.

CHAPTER 3: METHODOLGY

3.1. Research design

A research design is a framework or plan for a study used as a guide in collecting and analyzing data (Creswell, 2003). In general, research methods or approaches are divided into two broad divisions: quantitative and qualitative ones (Castellan, 2010). For this study both qualitative and quantitative design was employed so as to complement the two methods in data collection. Quantitative design was in form of biomonitoring assessment where number of organisms were caught and counted as well as water sample measurement. The qualitative research design was in form of interviews and participant observation whereby pictures of the study area was taken showing some of the human activities that takes place in some of the sampling sites

3.2. Description of the study area

3.2.1. Location

The study was conducted in the Chimvu River. Chimvu river is one of the streams that are found in the district of Thyolo. The river passes through residential areas as well agricultural lands. It flows in an easterly direction from Thunga hill in Bvumbwe up to where it joins Lichenza river. The river serves several purposes to residents that stay close to where the river passes. Mostly people use sand from the river for construction purposes, people also use the river for agriculture as well as domestic activities. Hence the river is social economically important for the population in its catchment. The study area incorporates seven sampling points. The distance between each sampling was 800 meters. This distance was chosen so as to ensure that sampling points should not be close to each other to avoid collecting samples that may be similar to another point. The study concentrated on activities taking place within and along the boundaries of the river

3.2.2. Climate

Malawi has a tropical and continental type of climate and so is the area under study. The annual rainfall of the area under study is about 1125 mm/year with the mean temperature range of 15 to 26 °C. The study area has two main seasons. The rainy season starts from November to April. The dry season starts from May to October.

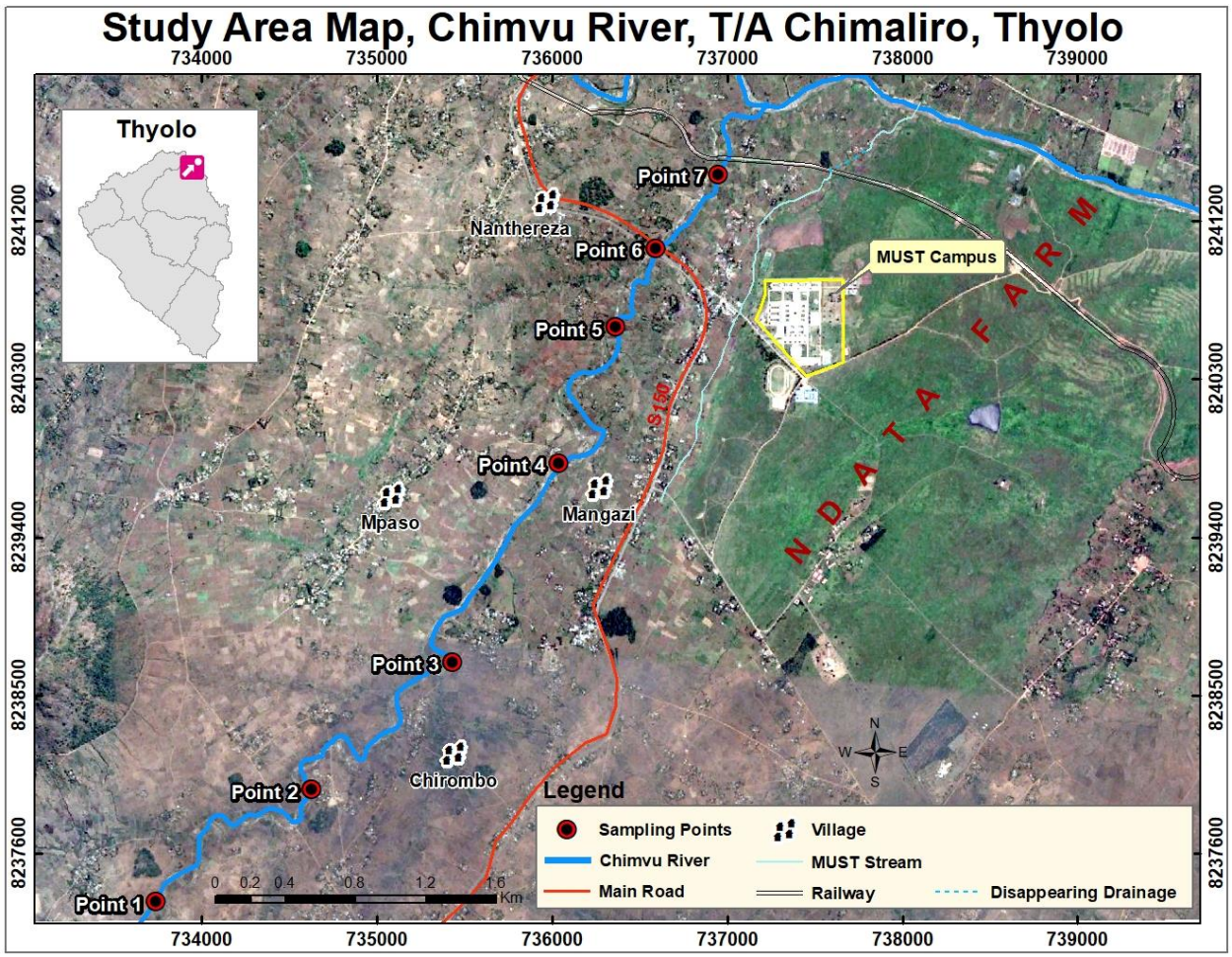


Figure 4. 1 :Map of study area

3.2.3. Demographic and Socio- economic Activities

The population for the whole Thyolo district is 130,984 (Government of Malawi, 2018). Most of the areas in Thyolo district are rural areas. The livelihoods of the rural people are dependent on rain fed agriculture and to some extent on irrigation along the river. The major crops grown are maize, vegetables, sugarcanes, beans and groundnuts.

There is extensive sand mining from the river as well as brick moulding and irrigated vegetable farming along the river banks. It is this brick moulding and sand mining that is making construction work possible in the area under study. People earn their living out of these activities as well as on vegetable farming

3.3. Sampling

Water samples were collected on a weekly basis from the sampling sites for a period of two weeks. Parameters that had been analyzed were selected considering the activities taking place in the Chimvu River catchment area and the limitations of available funds. However, the chosen parameters were sufficient enough to determine the quality of water. The following physical and chemical parameters were chosen: pH, Temperature, Turbidity, Dissolved Oxygen and Nitrate. Biomonitoring assessment was also undertaken on a weekly basis for two weeks. This was done in order to get averages of the sampled parameters as well as organisms

3.3.1. Selection of sampling site

Water quality sampling was done on seven sampling stations taking into considerations the human activities taking place within the catchment. The human activities considered were sand mining, agriculture and waste disposal. Detailed descriptions of sampling stations are described in table below

Table 1: Description of water quality sampling points in Chimvu River

Sampling site	Location	Description of sample site
1	Boundary between Katundu and Chirombo villages	There was lots of sand mining and stream bank cultivation at this sampling point
2	Chirombo village	There was human settlements, river bank cultivation and sand mining
3	Close to farming fields	Lots of maize fields and vegetable gardens at this sampling points

4	Close to graveyard	There was less human activities at this sampling point
5	Mr Banda Farm	Stream bank cultivation with maize and vegetable gardens
6	Chimvu River bridge	Sand mining and stream bank cultivation were the human activities at this sampling point
7	Chimvu Railway bridge	Sand mining and stream bank cultivation were the activities that happens at this sampling point

3.3.2. Selection of sampling parameters

Parameters to be analyzed were selected based on the activities taking place within the catchment which are a threat to water quality. Agricultural activities such as use of fertilizers was indicated by nitrate, Dissolved oxygen and pH, sand mining was indicated by turbidity. Finally, temperature was considered as a general parameter, which affects physical, chemical and biological processes (Chapman, 1996)

3.3.3 Sampling Procedure

Sampling was done according to the protocols provided by APHA in the Standard Methods for the Examination of Water and Waste Water 1989, 17th Edition. During the water sampling process, one litter polythene sample bottles were used for carrying the

water samples. Portable testing meters were used for onsite measurements of temperature, pH, and dissolved oxygen (Nyasulu, 2010)

3.3.4. Chemical and Physical water quality parameter analysis

3.3.4.1. pH

The sample water was taken in a small beaker and then the probe of the pH meter was placed inside the water for a few minutes. The meter showed the reading, but the final reading recorded was the one when the reading become static (Mudenda, 2017).

