

ASSESSMENT OF THE IMPACTS OF INDUSTRIAL EFFLUENTS ON WATER QAULITY IN MUDI RIVER

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THYOLO, MALAWI

JULY 2021

- **DECLARATION**

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

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ABSTRACT

For more than two centuries, industrialization has propelled our world into an advanced and highly technologized civilization that we know today. Every nation across the world has had series of advancement in industrialization that has reshaped the nation's economic development. For a long time, the industry has sincerely provided the main resources countries need for a lavishing economic development. with a wide variety of industries, the world has transitioned into different systems of productions with others preferring light industries to heavy industrial productions. However, one thing has always been common; every industry uses a huge amount of chemicals, and raw materials and raw materials to produce. Industrial processes have always produced the essential and the unessential in the form of bi-products. These bi-products in the form of effluents rapidly pollute surfaces including surface water which has been of great concern. The aim of this study was to assess the water quality status of the Mudi river due to industrial effluent. This study was in Makata industrial area and investigation was done by collecting water samples from three stationary points on the Mudi river which was selected by purposive sampling technique. 10 Samples of water were collected and analyzed using standard methods. Sampling was done at three different points; at source, in the middle of makata industrial area and a point after the makata industrial area, and a questionnaire was used to get primary data on the type of wastes industries produce. After analysis of parameters, it was found that; pH at all sites averaged 7.6 and it was within the MBS and WHO ranges. The temperature averaged 22.1 ^{o}C which were below MBS and WHO ranges, BOD averaged 80.5 mg/l, TDS averaged 231.3 mg/l and it was within the MBS and WHO standard ranges, DO averaged 3.81 mg/l and it was within the permissible ranges, COD was 165.3, turbidity was 23.1 which was above the permissible ranges of MBS and WHO standards. EC averaged 364.7 and was within the MBS and WHO ranges, Cd was 0.14, Lead was 0.09 and nitrates averaged 0.73. GPS coordinates for each sampling site were recorded and a map was generated in ArcGIS and using proximity analysis tool, a buffer of 30 meters. The findings showed that industries are involved in serious environmental hazards since most of them don't have Effluent Treatment plants (ETP).

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TABLE OF CONTENTS

CHAPTER 1 13

1. INTRODUCTION 13

1.1. BACKGROUND INFORMATION 13

1.1.1. WATER POLLUTION, THE CASE OF MALAWI 13

1.2. PROBLEM STATEMENT 15

1.3. RESEARCH QUESTIONS 15

1.4. RESEARCH HYPOTHESIS 16

1.5. RESEARCH OBJECTIVES 16

1.5.1. Main objective 16

1.5.2. Specific objective 16

1.6. STUDY RATIONALE 16

CHAPTER 2 18

2. LITERATURE REVIEW 18

2.1. CHAPTER INTRODUCTION 18

2.2. SOURCES OF WATER POLLUTION 18

2.2.1. Anthropogenic Activities 19

a. Industrial Activities 19

b. Deforestation 19

c. Human Settlements 19

2.3. PREVIOUS WORK ON WATER QUALITY ASSESSMENT 20

CHAPTER 3 22

3. METHODOLOGY 22

3.1. LOCATION OF THE STUDY AREA 23

3.2. RESEARCH DESIGN 25
3.2.1. Selection of the area 25
3.2.2. Selection of the industry 25
3.3. DATA COLLECTION 25
3.4. DATA PROCESSING AND ANALYSIS 28
3.4.1. Analysis of Physio-Chemical and metals 28
3.4.2. Industrial wastes analysis 29
3.4.3. Proximity analysis 29
CHAPTER 4 31
4. RESULTS AND DISCUSSIONS 31
4.1. RESULTS 31
4.1.1. Laboratory results 31
4.2. DISCUSSIONS 33
4.2.1. Variation of Chemical parameters among sampling points in Mudi river 33
4.2.2. Variations of Physical parameters 41
4.2.3. Variation of metals 42
CHAPTER 5 45
5. LIMITATIONS 45
CHAPTER 6 46
6. CONCLUSION AND RECOMMENDATIONS 46
6.1. Conclusion 46
6.2. Recommendations 47
CHAPTER 7 48

7. REFERENCES 48

CHAPTER 8 51

8. APPENDICES 51

ACRONOMYS/ABBREVIATIONS

DO	Dissolved oxygen
BOD	Biological oxygen demand
COND	Conductivity
TEMP	Temperature
TURB	Turbidity
TDS	Total dissolved solids
pH	Power of hydrogen
WHO	World Health Organization
MBS	Malawi Bureau of standards
NO_3	Nitrates
Cd	Cadmium

LIST OF FIGURES

Figure 1: Map of Blantyre showing Mudi river and makata industrial area 24
Figure 2: Polluted Mudi River 24
Figure 3: methodology in general 27
Figure 4 :map showing Mudi river, makata industrial area and sampling sites 28
Figure 5: Bar chart showing variation of DO among sampling points 33
Figure 6: Bar chart showing variation of BOD among sampling pointsError! Bookmark not defined.
Figure 7: Bar chart showing Variation of PH among sampling points 35
Figure 8: Bar chart showing Variation of COD among sampling points 37
Figure 9: Bar chart showing Variation of Turbidity among sampling points 38
Figure 10: Bar chart showing Variation of Nitrates among sampling points 39
Figure 11: Bar chart showing Variation of EC among sampling points 40
Figure 12: Bar chart showing Variation of TDS among sampling points 41
Figure 13: Bar chart showing Variation of Temperature among sampling points 42
Figure 14: Bar chart showing Variation of Lead among sampling points 43
Figure 15: Bar chart showing Variation of Cadmium among sampling points 44
Figure 16: A pipe discharging waste water from one of the industry into Mudi river 51

LIST OF TABLES

Table 1: GPS coordinates for the sites 25
Table 2: water sample analysis methods 28
Table 3: Standards for water quality parameters by WHO and MBS (source: Forsberg,2014, World Health Organization, 2018 31
Table 4: The summary of water quality for Mudi river at the measured sites (upper, middle and downstream) 32
Table 5: Variation of DO along Mudi river 33
Table 6: Variations of BOD along Mudi river 34
Table 7: Variations of PH along Mudi river 35
Table 8 : Variations of COD along Mudi river 36
Table 9: Variations of Turbidity along Mudi river 37
Table 10: Variation of Nitrates along Mudi river 38
Table 11: Variation of EC among sampling points 39
Table 12: Variation of TDS along Mudi river 41
Table 13: Variation of Temperature along Mudi river 41
Table 14: Variation of lead along Mudi river 42
Table 15: Variation of cadmium among sampling points 43
Table 16: Raw data for water quality parameters 50

CHAPTER 1

1. INTRODUCTION

1.1. BACKGROUND INFORMATION

Water is a vital resource to all forms of life and makes up 50-97% of the weight of all plants and animals and about 70% of a human body (Buchholz, 1998). Water is additionally an important resource for agriculture, manufacturing, transportation, and lots of other human activities. Despite its significance, water is the most poorly managed resource in the world (fakayode, 2005). Water can be contaminated by several sources. In farming areas, the routine application of agricultural fertilizers is the major source (Parizek, 1995); (Emonger et al, 2005).In urban areas, the careless disposal of industrial effluents and other wastes may greatly contribute to water pollution (Chindah et al, 2004).

The issue of water quality standards within the environment is a crucial issue for everybody. Water quality in bodies of water like lakes, rivers, and oceans has a direct impact to humans. Water quality standards vary widely due to differing environmental conditions and ecosystems, and therefore the intended use rights. Water Quality Assessment is the overall process of evaluation of the physical, chemical, and biological nature of water in reference to natural quality, human effects, and intended uses, particularly uses which can affect human health and therefore the health of the aquatic system itself (Chapman, 1996). There is got to have adequate research on water bodies everywhere within the world for effective and continued sustainable use for human and aquatic life.

1.1.1. WATER POLLUTION, THE CASE OF MALAWI

Malawi is one of the least developed countries found in sub-Saharan Africa with an estimated population of about 14,000,000 (Office National Statistical, 2008). The country is divided into three regions; North, Central and South((Government Malawi, 2004). Blantyre City is found within the southern region of Malawi. It was stablished by the Scottish Missionaries in the 1870s and declared a planning area within 1897. It is the Centre for communication, commercial activities, and cooperation in Malawi((Blantyre District Council , 2002). Meanwhile, the presence of industries has negatively attracted a number of people leading to an increase in population over the past few years (Sajidu et al, 2008). The rapid increase in population, weak institutional governance and legal framework, and inadequate physical planning are facilitating environmental degradation, pollution, deforestation, and uncontrolled development on fragile lands.

Recently, there has been this issue of discharging of industrial waste and sewage from broken pipes into the Mudi River and this has caused severe environmental pollution (Malawi Government, 2008). Malawi is one of the least urbanized countries in African since only 20% of Malawi's population is classified as urban. However, Malawi is one of the most urbanizing countries in Africa at 6.3% per annum, three times the global rate and nearly twice the Africa rate of 3.5% (Blantyre City Council, 2002). The growth of the city has not kept pace with the national economy. The most visibly affected areas of this rapid increase in population are access to quality water, solid waste collection and disposal, sanitary and sewerage facilities (Laudzala et al, 2007). Pollution of rivers has been a notable activity believed to be propagated as a result of the high population in Blantyre City.

Mudi River is one among the rivers that run through the Centre of Blantyre City and there are visible signs of practices that affect the number and quality of water in the river. The most visible practices are cutting down of trees and cultivation along the buffer zone of the river which increases the siltation of the river thereby reducing the depth of the river. Another likely practice includes but is not limited to the discharges of solid and liquid wastes from markets, industries, and sewer pipes. With Blantyre City as a watershed to many rivers, the water pollution can never be underestimated. This is because the pollution in the city does not only affect people in Blantyre

but also those who use the water in the subsidiary rivers that originate from the city. Mudi River provides water for domestic and other uses for communities that live down the stream.

1.2. PROBLEM STATEMENT

The water quality of the Mudi river has depreciated highly due to pollution which has rendered the water unsuitable for domestic use, aquatic system, and technological use. Water pollution is the contamination of water bodies that occur when a pollutant is indirectly or directly discharge into water bodies without adequate treatment to remove the harmful sediment (Muyibi et al, 2008). Pollution is gradually rendering water resources more contaminated and unavailable for use as industries continue to dispose of their liquid effluents directly into the Mudi River. The discharge affects the color, odor, and quality of water. In addition, it also affects the human activities in their daily life such as cooking, tourism, and washing as well as threatening aquatic life.

A wide range of impacts of effluents on human health continues to increase every single day in areas around the Mudi river with infections ranging from different skin diseases, gastric ulcers to dysentery etc. This simply presents the extent of pollution in the Mudi river as most industries and human activities continue to operate without complying with the standard Effluent Treatment Plan (ETP's). Most of the industries in the Makata Industrial Area operate without ETP's. Some industries have ETP's which are apparently not in operation thereby not maintaining the standard water quality of liquid effluent. This study was conducted in order to measure water quality status in Mudi River and to access the impact of industries on the water quality of Mudi river.

