

ASSESSMENT OF THE ENVIRONMENTAL IMPACT OF SAND MINING ON THUCHILA RIVER

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ABSTRACT

Thuchila River is one of the many rivers in Malawi that supports many anthropogenic activities which include irrigation, sand mining, laundry, hygiene and waste disposal. Sand mining is one of the anthropogenic activities that has been noted to cause many environmental issues in river ecosystems. The aim of this study was to assess the environmental impacts of sand mining on the Thuchila River.

The study approach involved Image analysis and water sample analysis. Firstly, water samples were strategically collected in well-labelled containers and sent to AgriLab for analysis of physical and inorganic chemical parameters. Secondly, aerial photographs were taken on the area and analysed.

Firstly, the findings suggest that the water from the river is safe for human consumption and irrigation as all the constituents except iron were within the World Health Organisation (WHO), Food and Irrigation Organisation (FAO) and Malawi Bureau of Standards (MBS) acceptable levels. Additionally, the findings suggest that the disturbance at the mining site cause anomalous changes in the trends of physical and inorganic chemical parameters. Secondly, the image analysis findings suggest that the development of the mining site and the extraction of sand affect many aspects of the landscapes.

This study however was limited to a single mining site. It would be interested to extend the study to several sites along the river in order to assess whether the findings can be replicated.

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ACRONYMS/ABBREVIATIONS

°C	Degree Celsius.
AMBIC	Ammonium Bicarbonate.
Ca	Calcium.
Cu	Copper.
EC	Electrical Conductivity.
FAO	Food and Agricultural Organization.
Fe	Iron.
Fe^{3+}	Ferrous ion.
GPS	Global Positioning System.
ICP	Inductively Coupled Plasma.
MBS	Malawi Bureau of Standards.
Mg	Magnesium.
MN^{3+}	Manganic ion.
Mn	Manganese.
Mo	Molybdenum.
MUSTREC	Malawi University of Science and Technology Ethics Committee.
N/A	Not Applicable.
NH4	Ammonium.
OES	Optical Emission Spectrometry.
pH	Power of hydrogen.
Ppm	Parts-per-Million.
S	Sulphur.
TA	Traditional Authority.
WHO	World Health Organization.
Zn	Zinc.

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1. CHAPTER 1: INTRODUCTION

This chapter gives a general background, location of the study area, objectives, significance and the research questions of the study.

1.1 Background

River sand has been a major raw material in the construction sector as far as the Egyptian Civilisation. (Kondolf G. , 1994) states that this is because alluvial deposits are of better quality than other deposits from other sources due to the sorting processes that separate weak material from strong ones. The other reason is that the deposits are easily extracted from in-channel and near-channel sources.

In recent years, the human population has increased and this has resulted in an increased rate of industrialization and urbanization. Although the sand is renewable for millions of years in geological times, (Mwangi, 2007) explains that it is considered a non-renewable resource as its regeneration is limited in human calendar years. This means that rivers have been under pressure to supply this resource to meet the increasing demand. This is the case across the world, especially in developing countries like Malawi.

According to (Pearce, 2019), sand mining is the world's largest mining endeavour and has its share of corruption as it is also the least regulated sector in mineral extraction. This has prompted it to possibly be the most environmentally destructive if not managed properly. (Koehnken, et al., 2020) noted that developing countries, like India, have recognized that, unless properly managed, sand mining has adverse environmental consequences even though it is economically beneficial to some of the people living around the rivers. Malawi is no stranger to this endeavour. In the profile created by (Mining Africa, 2017), sand is one of the major resources that is mined in the country. This means that it would be necessary to establish the effects

of sand mining on Malawi's rivers and come up with sustainable methods to fix the issues that may be caused by sand mining activities.

1.2 Study Area

The study was conducted on the Thuchila River. Thuchila is a stream which is in Thyolo district, Southern Region, Malawi. It also acts as an antecedent boundary between Thyolo and Mulanje as shown in Figure 1. The estimated terrain elevation above sea level is 529 metres. It is located within the coordinates: Latitude=16° 13' 0" S and Longitude= 35° 16' 59" E. According to Köppen Climate Type Code, it is in the Tropical Wet Savannah. This research focused on the part of the river that flows through the area of Traditional Authority (T/A) Ngolongoliwa which is on the north-western part of Thyolo District.

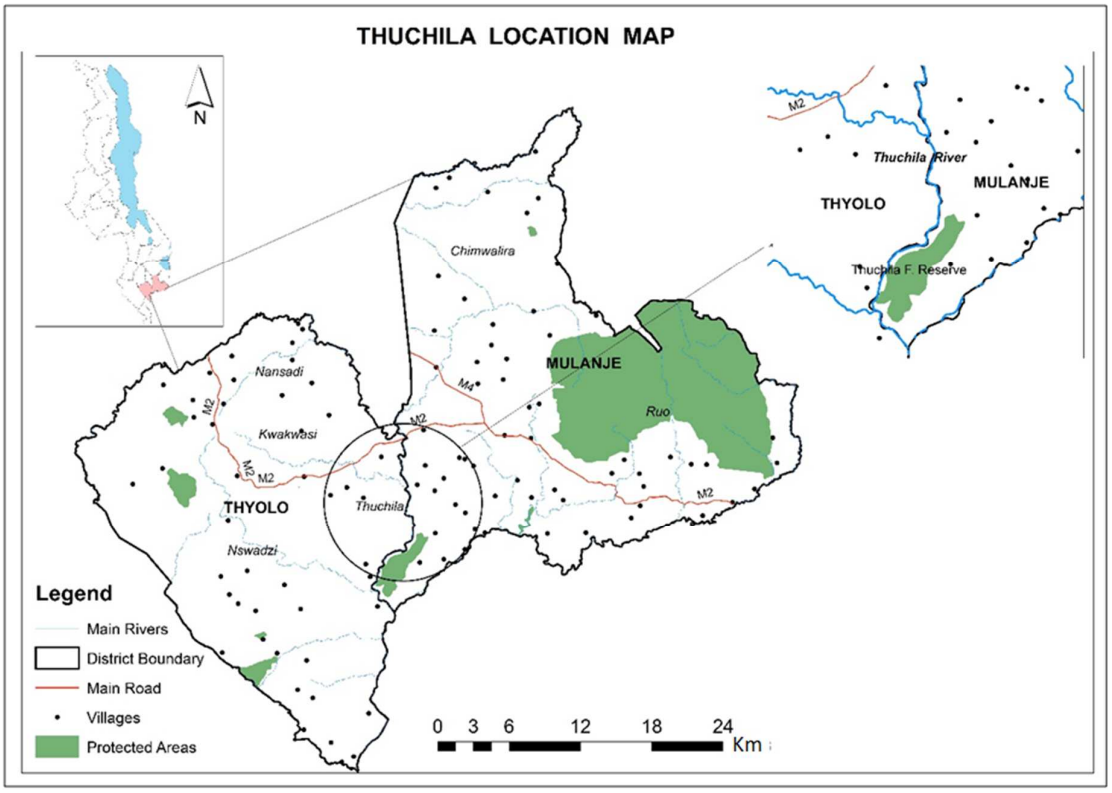


Figure 1: Map of the location of Thuchila River

1.3 Problem Statement

According to the report by (UN-HABITAT, 2011), Blantyre City is the commercial and industrial capital of Malawi that offers various economic opportunities.

Accordingly, Blantyre has had an increase in infrastructure construction. This has seen the need for various soil components such as river sand and gravel from various sites around the city and the neighbouring districts. Thyolo is one of the neighbouring districts and people in the district extract these soil components excessively without considering the impact on the environment. These activities have affected the environmental aspects of the areas around the mining sites along the Thuchila River as shown in Figures 2 and 3. This is the background that this research was based on to investigate this developing problem.



Figure 2: Affected landscape at the mining site (Source: field data, 1st May 2021)



Figure 3: Polluted water at the mining site (Source: field data, 1st May 2021)

1.4 Research Questions

The study aimed at answering the following research questions.

(a) Can sand mining alter the water composition of the Thuchila River?

(b) Is artisanal and small-scale sand mining the cause of the siltation of the Thuchila River?

(c) Can artisanal and small-scale sand mining cause any environmental issues on the Thuchila River?