3.3.4.2. Dissolved oxygen

The sample water was taken in the beaker and the probe of the DO meter was then placed inside and the reading was then taken (Mudenda, 2017).

3.3.4.3. Temperature

The sample water was taken in the beaker and the probe of the pH meter which shows readings for both pH and temperature was then placed inside and the reading for temperature was then taken

3.3.4.4. Turbidity

The tap water was taken in a 10 ml clean vial and then placed on the photometer aligning the mark, then the zero key on the photometer was pressed to prepare it for testing. Then water samples were placed in the other vial and then was placed on the photometer and the test key was pressed and then the results were shown on the photometer

3.3.4.5. Nitrate

Firstly, water samples were filtered by using aqua safe filtration membrane unit to remove suspended materials then a clean vial was filled with a 10 ml of water sample and closed with a cap. The vial was placed on the photometer chamber aligning the marks and then pressed the zero key. The vial was removed from the sample chamber, one level of spoon of nitrate test powder was added to the 10ml water sample in a vial and the tablet was crushed using a clean stirring rod. One tablet of nitrate test tablets was

added straight from the foil to the same water sample and it was crushed using a clean stirring rod, the vial was tightly closed with the cap and then swirled it several times until the tablets gets dissolved. The vial was then placed on the photometer aligning the marks, then pressed the test key and after 10 minutes of waiting, the reaction was finished and the measurement was then recorded. The filtered water samples were tested in duplicates.

3.4. Biomonitoring assessment

Biomonitoring assessment was also being used to sample aquatic life. Samples were being collected from the following biotypes: vegetation, sand and gravel. Aquatic organisms were collected using a SASS net, the net was positioned in a direction against the flow of the river in all biotypes. The sample collected were rinsed using the same river water to remove mud and have a clear sample. The contents from the net were put into a white tray having the same river water and different aquatic invertebrates' animals were identified using the South African Identification book. Samples were being collected three times from each biotype for statistical reason. After identification samples were being returned to the river. An average score of aquatic organisms was calculated by summing up sensitivity score of different groups of organisms and then divide with the number of groups of organisms present at the station. The average score was then being compared to the ecological conditions of the river to establish condition of the river (Dickens & Graham, 2002)

3.5. Interviews

Interviews were being carried with key informants in the catchment, and this was mainly focused on village headmen for each village in the catchment around Chimvu. The village headmen were being selected based on the fact that they have a knowledge of every activity happening around their areas. Interviews were conducted by using the developed checklist that helped to direct and guide the interviewer. The questions that were being asked focused on whether their areas have catchment management committees as stipulated by the Water Resource Act of 2013 in order to manage and protect the river, any conservation, management and protection measures developed by

the headmen in order to manage the river, whether government introduced any measurements for protection and conservation of Chimvu River

3.6. Quality Assurance and Quality Control

Quality Assurance and Quality Control plans were incorporated both in the field and laboratory. As part of the quality assurance and quality control plan all sampling bottles for water quality sampling were pre-labeled to avoid mixing the samples. Duplicate samples were obtained to verify the accuracy of the results. Measuring equipment were calibrated in the laboratory prior to measurements. The final results of a parameter were obtained by taking the mean values of all the data sets for each sampling site. SASS net used for collecting aquatic organisms was cleaned first with the river water before starting the operation, a white tray where after organisms were caught were emptied into it was cleaned first. This was done in order to ensure that organisms should be identified easily. A SASS book for identifying organisms was also used

3.7. Data analysis

The water samples were tested for normality and compared to local Malawi Bureau of Standards (MBS) water quality guidelines and World Health Organization (WHO) surface water quality standards and aquatic life threshold values. Data from water sample analysis and biomonitoring assessment was entered into Excel spread sheet. A descriptive graph of each variable and invertebrates caught from each sampling point was drawn using Microsoft Excel 2016 version. Correlation analysis was also done in order to measure the statistical relationship between SASS scores (health of the stream) and other variables. Mean values and standard deviation for the results were computed on the Excel. It was these mean values that were compared with the MBS and WHO guidelines for surface water quality standards. Table below was used for comparison of results obtained in Chimvu River with MBS and WHO standards of water quality

Source: (Forsberg, 2014)

Parameter	Units	WHO	MBS
pH		7.0-8.5	6.5-9.5

Temperature	^{0}C	<35	<35
Nitrate	(mg/l)	<45	<50
Dissolved Oxygen	(mg/l)	8.0	N/A
Turbidity	NTU	<50	<50

Table 2: Malawi bureau of standards (MS619:2005) and WHO (2011) guidelines for water quality

CHAPTER 4: RESULTS AND DISCUSSIONS

This chapter presents the results of the findings in the field and the discussions on these findings in accordance to the specific objects given in Chapter One. The results presented are the water quality parameter values of the samples. Biomonitoring assessment result are also presented.

4.1. Physio-chemical Results

The following parameters were monitored: pH, dissolved oxygen concentration (DO), turbidity, Nitrate and Temperature. Table 1 and 2 show the mean measured values of physio-chemical analysis for the sampling points as well as standard deviations respectively. The measured results for the parameters indicate that pH for all the sampling points in the river was largely neutral and was between 6.56 and 8.18. Dissolved oxygen for all the sampling was below the standard value of greater than 8 mg/l according to WHO guidelines on water, this can be due to agriculture activities that takes place along Chimvu River that may be contributing to low dissolved oxygen in the river. Turbidity values for almost all except one sampling point was below an agreed value according to WHO which is 50 NTU. Higher than an agreed turbidity value at sampling 2 could be attributed to sand mining and agricultural activities. Nitrate values in all sampling sites did not exceed the allowed standards for water quality.

Table 3: Mean and standard deviation values of Physio-Chemical parameters at each sampling point during sampling

Site	pH	Dissolved Oxygen(mg/l)	Turbidity (NTU)	Temperature(^{0}C)	Nitrate (mg/l)
1	7.9±0.72	4.97±0.43	50±5.66	28.1±3.88	2.1±0.32
2	6.9±0.27	2.92±0.76	63.5±2.24	29.05±3.01	2.43±0.58
3	7.56±0.27	5.51±1.09	42.5±0.71	28.18±3.67	2.61±0.19
4	7.54±0.34	7.3±1.83	7.5±0.90	26.5±4.22	1.62±0.11

5	7.21±0.72	4.93±0.58	45±8.49	28.58±1.59	2.94±1.12
6	7.37±0.39	5.67±0.70	32.5±6.36	24.88±1.89	2.11±0.82
7	7.76±0.07	5.78±1.05	33.5±12.02	22.18±1.20	1.73±0.39

4.1.1. pH

The pH of the stream ranged between 6.56 and 8. 18. A higher pH was registered at point 1 (figure 5) where pH recorded was 7.90. The other sampling points for example sampling point 2,3,4,5 and 6 recorded pH values of 6.90,7.56,7.54,7.21 and 7.37 respectively. The values were within the MBS and WHO acceptable ranges for surface water quality standards of 6.5 to 9.5 units. Changes in pH influence the availability and toxicity of important plant nutrients such as phosphate and ammonium. For example, pH values of > 8.0 cause ammonium ions to be converted to toxic unionized ammonia (Matowanyika, 2010). However, the pH range found by (Magwaza, 2020) whose study was conducted in November of 2020 within the same river when the rainy season was just starting was 7.50 and 8.81. This range is higher than the current range of 6.56 and 8.18. This implies that pH changes with change of season. This study was conducted in the month of May when the rainy was ending .This means that rainfal that was occuring a period untill this was being conducted lowers pH of the river which agrees with (Hem, 1985) that rainfall lowers the pH upon entering the river. The other reason could be due to decomposition of organic matter. During the wet season, decaying matter from the ground is washed down by rain into rivers. Decomposing matter produces carbonic acid which can lower the pH in a river (Hem, 1985)