1.3. RESEARCH QUESTIONS

This scientific research aimed towards finding solutions to the subsequent questions

I. What is the water quality status of the Mudi river with respect to the industrial effluents?
II. How does industrialization contribute to pollution in the Mudi river?
III. Is there spatial variation in water quality in the Mudi river?

1.4. RESEARCH HYPOTHESIS

I. Wastewater from manufacturing industries contributes to water pollution.
II. Industrial wastewater usually contains specific and readily identifiable chemical compounds

1.5. RESEARCH OBJECTIVES

1.5.1. Main objective

- The main objective of this scientific research was to assess the water quality status of the Mudi river due to the industrial effluents.

1.5.2. Specific objective

- The specific objectives were as follows

I. To analyze the physical, chemical water quality parameters and heavy metals of water in the Mudi river
II. To compare pollution levels of Mudi river against permissible water quality standards (e.g. Malawi Bureau of standards-MBS and World Health Organization – WHO) of water in the Mudi river with water quality standards values
III. To compare the spatial variation of pollution along with the sampling points

1.6. STUDY RATIONALE

Practically, the finding from this study will be useful in the following ways;

I. For the development and further understanding of environmental science. This study can contribute further understanding of the impact of industrial wastes on the environment around Mudi River.

II. For research purposes, the Information provided here can be used as a reference, comparative data, and basic consideration for researchers and observers of environmental problems in future studies.

III. For the community around Mudi. The finding of this study will help people to understand the condition of the river and take actions to guard it as well as develop actions to better utilize the resources provided therein.

IV. For the government. The government can make policy on the disposal of industrial wastes based on findings found in this study in order to keep water pollution under control.

CHAPTER 2

2. LITERATURE REVIEW

2.1. CHAPTER INTRODUCTION

Water is an essential component of our world. Its importance can never be underestimated. From being the most variable building material of the complex physical world to being the priceless resource that makes our planet habitable and life supportive. It is the requirement for all life supporting-activities. However, access to adequate and safe quality water still remains a challenge in most developing countries including Malawi. This is so because water as a natural resource is being polluted vastly by anthropogenic activities. Water pollution is defined as the discharge of any liquid, solid, gaseous, pathogenic organisms or other substances into the water likely to render it harmful, detrimental, or injurious to the health, safety, or welfare of the public and the environment(Chimuriwo, 2016).

The preliminary information in this study focuses on the review of previous findings in projects, reports, and journals that have been used to understand what other scientists had to say as well as identify the information gap among others. General information on water pollution from cited literature helped to relate with the findings of the study and a conclusion was drawn. Previous literature on laboratory test results of physicochemical parameters guided to compare and contrast the findings.

2.2. SOURCES OF WATER POLLUTION

Generally, most rivers are polluted by what is known as anthropogenic activities due to industrial and agricultural development. Industrialization attracts a high population as people move to industrialized areas in search of job opportunities. This high population tends to be unmanaged which poses a threat and pressure on the environment. Surrounding resources like rivers and lakes tend to be overwhelmed by the pressure poised by both industries and people which with poor management exposes such resources to high levels of pollution. Researches on water quality of

urban rivers have to be done continuously, especially where the rivers are being used for the domestic purpose; which is common in most African countries due to poverty and poor planning.

2.2.1. Anthropogenic Activities

Anthropogenic activities are human activities that negatively affect the water resource making it polluted and hence unsuitable for normal uses. The anthropogenic activities that mainly affect the river water bodies can be placed into three group

a. Industrial Activities

Industries are the common activities in most urban settings. Most of these industries produce wastes that end up being deposited somewhere (Zembere et al, 1999). Some industries produce toxic and hazardous wastes which affect plant and animals when left exposed to the environment (Taylor, 1996). For instance, Cadmium has been found in wastewaters of industrial sites (Ritter et al, 2002). The main source of cadmium is factories and companies that import or produce cadmium-containing products such as Nickel-Cadmium Batteries, PVC products, Cadmium pigmented Plastics, and Cadmium containing electronic components (Taylor, 1996).

b. Deforestation

This is the removal of vegetative cover and cutting down of trees and making the ground bare. Agricultural activities are the major source of deforestation in most circumstances. The ground is then exposed to the impacts of rainfall and wind; this leads to soil particles being loosened and carried away by runoff water when it is raining (GoM, 1994). This fast-moving rainwater enhances soil erosion, a process through which soil and sediments are transported into surface water bodies.

c. Human Settlements

The rapid urbanization that Malawi is undergoing has resulted in an increase in the demand for shelter and housing in urban areas. An Increased number of unauthorized constructions of dwelling structures in unplanned areas are using environmentally unsuitable materials. This has led to uncontrolled brick molding and cutting down of trees for curing the bricks and other constructions, thus creating a great disturbance to the natural environment. An increase in human

settlement requires better sanitation facilities for waste disposal for the population (Chindah et al, 2004). The habit of defecating in the bush by some people contaminates surface water through runoff. 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).

2.3. PREVIOUS WORK ON WATER QUALITY ASSESSMENT

Much research work on various steams on water pollution has been studied across the world, it has all come down to industrial effluent, untreated urban sewerage, unplanned industrialization, urbanization as the root causes. A study done on groundwater samples of Sangamner area, Ahmednagar district, Maharashtra, to evaluate the chemistry of ground water involved analysis of Physio chemical of 53 open wells water of water which was carried out using standard methods. The study reveals that intensive irrigation has serious impact on water quality. Physio-chemical studies such as temperature, Dissolved Oxygen, PH, total dissolved solids, chloride, total alkalinity, calcium and magnesium hardness, sulphate, phosphate and Nitrate of bore wells of water was conducted from 20 villages of Gondpipri town and its some interior Adivasi (backward) area in year 2010 to assess the water quality index. The results revealed that pH and TDS were within the limits provided by WHO and ISI. Calcium, Mg, Sulphate, were in permissible limits. But phosphate, Nitrates levels were higher values that prescribed values. This may attribute to the intensive use of fertilizers and pesticides in this remote Adivasi area.

Malawi, like other African countries, is experiencing rapid industrial growth, and this is making environmental conservation a difficult task (Kadongola, 1997). While developed nations go for stringent water quality requirements to control river pollution from point and non- point sources, the situation is different in developing countries like Malawi. Waste water treatment in Malawi is not given the necessary priority it deserves and therefore, industrial wastes are discharged into receiving water bodies without treatment. Degradation of water resources is the second most critical environmental problem, following deforestation (GoM, 1994). The Malawi Government Environmental Report (2002) stated that the BOD levels in the Mudi River in Blantyre and Lingadzi

River in Lilongwe exceeded the acceptable limits of the Malawi Bureau of Standards (MBS) which has serious effects on the levels of dissolved oxygen in the water and may lead to suffocation of aquatic animals due to reduced supply of oxygen.

A research work done on water pollution of Mudi River by Save Kumwenda in 2012 to investigate the physical, microbiological and chemical quality of the water in Mudi River in March 2011 to determine the current state of pollution in the river found that Industrial wastes have the potential to contribute strong acids to water bodies and may cause dented effects on both flora and fauna. In addition, cultivation along river banks and therefore the increasing use of fertilizers within the production of crops has led to increases in the concentration of Cadmium (Cd), Lead (Pb), Phosphorous (P), Copper (Cu), Zinc (Zn), and heavy metals in the soils (Kumwenda et al, 2012). Kumwenda recommended that there is a need to Maintain the sewage pipes, discourage cultivation along river banks, open defecation, and disposal of waste in the river to reduce biological and physical contamination levels in the Mudi river in Blantyre. Investigations have to be made to trace the possible sources of chemical pollutants which showed very high levels at sampling points other than the source. These chemicals are lead, chromium, zinc and copper.

Similar research on water pollution was also done by kuyeli et al to investigate temporal and spatial physicochemical water quality in Blantyre urban streams including the Mudi River. The results suggested that effluents from manufacturing industries in the city had a great potential of polluting the water bodies and could result in gross impairment of water quality in the receiving streams. Therefore it is suggested that Blantyre City Assembly and other environmental regulatory bodies such as Environmental Affairs Department and Water Resources Board should be more aggressive and effective in environmental monitoring, assessment, and enforcement of environmental laws and regulations to preserve the water resource from further degradation (Kuyili et al).

Kaonga et al also did a study to assess the ability of green algae to accumulate manganese, cadmium, and lead from water in Blantyre city and the results showed that s. equinoctials (a type of algae) had the capability of accumulating manganese, cadmium and lead therefore, it can be

used as an indicator for long term heavy metal water pollution monitoring. Another Study carried out by (Mvuma, 1999) and Lakudzala et al. in Mudi River in Blantyre found that industrial activities were contributing to the pollution and degradation of water ecosystems in the city and beyond.

- **CHAPTER 3**

3. METHODOLOGY

Different methods are being used to assess water quality in different rivers around the world with some researchers using Geo-Information Systems methods and skills for data collection and

analysis like remote sensing as well as the use of GPS for coordinates etc. On the other hand, other researchers opt to use water quality assessment measures that involve laboratory tests and other techniques.

With a major objective in trying to determine the physical and chemical composition and metals in the Mudi river, this study used water quality assessment methods which involved laboratory tests as well as GIS techniques to fill the gaps of previous studies. This has opted to effectively determine physicochemical parameters and heavy metals from industrial effluents.

The survey was conducted as academic research which makes the accuracy of results a paramount aspect. Proper procedures were followed strictly to attain the aforementioned objectives

3.1. LOCATION OF THE STUDY AREA

Blantyre City is found within the southern region of Malawi. It is the center for communication, commercial activities, and cooperation in Malawi. The study area is Mudi river near the Makata industrial area. It emanates from inside Blantyre city through the Shire highlands to the valley of the Lower Shire. Recently, there has been a rise in discharging of industrial waste and sewage from broken pipes into the Mudi River and this has brought severe environmental pollution.

