

IMPACTS OF COAL MINING ON STREAM WATER QUALITY; CASE STUDY OF MCHENGA COAL MINE IN RUMPHI DISTRICT

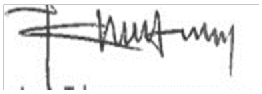
JOHN VASCO CHIDULE

Thyolo, Malawi

Dissertation submitted to Ndata School of Climate and Earth Sciences of the Malawi University of Science and Technology in partial fulfilment of the requirements for the Bachelor of Science degree in earth sciences.

July 2021

DISSERTATION APPROVED BY:



SUPERVISOR:
Dr, Isaac Tchuwa Signature: _____
19/07/2021

ASSESSOR:
Title, Initials, Name Signature: _____

DISCLAIMER

This document describes work undertaken as part of a program of study at Ndata School of Climate and Earth Sciences of the Malawi University of Science and Technology. All views and opinions expressed therein remain the sole responsibility of the author(s), and do not necessarily represent those of the School.

COPYRIGHT STATEMENT:

This copy of the dissertation has been supplied on condition that anyone who consults

it is understood to recognize that its copyright rests with its author and that no quotation from the dissertation and no information derived from it may be published without acknowledgement.

ABSTRACT

Water is one of the basic needs of the mining industry. All the operations of mining, directly or indirectly require water for their functioning. The mining industry has been utilizing water carelessly without anticipating the negative impacts it is having on the ecology and the biodiversity of the region (Singh 2008). Acid mine drainage has become a common phenomenon associated with mining. Deaths and diseases caused by contaminated water has roused concerns everywhere (Monjerezi, 2012). The critical situation requires carrying out water analysis of all the water bodies in and around the mines to determine the source, cause, effect and remedies of the different contaminants and pollutants. This is also a part of the corporate social responsibility that the mining industry has pledged to. The study is aimed at assessing the impacts of coal mining on the quality of stream water at Mchenga coal mine. Stream water resources in northern part of Malawi especially in the Livingstonia coal field in Rumphi district are not potable for drinking and other uses due to high contamination and pollution. Specific objectives, Geology of the area, Analysis of the physiochemical parameters and Comparing the results with WHO and MBS, helped to achieve the main objective of the study. The parameters that were determined for this purpose are temperature, pH, conductivity, TDS, DO, turbidity, acidity, sulphates, phosphates, sodium, potassium, calcium, magnesium and other trace metals (Atkins et al 2010). Due to heavy dependence of water as a main source in coal processing by the Mchenga coal mine as resulted into great pollution of streams. Direct discharge of untreated wastes or coal tailings in the streams have acerbated the pollution levels of the steams. In this study, the main hypothesis was “Mchenga coal mining activities in Rumphi district may have impacted negatively on stream water quality such that they do not exceed permissible water quality standards set by the Malawi Bureau of Standards (MBS) or WHO”. The study employed field and laboratory experiments to investigate this hypotheses and provide scientific data on the stream water quality that is used Comprehensive assessment of the quality of stream water at Mchenga area.

.

ACKNOWLEDGEMENTS

First and for most I would like to thank Almighty God for the guidance and protection upon my life.

I would like to express my deepest thanks to my supervisor, Dr. I. Tchuwa for the unwavering support and informative guidance throughout this study. In reviewing my work, he offered painful comments that kept me moving, showing the ways of dramatically improving them.

I would also want to extend my heartfelt appreciation Mr T Shaba and Mr Mzee Wandembo for their support for without their support and encouragement, I would have not completed this dissertation. I would thank respectfully to my mother and my uncle who taught me the value of learning.

TABLE OF CONTENTS

1. CHAPTER 1: GENERAL INTRODUCTION (BACKGROUNG INFORMATION) 1
1.1 Introduction and background information 1
1.2 Coal mining and stream water quality in malawi 2
1.3 Problem statement 3
1.4 Main and specific Objectives 4
1.5 Research questions 4
1.6 Study hypothesis 5
1.7 Significance of study 5
1.8 Thesis structure 5
2. CHAPTER 2: LITERATURE REVIEW 6
2.1 Introduction 6
2.2 Coal mining in Malawi 6
2.3 Mchenga coal mining company 7
2.4 Geology of the area 7
2.5 Stream water quality in malawi 8
2.6 Impacts of coal mining on the quality of stream water 9
2.7 Physiochemical parameters of water affects by coal mining 9
2.8 Conclusions 12
3. CHAPTER 3 : METHODOLOGY 13
3.1 Introduction 13
3.2 Research design 13
3.3 Geology of the study area 14
3.4 Stream location and water sampling 15
3.5 Sample types, methods used and preservation 16
3.6 Instruments used and procedure of Data analysis 17
3.4 limitation of the study 19
3.5 Conclusions 21
4. CHAPTER 4: RESUSLTS AND DESCRIPTION 22
4.1. Introduction 22
4.2. Tables and graphs 22
4.3. Conclusion 30
5. CHAPTER 5: DISCUSSION 31
5.1. Introduction 31
5.2. Physiochemical parameter 31
5.3. Conclusion 35
6. CHAPTER 6: CONCLUSION 36
6.1. Introduction 36
6.2. Summary conclusion 36
6.3. Recommendation 38
7. REFERENCE 39

ACRONYMS/ABBREVIATIONS

BGS British geological survey
AAS Atomic Absorption Spectroscopy

APHA American Public Health Association

D.O Dissolved oxygen

D.E Denbo

EC . Electric Conductivity

F.A.O Food and Agriculture Organization
M.B.S Malawi Bureau of Standards
K. Potassium
Na. Sodium
Mn. Manganese
MoIWD. Ministry of Irrigation, water and Development
pH. Power of hydrogen
R.U Rukulu
Sn. Selenium
T.D.S Totally Dissolved Solids
W.H.O World Health Organization
U.N United Nations

LIST OF FIGURES

Figure 3.1 Map showing location of Livingstonia coal field area in Rumphi District, Malawi 14

Figure 3.2,3,4,5,6,7,8,9 shows the sample points where physio-chemical parameters of stream water were measure 15

Figure 4.10 Plot of concentrations of pH for samples from the two streams in Mchenga mining area. Also shown on the plot is a bar representing World Health Organization (WHO) maximum permissible concentrations in drinking water (WHO 2008) 23

Figure 4.11 Plot of concentrations of Turbidity for samples from the two streams in Mchenga mining area. Also shown on the plot is a bar representing World Health Organization (WHO) maximum permissible concentration.....24

Figure 4.12 Plot of concentrations of Electrical Conductivity (EC) for samples from the two streams in Mchenga mining area. Also shown on the plot is a bar representing World Health Organization (WHO) maximum permissible concentration.....24

Figure 4.13 Plot of concentrations of Sodium for samples from the two streams in Mchenga mining area. Also shown on the plot is a bar representing World Health Organization (WHO) maximum permissible concentration..... 25

Figure 4.14 Plot of concentrations of Potassium for samples from the two streams in Mchenga mining area. Also shown on the plot is a bar representing World Health Organization (WHO) maximum permissible concentration.....25

Figure 4.15 Plot of concentrations of Manganese for samples from the two streams in Mchenga mining area. Also shown on the plot is a bar representing World Health Organization (WHO) maximum permissible concentration.....26

Figure 4.16 Plot of concentrations of TDS for samples from the two streams in Mchenga mining area. Also shown on the plot is a bar representing World Health Organization (WHO) maximum permissible concentration..... 26

Figure 4.17 Plot of concentrations of Hardness for samples from the two streams in Mchenga mining area. Also shown on the plot is a bar representing World Health Organization (WHO) maximum permissible concentration..... 27

Figure 4.18 Plot of concentrations of Selenium for samples from the two streams in Mchenga mining area. Also shown on the plot is a bar representing World Health Organization (WHO) maximum permissible concentration..... 27

LIST OF TABLES

Table 4.1 sampling locations ……..20
Table 4.2 results of physical and chemical parameters of water……22
Table 4.3 results of sodium, selenium, Manganese and Potassium……23

1. INTRODUCTION

1.1. INTRODUCTION/BACKGROUND

Water is the principal need of life on earth and is an essential component for all forms of life, from micro-organisms to man. Stream water and groundwater have been an important source of water for cooking, drinking and irrigation because it is considered generally safe, readily available and clean (Monjerezi, 2012). Reports show that about 1.5 million people in the world and about 60% of population in southern Africa use stream water and groundwater as their main source of drinking water (UNEP, 2002).