1.5 Research Objectives

1.5.1 Main Objective

The main objective of the study was to assess environmental impacts of Artisanal and Small-Scale mining of river sand on Thuchila River.

1.5.2 Specific Objective

The specific objectives of the study were as follows:

(a) To interpret the data from water samples for any trace of pollution; and

(b) To evaluate the areas of the riverbanks for changes in the landscape that could be caused by sand mining activities.

1.6 Significance of the Study

The findings of this study will be of great benefit to the community as it will be a steppingstone to coming up with new measures on correcting the problems at hand and preventing future problems. These measures can be applied to ensure that the supply of sand will be managed in a way that meets the demand of the resource but also keeps the river's ecosystem as stable as possible

.

2. CHAPTER 2: LITERATURE REVIEW

This chapter intends to bring a critical analysis of literature related to the present study. It describes the nature of sand and its significance, the state of the extraction industry at different scales, the general impacts of the activity and the different mitigation measures that have been implemented.

2.1. Introduction

Sand is used as fine aggregate for making concrete, mortars and plasters. Experts stated in (Mahima Groups Pvt. Ltd., 2012) that natural river sand is the most preferred choice as a fine aggregate material. River sand is a product of natural weathering of rocks throughout millions of years. River sand is becoming a scarce commodity. River (freshwater) sand is far superior for construction purposes than any other sand used in construction. It is mined from the riverbeds and banks. Excessive instream sand mining can considerably alter river systems and the channels hydraulics in addition to a reduction of productivity within the in-channel and near-stream areas.

Varieties of methods are adopted for alluvial sand extraction. (Kondolf, Smeltezer, & Kimball L, 2002) described several methods for the extraction of sand from the active channels and floodplain/terraces of riverine environments. The first type is bar scalping or skimming which involves the extraction of riverbed materials, especially sand and gravel, from the top of the bars. It is usually practised every year based on the rate of deposition of sediments. The other type is Dry pit channel mining which involves the excavation of sand within the active channel of dry intermitted or ephemeral stream beds using machines such as bulldozers, scrapers and loaders or manual means. The other type is Wet pit mining which involves excavation of a pit in the active channel below the surface water of a perennial stream or below the alluvial groundwater table. The final type is Bar excavation which involves a pit that

is excavated at the downstream end of the bar as a source of aggregate and as a site to trap sand and gravel. After completion of sand and gravel extraction, the pit may be connected to the channel at its downstream end to provide a side-channel habitat. Additionally, instream sand and gravel traps or bed load traps have been used to reduce sand movement in downstream channels for habitat enhancement. These traps can be potential sources of commercial aggregate, provided the quantity so collected is economically viable. Finally, Channel-wide instream mining is the extraction of sand and gravel from the entire active channel during the dry season. This kind of mining is practised in rivers having variable flow regimes. The bed is evened out and uniformly lowered.

2.2. Artisanal and Small-Scale Sand Mining and Gravel Mining in the World

Artisanal and Small-Scale Mining occurs in approximately 80 countries worldwide. There are approximately 100 million artisanal miners globally. It is widespread in developing countries in Africa, Asia, Oceania, and Central and South America. (Abbey, Nartey, Al-Hassan, & Amankwah, 2014) has stated that although the informal nature and the whole un-mechanized operation generally results in low productivity; the sector represents an important livelihood and income source for the poverty affected local population.

River sand mining is one of the artisanal and small-scale mining operations that is widespread in most developing countries and developed countries. The leading nations in sand mining and processing are the United States of America, Australia, Austria, Belgium, Brazil, India, Spain, Nigeria, Kenya and South Africa.

Although all these countries are involved in sand mining, the country that is largely involved in artisanal and small-scale sand mining (and greatly affected by it) is India. After reviewing Indian communities, (Kuttipuran, 2006) explained, that as urban areas grew, less wood was used with more concrete structures being required; leading to the demand for low-cost sand. Sand is one of the most accessible cheap and basic raw materials for the construction industry in India. In recent years, headlines were filled with reports of the sand mafias cashing in on the country's

construction boom. These mafias were conducting illegal extraction operations that were threatening the existence of the river systems. In January 2019, a video by a 17-year-old girl from a fishing village in the state of Kerala posted a video on a mobile phone app about the situation in her coastal community. "The land beneath our feet is sinking away," she said. It quickly became a sensation across the country and by February 2019, the country's National Green Tribunal; a government body aimed at settling environmental disputes; was made aware of the situation and started looking into the case (Pearce, 2019).

In Africa, sand has been used for thousands of years to construct houses, roads and dams. Today the demand for sand has increased greatly due to the increase in Africa's urbanisation. Sand mining in African states is done both legally and illegally. Kenya is one of the countries that is affected both positively and negatively by the unsystematic river sand mining. It has grown to be an essential component and a major source of the Kenyan economy. According to experts, the environmental impacts of river sand mining are not always obvious and hence have long been underestimated. In the past years, the Kenyan government realised the impact of sand mining on various components of the aquatic ecosystems through the systematic evaluation of the state of its environment (Padmalal & Maya, 2014).

2.3. Artisanal and Small-Scale Sand Mining and Gravel Mining in Malawi

Malawi is a developing country in south-eastern Africa. It is gifted with many water bodies which include lakes, rivers and streams. This makes it possible for sand to be a very reliable and cheap construction resource. As are many developing countries, Malawi has seen an increase in the urbanisation industry. This has required an increased supply for the resource. In 2019, one of Malawi's major newspapers, The Nation, wrote an article about the increase in illegal and unsystematic sand mining. It highlighted the fact that the Constitution had clearly stated the laws governing this sector and that the issue was the lack of regulation by the responsible authorities (Chitete, 2019). Since then, the government has made no major steps to control the situation, which has increased illegal and unsystematic sand mining. This has led to several environmental issues across most river systems.

2.4. Impacts of Artisanal and Small Scale River Sand Mining Worldwide

Sand is a very reliable resource to the construction industry. Its physical and chemical properties make it the perfect raw material. It is also cheap and easy to extract as it is found on the surface. With the increased demand for sand due to rapid development, this venture has become very popular. The availability of sand has sped up the development processes of many countries such as China, which is the largest consumer and importer of sand this century (Pearce, 2019). (Madyise, 2013) stated in their work that sand mining has helped African and Indian states to develop better infrastructures; reduce unemployment as more people are going for this as a source of income. It has also helped governments around the world to gain revenue from the extraction activities.

However, the continuous removal of sand has caused adverse effects on the environment. (Padmalal & Maya, 2014) has analysed several negative impacts of sand mining. Illegal and unsystematic mining of sand is the most disastrous activity as it threatens the very existence of these systems. It changes the physical characteristics of the river basin environments and disturbs its closely linked flora, fauna, and human life. The impacts of river sand mining cannot be readily felt at measurable levels, as it requires a decade or more to surface. Hence, rivers are said to possess ''long memories,'' which means that the channel adjustments to instream extraction or comparable perturbations may persist long after the activity has practically ceased. Sand mining disturbs the equilibrium that prevails in a river channel. The mining process intercepts the movement of sediments and triggers an initial morphological response to regain the balance between supply and transport. Most studies on the geomorphological effects of river sand mining have involved extraction rates lasting over a decade or more, resulting in large, measurable changes in channel geometry that are quite enough to be detected. Although the direct ecological effects of resuspended sediments arising from sand mining sites are well documented, the long term, indirect effects of sand mining on the biological system, especially on the food web are often difficult to measure.

2.5. Solutions and Mitigation Measures to Artisanal and Small Scale Sand Mining Worldwide

(Padmalal & Maya, 2014) noted that the exponential rise in the demand for construction-grade sand resulted from economic growth and the liberal development policies over the years have aggravated unsystematic scooping of sand from riverbeds and floodplains of most rivers in the world. Sustainable resource extraction needs to be achieved by every nation so that the natural resource requirements in future can also be catered for while satisfying the needs of the present generations. After reviewing the increased awareness of environmental problems, the accent on sustainable development has grown in recent times, particularly concerning activities, which degrade the environment and affect communities adversely.

Most countries have created legal frameworks to govern extraction activities. For example, India involved its National Green Tribunal investigate the case of the Sand Mining Mafias in Kerala state.