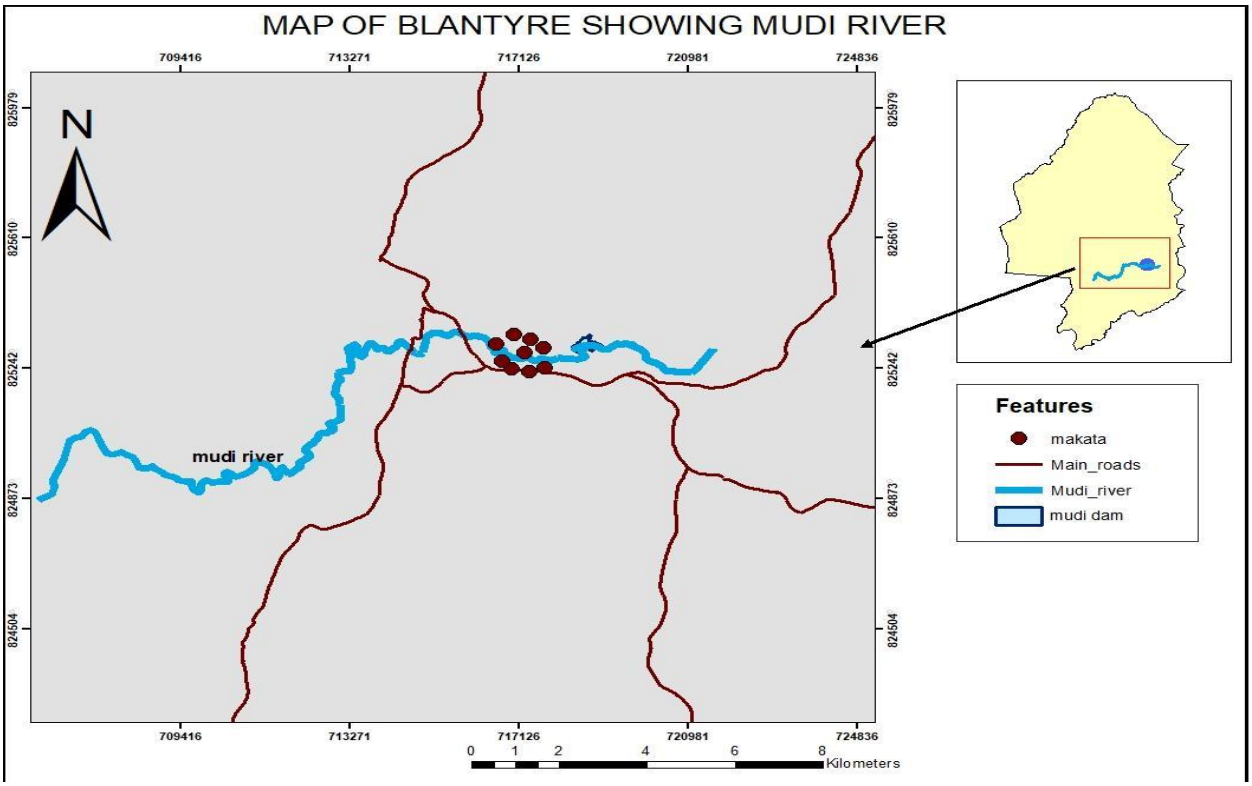


Figure 1. Map of Blantyre showing Mudi river and makata industrial area

Source: Made in ARCMAP



Figure 2: Polluted Mudi River

3.2. RESEARCH DESIGN

The qualitative and quantitative research methods were used in this research project

3.2.1. Selection of the area

About eight major industries are found in Blantyre city; Makata, Ginnery corner, maselema, limbe, chilimba (heavy industrial area), lunzu sur, maone and chitawira. Among these industrial areas, Makata industrial area was selected because of its proximity to the Mudi River.

3.2.2. Selection of the industry

Makata Industrial Area has about 8 industries; Chemicals, Oils, Plastic, Poultry, Electronics, etc. industries are available here. Among the 8 industries three industries were selected purposively. These were selected because they are situated near Mudi river.

3.3. DATA COLLECTION

Water parameters were measured both *in situ* and *ex-situ* from three stations for a period of three weeks due to time and resource constraints. In order to evaluate the river water quality, samples were collected from three points; upper stream site (a point before makata industrial area, middle stream site (in the middle of the makata industrial area) and in the lower stream site of the river (a point after makata industrial area).

Table 1: GPS coordinates for the sites

GPS coordinates for each sampling point recoded using a handheld GPS as shown in the table below;

Sample points	Latitude	Latitude	Elevation
Point A(upper stream)	0718154	8252691	1063
Point B(middle stream)	0715733	8253475	1027
Point C(lower stream)	0714731	8252840	996

Polyethylene (PE) bottles were used for carrying water samples after being sanitized by soaking in 50% Hydrochloric Acid (HCl) and rinsed with deionized water (Vega M et al, 1998). A cooler box with ice blocks was used for carrying and storing the bottles with samples while moving from one sampling point to the other and then Water samples from each sample point were immediately taken to the laboratory at 4°C and analyzed for the selected parameters. Three parameters were analyzed;

- Physical (TDS and TEMP)
- Chemical (TURB, BOD, PH, DO, EC, COD, and Nitrates)
- Heavy metals (Lead and Cadmium).

Using a potable AQUAREAD AM200 multi-probe meter, dissolved oxygen (DO) in mg/l, the temperature in ^{0}C, pH, electrical conductivity (EC) in µS/cm and total dissolved solids (TDS) in mg/l were measured at the field while the rest of the parameters were measured in the lab. Coordinates for each sample point were recorded at the field using a handheld GPS. One questionnaire was used to get data on the types of wastes the industries produce in the study area. This questionnaire was not random but rather target the 3 industries that were selected as mentioned below;

Cement industry

The cement industry uses raw materials like cliulcer, quarry dust, pozzolan and gypsum to produce cement. After the survey, it was found that the industry does not produce any by-products. This opens up to a high amount of wastes generated in form of solids. They also produce very minimal toxic wastes in the lab which are managed through distillation, landfilling while some are collected by the city council for disposal.

Oil industry

The oil industry produces Crude oil which uses soya meal seed is used as raw material. Soya meal is produced as by-product.

Fertilizer industry

This industry produces fertilizer e.g. NPK fertilizers and the major raw material that are used are nitrogen, potassium, and phosphate which generate wastes like coal and waste water.

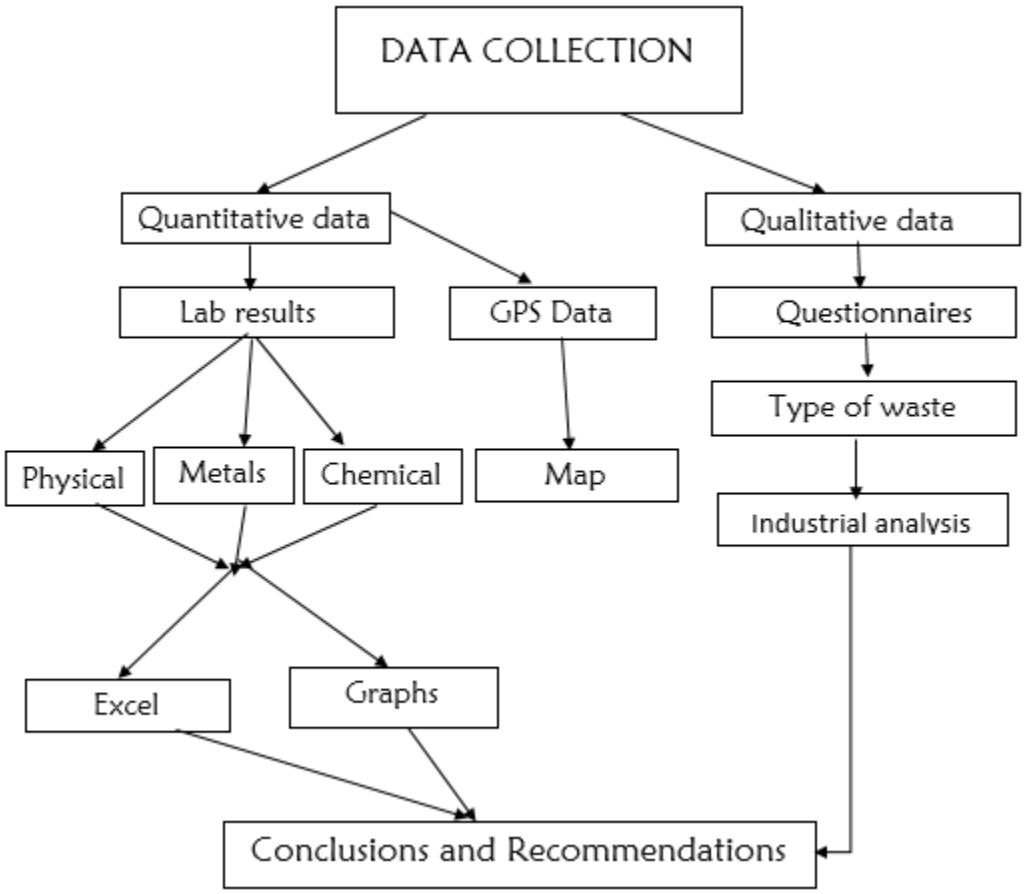


Figure 3 methodology in general

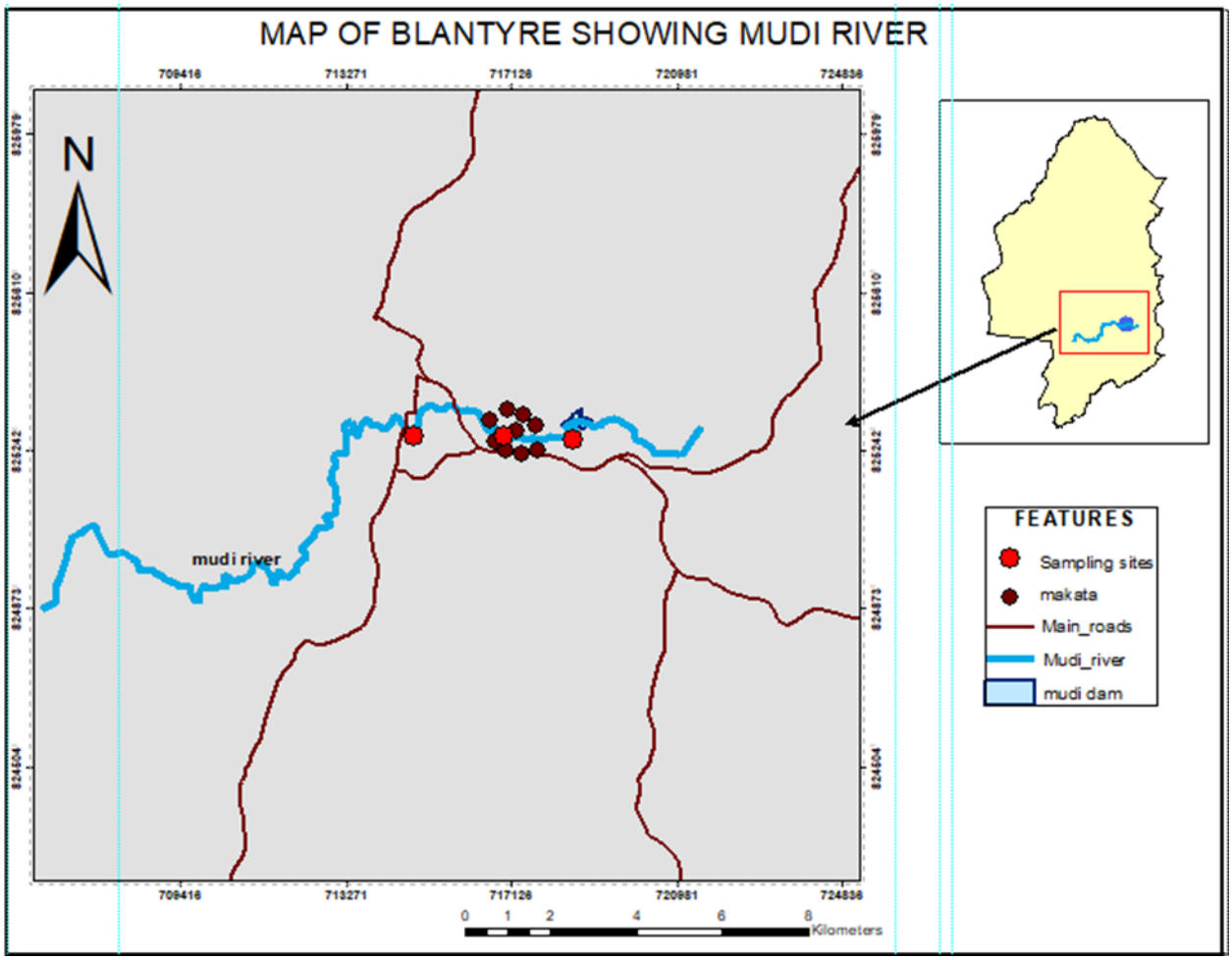


Figure 4 map showing Mudi river, makata industrial area and sampling sites

3.4. DATA PROCESSING AND ANALYSIS

Water quality data was analyzed using Excel 2016 to compute the mean values and the standard deviation. Bar graphs were plotted for each parameter to show variations of water quality among the river.