The world's water resources are under pressure and must be managed for human survival. The need for physio-chemical analysis of water is very vital and all sources of water must be known before consumption (BGS, 2004). Therefore, estimation of water quality is extremely important for proper assessment of the associated hazards. Various anthropogenic activities have greatly contributed to water pollution including mining activities (Staines, 2002)

Mining of coal deposit all over the world is being carried out under complex hydrogeological environments causing a range of water problems affecting the production and utilization cost (Dharmappa et al 1998). The extensive mining activities also adversely affect the environment. Due to lack of proper planning and negligence of regulations an appreciable amount of environmental degradation and ecological damage to water air, and soil occurs (Kundell, 2008). The problems associated with mining activities worldwide, are land degradation, disposal of overburden, deforestation, washing rejects, subsidence, water pollution due to wash off, discharge of mine water, acid mine drainage, coal washing operation, air pollution due to release of gases and dust, noise pollution, mine fires etc. Water pollution from coal includes negative health and environmental effects from the mining, processing, burning, and waste storage of coal, including acid mine drainage, thermal pollution from coal plants, acid rain, and contamination of groundwater, streams, rivers, and seas from heavy metals, mercury, and other toxins and pollutants found in coal ash, coal sludge, and coal waste (Singh 2008). Water contamination is inevitable. It is bound to occur due to the presence of various minerals in the rock. Therefore our efforts should concentrate on checking the pollution levels of different parameters and keeping it within the prescribed standards.

Water pollution due to man-made activities should be prevented in the best possible manner.

This is where coal mining has the biggest impact all over the world including in Malawi, but still our actions remain unchecked (Singh 2008). Coal mining activities worldwide can directly affect the quality of the water or indirectly through processes which may show its consequences at a later stage in the life of the mine. The gravity of the impact of these activities depend on a number of factors like the geology of the area, the mineral constituents of the coal, the composition of the overburden, scale of operations, rainfall distribution, etc. (Muthangya M and Samoei D, 2012).

1.1.1. COAL MINING AND STREAM WATER QUALITY IN MALAWI

In Malawi, about 37% of population depends on water from boreholes, while 26% of population depends on water from shallow wells and the remaining percentage depends on stream running water (Staines, 2002). This means therefore that stream water is the major source of drinking water among the local people in Malawi as well as wild animals. However, these streams bear contaminated waters that are not safe for drinking. The contamination is due to various anthropogenic activities in manufacturing and production industrial sectors in which streams are their waste disposal area. Mining activities also play a major role in stream water contamination due to heavy waste disposal in streams. Some of the most polluting mining products are from gold and coal mines, but coal is a special case for Malawi since it directly uses stream and groundwater as a resource for its production processes and later discharges it back into the streams.

Coal mining in Malawi is mostly done at Kaziwiziwi and Mchenga coal mines located in the Livingstonia coal field in Rumphi district northern part of Malawi. Mchenga is one of the oldest coal mining companies here in Malawi. It uses water acquired from nearby water source like any other coal mining company in the world as a resource in the exploratory drilling, coal washing and extraction processes. High dependence on water by the mine for its operations, Mchenga coal mining is suspected to be causing great negative impacts on the quality of stream water. Mine water drainage/Acid mine drainage, loose material runoffs, Oil and fuel spills, Pollutant leaching from overburden dump and Sewage discharges are major source of water pollution cause, which are not exceptional at Mchenga coal mining. Physio-chemical properties of water, such as Electric conductivity (EC), pH, Temperature, Dissolved oxygen (DO) and Total Dissolved solids (TDS) inorganic ions such as Nitrite, Chlorides, fluoride, Manganese, Cadmium, arsenic, Iron and lead are highly affected by the causes mentioned above.(Mkandawire, 2008). Water quality has been proved to be highly

affected in most of coal mines, worldwide, as well as in Malawi so it is with Mchenga coal mine, hence a research has been conducted to measure the levels of pollution and finding mitigations ways on how to control pollution levels have been proposed.

For this purpose, a complete survey of the water bodies surrounding Mchenga coal mining area was carried out to understand the negative impacts of the coal wastes on the quality of steam water. Water quality analysis provides an overall picture of the quality of water around the mines. It further helps identify the areas of concern, the parameters which are most harmful, contaminants which pollute the most and the areas which cause the contamination (Atkins et al 2010). In short it helps in identifying the source, the causes and the effects which consequently aids in finding the preventive measures.

1.2. Problem statement

Stream water contamination challenges have exacerbated due to anthropogenic activities in which streams have become the waste dumping sites (Staines, 2002). Globally stream water quality has become the major problem posing great threat on people's health. Many countries globally have reported extreme stream water pollution due to mining of coal, gold, uranium and other metallic mineral. Specifically, countries like Australia, Madhya, Pradesh, Pakistan and Kenya have exacerbated water pollution cases due to Coal mining in various districts within them (Muthangya & Samoei, 2012). Several coal mining companies have no proper waste depositing sites rather streams are used where both toxic and none toxic wastes are deposited. In Malawi improper deposition of coal waste in water bodies at Mtchenga coal mining area in Rumphi has been the major cause of stream water contamination whose contamination level remained unknown. Therefore, the question still remains: Does the stream water quality in the streams around Mtchenga coal mining area in Rumphi district meet the appropriate stream water standards?

Thus there was a need to conduct a study that determines the stream water quality status to provide important data that could be used in the development of stream water quality monitoring programs in various rivers in Malawi, using Mtchenga coal mining area as a model.

1.3. Main Objective of the study

This study is mainly aimed at assessing the effects of coal mining activities on the stream water quality at Mtchenga coal mining area in Rumphi district

1.4. Specific objectives include

1. Understanding the geology and structure of the area.
2.Analyzing water samples for various physio-chemical parameters.
3. Statically comparing physio-chemical parameters with Malawi beaural of standards and World health organization standards

1.5. Research question

Does the stream water quality in the streams around Mtchenga coal mining area in Rumphi district meet the appropriate stream water standards?

1.6. Study hypotheses

Mchenga coal mining activities may have impacted negatively on stream water quality.

1.7. Significance of study

The quality of water determines the quality of lives (Mkandawire 2008). The significant population of Malawi is at a health risk due to consumption of polluted water concentrated with hazardous chemical elements. Some authors have reported high levels of fluoride in stream waters due to mining activities in districts of Mangochi, Mzimba and Rumphi respectively (Sajidu et al, 2007; Msonda et al, 2007). In Rumphi this must be the influence of various coal mining activities taking place in Livingstonia coal field. Therefore it is important to determine the quality of stream water as one of the prerequisites for appropriate planning of developments that ensures the health and safety of consumers in rural areas. Most importantly, the study contributes important scientific data that supports the attainment of the United Nations Sustainable Development Goals (SDGs) (2015-2030) for increased access to clean and safe drinking water (UN, 2016).

1.8. Thesis structure

This thesis is structured as follows; Chapter One is the general which ends by unlocking the key question of the study followed by objectives (both main and specific) and study significance. Chapter Two is the literature review of the study which highlights what others have done already and identifies the areas that haven't been done or covered. Chapter three discusses the first objective i.e. determining the stream water quality of the two streams, north Rukulu and Denbo in Chiguliro village where Mchenga coal mine is located. Chapter four describes results of the collected data from the two streams under study and lastly chapter five, present the discussion of the results and compares the obtained results with WHO standards but also it

consists of the conclusion.

2. LITERATURE REVIEW

2.1. Chapter introduction

This chapter is the critical review of the literature related to the study at hand. According to Dock (2005), mining is one of mankind's oldest industries. Mining activities generate effluent containing a number of chemical pollutants, which adversely alter the quality of both surface and groundwater resources that often cause significant pollution (Koryak, 1997). While Ellis (1989) suggests that the effect of degraded water quality is not only felt in the local area of the mine, but often felt downstream of the mine far away from the source of pollution, Harrison (1990) argues that, as pollutant is introduced into a water source such as a river, the concentration of the specific pollutant is initially high, owing to the ability of a river to disperse a pollutant as a result of the river's flow. However, the concentration of the pollutant becomes less and less as the pollutant moves further away from its point of introduction.

Degraded water quality has an effect on the aquatic life in the river or lake (Loeb & Specie, 1994). It may also impact on the agricultural sectors of the area, if the degraded water is used for irrigation or livestock consumption. This could be disastrous for farmers who rely on the degraded river as a main source of water, the reduced water quality could potentially have a detrimental effect on crop yield and impact on livestock health (Harrison, 1990).