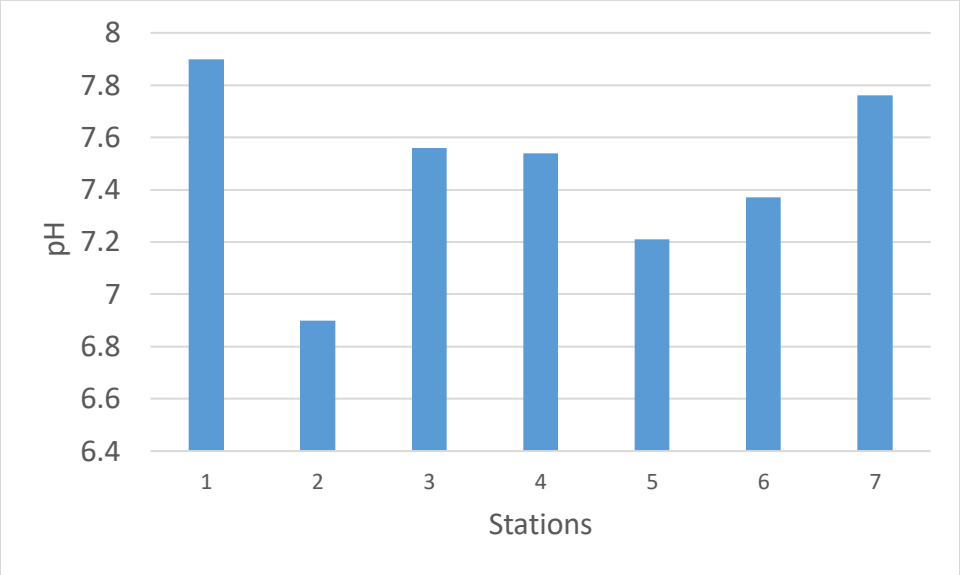


Figure 5. 1 :Variation of pH values between point 1-7 along Chimvu river

4.1.2. Temperature

The temperature of the river did not show much variation across the river profile. The temperature range of Chimvu river was between 22.18^{0}C to 29. 05^{0}C.The temperature was within the MBS and WHO threshold limit of below 35^{0}C as shown in the graph below. This shows that the temperature values were all acceptable, below MBS and WHO threshold of 35^{0}C.

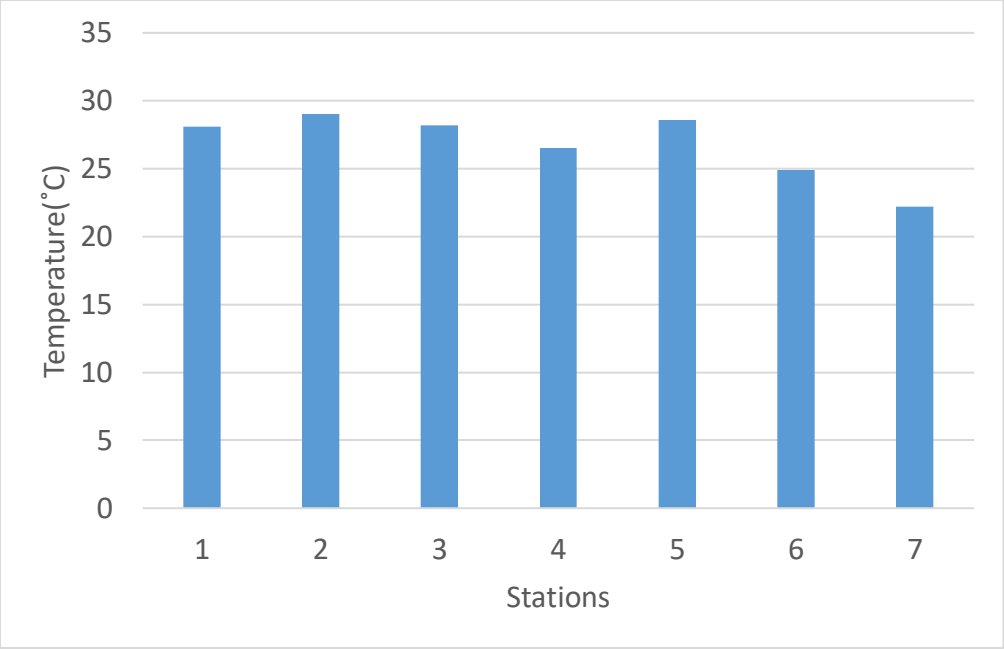


Figure 6. 1 :Variation of temperature between point 1-7 along Chimvu river

4.1.3. Dissolved oxygen

The highest average value of 7.3mg/l was recorded at point 4 while the lowest value of 2.92 mg/l was recorded at point 2 (figure 7.1) The stream was characterized with low DO at all sampling points and this could be attributed to agricultural activities and sand mining. The highest value at point 4 could be due to enough vegetation around this area which produce enough oxygen to aerate the water (Nyasulu, 2010). While the low values at point 2 could be due to agricultural activities happening along this point. Oxygen is very important in all forms of aquatic life as most of the aquatic organisms depend on it for their functioning.

Determination of dissolved oxygen concentrations is a fundamental part of a water quality assessment since oxygen is involved in, or influences, nearly all chemical and biological processes within water bodies. Concentrations below 5 mg /l may adversely affect the functioning and survival of many aquatic organisms as well as the biological communities of the aquatic ecosystem and below 2 mg /l may lead to the death of most aquatic organisms. The measurement of DO can be used to indicate the extend of pollution by organic matter, the destruction of organic substances and the level of self-

purification of the water (Chapman, 1996). Decaying plants parts such as maize stems that gets thrown into the river after harvesting of maize could cause a reduction in the concentrations of dissolved oxygen in the river (figure 8) (Matowanyika, 2010). Fertilizers from some of the maize fields close to the river may also be contributing to the decrease in oxygen concentration around those points, during the time of this study there were lots of irrigated maize fields. This because when the fertilizers get washed into the surface water bodies by running water, they cause an excessive growth of aquatic algae which over time they get decomposed by bacteria which then will require the use of oxygen available hence making dissolved oxygen unavailable for some of the aquatic organisms present in water (Chimuriwo, 2016). Sand mining could also be contributing to the reduction of dissolved oxygen in the river. Sand dredging process may release nutrients from sediments and promote eutrophication (Zou, Zhu, & Toloneni, 2019). The concentration of DO most of the sampling points in the stream was below the standard limit of WHO (8 mg/L) for aquatic freshwater i.e., out of specification. (Mudenda, 2017) . However, by comparing the results for dissolved oxygen concentration for sampling point 5 to 7 which were studied by (Magwaza, 2020) and this study it was observed that DO ranges according to (Magwaza, 2020) study was between 0.92 to 5.26 mg/l while this study found that the DO concentration ranged between 6.56 to 7.85 which is higher . This implies that Change in season influences the concentration of DO in the river. Run-off containing organic matter from the rain and agricultural fields increase suspended solids in water. Suspended solids prevent aquatic plants from accessing light. The process of photosynthesis is reduced without light, leading to a reduction in the amount of dissolved oxygen in the water. Dissolved oxygen is very important for macroinvertebrates and other aquatic organisms (Mudenda, 2017).