3.4.1. Analysis of Physio-Chemical and metals

Table 2: *water sample analysis methods*

PARAMETER	METHOD

DO	Potable AQUAREAD AM200 multi-probe meter
BOD	5 Day-BOD test
EC	Potable AQUAREAD AM200 multi-probe meter
TDS	Potable AQUAREAD AM200 multi-probe meter
PH	PH Meter
Temperature	PH meter
Turbidity	Portable turbidity meter
Cadmium	Atomic Absorption Spectrometric(AAS)
Lead	Atomic Absorption Spectrometric(AAS)
Nitrates	UV Spectrophotometric Method
COD	COD –Closed Reflux Method

3.4.2. Industrial wastes analysis

Questionnaires were used to get the primary data on the type of wastes the industries produce, they also produce a range of bi-products from respective raw materials. From the survey it was found that some of wastes they produce contains chemicals and heavy metals that can put environment at risk for example coal contains heavy metals like Lead, mercury, arsenic etc. other wastes generated from these industries are in form of solids like remains of soya meal seeds and remains of cement from oil and cement industry respectively.

3.4.3. Proximity analysis

Proximity is the analysis of locations of features by measuring the distance between them and other features in the area. Buffer analysis tool in ArcGIS was used to produce a 30 meter a buffer around the Mudi river. It is shown that majority of these industries are not within the buffer zones.

However, those ones that are near the Mudi river are suspected of contributing to the pollution of the Mudi river.

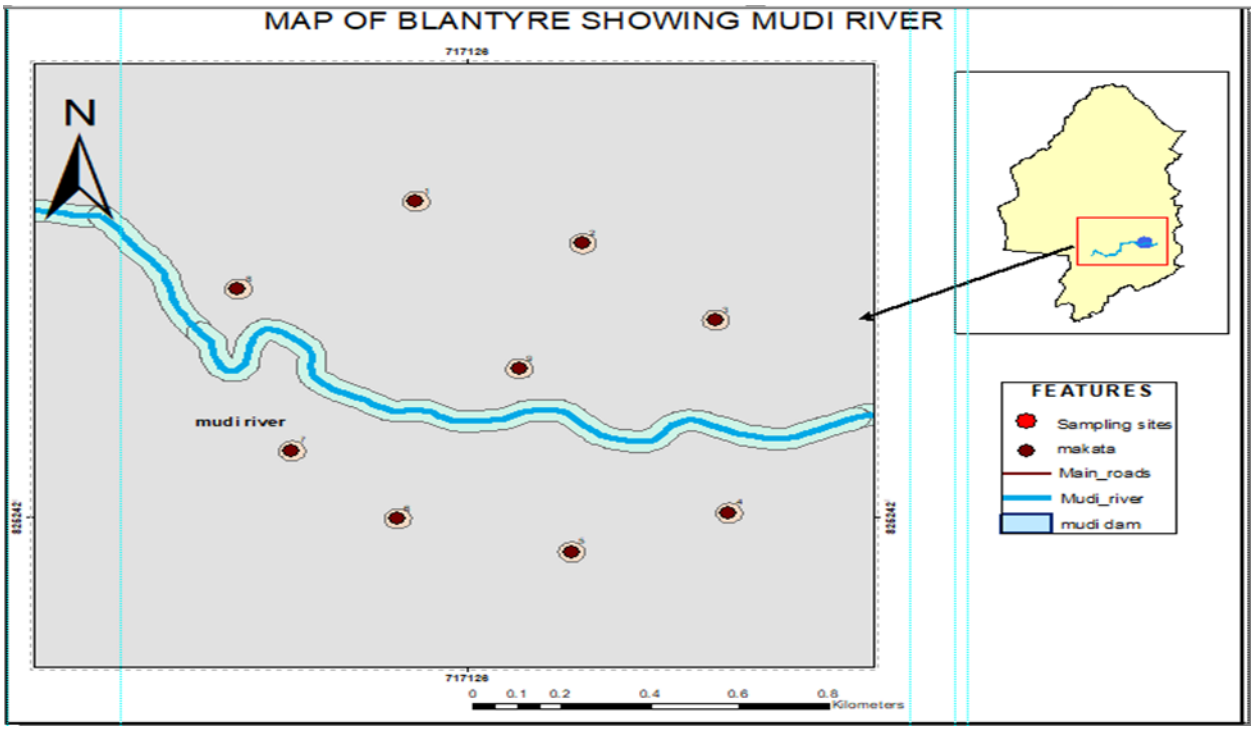


Figure 5: Map showing buffer zones around the Mudi river

- CHAPTER 4

4. RESULTS AND DISCUSSIONS

4.1. RESULTS

Table 3: Standards for water quality parameters by WHO and MBS (source: Forsberg,2014, World Health Organization, 2018

PARAMETER	MBS	WHO
PH	5.0-9.5	7.0-8.5
EC	150 ⌈S/cm	500µS/cm
TDS	450 mg/l	500 mg/l
Temperature	25°C	25°C
DO	N/A	8 mg/l
NO_3	45 mg/l	50 mg/l
TURB	<5	<5
Lead	<0.01	<0.01
Cd	<0.003	0.003
BOD	N/A	<20
COD	N/A	<70

4.1.1. Laboratory results

Standard Deviation (σ) and Standard error formula(SE)

$$\sigma = \sqrt{\frac{\Sigma (X - \bar{X})^2}{n-1}} \qquad SE = \frac{\sigma}{\sqrt{n}}$$

Table 4: The summary of water quality for Mudi river at the measured sites (upper, middle and downstream)

Sites	Temp	PH	BOD	DO	TURB	TDS	EC	NO3	Lead	COD	Cd
Upper	21.6	8.04	8.96	6.6	4.9	136.3	217	0.03	0.002	20.01	0.005
Middle	22.7	7.29	122.9	2.53	34.2	326.3	304	0.34	0.128	247.14	0.18
Lower	22.0	7.37	109.5	2.3	32.6	231.3	573	1.83	0.14	228.64	0.23
Average	22.1	7.57	80.5	3.81	23.9	231.3	364.7	0.73	0.09	165.3	0.14
SD	0.56	0.14	62.3	2.42	16.47	95	185.59	0.96	0.004	126.13	0.12
SE	0.32	0.08	35.97	1.39	9.51	54.8	107.15	0.55	0.002	72.82	0.07

The table above indicates variations of water quality parameters among the sampling points. The results showed a variation of water quality parameters spatially. There was a slightly difference in temperature in the upper, middle as well as in downstream, the temperature recorded a high value of 22.5 the upper stream than other sampling points and this could be due to environmental conditions like cloud cover and atmospheric temperatures at the time of sampling. PH showed a

high value of 8.04 in the upper stream and lower values of 7.29, 7.57 in the middle and downstream respectively. BOD, COD, TDS, and TURB were also higher at the middle than other sampling points. Lead, Cadmium, EC, and nitrates showed high values downstream than other sampling points. DO values were higher at the upper stream as compared to other sampling points. Standard deviation for temperature was 0.56, 0.14 for PH, 62.3 for BOD, 2.42 for DO, 16.47 for turbidity, 95 for TDS, 185.5 for EC, 0.96 for nitrates, 0.004 for Lead, 126.13 for COD and 0.12 for cadmium

4.2. DISCUSSIONS

4.2.1. Variation of Chemical parameters among sampling points in Mudi river

Table 5: variation of DO along Mudi river

Parameter	Point A(upstream)	Point B (middle stream)	Point C(downstream)
DO	6.6	2.53	2.3