2.2. Coal Mining in Malawi

Malawi has been known for some time to contain coal deposits and this has been the country's strategic target commodity. Malawi has four main coal-bearing areas, of which two are located in the Shire Valley, Southern region, and two in the Northern region near to Lake Malawi. The most important coalfields of the Northern region, are the most promising coalfields in Malawi which are the Livingstonia and Ngana on the Tanzania border (Mshali. 2000). Stratigraphically, northern Malawi, is dominated by the Karroo System strata, preserved in a number of N—S trending basins and down-faulted troughs and they display both unconformable and faulted relationships to the underlying Basement Complex gneisses. Coal is the only mineral of economy is interest known to occur in the Karroo System (Permo-Triassic). Malawi has over 22 million tons of proven coal reserves in a number of coal fields across the country (Nyirenda. 2009). The largest coal field is the Livingstonia coal field with probable reserves of over 2-5

million tones and proven reserves of 4 million tons of coal with ash content of 17 %, sulphur of 0.5 % and calorific value of 6,800 kcal /kg. Livingstonia coal field is a 90 km^2 stretch in Rumphi district in the Northern Region of Malawi. CPL- Mchenga, Kaziwiziwi and Eland/Nkhachila coal mines are the three major coal mining companies producing coal in Malawi. CPL - Mchenga and Kaziwiziwi coal mines are within the Livingstonia coal field whereas Eland/Nkhachila is a coal mining company at Mwabulambo in Karonga. All these coal companies produce coal for industrial use in cement, tobacco, sugar, tea, brewery, textile, and food processing and ethanol companies. Other coal mining companies of which some are operational but on small scale and some are abandoned or suspended include Mean Jalawe, Phoka, Chiweta, David duwi at Livingstonia and Chombe/Thekero coal mines, all in Rumphi district.

2.3. Mchenga Coal Mining Company

Mchenga coal mines limited (MCM) is currently the second largest mining company in Malawi after the temporary suspended uranium mining company in Karonga. MCML started its operations in 1987 again under the proprietorship of MIDCOR. The mine is located in the south east corner of the 90 km2 Livingstonia coal field in Rumphi district in the Northern region of Malawi (Mshali. 2000). Specifically, the mine is located in Chiguliro village in Traditional Authority Njikula covering an approximate area of 17.5 km^2. For 12 years, until 1999, the mining company was still a government owned company of which MIDCOR controlled the company for 8 years from 1987 to 1995 before transferring its control to Malawi Development Corporation (MDC) and Malawi Investment Development Bank (INDE-BANK) who controlled the company for 4 years from 1995 before it was privatized in 1999 to Coal Products Limited (CPL) company whose investors are owning the company to date.

2.4. Geology of Mchenga mining area in Chiguliro village

Mchenga coal mine is located at the latitude of 10.7151 or 10 42 54.3 south and longitude of 1542 or 34 9 15 east. Stratigraphically, the area is dominated by the Karroo System strata, preserved in a number of N—S trending basins and down-faulted troughs and they display both unconformable and faulted relationships to the underlying Basement Complex gneisses (Singh 2008). Coal is the only mineral of economic interest known to occur in the Karroo System (Permo-Triassic). Thicknesses of the coal seams vary from 0.10m to 3.0m with some notable lateral and horizontal variations. Thick and workable seams occupy the lower portion of the Coal Measures and are exposed along the North Rumphi River bank. Coal quality belongs to

sub-bituminous 'A' to 'C' on ASTM classification (1991), being characterized by low moisture content (0.8 to 1.3 with percent) and sulphur content (0.49 to 0.85 with percent), high ash content (9.0 to 17 with percent) and volatile matter (24 to 32.9 with percent), fixed carbon (53.6 to 62.6 with percent), calorific value (7,015 to 7,670 kcal/kg); c) Mineral matters constitute approximately 9.55 to 38.34 with percent of the coal samples, predominantly clays (interstratified illite/smectite and kaolinite) with varying proportions of quartz, mica and feldspars, as well as minor calcite and pyrite and their geochemistry, being characterized by enrichment of SiO2 from 5.37 to 20.56 with percent, Al2O3 (2.63 to 11.21 with percent) and K2O (0.32 to 3.65 with percent) with trace concentrations of CaO (0.04 to 0.41 wt. percent), MgO (0.08 to 0.65 with percent) and P2O5 (0.018 to 0.037 with percent) and Na2O, Mn, Sn with concentration notably below 0.01 with /percent (Muthangya & Samoei, 2012). Calcite and pyrite constitute minor concentration in both sandstones and shales.

2.5. Groundwater/ stream water quality in Malawi

There is no universally accepted definition of "Water quality". Many authors use the term to describe the composition of major ions, metals and biota. Chavula & Mulwafu (2007) states that Water quality refers to the description of non-aqueous components of a volume of water comprising of suspended sediments, biota and dissolved species (Salts). Among others, the dissolved species includes Total dissolved solids, Carbonates, Chlorides, Sulphates, Nitrates, Iron, Cadmium, Chromium, Arsenic and Lead. Groundwater is of variable qualities and quantities, unevenly distributed in time and space.

2.6. Impacts of coal mining on the quality of stream water

Mining of coal deposit all over the world is being carried out under complex hydrogeological environments causing a range of water problems affecting the production and utilization cost (Saka. 2006.). Singh (2008) states that extensive mining activities also adversely affect the environment due to lack of proper planning and negligence of regulations an appreciable amount of environmental degradation and ecological damage to water, air and soil occurs. Globally mining activities have resulted into land degradation, disposal of overburden, deforestation, washing rejects, subsidence, water pollution, acid mine drainage, air pollution, noise pollution, mine fires and etc. Water pollution from coal mines have negative health issues and environmental impacts. Furthermore, coal mining has resulted into acid mine drainage, thermal pollution by coal plants, acid rain, and contamination of groundwater, streams, rivers, and seas by heavy metals, mercury, and other toxins and pollutants found in coal ash, coal sludge, and coal waste (Singh 2008). Water contamination is inevitable.

2.7. Physio-Chemical parameters of water that are affected by coal mining

pH value. The pH value is an important parameter to decide if water is acidic or alkaline in nature and play a significant role in its appropriateness for domestic, industrial and agricultural uses. The minimum and maximum allowable limit for pH in drinking water as given by CPCB and WHO is 6.5, 8.5 respectively. As a result of coal mining there are great variations in pH range due to the chemical composition of the coal (Atkins et al 2010). Hence there was a need to conduct a research in order to monitor the impacts the Mchenga coal mining has on pH of stream waters.

Total Dissolved Solids (TDS). The presences of total dissolved solids (TDS) in water resources also play a significant role to decide its suitability of water for different uses (WHO). In most of the coal mines, the levels of (TDS) is very high due to the use of water in the process of extraction of coal both from surface and underground mines (Atkins et al 2010). Operations such as coal cutting in underground mines, dust suppression, coal preparation, coal washing, domestic use in mines, hence there was a need to conduct research as assess the levels of (TDS) on stream water around Mchenga.

Electrical Conductivity (EC). Electrical conductivity (EC) depends on the temperature and indirectly measure the salinity. Due to high dissolution of coal seams in water resources or bodies, there is high probability that the salinity of the water will be affected thereby affecting the electrical conductivity of water (Xu & Gao 2009). Waters of high electrical conductivity have great negative impact on the crops hence affecting agriculture. Therefore, we needed to research on this to see the impacts that Mchenga coal mining is causing on the electrical conductivity of stream water

Hardness. The acceptable limit of Hardness is (500-1500) mg/L as per (WHO) recommendations. But due to coal seams and its dissolution, the hardness of water is easily affected (Atkins et al 2010). If hardness of water is affected by dissolution of coal seams, then so it is with the streams that Mchenga coal mining uses its waters for process and for discharge. Hence conduction of a research to measure the impact the mining brings on the hardness of water.

Magnesium (Mg2+). The permissible limit of magnesium is (30-150) mg/L (WHO). The occurrence of magnesium in water is due to the presence of Augite, Biotite, Olivine and Talc minerals (Singh 2008). There is a great probability of high magnesium in the stream water surrounding the Mchenga coal mine, since olivine, biotite are the most common minerals in the mineralogical composition of Karoo system.

Manganese: Manganese compounds are abundantly found in soils. The permissible limit of manganese is (0.05) mg/L. Manganese is one of the 3 essential toxic trace elements i.e.