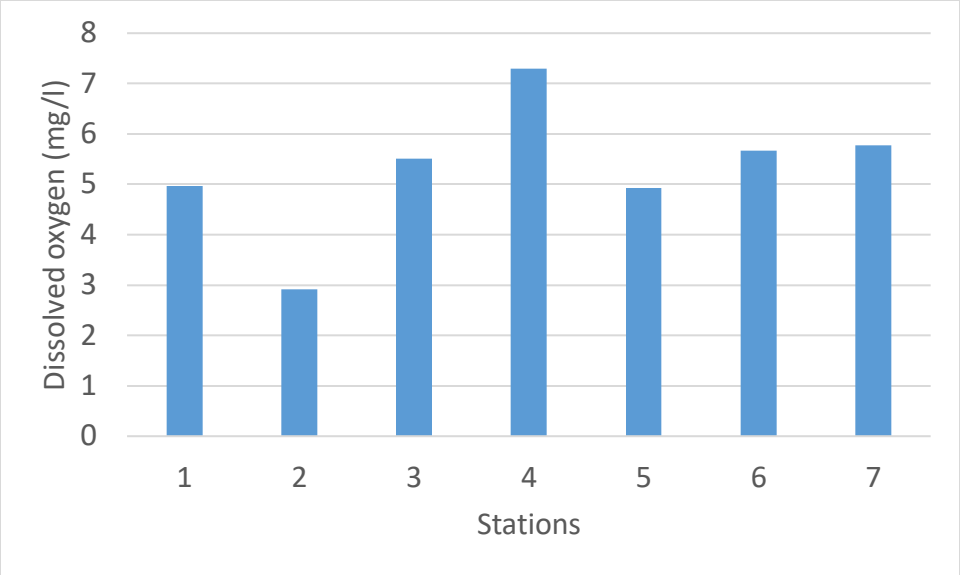


Figure 7. 1 :Variation of dissolved oxygen along Chimvu river



Figure 8. 1 : Some of the maize cobs that gets thrown in Chimvu River causing a decrease in dissolved oxygen concentration

4.1.4. Turbidity

The results showed very high levels of turbidity (63.5NTU) at point 2 (figure 10) which can be attributed to siltation due to stream bank cultivation, plant fibers and sand mining activities around this point. Sand mining stirs the sediments of the river, hence increasing the turbidity (Nyasulu, 2010). The lowest turbidity of 7.5NTU was recorded at point 4 where there are less agricultural activities as well as no sand mining activities since the area around this point is full of vegetation hence the maize fields are not close to the river. High turbidity levels reduce light penetration leading to a decrease in the rate of photosynthesis and therefore primary production in a river (Dallas H. , 2004). MBS and WHO upper limit for turbidity in rivers and streams is 50. The results from the sampling points shows that point 2 recorded highest turbidity level that exceeded the upper limit.

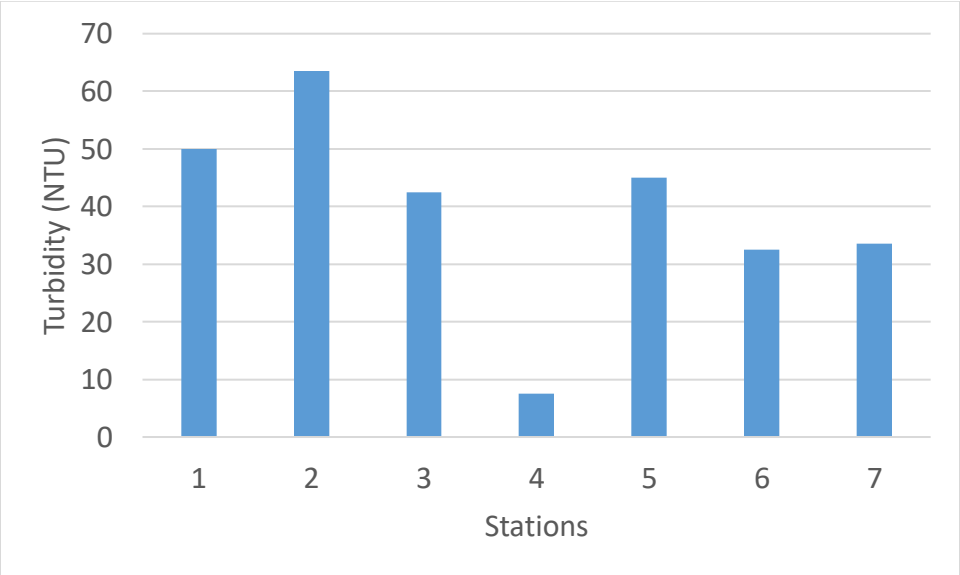


Figure 9. 1 :Variation of turbidity between point 1-7 along Chimvu river



Figure 9. 2 : A picture showing highly turbid water at Sampling point 2

4.1.5. Nitrate

Nitrate concentrations ranged from 1.56 mg/l to 3.3 mg/l among the sites. The concentrations of the total nitrates were high at site 5. The agricultural activities around the Chimvu river might be contributing to high nitrate at this point (Chimuriwo, 2016). Sand mining which occurs in the catchment of chimvu river may also contribute to the increase in nitrate in the river (Zou, Zhu, & Toloneni, 2019).

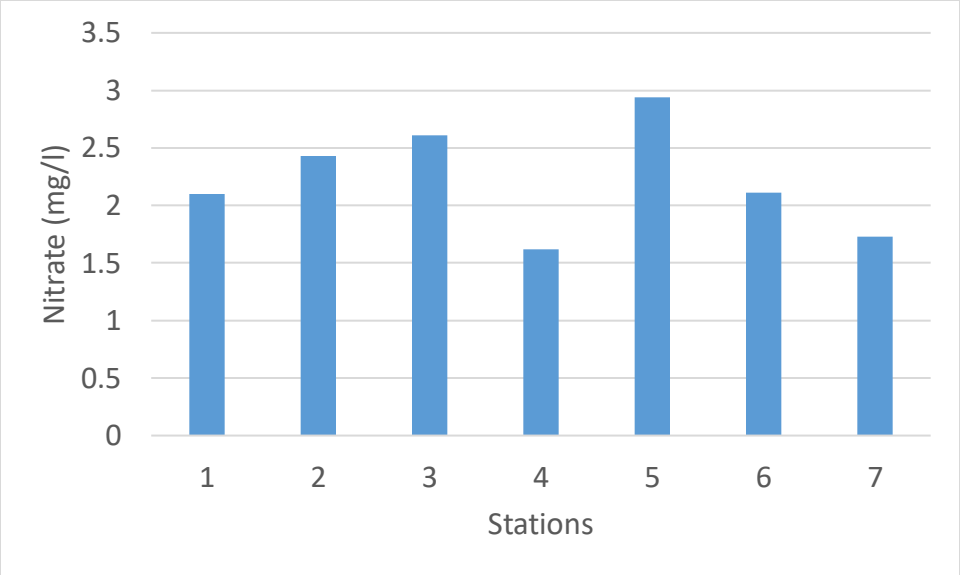


Figure 10. 1 :Variation of Nitrates between point 1-7 along Chimvu river

4.2. Presence of aquatic organisms

SASS score was used in assessing the water quality of Chimvu River based on the availability of macroinvertebrates. During the period of data collection, a total of 296 aquatic organisms were sampled and identified in the river. Each organism was allocated a SASS score based on SASS 5 method (table 2) to give the overall score for each sampling point so as to determine the condition for each sampling point. The organisms were grouped according to their sensitivity to pollution to give the overall picture of the distribution of diversity in the stream during the period of study: Pollution sensitive (15.2%), semi-pollution tolerant (45.27%) and pollution tolerant (39.53%).