Some countries have opted to protect or restore the health and stability of rivers by protecting the naturally occurring physical processes that create and maintain the river systems. (Padmalal & Maya, 2014) has noted that this is done by implementing a combination of two methods that minimize the disturbance of stream channel which include minimizing channel modifications and limiting the volume of sand extraction below the level of natural replenishments. Some countries have opted for the restoration of rivers. This is achieved by bringing down the level of sand extraction and allowing the system to recover by itself. (Cairns Jr., 1988) stated that restoration is the re-establishment of the structure, functions, and natural diversity of an area that has been altered from its natural state by human interference.

3. CHAPTER 3: RESEARCH METHODOLOGY

3.1. Introduction

This section discusses the methodology for the research. It gives an account of the study area, research design, and the methods of data collection, analysis and presentation.

3.2. Study Design

The design of this study utilized (Creswell, 2014)'s quantitative research method. It involves viewing a theory as a scientific prediction or explanation of what the researcher intends to find. This research used (Kerlinger, 1979)'s definition of a Theory to design the nature of the study. He states that a theory "is a set of interrelated variables that present a systematic view of phenomena by specifying relations among variables to explain natural phenomena". (Padmalal & Maya, 2014) states that human development activities like sand mining cause damage to river ecosystems. Accordingly, two variables (Water Quality and River Landscape/Morphology) were chosen, for this research, as sources of scientific evidence for the impacts of sand mining on the Thuchila River System.

Question	What is the Scientific Evidence of the Impacts of Mining on River Water Quality and Morphology/Landscape?
Subject of Study	Thuchila River
Interference	Unsystematic Mining of Sand
Comparator	Landscape and Water Quality Conditions at Pristine, Disturbed and Recovery Sites
Outcome	Change in Ecosystem Aspects of Morphology/Landscape and Water Quality

Table 1: Summary of Major Elements in the research

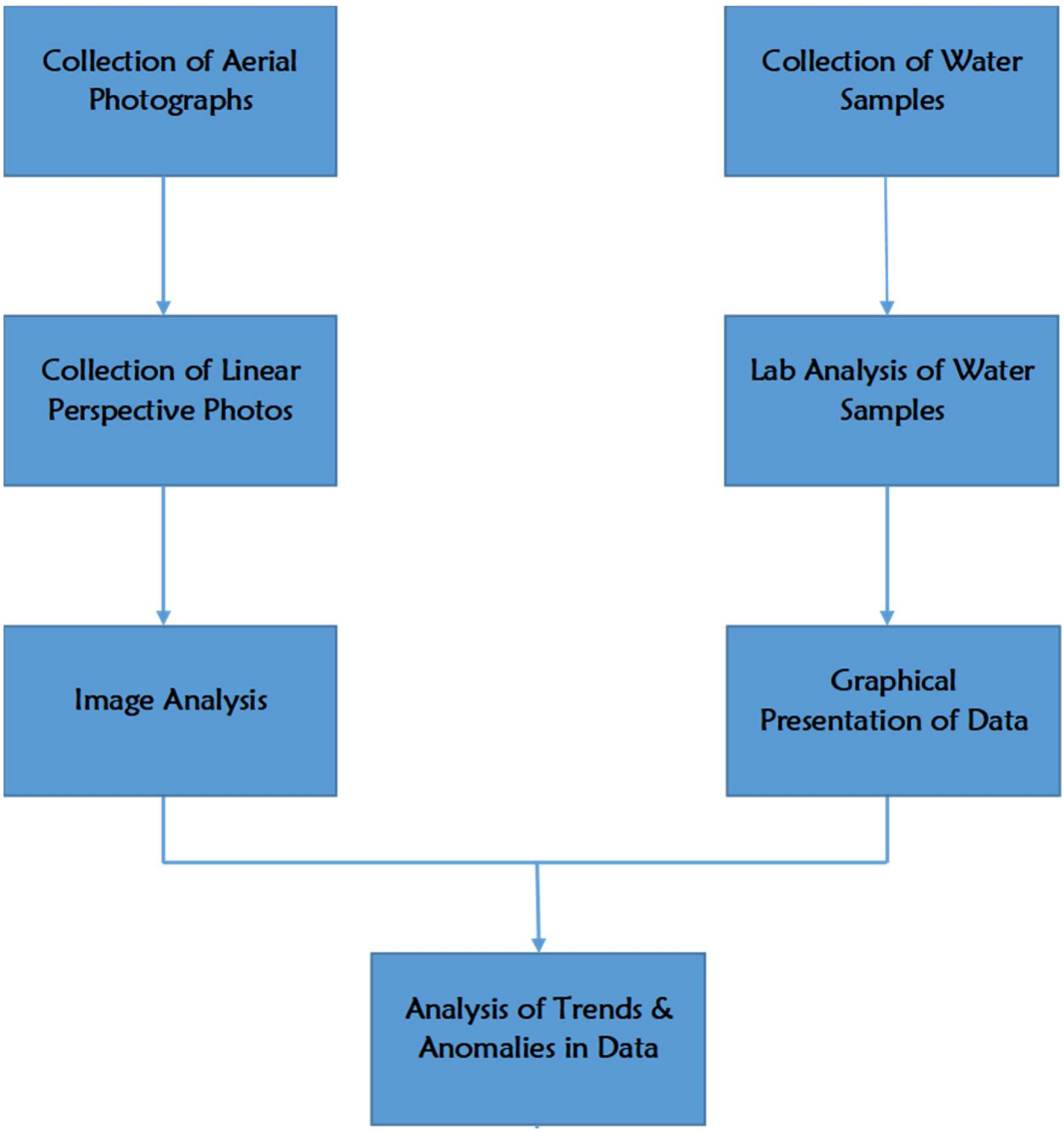


Figure 4: Flow Chart of the Methodology of this Research

3.3. Landscape Data Collection

3.3.1. Aerial Photographs

Following ethical approval from MUSTREC (reference number U04/2021/089) and from Thyolo District Council, Aerial Photographs of the disturbed site were collected from Nkwazi Aeros. The photos were taken in May, which is in the cool-dry season.



Figure 5: Aerial View of the "Disturbed" Site (Source: Nkwazi Aeros, 25th May 2021)

3.3.2. Linear Perspective Photos

These were photos taken with a handheld camera at ground level. These were taken when collecting water samples.

3.4. Water Sampling

3.4.1. Sampling Technique

The sampling technique chosen for this research was Grab Sampling, which was adapted from the work of (Kalkhajeh, 2019). It can be done at a single location or several locations to represent a cross-sectional mean concentration. This method does not show temporal and spatial correlation. In other words, it does not take into account the time and spatial location the samples were collected because of the dynamic nature of rivers. Factors such as time, river dimensions, temporal and spatial variations in water flow and temperature did not affect the sampling location.

3.4.2. Sampling Stations

Twelve samples were collected from four sampling stations, shown in Figure 6 namely:

a) Pristine. This was set as an area unaffected by sand mining. It was located 1km upstream from the Mining Site. This is shown as Point 4.
b) Disturbed. This was set as the actual location of the Mining Site. This area was to show how sand mining causes direct effects on the river's landscape. This was further divided into Disturbed Upstream and Disturbed Downstream sampling stations. These were shown as Points 1 and 2 respectively.
c) Recovery. This was set as an area that either shows how the river is adapting to the disturbance (Sand Mining). It was located 1km downstream from the Mining Site. This was shown as Point 3.