Over exposure to manganese mainly affects the respiratory tract and brain functions. Manganese poisoning leads to hallucinations, forgetfulness, and nerve damage. It also causes Parkinson, lung embolism and bronchitis.

Sulfate (SO42-). Khandelwal and Singh (2005) states that the presence of a higher range of sulfate in mine water may be due to due to presence of Miocene sediments having gypsum and limestone. Understanding the geology of the Karoo system where Mchenga coal mining is located, there exist sandstone which gives us guide that there must be some limestone present which may result into higjh sulfate levels in water once in contact with the surface water. Therefore, a need to conduct a research to test the sulfate levels.

Turbidity. Turbidity in the study area was varied between (0-6.3 NTU). The acceptable limit of turbidity is 5-25 NTU (WHO). All values nearly in the range of prescribed limits. Due to high levels of dissolved and undissolved solids in water, the turbidity of water is affected greatly. In coal mines, most of the coal waste areas are open and the waste are discharged into the streams hence increasing the solids in water affecting its turbidity.

Gaps in other studies.

Studies conducted by Chavula & Mulwafu in 2007 focused much on salinity levels in the streams around Mchenga coal mining in relation to the geology of the area of which other parameters such as pH, TDS, EC, Na, K, and Sn were not checked give room for more and further research. Furthermore, studies done by Mkandawire in 2008 focused on the levels of water pollution by looking at the physical parameters of water only without the check of chemical parameters hence giving room to conduct further research to determine contamination levels by checking both physical and chemical parameters of water in relation to the geology of the area. Lack of water quality data (reports) by Mchenga mining company give more room to conduct further studies in order to determine how coal mining activities affect the quality of stream water around the streams of north Rukulu and Denbo River.

Conclusion

Chapter two was a critical review of the literature related to the study at hand. It has covered the study area in which Mchenga is located, the most physiochemical parameters of water that are easily affected by coal mining activities (pH, TDS, Mn, Mg, Sn, P, K, EC, & Na). Furthermore, it has covered, the background of stream water quality and highlighted the impacts of coal mining activities on stream water quality. The chapter is of great importance in such a way that it has identified areas or gaps shown in the last section of the chapter that needs further research in order to determine the exact effect of coal mining activities on the quality of stream water.

3. METHODOLOGY

3.0 Introduction

This chapter describes the research design, the area of study, methods and materials that were used in during sample collection and sample analysis in order to achieve the objectives of the study

3.1. Research design

This section illustrates several main themes of this research and highlight important methodological considerations that shapes how this research was conducted. These methodological considerations and choices are discussed in detail in this chapter.

Quantitative research method, was adopted and applied in this research. The quantitative research method was used to ascertain whether streams surrounding Mchenga coal mine are polluted. The quantitative method used allowed and helped in mathematical assessment of the pollution state of the streams. The data-gathering tools, or research instrument used was Physicochemical Analysis. The aim of physiochemical analysis was to evaluate the heavy metal concentration and water quality.

Location of every sampling point was acquired using a handheld Garmin GPS device as shown in figures 3 and 4 and were recorded in a field book. Finally, water samples were collected from the sampling point as shown in figures 3 and 4 and taken for laboratory analysis at Water department lab in Blantyre for further analysis in order to achieve the objective of the study.

In addition, desk work was also applied. This was a major method of obtaining information through literature review on what others have done already, on how to conduct ground water quality assessment. The information related to the study topic was taken from past reports, books, journals as well as the internet. Geological information of the study area was also sourced from the bullets that were accessed at Geological Survey Departments. The geological characteristics of the area seem to have contributed to the chemical composition of the water derived from the streams around the Mchenga coal mining

3.2. Geology of the Study area (Mchenga coal mine field in Chiguliro village)

The mine is located in the south east corner of the 90 km2 Livingstonia coal field in Rumphi district in the Northern region of Malawi (Mshali. 2000). Specifically, the mine is located in Chiguliro village in Traditional Authority Njikula covering an approximate area of 17.5 km square. Stratigraphically, the area is composed of the Karroo System strata which are preserved in a number of N—S trending basins and down-faulted troughs and they display both unconformable and faulted relationships to the underlying Basement Complex gneisses. Coal is the only mineral of economic interest known to occur in the Karroo System (Permo-Triassic).The area has been chosen for it bears Mchenga coal mine within itself and is bordered by two major streams. The mine uses water as its main source for coal production which is later discharged into the bordering streams of North Rukulu and Denbo, without any proper water treatment which is then used by the people in the communities along these streams as it flows down into the lake. But also due to lack of enough data on water quality assessment done by other researchers on the impacts of coal mining on stream water quality, granted a go ahead permission to carry out this research study in order to determine the impacts of coal mining activities on the quality of stream water in the two streams mentioned above. Also to check what health issues can the coal waste have on people's lives as a result of drinking water from these polluted streams.

Below is the map showing the study area

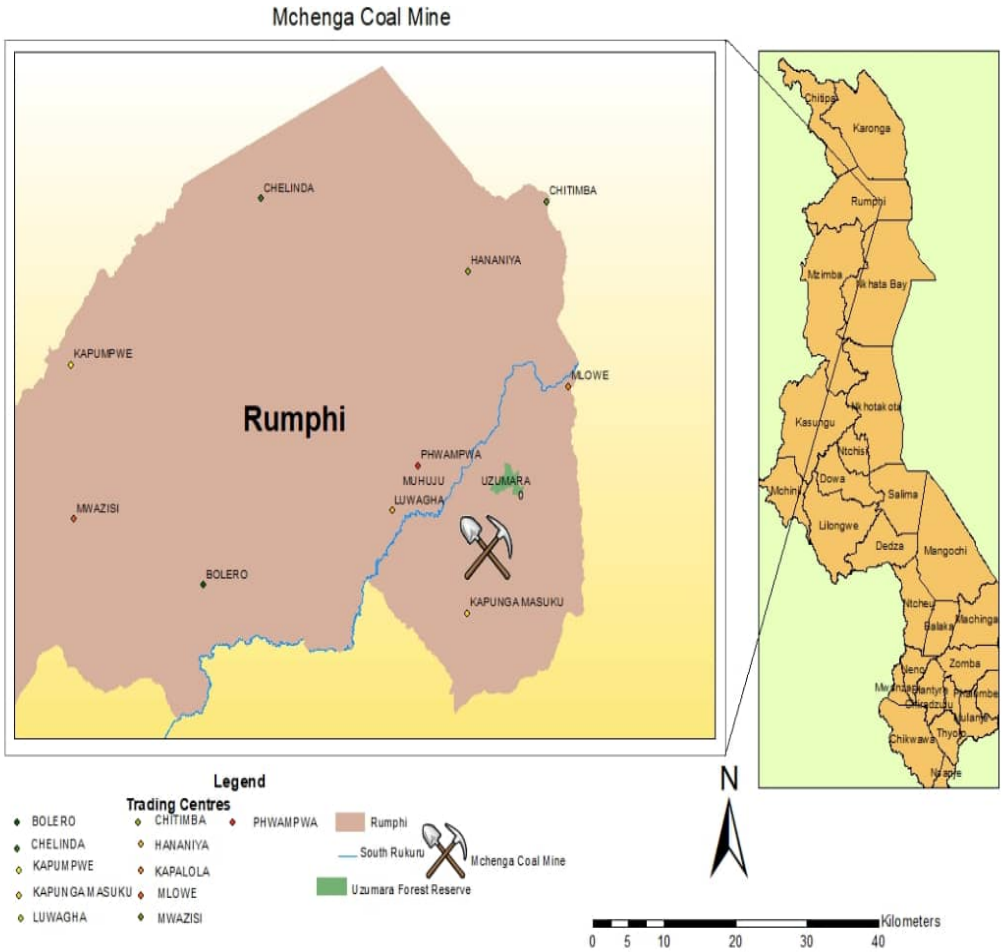


Figure 1: Map of Malawi showing the study area of Njikula with Mchenga coal.

3.3. Stream location and Water Sample Collection

The research mainly targeted streams that are often used by the mining company for its processes and also used by the villagers for drinking and irrigation purpose. Water samples were collected from 2 streams which Mchenga uses for its coal production and waste management with four sampling points each. The scientific justification of four sampling points for each stream is for average calculation of each parameter for data accuracy. Stream allocation was done through desk work basing on the direct discharge of the mine Tailings into these streams.