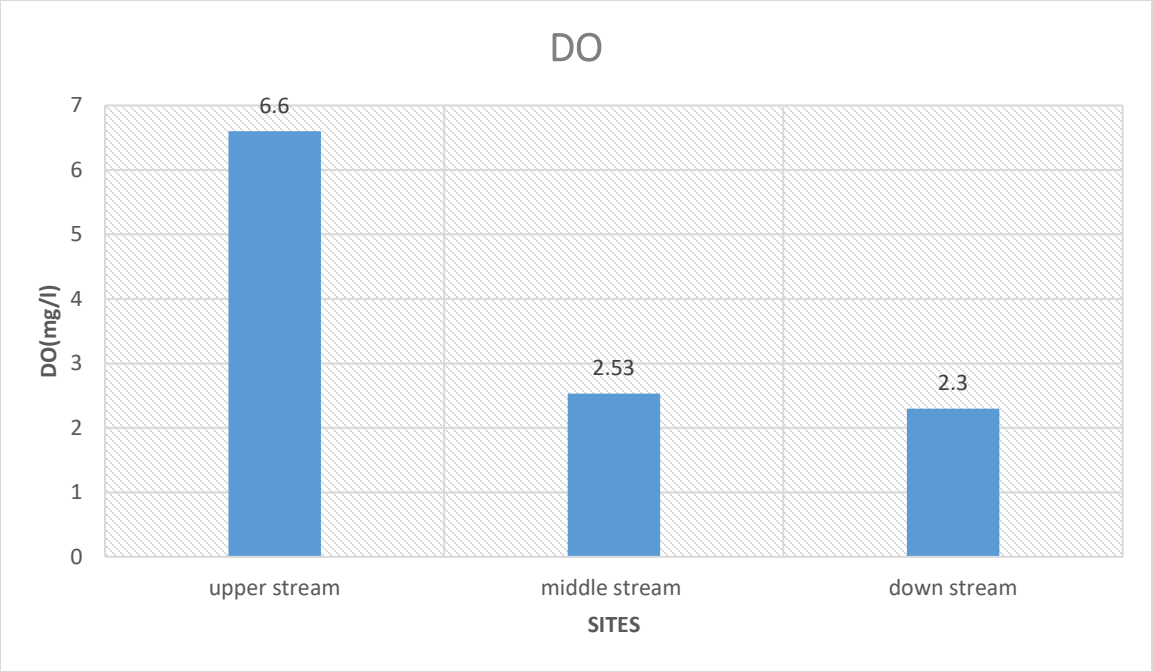
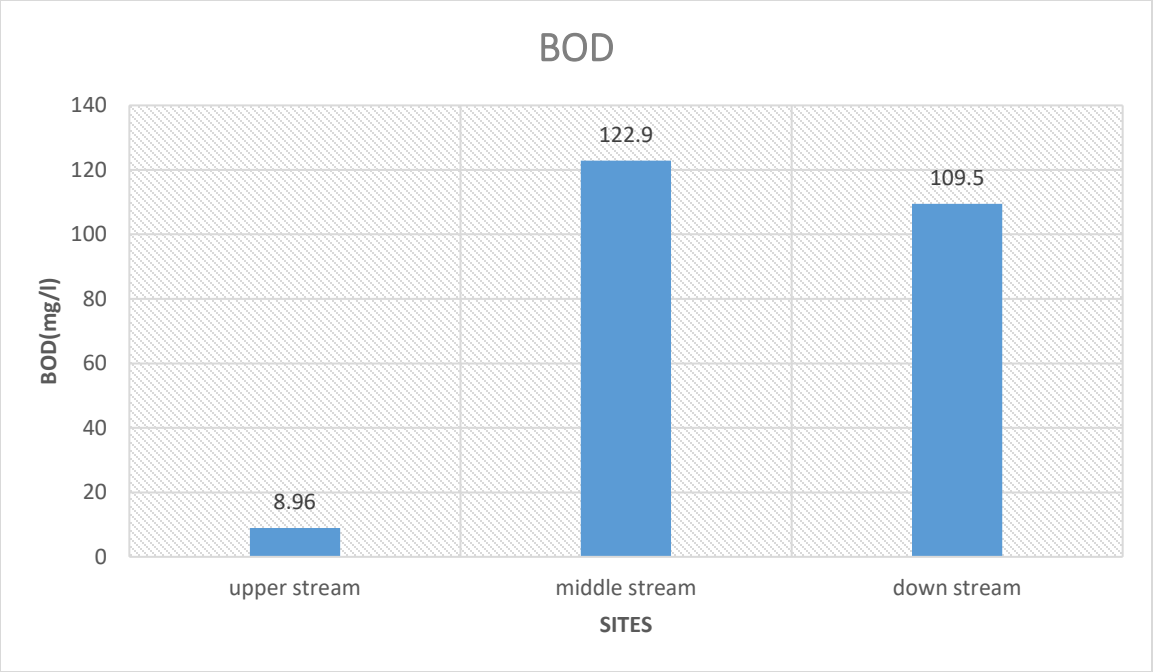


Figure 6: Bar chart showing the variation of DO among sampling points

DO is a measure of how much oxygen is dissolved in the water i.e. the quantity of oxygen available to living aquatic organisms. The amount of DO in a stream or lake can tell us tons about its quality. However, the decrease of dissolved oxygen concentration is dangerous for aquatic life. The values of DO of the analyzed water samples of Mudi river were within the range of 2.3-6.6 mg/l. The upper stream recorded a high value of 6.6mg/l while 2.53 and 2.3 were recorded at the middle and downstream respectively. This reduction of values at the middle and downstream could be due to discharge of organic materials e.g. from agricultural slurry sewage treatment works, storm overflows, agricultural slurry, silage liquor. Such low value does not support the survival of aquatic life. Enrichment by nutrients leads to lower oxygen levels resulting in eutrophication. Dissolved oxygen values for all the sites were below WHO standards.

Table 6: variations of BOD along Mudi river

Parameter	Point A(upstream)	Point B (middle stream)	Point C(downstream)
BOD	8.96	122.9	109.5



BOD is a measure of the amount of oxygen required to remove waste organic matter from water in the process of decomposition by aerobic bacteria (those bacteria that live only in an environment containing oxygen. When BOD levels are high, dissolved oxygen(DO) levels decrease because the oxygen that is available in the water is being consumed by the bacteria. Since less dissolved oxygen present in the water, aquatic life may not survive. If there is no organic waste present in the water, there would not be as many bacteria present to decompose it and thus the BOD will tend to be lower and therefore the DO level will increase. The value of BOD of water samples of Mudi river ranges from 8.96-122.9. Higher BOD values were found in the middle of the makata industrial (exceeded the WHO standards) area followed by 109.5 downstream and a lower value of 8.96 in the upper stream. The biological oxygen demand (BOD) was high in the middle because most of the industries are situated near the bank of the river. They discharge organic material like sewage wastes, storm overflows, domestic wastewater (human waste and food waste), and industrial wastewater.

Table 7: variations of PH along Mudi river

Parameter	Point A(upstream)	Point B (middle stream)	Point C(downstream)
PH	8.04	7.29	7.37

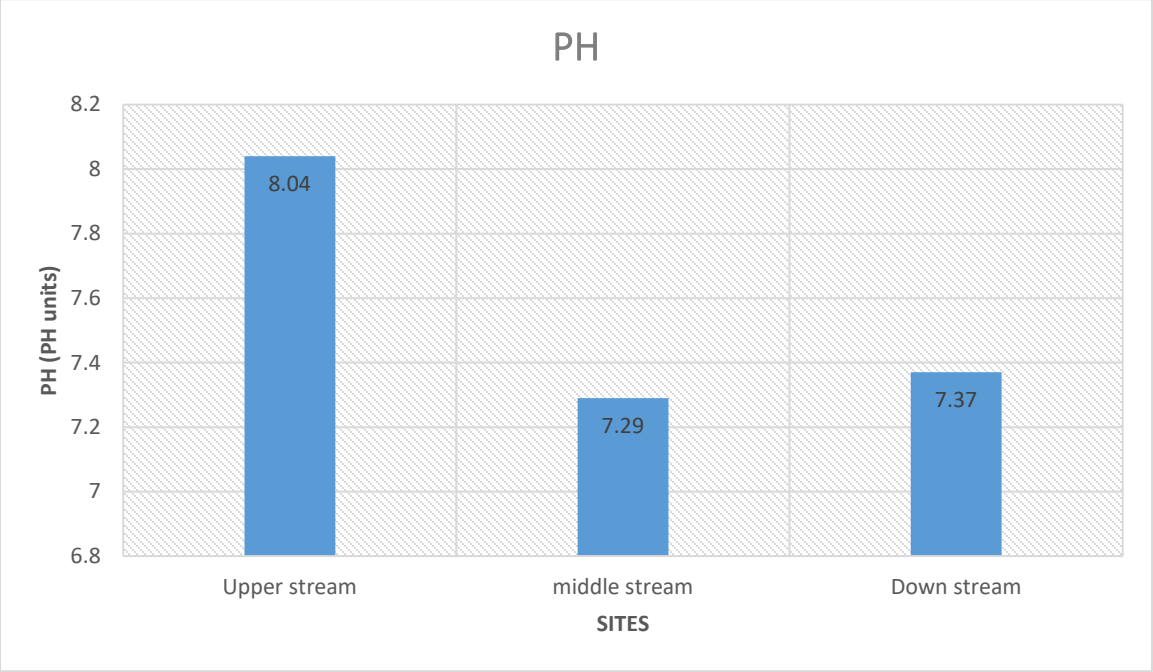
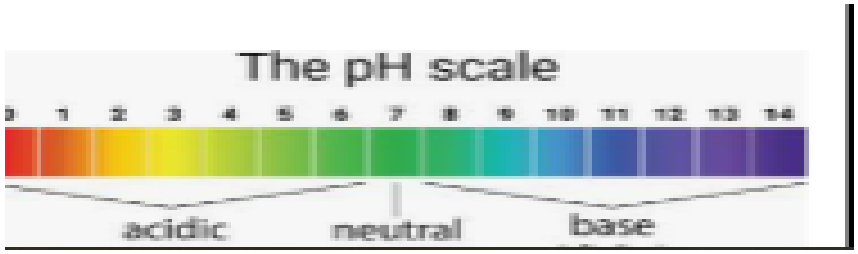


Figure 8: Bar chart showing the Variation of PH among sampling points

The acidity and alkalinity of water are expressed by PH. The range is from 0 to 14, with 7 being neutral. PHs of less than 7 indicate acidity, whereas a PH greater than 7 indicates a base as shown in the figure below;



The PH of water determines the solubility and biological availability of chemical constituents such as nutrients (phosphorus, nitrogen, and carbon) and heavy metals (lead, cadmium, etc.). In the case of heavy metals, the degree of their solubility determines their toxicity. Metals tend to be more toxic at lower PH because they are more soluble. The spatial mean values of PH varied between 7.29-8.04. A higher PH value of 8.04 was found in the upper stream, 7.29 in the middle of the makata industrial area and 7.37 downstream. The waters in the middle and downstream sites recorded were slightly in an acidic condition. The pH values in the river were comparable to studies done in other African rivers. For example, a study by Chimuriwo (2016) reported pH values ranging between 3.65 to 7.31 along the Mukusivi river in Zimbabwe, and in the upper site the waters were slightly acidic while downstream the waters were slightly alkaline. And also a mean value of 7.46 was also obtained by kuyeli((Kuyeli et al, 2012). This was a result of acidic discharges including fertilizer manufacturing, food processing, and abattoirs emanating from industrial activities surrounding the Msasa area.