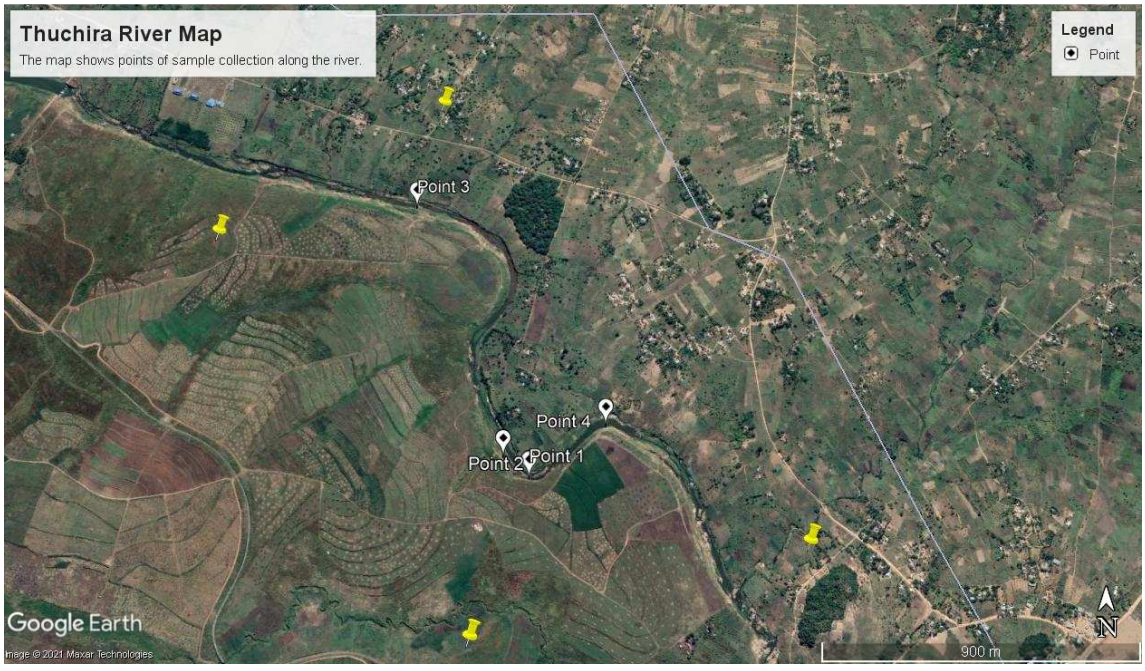


Figure 6: Study Area Polygon and the Sample Sites

3.4.3. Sample Collection

The twelve samples were collected using plastic sample bottles collected from AgriLab, in Blantyre. From each station, three samples were taken at positions named:

(a) The Northern side of the river was labelled **A.**
(b) The Middle of the river was labelled **B.**
(c) The Southern side of the river was labelled **C.**

The coordinates for each sample site were taken a GPS and uploaded to an app provided by AgriLab called Soil Collect.

The consistency in the process of data collection was maintained by using the same data collection tools, sample bottles, procured from AgriLab in order to ensure reliable results.

3.5. Data Analysis

3.5.1. Landscape

The data was analysed by observing the disturbance of the landscape that may have been caused by the mining activity in the study area.

3.5.2. Water Samples

As stated by (Omer, 2019), there are three types of water quality parameters: physical, chemical and biological. Physical parameters include turbidity, temperature, colour, taste and odour, dissolved solids and Electrical Conductivity (EC). Chemical parameters may include pH and major ions among others. Biological parameters may include bacteria, algae, viruses and protozoa. This study was limited to EC, pH and some major ions.

The water samples were analysed at Agrilab in Blantyre. The water samples were analysed for pH, EC and major ions namely Calcium (Ca), Magnesium (Mg), Sulphur(S), Copper (Cu), Iron (Fe), Manganese (Mn); Zinc (Zn), and Molybdenum (Mo).

The temperature conditions of the laboratory were monitored and maintained daily to be within the range of 21 ± 2°C. In the event of temperature fluctuations outside of the working range, the analysis was stalled until the temperature returned to a constant value within the working range

Table 2 shows all the parameters analysed and the methods used.

Parameter	Units	Extraction method		Equipment	Measurement Uncertainty
pH	N/A	H2O (1:5)	Probes	pH Robot	0.0344
EC (Electrical Conductivity)	μS/cm	H2O (1:5)	Probes	EC Robot	0.23
Ca (Calcium)	ppm	1 M NH4-acetate (1:10)	Optical Emission Spectrometry	ICP-OES	N/A
Mg (Magnesium)	Ppm	1 M NH4-acetate (1:10)	Optical Emission Spectrometry	ICP-OES	N/A
S (Sulphur)	Ppm	1 M NH4-acetate (1:10)	Optical Emission Spectrometry	ICP-OES	N/A
Cu (Copper)	Ppm	AMBIC I	Optical Emission Spectrometry	ICP-OES	0.209
Fe (Iron)	Ppm	AMBIC I	Optical Emission Spectrometry	ICP-OES	0.209
Mn (Manganese)	Ppm	AMBIC I	Optical Emission Spectrometry	ICP-OES	0.209
Zn (Zinc)	Ppm	AMBIC I	Optical Emission Spectrometry	ICP-OES	0.209
Mo (Molybdenum)	Ppm	Aqua Regia	Optical Emission Spectrometry	ICP-OES	N/A

Table 2: Parameters Measured and Methods Used

4. CHAPTER 4: RESULTS AND DISCUSSION

This chapter will give an outline of the results of the study, the discussions, as well as an explanation of the study findings.

4.1. Water Quality

This section presents the data from the chemical laboratory analysis. The data is summarized by presenting the data in table form, where the parameters are compared with the acceptable levels stated by WHO (WHO, 2011), FAO (Ayers & Westcot, 1985) and MBS (MBS, 2005).

4.1.1. pH

The pH of water measures the acidity or basicity of water. Safe ranges of pH for drinking water are from 6.5 to 8.5. A high pH (basic solution) results in a bitter taste and decreases in the effectiveness of the chlorine disinfection. Additionally, the amount of oxygen in water increases as pH rises. On the other hand, low-pH water (acidic solution) corrodes metals and other substances. Pollution can modify the pH of water, which can damage animals and plants that live in the water.

LOCATION	PRISTINE	DISTURBED UPSTREAM	DISTURBED DOWNSTREAM	RECOVERY
A	8.07	7.66	7.87	8.03
B	7.94	7.63	7.89	8.13
C	7.97	7.97	7.9	8
FAO	8.4	8.4	8.4	8.4
MBS	9.5	9.5	9.5	9.5

Table 3: pH levels of water at the various sampling sites

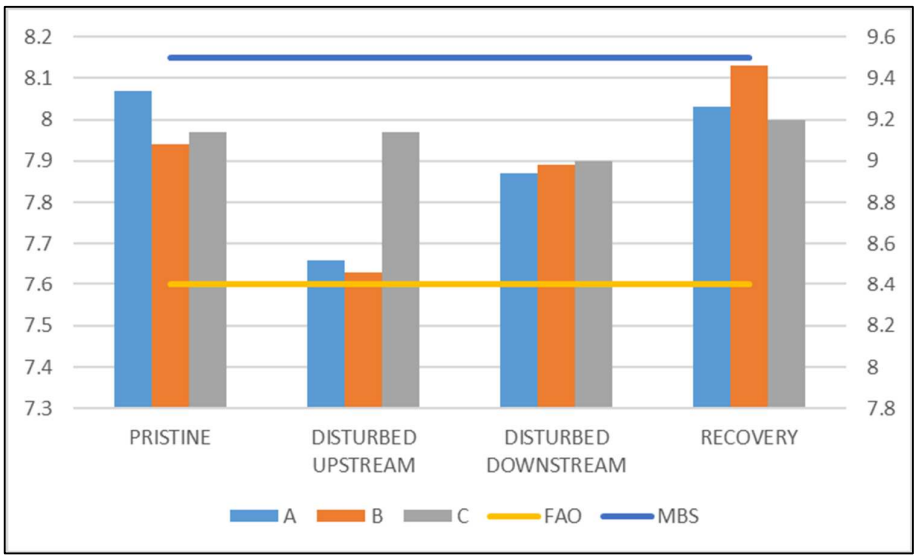


Figure 7: pH levels At the Different Sampling Sites Compared to Maximum Acceptability Values

According to Figure 7, it can be noted that the pH decreases from the pristine area to the disturbed upstream area. Then from the disturbed upstream area, the pH levels steadily rise. This would indicate that the sand mining activity, located between the disturbed upstream and disturbed downstream, caused the rise in pH levels.

4.1.2. Electrical Conductivity (EC)

The electrical conductivity of water measures the ability of a solution to conduct an electrical current, which may be an indicator of the concentration of ions in the water because the conductivity increases as the concentration of ions increases. It is one of the main parameters used to determine the suitability of water for irrigation.