Eight sampling sites were selected for the two streams, each stream with four sampling sites with their location of the sampling points marked by the GPS co-ordinates for easy access both during and after the rainy season whilst ensuring that valid and quality data is collected. Of the four selected sampling sites per stream, one site (S1) was located on the upstream of each stream where drains of coal waste are

discharged into the stream (confluence point of stream and tailing drain). Two sites (S2 and S3) were located at the main river downstream of North Rukulu and Denbo. S4 was chosen for the sole purpose of assessing the quality of the seepage water from the tailings of Mchenga coal mine dam into the rivers mentioned above. Below are the photos in two columns showing the two streams from which water samples were obtained. Photos for South Rukulu stream at the left column and Denbo stream at the right column. Each stream with four sampling points, from first point to the fourth point respectively.

Figures 2, 3, 4, 5, 6, 7, 8, 9 below show the sampling points, four from each stream, Rukulu (right column) and Denbo (left column)



Location for sample 1 at south Rukulu



location point for sample 1 at Denbo



Location for sample 2 at south Rukulu



location point for sample 2 at Denbo



Location point for sample 3 at south Rukulu



location point for sample 3 at Denbo



Location point for sample 4 at south Rukulu



location point for sample 4 at Denbo

3.4. Preservation of samples

Sampling was carried out to obtain representative samples which mirror the environment in which they are present. The water body (streams) from where the samples were collected was not isolated rather it was within the confines of the mining area and linked to the operations directly or indirectly. The samples collected were handled carefully such that no significant changes were encountered between the time of collection and parameter measurement. The samples were stored in a laboratory with proper preserving facilities as soon as possible. To obtain accurate results and representative data, collection of the water sample was pre-planned and done in a systematic manner rather than just randomly. Thus prior consultation was considered before carrying out any sampling to guarantee selecting specimens which depicted the scenario of the area

3.5. Types of Samples

a. Grab samples: is the type of sample taken spontaneously to represent the overall

surrounding environmental features including the composition of the water only at that time and place. Discrete grab samples are taken at a selected location, depth, and time. Depth-integrated grab samples are collected over a predetermined part of the entire depth of a water column, at a selected location and time in a given body of water.

b. Composite samples: They are number of single samples taken from the same area to give results on an average. This is done when the variations within the same is large and a single sample cannot give an overall picture of the location. Composite samples can be obtained by combining portions of multiple grab samples or by using specially designed automatic sampling devices.

3.6. Sampling methods

a. Manual sampling: Manual sampling method involves minimal equipment in which water samples are directly collected from the stream at marked stations. This is the method that was applied to carry out this research, since it is cheaper for a short period of time and short distances and area.

b. Automatic sampling: Automatic sampling method is good for it can eliminate human errors in manual sampling, can reduce labour costs, may provide the means for more frequent sampling and can be used increasingly. An automatic water collector device was installed within 30 minutes of water collection in area of bad surface conditions. This method was applied in this study for its advantages over the manual sampling methods in order to collect error generated by manual sampling method.

Table-1: Details of water samples collected

Sample no.	Place from where sample was collected from the two streams
Sample 1 RU	Upstream of South Rukulu stream
Sample 2 RU	Downstream of South Rukulu stream
Sample 3 RU	Downstream of South Rukulu stream
Sample 4 RU	Seepage at the tailings of the mine
Sample 5 NYU	Upstream of Denbo stream
Sample 6 NYU	Downstream of Denbo stream
Sample 7 NYU	Downstream of Denbo stream
Sample 8 NYU	Seepage at the tailings of the mine

Instruments used and their procedures on how to use them

To achieve the objectives of the study, the collected water samples were analyzed in

the laboratory using three main instruments, Multi water quality checker, Flame Atomic Absorption Spectrophotometry, Flame Photometry

Multi Water Quality Checker

The multi water quality checker is a simple device that allows maximum of 11 simultaneous measurements for various parameters. It has integrated control unit and sensors. The device design allows for easy on-site measurement with a variety of functions to measure the water quality of river water, waste water and ground water.

Calibration

1) The sensor guard was removed and the sensor probe was washed with distilled water several times.
2) The transparent calibration cup was removed.
3) The calibration cup was filled with a pH 4 standard solution up to the mark.
4) Select the Auto Calibration option under CAL and dip the sensor into the standard solution in the transparent calibration cup.
5) The black calibration cup was placed over the transparent cup and the ENTER key was pressed to begin calibration after all the values have been stabilized.

Procedure

1) The sensors were checked and washed with distilled water.
2) The option "SINGLE MEASUREMENT" was selected.
3) The sensor was then dipped into the sample such that no air bubbles remain around the sensors.
4) Once the readings have stabilized, the MEAS key is pressed to acquire the 5- second average.

The measurement is saved by pressing the ENTER key

Flame Atomic Absorption Spectrophotometry

Atomic absorption spectrophotometry is an instrument that is used for quantitative analysis of different elements in water as well as solids. It works on the principle that each metal has a characteristic wavelength in which absorbance takes place. The sample is atomized by aspirating into a flame. A beam of light is allowed to pass through the flame and received by

a monochromator which singles out the specific wavelength and then falls on to a detector which records the amount of light absorbed by the atomized form of the sample.

Apparatus

i. Atomic absorption spectrometer
ii. Burner
iii. Lamps
iv. Pressure reducing valves
v. Vent

Procedure

1. The apparatus was set and adjusted according to manufacturer's guidelines.
2. Flame was generated using acetylene and stabilized.
3. The apparatus was calibrated by aspirating the blank solution containing the same amount of acid as in the standards and samples.
4. At least three standards were aspirated and its absorbance measured.

The samples were then aspirated in the flame, its absorbance measured and the concentration was calculated and displayed on the screen.

Frame Photometry

Flame photometry or flame emission spectroscopy is an atomic spectroscopy like the atomic absorption spectroscopy that requires no light beam to measure the concentration. It directly measures the emitted wavelength when the atoms are transitioning from excited to ground state. For the conversion of the atoms from ground state to excited state a flame is used unlike in the absorption technique where a lamp is required.

In the atomic emission spectroscopy, a jet of compressed gas was used to convert the samples solutions to aerosol form which was atomized by a flame, carried to, by the flow of the gas. In the process of atomization the metal constituents of the samples were converted to gaseous atoms, which were then ionized. The electrons absorb the heat from the flame and got excited to a higher state. On returning to the ground state, each metal emitted light of specific wavelength which was detected and used to find the concentrations of the metals.

Procedure

1. The standard solutions were samples were prepares accordingly.
2. The apparatus was set according to the manufacturer's guidelines.

Initially distilled water was used for blanking.

3. The standards were then analyzed and their absorbance readings noted.
4. The samples were then aspirated to get their absorbance readings.
5. A graph was plotted between the concentration of the standards and their absorbance readings.
6. Using the absorbance reading of the samples and the plot obtained the previous step, the concentrations of the element in the samples were be obtained.

Data analysis. The collected water samples were analysed in the lab by the use of the three machines as mentioned in the above procedures. Furthermore, Microsoft excel software was used to tabulate the data and compare the data with WHO standards by the use of graphs. The Average values of the parameters were also calculated by the use of Microsoft excel, which were compared to WHO standards for better conclusion.

Limitations of the study. Human errors in results recording and technical knowhow of the machines (instruments) used. Secondly, mechanical error, which is lack of accuracy in the instruments used. Lastly, lack of funds and resources for further analysis of other water parameters in the lab.

Conclusion. The chapter focus on the research design and number, types of samples collected as well as the methods used to collect the samples. Eight samples were collected from the two

streams, four from each stream at a constant interval. Two types of samples were collected, the grab and composite samples which were collected by manual and automatic methods of sampling. Furthermore, the chapter cover the instruments used for concentration determination and methods through which data was analyzed. Lastly the limitation of t

4. RESULTS, DESCRIPTION AND DISCUSSION

4.1. RESULTS AND DISCRIPTION

Introduction

This chapter focuses on the physiochemical results of the collected water samples which were obtained after the analysis of the samples in the lab. Different parameters are affected differently basing on the level of contamination, hence different results. The results are summarized in the tables and in the graphs. Each analyzed parameter has its own graph that displays the level of its contamination.