The stream was characterized with few pollutions sensitive and many semi-tolerant and tolerant organisms, an indication that the health of the stream was in a bad condition. At sampling point 1 a total of 66 organisms were collected, of the organisms collected at this sampling point, semi-pollution tolerant were the most abundant group of organisms at this sampling point, semi-pollution tolerant organisms that were collected at this sampling point are predacious diving beetles, damselflies, caddisflies, dragon flies and crane flies, in total 36 semi-pollutions tolerant organisms were caught at this sampling

point. Pollution tolerant organism at this sampling point was represented by midges, leeches and giant water bugs in total 17 pollution tolerant organisms were collected, while pollution sensitive organisms which were less abundant at this sampling point were represented by riffle beetles and mayflies in total 13 pollution sensitive organisms were caught at this sampling point.

Sampling point 2 recorded same number of aquatic organisms as sampling point 1. Semi pollution tolerant organisms were also abundant at this sampling point and were represented by dragonflies, caddisflies, predacious diving beetles, water scavenger beetles and damselflies, a total of 43 semi-pollutions tolerant were collected at this sampling point. Pollution tolerant organisms at this sampling point were represented by creeping water bugs, leeches, snipe flies and midges, a total of 15 pollution tolerant organisms were caught at this sampling point. A total of 8 pollution sensitive organisms that were represented by mayflies and riffle beetles was recorded at this sampling point. Similar to Point 1 this sampling point had less pollution sensitive organisms.

Sampling point 3 registered lower number of organisms by comparing with sampling point 1 and 2. A total of 41 organisms were collected at this sampling point. Of those organisms collected semi-pollution tolerant organisms represented by dragonflies, caddisflies and damselflies recorded a total of 17 semi-pollution tolerant organisms. Pollution tolerant organisms which were the most dominant organisms at this sampling point were represented by midges, worms, giant water bugs, broad shouldered water striders, leeches and snails and recorded 22 pollution tolerant organisms, while pollution sensitivity organisms which was only represented by mayflies recorded only 2 organisms.

Sampling point 4 recorded 40 aquatic organisms. Of the 40 organisms that were collected at this sampling point 19 organisms belonged to the semi-pollution tolerant group of organisms which were represented by dragon flies, predacious diving beetles, caddisflies, water scavenger beetles and damselflies. Pollution tolerant organisms that were represented by water boatmen, water scorpions, worms and snails counted 11 organisms in total while pollution sensitive organisms that was represented by mayflies

counted 10 organisms. This sampling point had high pollution sensitive organisms than sampling point 1, 2 and 3.

Sampling point 5 recorded 38 organisms in total. Of 38 organisms that was present at this sampling point, 23 organisms belong to the pollution-tolerant organisms which at this point was represented by moth flies, worms, and backswimmers. Semi -pollution tolerant organisms at this point were dragon flies and damselflies and counted 13 organisms while mayflies which represented pollution sensitive organisms were only 2.

Sampling point 6 recorded low number of organisms for all the sampling points and a total of 23 organisms were caught at this sampling point. Of those organisms, 3 organisms belong to semi-pollution tolerant and were represented by predacious diving beetles and damselflies, pollution tolerant organisms that were represented by snails, moth flies, leeches, worms and backswimmers were 16 in total while pollution sensitive organisms which at this were represented by mayflies were 4 in total.

Sampling point 7 recorded 33 organisms in total, of those organisms 14 organisms were semi-pollution tolerant organisms and were represented at this sampling point by dragonflies, crane flies, marsh beetles and damselflies. Pollution tolerant organisms at this sampling point were represented by worms, leeches and creeping water bugs which were 13 in total while pollution sensitive organisms which were represented at this sampling point by mayflies were 6 in total

From the results presented above it indicates that Chimvu river is being moderately polluted. Some of organisms that were collected in most of sampling points belongs to pollution tolerant as well semi-pollution tolerant. Human activities such as sand mining and farming practices which occurs along the river contributes to having low population of pollution sensitive organisms (Ojija & Laizer, 2016) (JD, Ijumba, & Mgaya, 2014). For example, the use of fertilizers in most of the sampling point increases the amount of nutrients entering the water and this led to a reduction in dissolved oxygen causing a decrease in faunal abundance especially pollution sensitive organisms in Chimvu River (Mason, 1992). Farming activities near the stream also causes soil erosion and

consequently increasing suspended particles into the stream which makes the environmental condition in the stream not suitable for species which are very pollution sensitive.

The direct sand extraction can cause a mass death of organisms that live on the bottom of water bodies such as benthic animals. Dredging-induced habitat degradation in sand mining areas may hamper the recolonization of macroinvertebrate (Zou, Zhu, & Toloneni, 2019). Intensive sedimentation during the sand mining process may form new surface sediment with a lower content of nutrients and organic detritus. These results indicate that macroinvertebrates could hardly assimilate energy from the sediment (Maya, Padmalal, & Sreebha, 2008). This then could lead to less abundance of aquatic organisms in the river

Table 4 below summarizes the organisms that were caught in Chimvu river based on pollution tolerant, semi-pollution tolerant and pollution sensitive organisms

Groups	Collected macro invertebrates	Total Number of species	Abundance in %
Pollution tolerant	1.Riffle beetles	8	2.70
	Mayflies	37	12.5
Total		45	15.2
Somewhat pollution tolerant	Crane fly	7	2.36
	Caddisflies	16	5.41
	Damselflies	34	11.49
	Dragonflies	54	18.24
	Predacious diving beetles	11	3.72
	Water scavenger beetles	4	1.35
	Minute-moss beetles	2	0.68

	Marsh beetles	6	2.03
Total		134	45.27
Pollution Tolerant	Snails	11	3.72
	Midges	11	3.72
	Giant water bugs	6	2.03
	Creeping water bugs	7	2.36
	Water striders	2	0.68
	Water boatmen	2	0.68
	Backswimmers	7	2.36
	Aquatic worms	23	7.77
	Leeches	37	12.5
	Snipe flies	3	1.01
	Moth flies	6	2.03
	Water scorpions	2	0.68
Total		117	39.53
0Total Number of all invertebrates		296	

Table 4:Summary of aquatic organisms based on three groups of organisms which are pollution tolerant, semi-pollution tolerant and pollution sensitive organisms