LOCATION	PRISTINE	DISTURBED UPSTREAM	DISTURBED DOWNSTREAM	RECOVERY
A	283	279	285	276
B	283	276	284	269
C	284	289.5	281	274
FAO	0-3000	0-3000	0-3000	0-3000
MBS	700-1500	700-1500	700-1500	700-1500

Table 4: The EC values of water at the various sampling sites

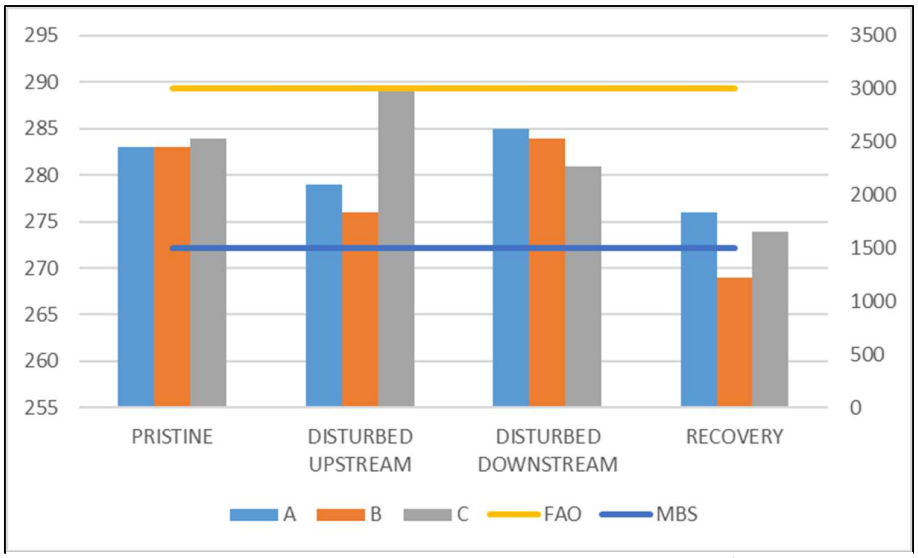


Figure 8: EC Levels at the Different Sampling Sites Compared To Maximum Acceptability Values

According to Figure 8, it can be noted that the EC values also follow a trend. The EC levels decrease from the pristine area to the undisturbed upstream. Then, it can be noted that there was a sharp rise in the EC levels after the disturbance. At the Disturbed downstream, the EC levels start to decrease. This difference in EC between the Disturbed Upstream portion and Disturbed Downstream portion indicates that sand mining causes precipitation of dissolved ions in the water.

4.1.3. Calcium (Ca)

Calcium causes one of the greatest portions of hardness in naturally occurring waters. High hardness can cause a laxative effect.

LOCATION	PRISTINE	DISTURBED UPSTREAM	DISTURBED DOWNSTREAM	RECOVERY
A	24.39	25.81	25.26	25.22
B	25.28	25.23	26.7	23.83
C	25.02	26.59	24.36	25.31
FAO	0-400	0-400	0-400	0-400
MBS	80-150	80-150	80-150	80-150

Table 5: The concentration of calcium in the water at the various sampling sites

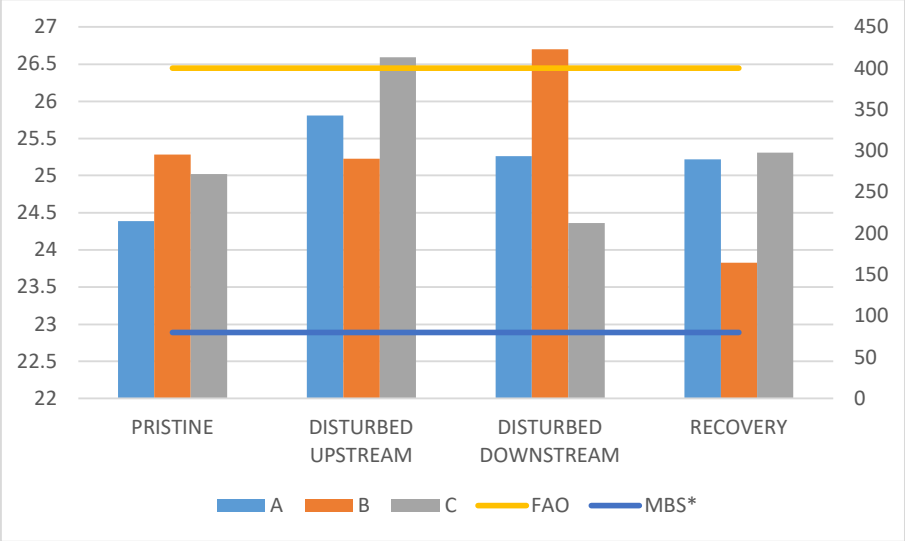


Figure 9: Calcium Concentration At The Different Sampling Sites Compared To Maximum Acceptability Values. MBS* Used the Lowest Acceptable Value.

The data did not show any clear trend.

4.1.4. Magnesium (Mg)

Magnesium causes one of the greatest portions of hardness in naturally occurring waters. High hardness can cause a laxative effect.

LOCATION	PRISTINE	DISTURBED UPSTREAM	DISTURBED DOWNSTREAM	RECOVERY
A	11.08	11.28	11.39	11.06
B	11.48	11.15	11.81	10.85
C	11.25	11.68	11.03	11.14
FAO	0-60	0-60	0-60	0-60
MBS	30-70	30-70	30-70	30-70

Table 6: The concentration of Magnesium in the water at the various sampling sites

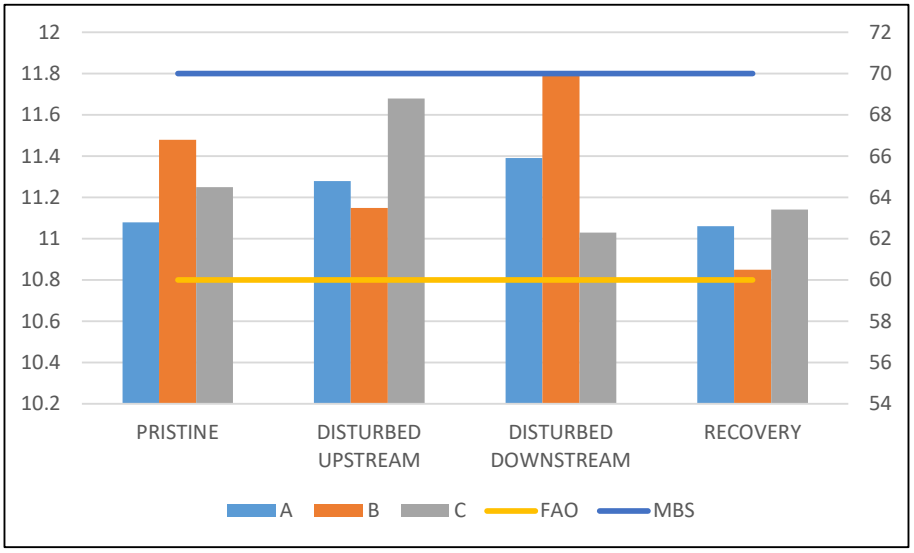


Figure 10: Magnesium Concentration at the Different Sampling Sites Compared to Maximum Acceptability Values

The data did not show any clear trend.

4.1.5. Sulphur (S)

According to (WellCare, 2007), sulphur is a secondary water contaminant, with no direct threat to human health. Sulphur gives water a bitter taste and can cause a laxative effect that may lead to dehydration and nausea.