Table 2: Results of Physical parameters of the samples

Sample	TDS (mg/L)	Turbidity (NTU)	Conductivity (ms/cm)	pH	Hardness (ppm)
Sample 1	680	25.5	2.1	5.04	523
Sample 2	730	29	1.7	4.5	512
Sample 3	720	28	1.9	4.8	503
Sample 4	690	28.4	2	3.8	507
Sample 5	800	27.8	1.6	5.01	519
Sample 6	620	30	1.84	4.4	520
Sample 7	650	26.4	1.94	4.6	518
Sample 8	750	29.4	1.6	3.9	501

Table 3: Results for sodium, selenium, manganese and potassium using flame photometry

SAMPLE NO.	SODIUM	SELENIUM	MANGANESE	POTASSIUM

SAMPLE 1	55	0.04	1.99	30
SAMPLE 2	58.4	0.035	2	35
SAMPLE 3	60.4	0.016	1.7	34.3
SAMPLE 4	67	0.015	1.2	40
SAMPLE 5	60.4	0.079	1.6	39.4
SAMPLE 6	70	0.015	1.1	31
SAMPLE 7	69.4	0.07	1.8	34
SAMPLE 8	58.3	0.087	1.5	25

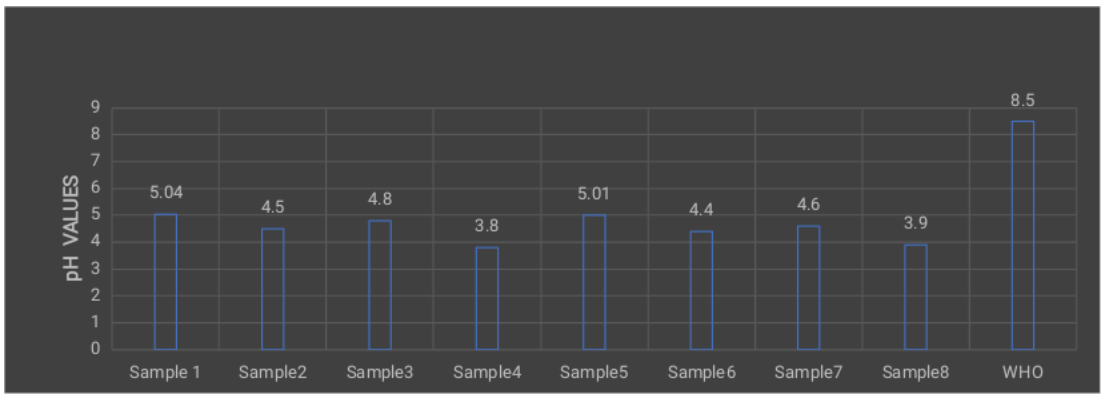


Figure 10 Plot of pH for streams in Mchenga mining area. Also shown on the plot is a bar representing World Health Organization (WHO) maximum permissible concentration

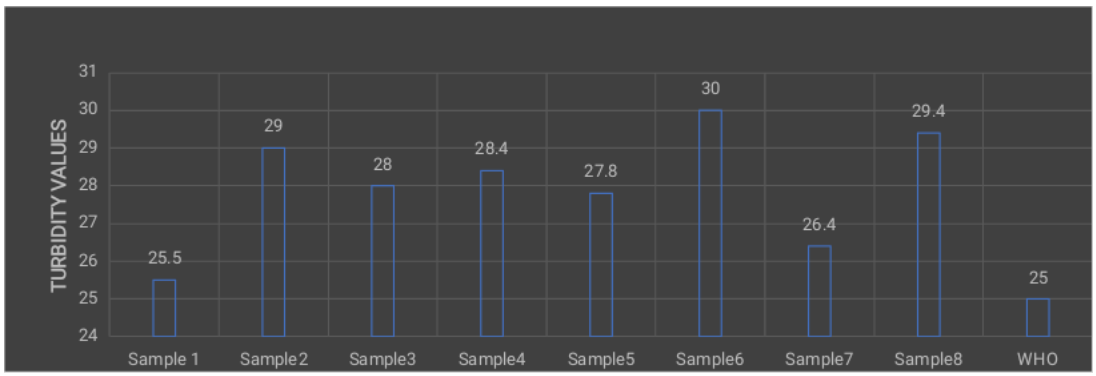


Figure 11 Plot of Turbidity for streams in Mchenga mining area. Also shown on the plot is a bar representing World Health Organization (WHO) maximum permissible concentration

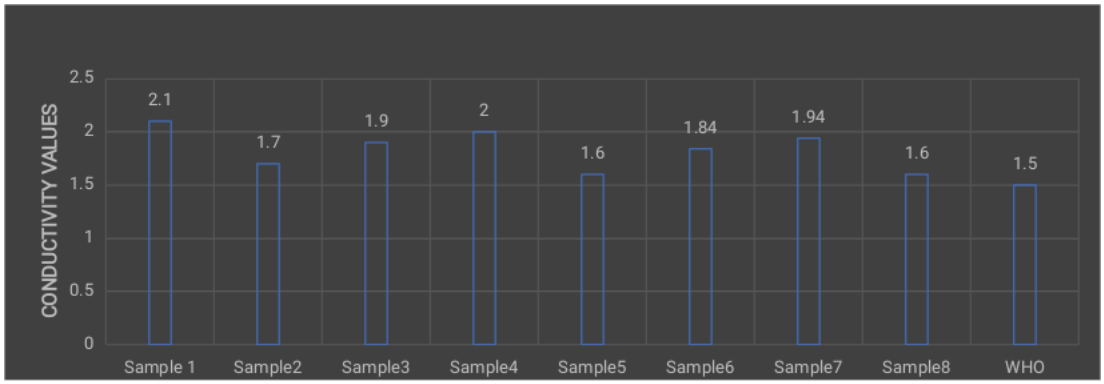


Figure 12 Plot of Electrical conductivity for streams in Mchenga mining area. Also shown on the plot is a bar representing World Health Organization (WHO) maximum permissible concentration

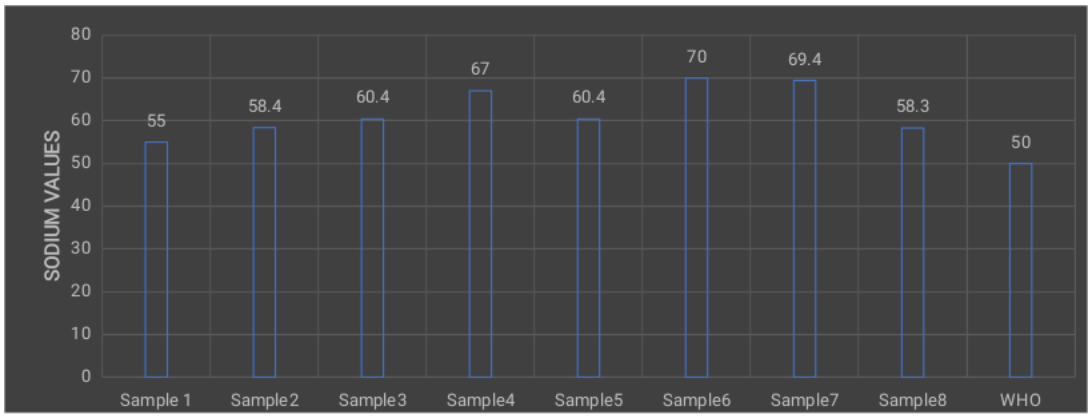


Figure 13 Plot of Sodium for streams in Mchenga mining area. Also shown on the plot is a bar representing World Health Organization (WHO) maximum permissible

concentration.

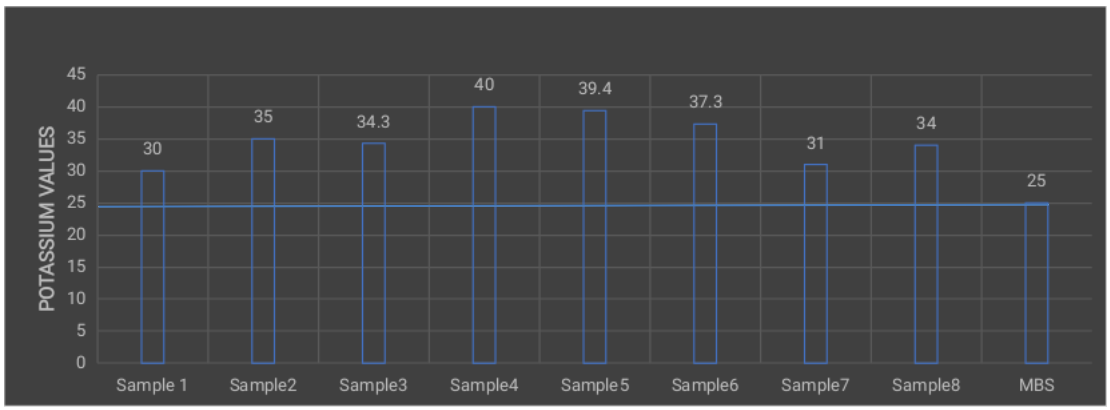


Figure 14 Plot of Potassium for streams in Mchenga mining area. Also shown on the plot is a bar representing World Health Organization (WHO) maximum permissible concentration.