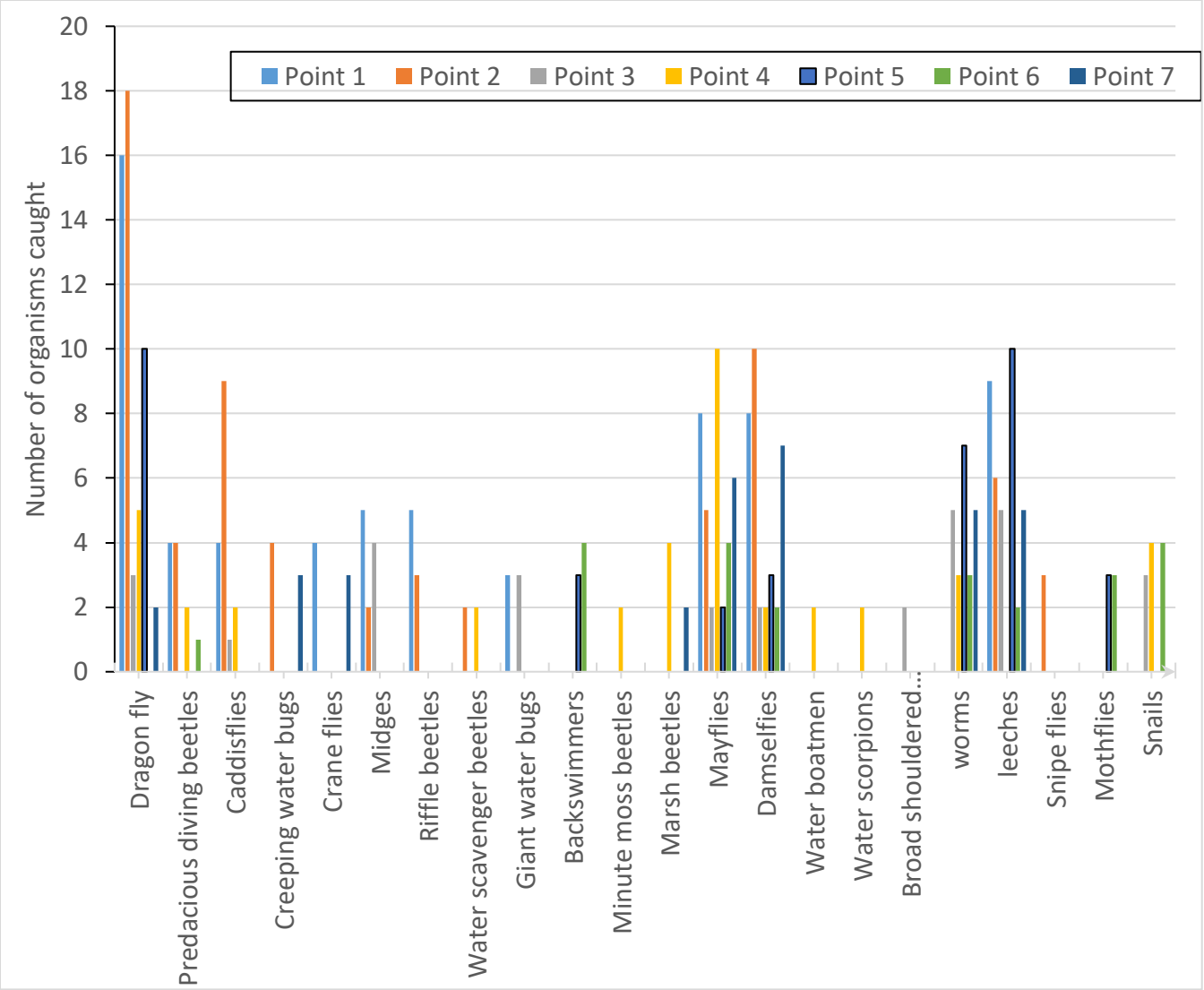


Figure 10. 2:Distribution of aquatic organisms in Chimvu River during sampling period

4.3. SASS scores

The average SASS score of aquatic organisms was calculated by summing up the sensitivity score of different organisms and then divide by the number of groups of organisms present at that station. A worksheet was used to indicate the water quality (natural, good, fair, poor or very poor) at every sampling point. Sampling point 1 and sampling point 2 had a better SASS score than the rest of the sampling point (7.18 and

7.09) respectively which is an excellent ecological condition this so because these points recorded high number of organisms and some of the organisms are pollution sensitive organisms. The lowest SASS score of 4.29 was recorded at sampling point 6 and this score shows that this sampling point had very poor ecological condition. Activities such as agriculture and sand mining which occurs along Chimvu river might have contribute on lowering of SASS scores in some of the sampling points. This is because these activities cause pollution which may affect the availability of some organisms such as pollution sensitive organisms which have high sensitivity scores. Points that low SASS scores means that they have low population of pollution sensitive organisms. The graph below shows the SASS score for every sampling point.

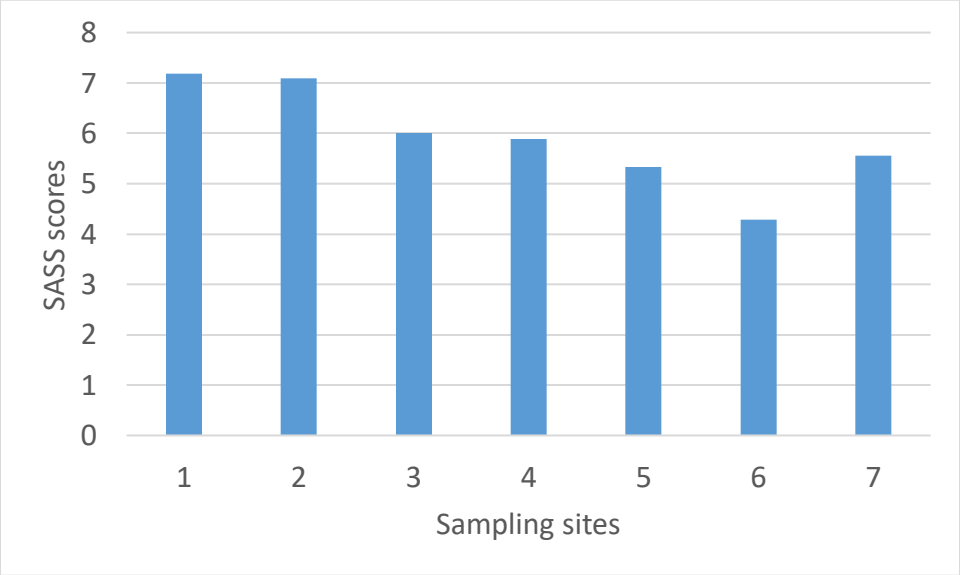


Figure 11. 1: A graph showing the Average SASS for sampling points in Chimvu River

The average SASS score that was obtained at every sampling point was compared to the table below to find the ecological aquatic condition of the river

Ecological condition	SASS score
Natural/excellent(not/less polluted)	≥6.9
Good(less polluted)	5.9 to 6.8
Fair(moderately polluted)	5.4 to 5.8