LOCATION	PRISTINE	DISTURBED UPSTREAM	DISTURBED DOWNSTREAM	RECOVERY
A	1.81	2.295	2.095	2.077
B	2.17	2.102	2.32	1.773
C	2.029	2.201	1.971	2.067
FAO	0-60	0-60	0-60	0-60
MBS	0	0	0	0

Table 7: The concentration of sulphur in the water at the various sampling sites

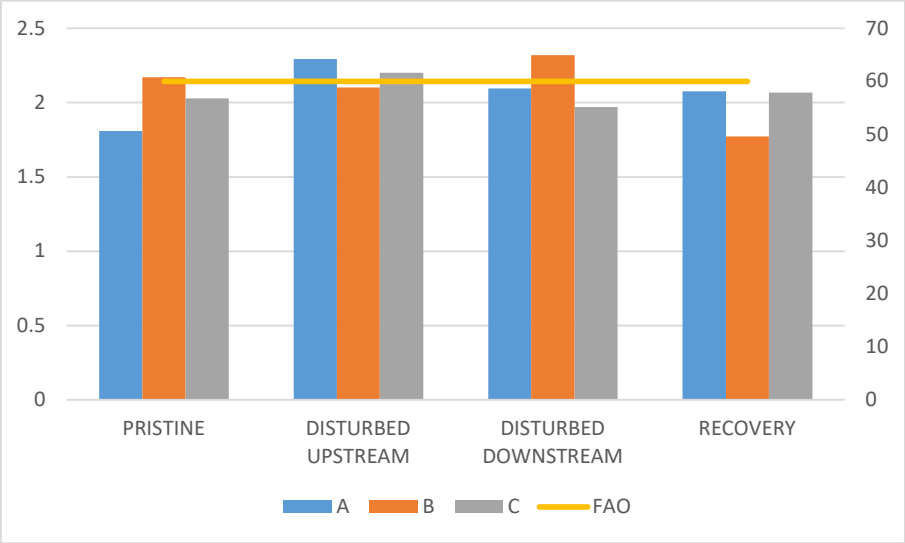


Figure 11: Sulphur Concentration at the Different Sampling Sites Compared To Maximum Acceptability Values

The data did not show any trend that could be related to sand mining.

4.1.6. Copper (Cu)

Copper is usually nontoxic when found in small concentrations, like in Table 8.

LOCATION	PRISTINE	DISTURBED UPSTREAM	DISTURBED DOWNSTREAM	RECOVERY
A	0.002	0.002	0.002	0.002
B	0.002	0.002	0.002	0.002
C	0.001	0.002	0.002	0.003
WHO	2	2	2	2
MBS	0.5-1.0	0.5-1.0	0.5-1.0	0.5-1.0

Table 8: The concentration of copper in the water at the various sampling sites

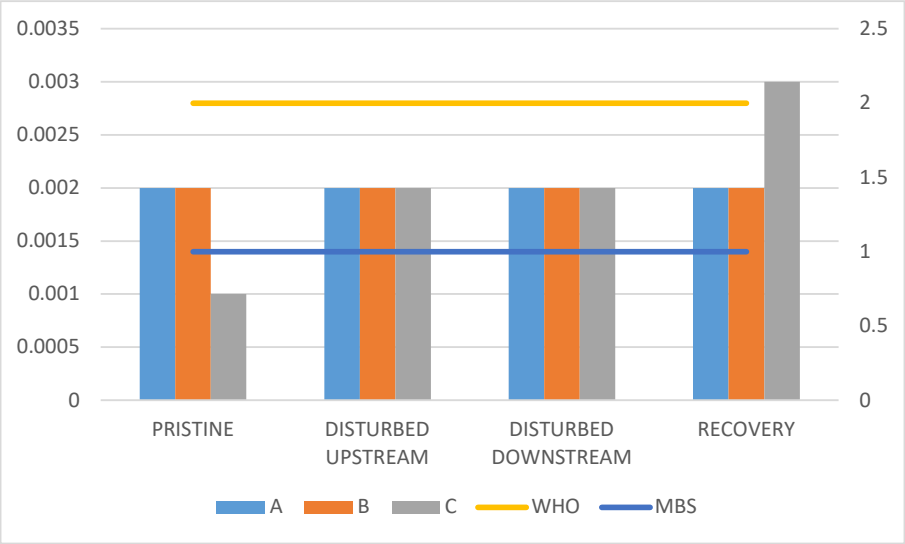


Figure 12: Copper Concentration at the Different Sampling Sites Compared To Maximum Acceptability Values

The data did not show any trend that could be related to sand mining.

4.1.7. Manganese (Mn)

Manganese does not cause health problems; it imparts a bitter taste to drinking water, even at low concentrations. It naturally occurs in rocks and soils. When rocks and soils are disturbed, it is exposed to air; it becomes a soluble manganic (MN^{3+}) form, which makes water turbid and unacceptable to most people. This form can also cause black or brown stains on fabric and plumbing fixtures.

LOCATION	PRISTINE	DISTURBED UPSTREAM	DISTURBED DOWNSTREAM	RECOVERY
A	0.006	0.008	0.003	0.007
B	0.004	0.005	0.005	0.008
C	0.004	0.005	0.004	0.008
WHO	0.4	0.4	0.4	0.4
MBS	0.05-0.1	0.05-0.1	0.05-0.1	0.05-0.1

Table 9: The concentration of Manganese in the water at the various sampling sites

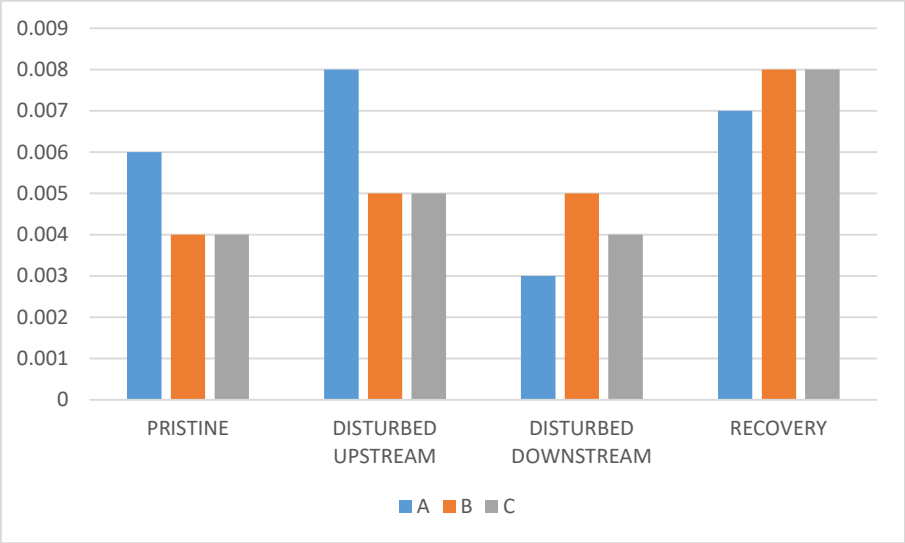


Figure 13: Manganese Concentration at the Different Sampling Sites

According to Figure 13, it can be noted that the concentration of manganese follows a trend, as well. This trend shows that the concentration increases from the pristine area to the disturbed upstream area. Then there was a decrease in concentration at the disturbed site. After that, it can be noted that the concentration increases. This would suggest that manganese is present in significant amounts in soils (sediments) but in an insoluble form. However, (Ypolit & et. al., 2021) stated that once introduced to the river, manganese dissolves, which would account for the increased concentration of these constituents in the water.

4.1.8. Iron (Fe)

Iron does not cause health problems; it imparts a metallic taste to drinking water, even at low concentrations. It naturally occurs in rocks and soils. When rocks and soils are disturbed, it is exposed to air and becomes a soluble ferrous (Fe^{3+}) form, which makes water turbid and unacceptable to most people. This form can also cause reddish-brown stains on fabric and plumbing fixtures.