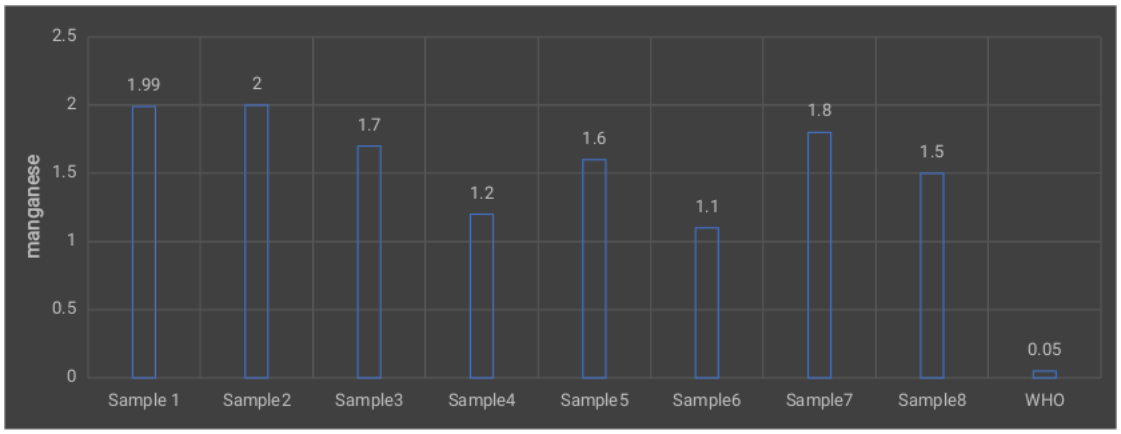


Figure 15 Plot of Manganese for streams in Mchenga mining area. Also shown on the plot is a bar representing World Health Organization (WHO) maximum permissible concentration.

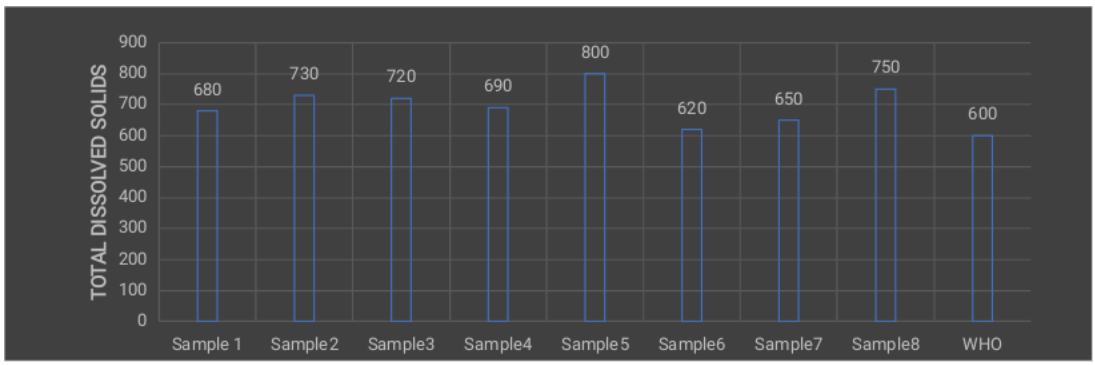


Figure 16 Plot of TDS for streams in Mchenga mining area. Also shown on the plot is a bar representing World Health Organization (WHO) maximum permissible concentration.

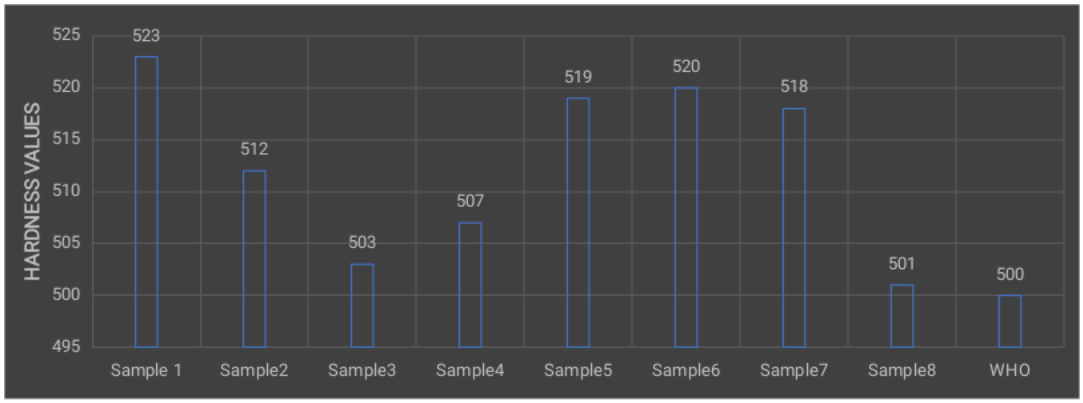


Figure 17 Plot of Hardness for streams in Mchenga mining area. Also shown on the plot is a bar representing World Health Organization (WHO) maximum permissible concentration.

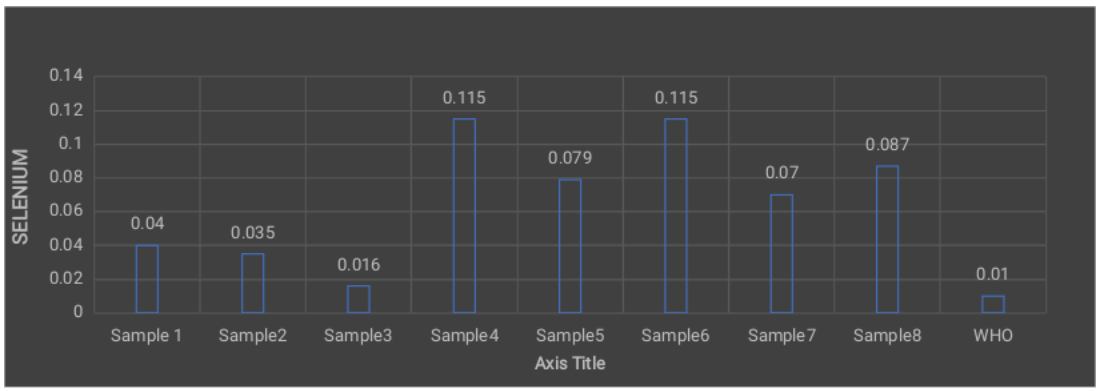


Figure 18 Plot of Selenium for streams in Mchenga mining area. Also shown on the plot is a bar representing World Health Organization (WHO) maximum permissible concentration.

4.2. DISCUSSION

4.0 Introduction

The mining industry has been expanding at a rapid rate keeping in mind the demand of the present day. For this bigger, stronger and faster machines and equipment have been invented to keep pace. The mining industry has been expanding at a rapid rate keeping in mind the demand of the present day. For this bigger, stronger and faster machines and equipment have been invented to keep pace with the demand. Technological developments have been taking place and with it, concerns about the future of the planet. This has flagged greater safety and environmental protection measures to check the pollution caused by the mining industry. The

measures taken with respect to water pollution is commendable but we still have a long way to go before we can pull the planet out of the critical situation it is presently in.

The analysis was carried out using certified instruments namely multi water quality analyzer, flame photometry and atomic absorption spectrophotometry. Malawian standards and WHO standards were used to compare the concentrations of various parameters and accordingly assess the danger each element pose to the environment and on peoples life.

From the observation tables we found that the water samples from both the streams are

4.3. pH

The pH of water is a measure of its reactive characteristics. Low values of pH (pH5.5) indicate an acidic water. The pH affects the treatment and use of water (Heath, 2004). The following are the pH values that were recorded from the water samples of the two streams, north Rukulu with 5.04, 4.5, 4.8, 3.8 point one to point four respectively. Denbo with 5.01, 4.4, 4.6, 3.9 point one to point four respectively. Nelson (2002) defined a pH less than 7 as acidic and a pH greater than 7 as alkaline. As such both streams (north Rukulu and Denbo) around Mchenga coal mine in Chiguliro area are acidic. The pH values do not exceed the minimum acceptable limit of 6.5 recommended by WHO. However, all the stream pH concentration is below the minimum acceptable limit of 6.5. It was therefore concluded that the pH values of the groundwater in the study area were not within the acceptable limits and that they did cause colour and taste perception problems.