Poor (more polluted)	4.8 to 5.3
Very Poor (Critically polluted)	≤4.8

Table 5:Ecological aquatic condition based on SASS 5 methods

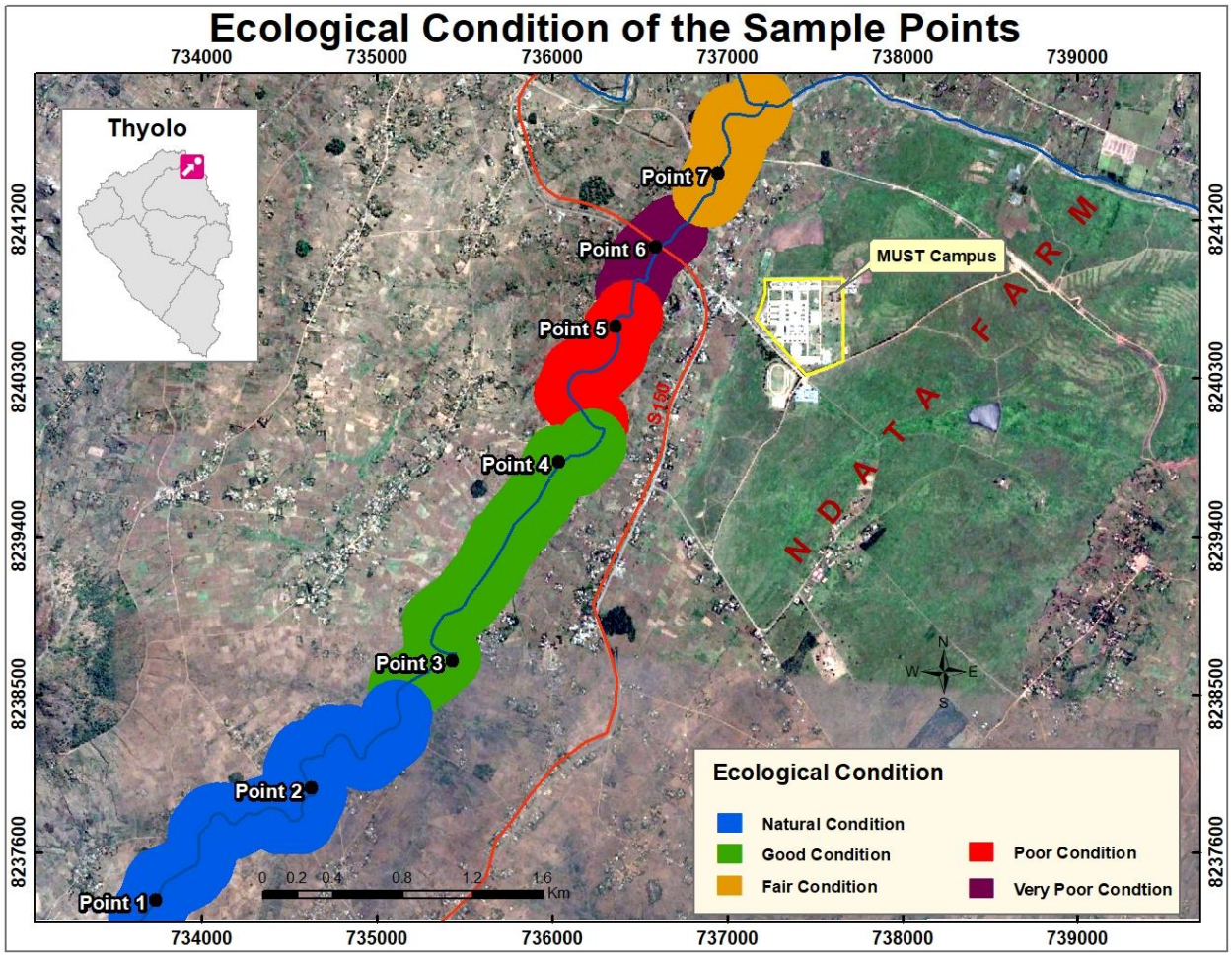


Figure 11. 2 :Map showing the ecological conditions for each Sampling point in Chimvu River

Chimvu river is dominated by moderately pollution sensitive organisms or somewhat pollution tolerant macroinvertebrates such damselflies, dragon flies, water scavenger beetles, predacious diving beetles, marsh beetles, minute-moss beetles and caddisflies.

These organisms survive in fair water quality because their habitat requirements are not strict as pollution sensitive organisms such as mayflies. The presence of these organisms in Chimvu river indicate that Chimvu river is moderately polluted (Ojija & Laizer, 2016). The large abundance of moderately-pollution sensitive organisms (45.27%) in Chimvu river indicate that Chimvu river is not clean but moderately polluted aquatic ecosytem (Ojija & Laizer, 2016). Pollution sensitive organisms are also less abundant in Chimvu river (15.7%) which shows that water quality of Chimvu river does not support macroinvertebrates that require good water quality. However, by comparing these results with those of (Magwaza, 2020) it can be said that the ecological condition of the river improves with the changing season. (Magwaza, 2020) conducted her study during the month of November, when the rainy season was just starting, so as the rainy season was progressing there was an increase in number of organisms in the river. For example, at point 5, 6 and 7 where (Magwaza, 2020) conducted her studies SASS were found to be 3.4,3.571 and 4 respectively while this study found the SASS scores at these points to be 5.33, 4.29 and 5.56 which definitely shows an improvement in the ecological condition. Invertebrate's flourish and breed during the rainy season, as their short lifespan prescribes reproduction 'maxima' during the period, thereby facilitating the greatest chances for survival. Not only the availability of food during the rainy season from increased river discharges/flows and incoming nutrients increases the turnover of the organisms, but the discharge also helps flush nutrients, making the aquatic environment more habitable during the rainy season (Ndebele – Murisa, 2012). Sand mining nearby the stream causes the population of organisms in the stream to be lower because sand mining causes the formation of new sediments as a result of sand dredging processes which may lower the nutrient content of the river and organic detritus hence making the river not habitable by some organisms such as pollution sensitive organisms. Farming activities that happen near the stream causes soil erosion and subsequently increasing suspended particles in the stream which may damage the aquatic habitats of organisms. Use of fertilizers is also another contributing factor on low abundance of aquatic organisms in Chimvu River

4.4. Correlation of water quality parameters and SASS scores

Water quality parameters and SASS scores were correlated to determine if one was influenced by the other in the study area. Results indicated that there was significant correlation between SASS score and temperature (0.542), temperature and nitrate (0.681), temperature and turbidity (0.508), pH and dissolved oxygen (0.59), Dissolved oxygen and turbidity (-0.956), Dissolved oxygen and nitrate (-0.570) and nitrate and turbidity (0.642). No significant correlation was noticed between SASS score and pH, SASS score and Dissolved oxygen, SASS score and nitrate, SASS score and Turbidity, Temperature and pH, Temperature and Dissolved oxygen, as well as pH and Turbidity

	SASS score	Temperature	pH	Dissolved oxygen	Nitrate	Turbidity
SASS score	1					
Temperature	0.542	1				
pH	0.045	-0.444	1			
Dissolved oxygen	-0.479	-0.0496	0.592	1		
Nitrate	0.0261	0.681	-0.518	-0.570	1	
Turbidity	0.499	0.508	-0.385	-0.956	0.642	1

Table 6: Correlation of SASS score, temperature, pH, Dissolved oxygen, Nitrate and Turbidity in Chimvu River

4.5. Summary of biomonitoring assessment and physio-chemical analysis results obtained in Chimvu River

Human activities carried out within Chimvu River catchment have detrimental effect on its water quality. The high turbidity obtained in some of the sampling points could be attributed to agricultural activities in the banks as well as sand mining. Low concentration of dissolved in the river could also be attributed to agricultural activities especially through the use of fertilizers which contains nitrogen hence causing an increase in level of nitrate in some sampling points. Disposal of plant materials such as maize is also another reason why dissolved oxygen is low in the river. All of these activities mentioned such as sand mining and agriculture is having an effect on the availability of aquatic organisms in the river. It was observed that the river has a low population of pollution sensitive organisms such as mayflies which can't survive in water of bad quality. The abundance of pollution tolerant and semi-tolerant organisms in the river is a clear indication that the river is being affected by some of the human activities such as sand mining and agriculture since these activities causes water quality problem in the river such as increased turbidity which pollution tolerant organisms can be able to survive.

4.6. People's perception of Chimvu river and the specific measures they follow to conserve Chimvu River

During the study chiefs of the villages surrounding Chimvu River were questioned whether their villages are aware of the existing legislation that provides for the conservation and management of rivers. However, of all the chiefs that were questioned said they do not aware if there is any law in this country that is aimed at conservation and management of rivers. However, some of the chiefs said that they only know of the conservation measures that they get when listening to radios

Chiefs were also asked if them and their people have any knowledge on the impacts of human activities on rivers. From the responses that were provided most of them replied that they are aware of those impacts and they mentioned of impacts such as soil erosion

as a result of cultivating along the river banks. However, none of them talked of the impacts that human activities have on aquatic organisms that are found in streams

The chiefs were also asked if their villages practice any conservation measures to manage the river. According to their responses some of them said that they encourage their people to plant trees close to rivers since they are aware that by planting trees close to the river will help in ensuring the river is protected from soil erosion.

The chiefs were also asked if any government or non-government organization ever come in their areas to ask them to work hand in hand with the community to manage the rivers. All the chiefs replied that no any organization ever came to their areas to ask them to collaborate on managing the river.

Malawi legislative laws such as Environmental Management Act provides for the prohibition of doing any activity close to the rive that may damage the river. However, observations that were made during this study indicate that no any of such legislation is being followed by people surrounding the river. Most of the people's farming land are located in close proximity to the river. The Act also provides for establishment of catchment management committees for management of water resources. however, of all chiefs that were asked none of them said of the existence of such committees in their villages.