Table 8 : variations of COD along Mudi river

Parameter	Point A(upstream)	Point B (middle)	Point C(downstream
COD	20.01	247.14	228.64

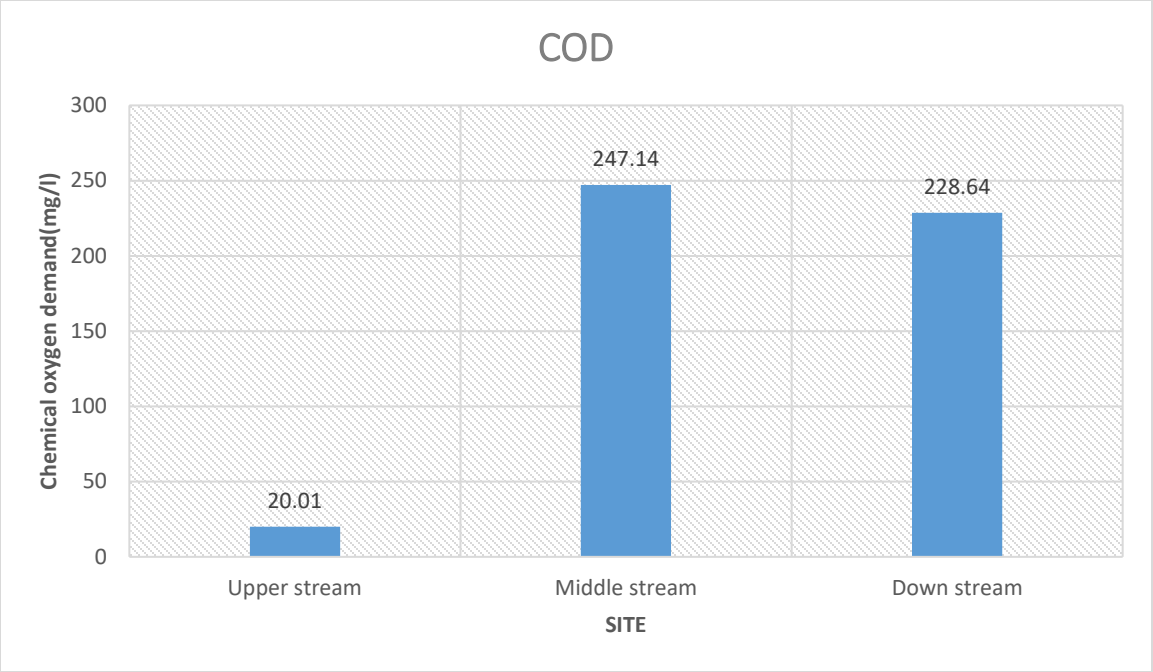


Figure 9: Bar chart showing the Variation of COD among sampling points

Chemical oxygen demand (COD) is the estimate of oxygen required for the portion of organic matter in wastewater that is subjected to oxidation and also the amount of oxygen absorbed by organic matter from boiling acid potassium dichromate solution. Higher COD levels mean a greater amount of oxidation organic material in the sample, which will reduce dissolved oxygen (DO) levels. COD values were lower at the source (upper stream) with 20.01 mg/l and increased in the middle stream (247.14 mg/l) and it was low again downstream (228.64 mg/l). Higher COD value in the middle could be due to residual food wastes from bottles and cans, emulsified oils are all high in COD and are common sources of COD for industrial storm water.

Table 9: variations of Turbidity along Mudi river

Parameter	Point A(upstream)	Point B (middle)	Point B (middle)
Turbidity	4.9	34.2	32.6

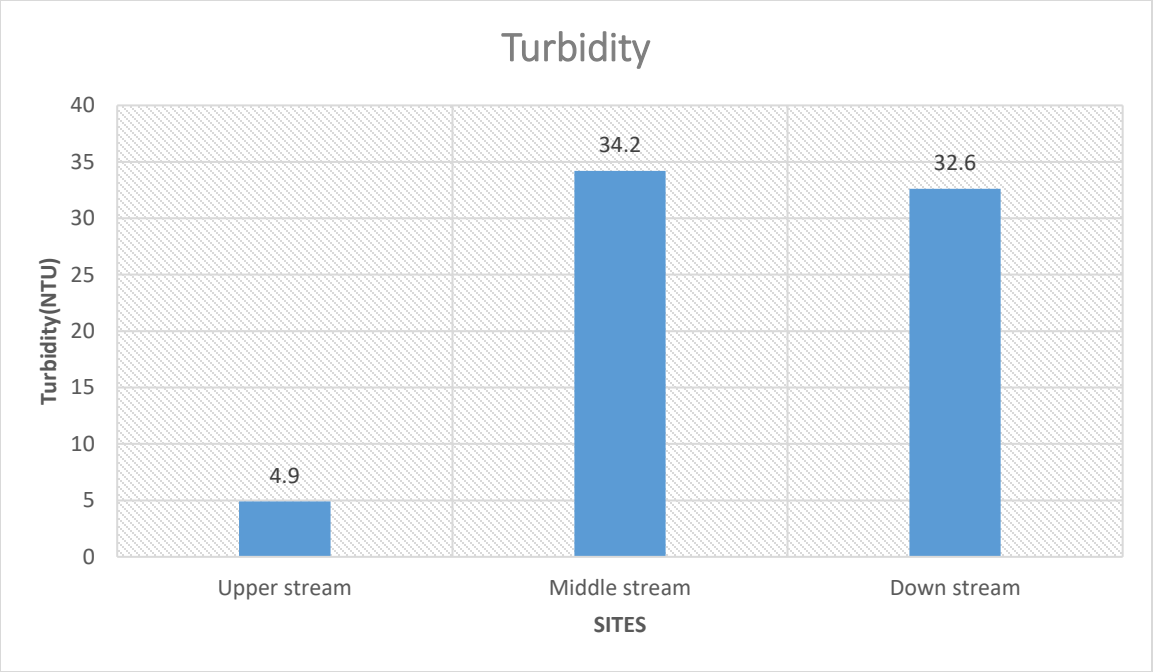


Figure 10: Bar chart showing Variation of Turbidity among sampling points

Turbidity is defined as a measure of the degree to which the water loses its transparency due to the availability of suspended particulates. The more total suspended solids are presence in the water, the murkier it becomes and the higher the turbidity. In drinking water, the higher the turbidity level, the higher the risk that people may develop gastrointestinal diseases and high turbidity can also make it difficult for fish to see and get prey, and it may kill eggs laid on the bottom of lakes and rivers. Turbidity was high (34.2 NTU) in the middle of the industrial area followed by 32.6 in the lower stream and a lower value of 4.9 at the source (upper stream), water at the upper stream was clear as compared to other sites and this is an indication of no or little amount of suspended particulates in the water. Higher values of turbidity in the middle of the industrial area could be due to suspended materials as a result of dissolved solids and chemicals. Middle and downstream values were above the WHO and MBS standards.

Table 10: Variation of Nitrates along Mudi river

Parameter	Point A(upper stream)	Point B (middle stream)	Point C (Downstream)
Nitrates	0.03	0.034	1.83

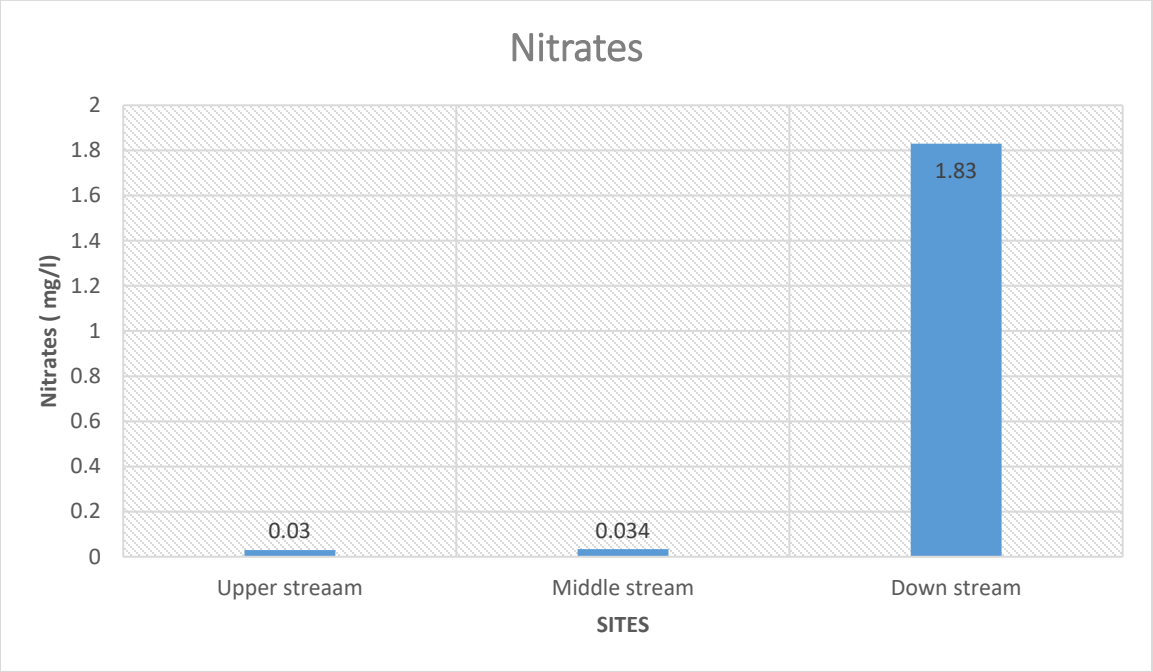


Figure 11: Bar chart showing Variation of Nitrates among sampling points

Nitrates values varied along the Mudi river as concentration decreased from upper stream to middle stream and then the concentration increases downstream. The average of nitrates along Mudi river recorded 0.73 mg/l. These values are below MBS and WHO standards i.e. there is little amount of nitrate in the river.However, a study by (Ngwira and Lakudzala, 2018) recorded the concentration of nitrates in the effluent to be 0.031 mg/l, and they concluded that the industry effluents did not affect the level of nitrates in the river water of Nakhaka in Malawi hence they suggested that the industry uses materials that are not rich in nitrogen. High levels of nitrates in water can be a result of runoff or leakage from fertilized soil, wastewater, landfills, animal feedlots, septic systems, or urban drainage.

Table 11: Variation of EC among sampling points

Parameter	Point A(upper stream)	Point B (middle stream)	Point C (Downstream)

EC	217	304	573

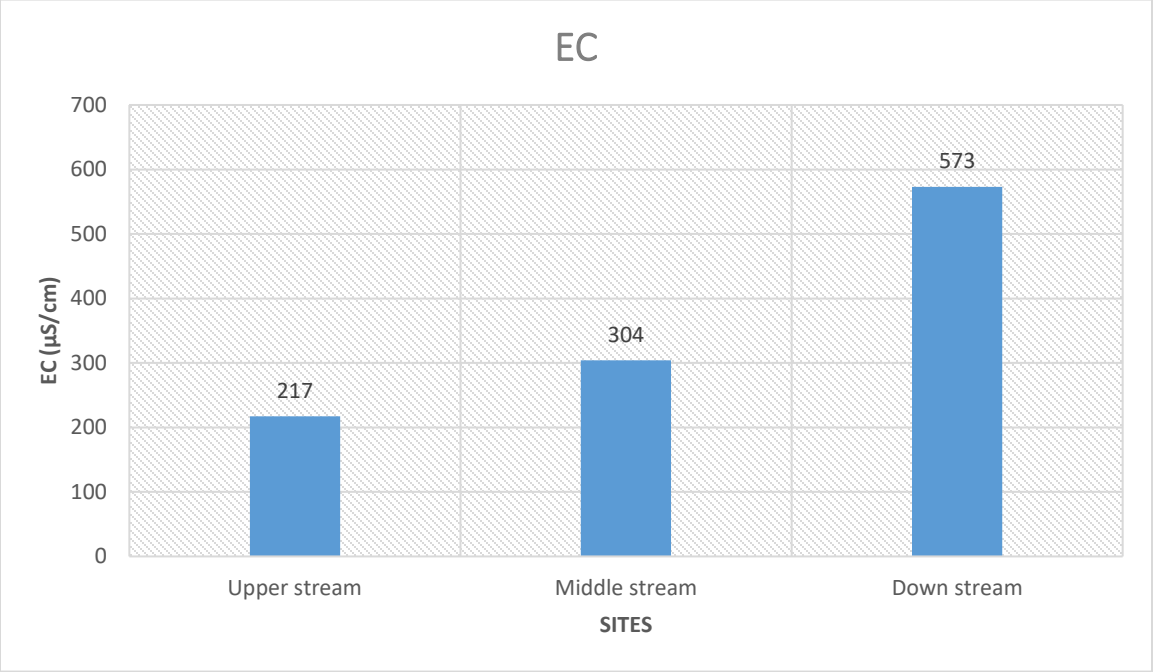


Figure 12: Bar chart showing Variation of EC among sampling points

Electric conductivity is the ability of the water to conduct an electrical current and is an indirect measure of the ion concentration. The more ions present, the more electricity that can be conducted by the water. EC is also an indirect measure of Total Dissolved Solids. Electrical conductivity is directly proportional to Total Dissolved Solids. This measurement is done at 25 degrees Celsius and expressed in Micro Siemens per centimeter (µS/cm). EC value was lower in the upper and increased at the middle and then increased further downstream with an average of 364.7 µS/cm. And this indicates that there are more dissolved solid downstream.