LOCATION	PRISTINE	DISTURBED UPSTREAM	DISTURBED DOWNSTREAM	RECOVERY
A	0.313	0.562	0.258	0.633
B	0.333	0.576	0.429	0.7
C	0.356	0.322	0.326	0.687

WHO/FAO	N/A	N/A	N/A	N/A
MBS	0.01-0.2	0.01-0.2	0.01-0.2	0.01-0.2

Table 10: The concentration of Iron in the water at the various sampling sites

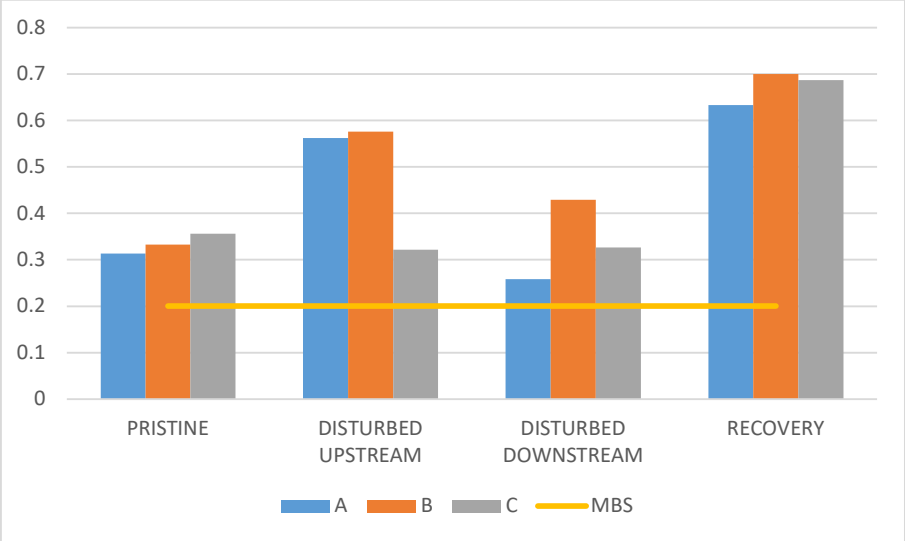


Figure 14: Iron Concentration at the Different Sampling Sites Compared To Maximum Acceptability Values

About Figure 14, it can be noted that the concentration of iron follows a trend. This trend shows that the concentration increases from the pristine area to the disturbed upstream area. Then there is a decrease in concentration at the disturbed site. After that, it can be noted that the concentration increases. This would suggest that iron is present in significant amounts in soils (sediments) but an insoluble form. However, (Ypolit & et. al., 2021) stated that once introduced to the river, iron dissolves, which would account for the increased concentration of these constituents in the water.

4.1.9. Zinc (Zn)

Zinc is usually nontoxic when found in small concentrations, like in Table 11. It can cause undesirable tastes in drinking water. At high concentrations, zinc causes a milky appearance in the water.

LOCATION	PRISTINE	DISTURBED UPSTREAM	DISTURBED DOWNSTREAM	RECOVERY
A	<0.01	<0.01	<0.01	<0.01

B	<0.01	<0.01	<0.01	0
C	0	<0.01	0	0
WHO/FAO	N/A	N/A	N/A	N/A
MBS	3.0-5.0	3.0-5.0	3.0-5.0	3.0-5.0

Table 11: The concentration of zinc in the water at the various sampling sites

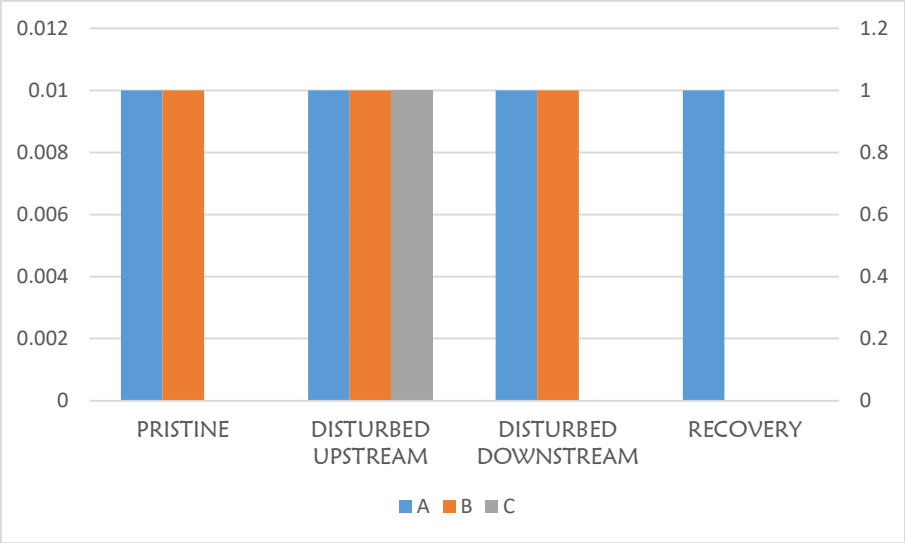


Figure 15: Zinc Concentration at the Different Sampling Sites

The data shows that the Zinc in the water is found in very trace amounts.

4.1.10.Molybdenum (Mo)

LOCATION	PRISTINE	DISTURBED UPSTREAM	DISTURBED DOWNSTREAM	RECOVERY
A	<0.01	<0.01	<0.01	<0.01
B	<0.01	<0.01	<0.01	<0.01
C	<0.01	<0.01	<0.01	<0.01
WHO/FAO	N/A	N/A	N/A	N/A
MBS	N/A	N/A	N/A	N/A

Table 12: The concentration of molybdenum in the water at the various sampling site

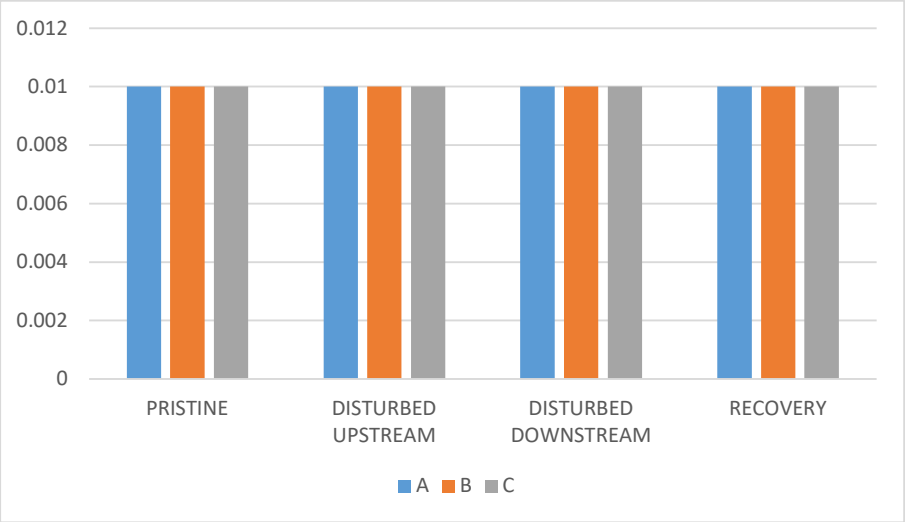


Figure 16: Molybdenum Concentration at the Different Sampling Sites

The concentration of Molybdenum in the water was too low to identify any trends in the data.

4.2. Landscape and Morphology

4.2.1. Satellite image

The satellite images of the mining site, like Figure 17, were not clear enough for image analysis. Therefore, aerial photographs and linear perspective photos were taken for this research.



Figure 17: Satellite Image of the Mining Site

4.2.2. Aerial Photographs



Figure 18: Aerial Photograph of Disturbed Site (Source: Nkwazi Aeros, 25th May 2021)



Figure 19: Aerial Photograph of Access Road (left) and Divided River (right) (Source: Nkwazi Aeros, 25th May 2021)

The aerial photographs show how the area developed to suit the sand mining activities. It is seen that the river divides itself (Figure 19) and this division is maintained for sand mining purposes. Another notable feature that can be noted, in figures 18 & 19 is the access road that extends from the bank to the middle of the river. This was done for the trucks to easily access the finer sand in the middle of the river.

4.2.3. Linear Perspective Images



Figure 20: Photo of the Sand Mining Site (Source: field data 12 July 2021)



Figure 21: Abandoned Sand Deposit (Source: field data 12 July 2021)



Figure 22: Access Road to Sand Deposit in the Middle of the River (Source: field data 12 July 2021)



Figure 23: Photo of Miners Loading Sand into a Truck (Source: field data 12 July 2021)

From the linear perspective view, it can be noted that there is severe damage to the landscape of the river. This damage comes from the benches made (Figures 20 and 21), the road constructed to access the mine site (Figure 22) and the actual excavation of sand (Figure 23).

4.3. Study Limitations

(a) Lack of reliable data for Landsat (Satellite Image) analysis. This study did not use satellite images because there were no clear images from the software used (Google Earth Pro).

(b) Water Quality Analysis. The research was restricted to analyse inorganic chemical constituents only because of the services provided by the lab.

(c) Qualitative Research. Surveying with the local people would have given more background information on landscape characteristics in the absence of satellite images from past years.

(d) Lack of time to assess more ecosystem parameters for signs of pollution.

5. CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

This study aimed at assessing the environmental impacts of sand mining on the Thuchila River. The results from the data analysis show that the sand mining activities do cause changes in environmental aspects of the Thuchila river system.

Firstly, although the disturbance due to the mining activity at the site under study affected some of the water quality parameters, the water is generally safe for human consumption and other domestic activities because the levels met the FAO, WHO and MBS standards for irrigation and drinking water respectively. Some of the parameters do show clear trends as the river flows through T/A Ngolongoliwa, Thyolo. Interestingly, the data does show that after some distance from the mining site, the river naturally starts to recover. It would, therefore, be advisable to space mining sites in such a manner that allows the river to recover on its own.

Secondly, the development of the mining site and the actual sand mining causes many changes in the landscape. The changes come from the benches made on the riverbanks, the roads constructed to access the mine site, and the actual excavation of sand.

This study was limited to a single site and single season. The study therefore recommends additional assessment of Thuchila river in different sites and seasons focusing on historical morphological changes, river dynamics, biological aspects at the basin level in order to map the extent of the environment impact in relation to the amount of sand extracted. This would help gather information to come up with other measures to reduce and control any further environment degradation.

Dissemination of the results will be through reports to Thyolo District Council, Department of Environmental and Sanitation. Copies of the dissertation will be submitted to MUST library.

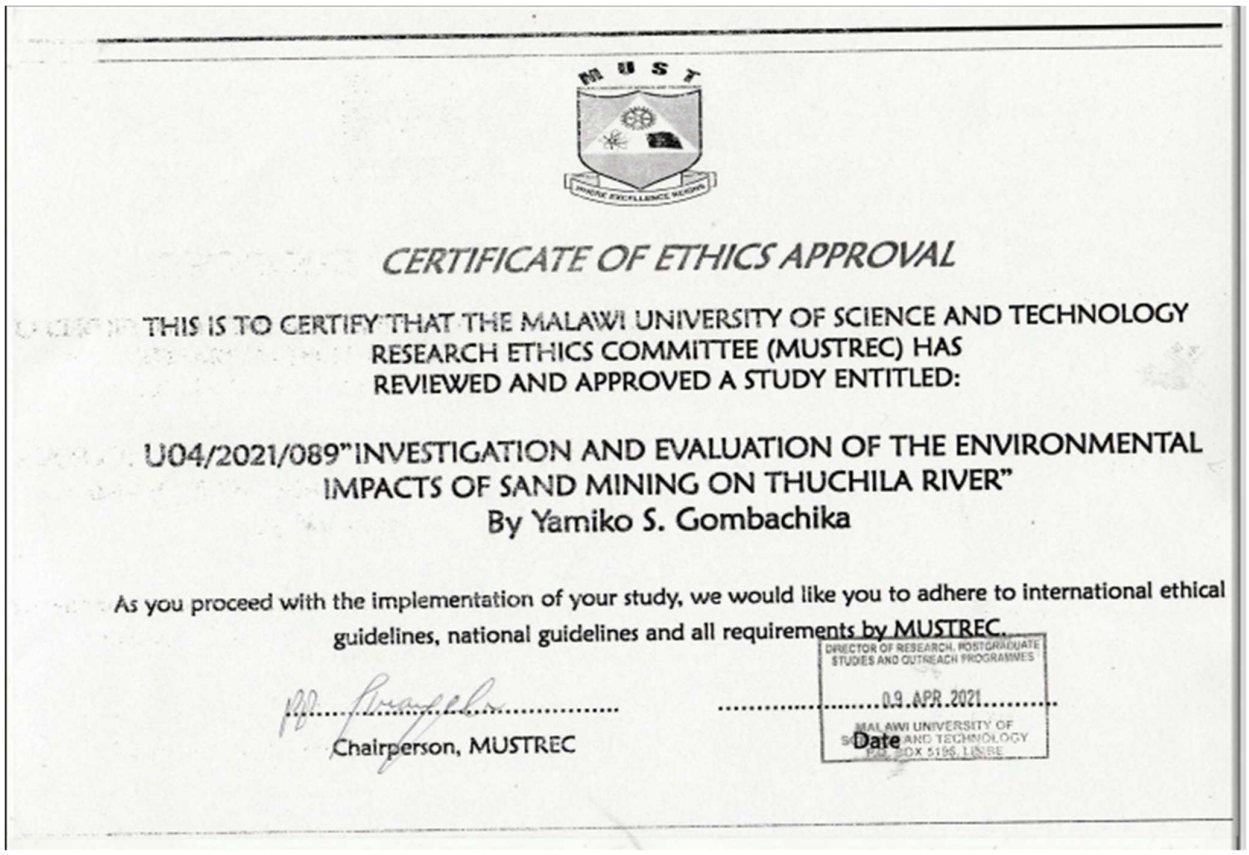
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APPENDICES

APPENDIX A ETHICS APPROVAL CERTIFICATE FROM MUSTREC



CERTIFICATE OF ETHICS APPROVAL

THIS IS TO CERTIFY THAT THE MALAWI UNIVERSITY OF SCIENCE AND TECHNOLOGY RESEARCH ETHICS COMMITTEE (MUSTREC) HAS REVIEWED AND APPROVED A STUDY ENTITLED:

U04/2021/089"INVESTIGATION AND EVALUATION OF THE ENVIRONMENTAL IMPACTS OF SAND MINING ON THUCHILA RIVER"
By Yamiko S. Gombachika

As you proceed with the implementation of your study, we would like you to adhere to international ethical guidelines, national guidelines and all requirements by MUSTREC.

DIRECTOR OF RESEARCH, POSTGRADUATE STUDIES AND OUTREACH PROGRAMMES
09 APR 2021
MALAWI UNIVERSITY OF SCIENCE AND TECHNOLOGY P/BAG 5196, LIMBE

Chairperson, MUSTREC

Date

APPENDIX B PERMISSION LETTER FROM THYOLO DISTRICT COMMISSIONER

THYOLO DISTRICT COUNCIL

PRIVATE BAG 5, THYOLO, MALAWI.
TELEPHONE NOS. 01473200 / 480 / 540 FAX NO 01473453
All correspondences to be addressed to The District Commissioner Email Address: thyolocouncil@yahoo.com.

REF.NO.TDC/Adm/13 5th May, 2021.

TO : YAMIKO GOMBACHIKA

PERMISSION TO COLLECT DATA

Thank you very much for your letter dated 1st April, 2021 for the subject above.

Permission has been granted for you to collect Data in Thyolo District.

Yours faithfully,

Dr Arnold Jumbe
DISTRICT COMMISSIONER

THE DISTRICT COMMISSIONER
THYOLO DISTRICT COUNCIL
05 MAY 2021
PRIVATE BAG 5
THYOLO

APPENDIX C SAMPLE INFORMATION PAGE FROM AGRILAB

Yamiko Gombachika Water Test Results

AGRILAB
Part of the FES Group

FARMING AND ENGINEERING SERVICES LIMITED

*Kaohsiung Road, Mandala, PO Box 918, Blantyre, Malawi

www.agrilabmw.com

Report reference #: agrilabmw/2021/YG/001/v1

Client:	Yamiko Gombachika	**Sample Type:**	Water	**Lab. Temperature:**	21 ± 2°C
Client Email:		**Crop type:**	N/A	**Reporting Date:**	12/05/2021
Client Address:		**Samples Receipt Date:**	07/05/2021	**Approval Date:**	20/05/2021
Approved by Lead Chemist:	Wesley Feldmann	**Samples Analysis Date(s):**	10-11/05/2021	**Lead Chemist Signature:**	W Feldmann

* Agrilab consists of one permanent facility and all testing was conducted at the address provided

APPENDIX D LETTER OF AGREEMENT WITH NKWAZI AEROS

NKHWAZI
AEROS

20 July,2021

TO: Whom It May Concern

FROM: Mr. Hope Chilunga

Managing Director & Drone Pilot

To Whom It May Concern

Nkhwazi Aeros a Malawian preferred commercial drone services provider managed to capture aerial footage on Licheza river on a study of finding the effect of sand mining around Licheza river. The study was conducted by Miss Yamiko Gombachika.

Please feel free to contact me if you have any questions at:

(+265)0993602803 hchilunga@poly.ac.mw



Hope Chilunga

Pilot & Managing Director