4.7. Observed activities in Chimvu River

The seven sampling sites were chosen because of their easy accessibility and that they seemed to be representative of the different human activities profiles along the stretch of the river channel. Agricultural activities such as crop farming, release fertilizers that runoff into the river. Sand mining is also rampant close to the river. Other anthropogenic activities taking place along Chimvu River were washing and bathing. Stream bank cultivation, which is uncontrolled and rampant, was observed in most of the sampling sites. Agricultural activities such as crop farming were seen close to the river course as shown in figure below



Figure 12. 1 :Some sections of the river showing some farming lands located close to the river



Figure 12. 2: Some sections of the river showing some farming lands



Figure 13. 1 : A tomato garden that is located close to Chimvu River at sampling point5



Figure 14. 1:Irrigated maize fields along Chimvu River

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The status of water quality of Chimvu River is not very clean because its aquatic environment is moderately polluted. This may be dangerous to aquatic fauna and flora that need very clean water to survive. Dissolved oxygen which is an important water quality parameter for the aquatic life was not conforming with acceptable range as according to WHO guidelines on water quality. Temperature was in good range for all sampling point. This also was the same with both pH and nitrate. Turbidity varied in most of the sampling points where some sampling points recorded turbidity above an agreed value as stipulated by WHO. On the population of organisms, Chimvu River has low population of pollution sensitive organisms by comparing with pollution tolerant and semi-pollution tolerant organisms. This means that the river is not healthy. Sand mining and agriculture activities are the main activities that may be attributed to the poor water quality of Chimvu River

5.2. Recommendations

- The relevant authorities should regularly monitor and control the source of pollutants arising from human activities such as sand mining, agriculture and domestic activities that may have an effect on Chimvu river and other rivers in Malawi.
- Biomonitoring assessment techniques be adopted for use by relevant authorities as tools for assessing the condition of rivers and other streams in Malawi.
- Existing environmental laws should be enforced to prevent stream bank cultivation and sand mining along the river

5.3. Limitations

The time limit for conducting the research project was not enough as water quality assessment of river needs much time to conduct the field work in order to generate adequate data values of the selected parameters for producing temporal and spatial variation maps due to its dynamic state.

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Appendices

Appendix A: Table of physical and Chemical water analysis results

Table 7: Raw data for water quality parameters collected in Chimvu River

Station	Visit	Number of replicates	pH	Dissolved oxygen	Temperature	Turbidity	Nitrate
1	1	1	7.61	4.87	24.9	46	1.78
	1	2	7.69	4.41	24.6		1.77
	2	1	8.18	5.39	31.2	54	2.36
	2	2	8.12	5.19	31.7		2.31
2	1	1	6.59	2.41	26.7	62	2.73
	1	2	6.76	2.17	26.2		1.79
	2	1	7.11	3.26	31.7	65	3.07
	2	2	7.13	3.82	31.6		2.11
3	1	1	7.79	4.67	24.9	42	2.69
	1	2	7.17	4.49	25.1		2.70
	2	1	7.69	6.63	31.4	43	2.33
	2	2	7.58	6.26	31.3		2.71
4	1	1	7.82	6.27	22.9	8	1.45
	1	2	7.84	5.25	22.8		1.69
	2	1	7.21	8.68	30.1	7	1.68
	2	2	7.28	9.01	30.2		1.65
5	1	1	7.82	4.67	27.3	39	3.64

	1	2	7.85	4.24	27.1		1.50
	2	1	6.59	5.49	29.9	51	3.99
	2	2	6.56	5.31	30.0		2.61
6	1	1	7.74	5.13	23.3	37	2.0
	1	2	7.67	5.01	23.2		1.12
	2	1	7.01	6.27	26.8	28	3.11
	2	2	7.07	6.68	26.2		2.21
7	1	1	7.82	4.94	21.1	25	1.74
	1	2	7.80	4.82	21.2		1.80
	2	1	7.70	6.51	23.4	42	2.16
	2	2	7.71	6.86	23.0		1.21

Appendix B: Table of macroinvertebrates that were collected in Chimvu River

Table 8 :Summary of aquatic macroinvertebrates present in Chimvu River

Invertebrates	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Total	Percentage
Dragon fly	16	18	11	5	10	0	2	62	20.946
Predacious diving beetles	4	4	0	2	0	1	0	11	3.716216
Caddisflies	4	9	1	2	0	0	0	16	5.4054

Creeping water bugs	0	4	0	0	0	0	3	7	2.3649
Crane flies	4	0	0	0	0	0	3	7	2.3649
Midges	5	2	4	0	0	0	0	11	3.7162
Riffle beetles	5	3	0	0	0	0	0	8	2.7027
Water scavenger beetles	0	2	0	2	0	0	0	4	1.3514
Giant water bugs	3	0	3	0	0	0	0	6	2.027
Backswimmers	0	0	0	0	3	4	0	7	2.3649
Minute moss beetles	0	0	0	2	0	0	0	2	0.6757
Marsh beetles	0	0	0	4	0	0	2	6	2.027
Mayflies	8	5	3	7	2	4	8	37	12.5
Damselflies	8	10	2	2	3	2	7	34	11.486

Water boatmen	0	0	0	2	0	0	0	2	0.6757
Water scorpions	0	0	0	2	0	0	0	2	0.6757
Broad shouldered water striders (Bugs)	0	0	2	0	0	0	0	2	0.6757
Worms	0	0	5	3	7	3	5	23	7.7703
Leeches	9	6	5	0	10	2	5	37	12.5
Snipe flies	0	3	0	0	0	0	0	3	1.0135
Mothflies	0	0	0	0	3	3	0	6	2.027
Snails	0	0	3	4	0	4	0	11	3.7162
Total	66	66	41	40	38	23	33	296	
Percentage	22.297	22.297	10.473	12.5	12.838	7.77	11.824	100	

Appendix C: Summary of SASS score for Sampling points in Chimvu River

Table 9: SASS scores and stream rating for each sampling point along Chimvu River. Note: Natural=>6.9, Good= 5.9 to 6.8, Fair=5.4 to 5.8, Poor=4.8 to 5.3, Very poor=<4.8

Group	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Mayflies-Baetidae	12	N/A	N/A	12	12	12	12
Mayflies-Caenidae	6	6	6	6	N/A	N/A	N/A
Mayflies-Oligoneuridae	15	N/A	N/A	N/A	N/A	N/A	N/A
Mayflies-Polymitarcyidae	N/A	N/A	10	N/A	N/A	N/A	N/A
Mayflies-Tricolythidae	N/A	9	N/A	N/A	N/A	N/A	N/A
Mayflies-Teloganonidae	N/A	12	N/A	N/A	N/A	N/A	N/A

Caddisflies	9	9	9	9	N/A	N/A	
Crane flies	5	N/A	N/A	N/A	N/A	N/A	5
Midges	10	10	10	N/A	N/A	N/A	
Mayflies-leptophteblidae prongilis	N/A	N/A	N/A	N/A	N/A	N/A	9
Damselflies	4	4	4	4	4	4	4
Dragon flies	6	6	6	6	6		6
Bugs	5	5	5	5	5	N/A	5
Beetles	5	5	N/A	5	N/A	5	5
Leeches	2	2	2		2	2	2
Worms	N/A	N/A	2	2	2	2	2
Moth flies	N/A	N/A	N/A	N/A	1	1	N/A
Snipe flies	N/A	10	2	N/A	N/A	N/A	N/A
Snails	N/A	N/A	4	4		4	N/A
SASS score	79	78	60	53	32	30	50
Number of taxa	11	11	10	9	6	7	9
Average score per taxon	7.18	7.09	6	5.89	5.33	4.29	5.56
Rating	Natural	Natural	Good	Good	Poor	Very poor	Fair

Appendix D: Questionnaire for Chiefs along Chimvu River

The responses to this survey will assist Jaime Sabiti in determining the if people along Chimvu River follow any conservation measures to protect the river or if they follow the laws and legislation on river management and conservation as according to Environmental Management Act of 2017. The respondent was to fill or answer orally

1. Name of Chief or village elder…….
2. Name of village you represent…….....
3. What kind of human activities are carried out by your villagers along Chimvu River?.....
4. Are you aware of the impacts that these activities have on water quality of rivers….?
5. Are there any measures that you as chiefs established to conserve and protect Chimvu River……?
6. Are you aware of any existing legislation on the conservation and management of river in Malawi……?
7. If yes do you follow any of those legislation……..?
8. Has any government or non-governmental ever come in your village to educate your people about the importance of river management and conservation……?
9. Are there any catchment management committees in your village that is aimed at managing the river ……?
10. Any other information that may be relevant to my topic of concern…….?