4.2.2. Variations of Physical parameters

Table 12: Variation of TDS along Mudi river

Parameter	Point A(upstream)	Point B (middle)	Point C(downstream)
TDS	136.3	326.3	231.3

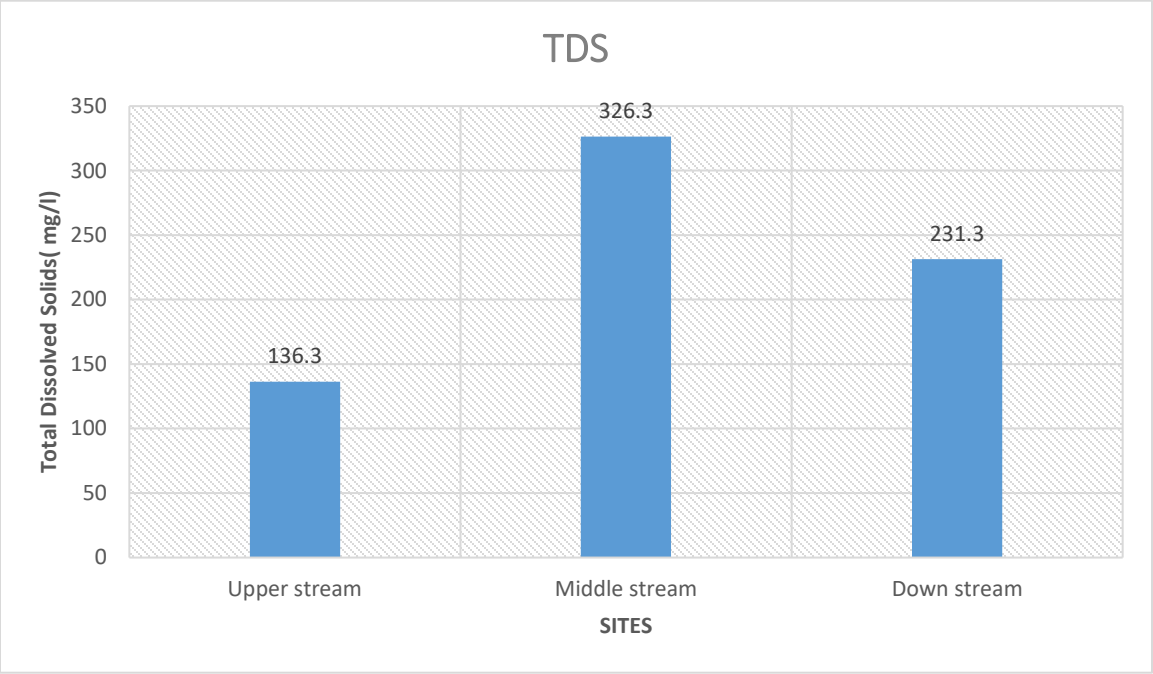


Figure 13: Bar chart showing Variation of TDS among sampling points

The total dissolved solids(TDS) indicate the availability of various kinds of minerals like ammonia, nitrite, alkalis, phosphate, alkalis, some acids, and metallic ions, etc. which contain both colloidal and dissolved solids in water. It is also an important chemical parameter of water. TDS values decreased in the upper stream and middle stream of the river and then increased Downstream with an average value of 239 mg/l along the river. A higher amount of TDS in the middle could be due to more dissolved substances that contains chemicals from industries.

Table 13: variation of Temperature along Mudi river

Parameters	Point A(upstream)	Point B(middle stream)	Point C(downstream
TEMP	21.6	22.7	22

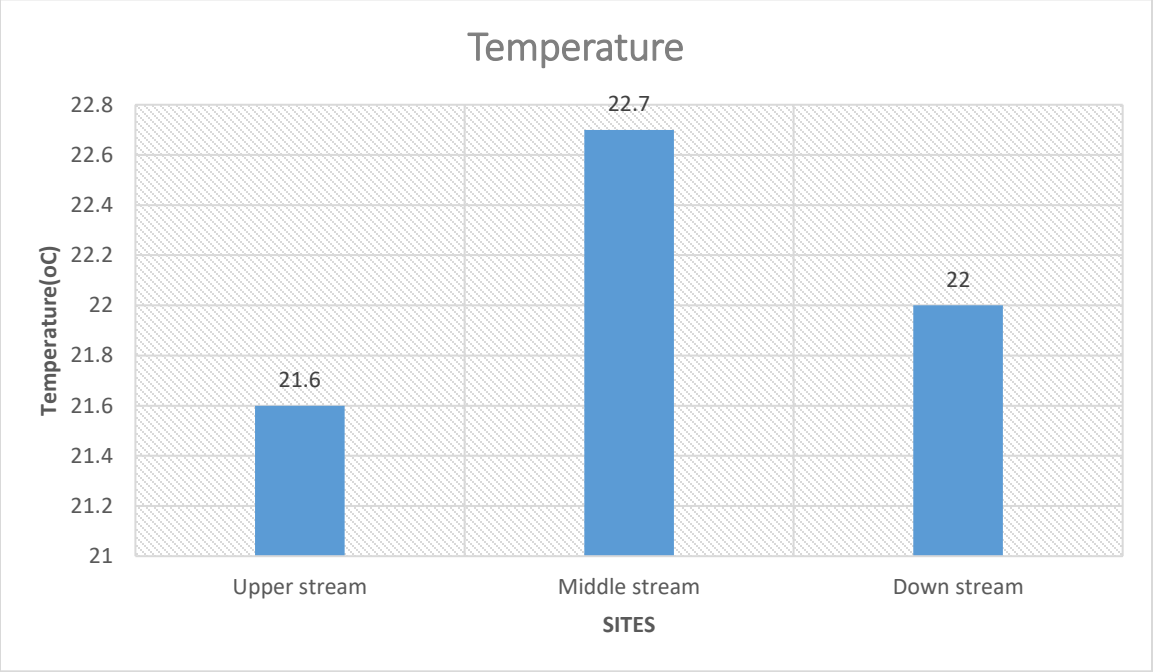


Figure 14: Bar chart showing Variation of Temperature among sampling points

Temperature is also an essential chemical parameter of water because of its influence on water chemistry. Most of the chemical reaction's rates generally increase at a higher temperature. Temperature also affects the amount of oxygen present in water as water at lower temperature tends to hold more oxygen while water at higher temperature tends to hold less oxygen. The temperature was lower in the upper stream and high at the middle and decreased again Downstream. The temperature value averaged 22.2 ^{o}C of which is below MBS and WHO standards.

4.2.3. Variation of metals

Table 14 Table : variation of lead along Mudi river

Parameters	Point A(upper stream)	Point B (Middle stream)	Point C(Downstream)
Lead	0.002	0.128	0.14

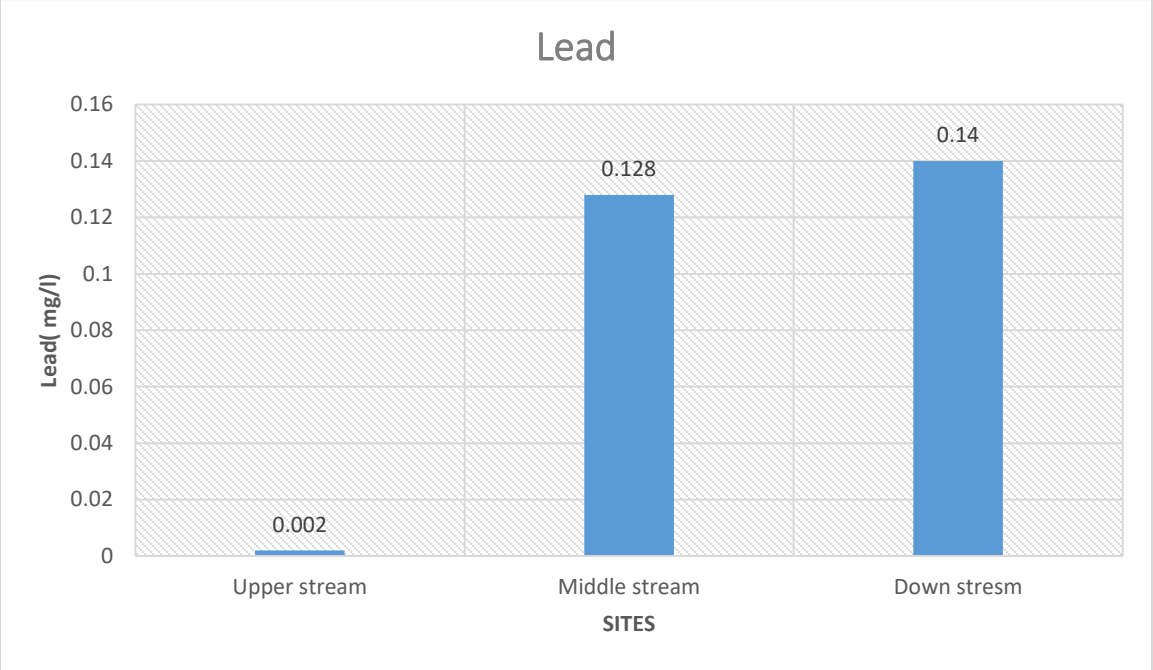


Figure 15: Bar chart showing Variation of Lead among sampling points

Lead is a toxic heavy metal that has adverse effects on human health. The common sources of lead are lead wastes, cell batteries; lead solders, lead gasoline and lead-based paints. Excess exposure to lead can damage nervous systems and can also cause blood and brain disorders (Gurruswammy, 2000). Lead can lead to miscarriages in pregnant women. Lead values increased from upper stream to Downstream with an average of 0.09 According to the World Health Organization and US Environmental Protection Agency guidelines, the Maximum allowable concentrations of lead in

drinking water is 0.01 mg/l and 0.015 mg/l, respectively. The average value was above the limits of MBS and WHO.

Table 15: variation of cadmium among sampling points

parameter	Point A(upper stream)	Point B (Middle stream)	Point C(Downstream)
Cd	0.005	0.18	0.23

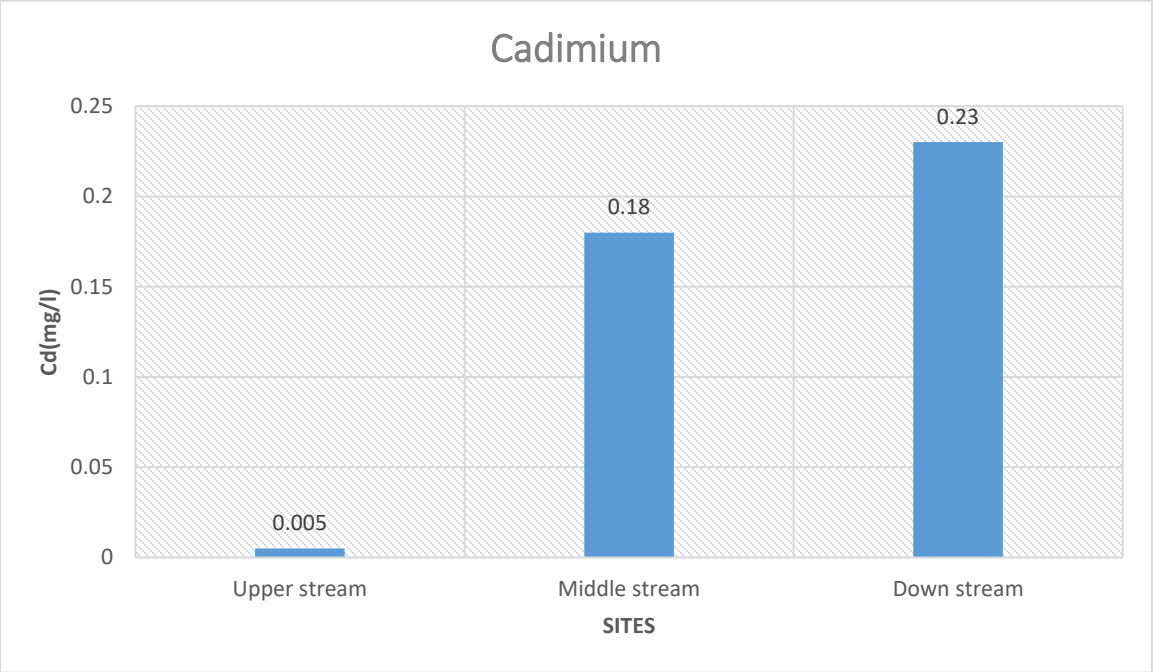


Figure 16: Bar chart showing Variation of Cadmium among sampling points

Cadmium is another toxic heavy metal. It can be released from car exhaust, metal processing industries, battery, and paint manufacturing. Higher levels of cadmium can also be present in soils or water from manufacturing industries. Cadmium can cause lung damage and thereafter death if it is present in a higher amount in water. Cadmium values varied along with the sampling sites as the concentration decreased from upper stream to middle of the industrial area then the concentration decreased downstream this is so because metals have this behavior of accumulating downstream.

CHAPTER 5

5. LIMITATIONS

A major limitation of my study was the resistance of the industry owners to cooperate as they had a different idea on the purpose of the results of the study. The time limit for conducting the research project was also very limited which did not satisfy the requirement for enough time to properly assess the water quality assessment of the river. There was a need for time enough to properly conduct the fieldwork in order to generate adequate data values of the selected parameters which were supposed to be used for producing temporal and spatial variation maps due to their dynamic state. The variations in weather conditions also affected the outcomes on some of the water quality parameters results like the temperature of the water.

CHAPTER 6

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

This study investigated the quality of water of the Mudi river in Blantyre, Malawi. Several water quality parameters were measured such as pH, TURB, COD, Lead, Cd, EC, TDS, Temperature, DO, BOD, and Nitrates at three sites namely a point before the makata industrial area, in the middle of the makata industrial area and a point after the makata industrial area. The findings were compared to Malawi Bureau of Standards (MBS) and World Health Organization (WHO) and some of the values were below the minimum value standard for Malawi Bureau of Standards (MBS) and WHO standards especially at the point before the makata industrial area such as temperature, pH and nitrates while parameter like BOD, TURB, Lead, and Cd was above WHO standards both in the middle of makata industrial area and after the industrial area.

A general conclusion can be drawn here that most of the industrial pollutants are directly or indirectly discharged into Mudi River thereby increasing its levels of contamination. Mudi river is polluted by human activities, industrial effluent, untreated sewage, wastewater, oil dumping, silt, encroachment etc. Pollutants entering the streams are both in solid and liquid forms. Concerning all measured parameters, it could be concluded that pollution of Mudi water reached a critical point with increasing tendency day by day. Consequently, so as to decrease pollution from various sources appropriate steps must be taken immediately. If the required steps are not taken, very soon it might be a source danger point for pollution.

This study has revealed that the industries are involved in serious environmental hazards I.e. accumulation of some elements in the middle and the lower part of the river and this indicate that the industrial area is the disposal point of wastes since there is no other source of pollution apart from it and also there are no settlements that may have contributed to pollution. Adequate preventive measures should be taken in industrial activities to ensuring a healthy environment. The

adverse effect of industries is severe. But considering the economic benefit, we cannot ignore this sector.

6.2. Recommendations

Some recommendations are given below to mitigate this problem.

- It is recommended that the Effluent Treatment plant (ETP) for each industry must be made necessary.
- Desire degree of treatment of effluent to achieve the standard.
- Proper operation and maintenance of ETP should be monitored continuously by the regulatory authorities like the Environmental Affairs Department as well the Malawi Bureau of Standards
- Community awareness of the activities that alter the water quality of rivers should be the basis of achieving the attainment of the Sustainable Development Goals.

CHAPTER 7

7. REFERENCES

Buchholz. (1998). *principle of environmental management.* the greetings of business second prentice Hall: London, UK.

Chapman D. (1996); Water Quality Assessments- A Guide to use of Biota, Sediments and Water in Environmental Monitoring; 2nd Edition. (1996).

Chindah et al. (2004); Distribution of hydrocarbons and heavy metals in sediment and a crustacean (shrimps-Penaeus notialis) from the bonny/new Calabar River estuary, Niger Delta. Ajeam-Ragee. (2004).

Fakayode S.O. (2005); Impact of industrial effluents on water quality of the receiving Alaro River in Ibadan, Nigeria, Ajeam-Ragee.

Lakudzala D.D.(Mrs.); Tembo K.C. and Manda I.K. (1999); An Investigation of Chemical Pollutants in the Lower Shire River, Malawi, University of Malawi, The Polytechnic; Blantyre, Malawi Journal of Science and Technology..

UNECE.(1994); Standard Statistical Classification of Surface Freshwater Quality for the Maintenance of Aquatic Life. In: Readings in International Environment Statistics, United Nations Economic Commission for Europe, United Nations, New York and Geneva. New York and Geneva: UNECE; 1994

Sajidu S.I., Masamba W.R.L., Henry E.T. and Kuyeli S.M. (2007); Water quality in streams and wastewater treatment plants of Blantyre, Malawi. Journal of Physics and Chemistry of the Earth

Kadongola. (1997). Kadongola W.K. (1997); Environmental Impacts of landfills. Msc. Thesis, University of Botswana.

Kumwenda et al. (2012). Determination of Biological , Physical and Chemical Pollutants in Mudi River , Blantyre , Malawi. *journal of Bsic and Applied scientific Research*, ISSN 2090-4304.

Kuyeli SM. (2009)Temporal and spatial physicochemical water quality in Blantyre urban streams. Malawi Journal of Science and Technology;9(1):5–10..

Kaonga C.C., Chiotha S.S., Monjerezi M., Fabiano E., Henry E.M. (2008); Levels of Cadmium, Manganese and Lead in Water and Algae; Spirogyra Equinoctials. International Journal of Environmental Sciences and Technology..

Ugochukwu C.N.C. (2004); Effluent monitoring of an oil servicing company and its impact on the environment.

Chimuriwo, B. (2016). *An Assessment of water quality along Mukuvisi River , Harare , Zimbabwe*. *November*.

Mvuma G.G. (1993); River Pollution in a Third World; An Inventory Assessment to Evaluate Environmental Status of Mudi River, Proceedings of a Conference held at Chancellor College; Zomba, Malawi..

Parvin Aktar et al. (2017). Assessment of water Quality status of Turag River due to Industrial Effluent. *international journal of engineering and information system(IJEAIS)*, 1(6). pp. 105-118.

Ritter et al. (2002) Ritter L., Solomon k. and Sibly P. (2002); Sources, pathways and risks of contaminants in surface water and ground water: A perspective prepared for the Walkerton enquiry Journal of Toxicology and Environmental Health.

Taylor E.W. (1996); Toxicology of Aquatic Pollution, Physiological, Cellular and MolecularApproaches; Cambridge University Press.

Emongor V., Kealotswe E., Koorapetse I., Sankwasa S. and Keikanetswe S. (2005); Pollution indicators in Gaborone effluent. J. Appl. Science.

WHO and UNICEF (2000); Global Water Supply and Sanitation Assessment 2000 Report Geneva and New York, WHO and UNICEF..

Zembere S., Maruwo B. and Ngwangwa M. (1999); Industrial Solid Wastes and Methods of Disposal by some Manufacturing Companies in Malawi; University of Malawi, the Polytechnic, Blantyre: Malawi Journal of Science and Technology (1999).

- CHAPTER 8

8. APPENDICES

Table 16:Raw data for water quality parameters

Weeks	Sites	BOD	EC	PH	TDS	Temp	COD	Nitrates	DO	Cadmium	Lead	TURB
1st week	Upper	8.4	217	8.11	137	20.3	19.96	0.044	5.65	0.001	0.001	4.46
	Middle	125.4	305	7.12	205	22.3	247.61	0.491	1.5	0.190	0.127	33.4
	Lower	105.24	574	7.47	251	21.0	233.40	1.823	0.9	0.230	0.141	34.6
2nd week	Upper	8.9	215	8.41	130	23.3	20.22	0.042	6.61	0.004	0.003	4.8
	Middle	109.9	298	7.58	386	23.8	249.62	0.049	3.3	0.181	0.129	32.5
	Lower	99.2	568	7.31	220	23.5	232.30	1.831	1.7	0.232	0.135	32.9
3rd week	Upper	9.6	219	7.62	142	21.2	19.87	0.041	7.4	0.010	0.001	5.3
	Middle	133.4	309	7.17	388	22.0	244.20	0.493	2.8	0.156	0.128	36.7
	Lower	124.1	578	7.33	223	21.5	220.23	1.822	4.2	0.235	0.142	30.4



Figure 17: A pipe disposing waste water from one of the industry into Mudi river