4.4. Turbidity

Turbidity is a measure of the degree to which the water loses its transparency due to the presence of suspended particulates. The more total suspended solids in the water, the murkier it seems and the higher the turbidity. Turbidity values range from 25.5 to 30 mg/l. All the eight samples from the two streams reported turbidity values above the limit of 25 mg/l. sampling point number 2 of Denbo stream reported the highest turbidity of 30 mg/l and the suspended solids were visible. This can be a consequence of the corrosion of the metals in the soil with the acidity of the water.

4.5. Electric Conductivity

The study recorded maximum EC value of 2.1 mg/l. The EC values of all the sampled water from the two streams exceeded the acceptable EC limit of drinking water (WHO, 2008). The causes of the increase in the EC values of Mchenga coal mine in Chiguliro area is attributed to the geological factors of the area which consists of high manganese, selenium as well as sodium and potassium metal elements that occur with the coal which gives out free electrons

as they react with acidic water. , the area is composed of the Karroo System strata which display both unconformable and faulted relationships to the underlying Basement Complex gneisses which also contain pyrite and syenites. Dissolution of syenites releases large amount of Calcium and Sodium into groundwater hence increasing the TDS and EC

4.6. TDS

Saka, 2006 reported that EC is strongly correlated with major ions in the groundwater. The TDS for the of the stream samples ranges from 700 mg/L to 1500mg/L. As per TDS classification in Table 1.1 stream water is Brackish (TDS: 700 -1500mg/L). Based on the TDS concentration allowed for drinking water all the streams exceeds the prescribed limit of 600 mg/L (2.2). High TDS concentrations decrease palatability of water and cause gastrointestinal irritation to consumers. Total dissolved solids are has a result of coal tailings and dissolution of the metals by the acid and other chemical weathering processes.

4.7. Hardness.

Hardness is a measure of the calcium and magnesium content in a water sample which is responsible for the precipitation of soap. The hardness of a sample is measured in terms of equivalent $CaCO_3$ in mg/L. The acceptable limit of Hardness is (500-1500) mg/L as per (WHO) recommendations. But due to coal seams and its dissolution, the hardness of water is easily affected (Atkins et al 2010). All the water samples have high values of hardness that are above the minimum acceptable drinking limits set by WHO, however the values are not above the maximum acceptable drinking limits hence having no effect on the quality of the stream water in terms of hardness since they are still within the permissible limit.

4.8. Sulphates.

Khandelwal and Singh (2005) states that the presence of a higher range of sulfate in mine water may be due to due to presence of Miocene sediments having gypsum and limestone. Understanding the geology of the Karoo system where Mchenga coal mining is located, there exist rocks which gives us guide that there must be some sulphates present within them which may result into high sulfate levels in water once in contact with the surface water.

4.9. Selenium.

Selenium is a non-metallic element and among the rarest of the elements, even rare than silver. Due to high selenium levels in the soil, the waters are contaminated at high rate as the tailings

get discharged in the streams. Coal mining as resulted into exposure of selenium in the soil to the upper surface on which it is washed down by discharged production water into the streams where it causes contamination. So both mining and geology of the area have an impact on the quality of stream water in the streams around Mchenga coal mine area. The permissible limit of selenium is (0.01), but looking at the levels of selenium is beyond the permissible limit of WHO. Therefore they is a need of finding mitigation factors to control further spread of selenium.

4.10. Manganese

The levels of manganese concentration is increasing at a rapid rate are the area due to mining activity and geology of the area. High levels of manganese (2mg/l) have resulted into high electrical conductivity of water since there are more cations in water. Manganese concentration cannot be scientifically quantified and hence suggested to be the influence of geology of the area. There is a need to control the increase in concentration of manganese in the stream by using proper methods of mining that control the washing down of manganese from the soil.

4.11. Sodium

Sodium is an important dietary mineral that ends up in naturally in water from rocks and soils. Sodium is present mainly in its compound form. In its elemental form, it comes class 2 hazard i.e. it is extremely harmful. Sodium compounds are naturally present in water but their concentrations can vary depending on the geology and the level of contamination as so it is with Mchenga area. The levels of sodium have greatly increased above the permissible limit (55 to 70 mg/l). Increased intake of sodium may result in high blood pressure, arteriosclerosis, oedema, hyperosmolarity, confusion, increased risk of infection, etc. therefore to protect the people living along these stream, the levels of sodium should be monitored and controlled.

4.12. Potassium

Potassium like sodium is an important dietary mineral occurring in water from the minerals during the weathering process. It is very reactive in its elemental form and making it very harmful. Basing on the results obtained, there is an alarming rate in increase of potassium levels (25.5 to 40 mg/l) which also results into increase in electrical conductivity of water. The geology of the area has a great influence in potassium generation due to its potash content. Increased levels of potassium in the body could lead to hypertension, adrenal insufficiency, coronary artery disease in human being drinking water with high levels of potassium. Therefore, to minimize and control the levels of potassium proper methods of mining should be followed.

4.13. Conclusions.

Some of the stream water samples have their physiochemical parameters such as Selenium, total dissolved solid, electrical conductivity, turbidity, Hardness, Manganese, potassium and sodium exceeding the acceptable limits of WHO recommended guidelines. But some of the parameters are within their permissible limits. Basing on the findings it shows that, stream water pollution is really as a result of coal mining activities through which metals in the soil are exposed to the surface as coal is being mined (geology alteration) and washed down by surface water resulting into high concentration in streams water. Therefore, the hypothesis of the study is accepted to be true that coal mining is really impacting the quality of stream water.

4.14. Title section

This is Body Text style. Use this for the body text. Font Maiandra 12. This is Body Text style. Use this for the body text. This is Body Text style.

4.14.1. Title sub-section

This is Body Text style. Use this for the body text. Font Maiandra 12. This is Body Text style. Use this for the body text. This is Body Text style. Use this for the body text. This is Body Text style. Use this for the body text this is Body Text style.

5. CONCLUSION AND RECOMENDATION

5.1. Conclusion

Introduction

The overall aim of this study was to assessing the effects of coal mining activities on the stream water quality at Mtchenga coal mining area in Rumphi district. A series of field data collection and laboratory experiments were conducted to achieve the study objectives. The following are summary conclusions with reference to the aim and specific objectives of this study.

5.1.1. Summary Conclusions

In chapter one of this thesis, back ground information of coal mining worldwide, Malawi and finally in Rumphi district was provided in relation to its impact on the quality of stream water. In chapter two a literature review on stream water quality in Malawi and Rumphi was conducted. The review identified key knowledge gaps in the context of stream water quality in rural areas. This led to the assessment of water quality status of two streams (north Rukulu and Denbo streams) used in the area. The following are general conclusions based on the specific objectives of this study.

5.1.2. Specific objective: Understand the geology and structure of the area.

The objective was formulated based on the hypothesis that Mchenga coal mining activities may have impacted negatively on stream water quality. Two streams with eight samples (four from each stream) were used as models to assess the variation of Physio-chemical parameters that affects with time since the physio-chemical parameters affects the stream water quality. Findings revealed that a concentration of Na, K, Sen, Mn and other compounds that exceeded the acceptable limits of WHO drinking standards originated from the rocks within the area. The findings further revealed that contamination of water is an issue in the study area and its cause was attributed to geological processes because there were no any artificial sources of contamination that were observed.

5.1.3. Specific objective: Analyze water samples for various physio-chemical parameters to quantify the level of contamination.

To quantify level of contamination of the streams around Mchenga coal mining area, Electric conductivity of stream water, Total dissolved solids and hardiness of stream water were used to quantify the level of contamination hazards. Findings from this study revealed that both the streams recorded high levels of electrical conductivity, total dissolved solids and hardiness from all the eight samples collected. The water in both streams is poor for drinking.

5.1.4. Specific objective: Statically compare physio-chemical parameters with Malawi beaural of standards and world health organization standards.

The findings revealed that there were no significance differences of K, Na, EC, pH, Sulphates, Turbidity, Sen, Mn and Total dissolved solids levels within the stream sampling points. But there is a great significant difference of the above mentioned parameters to who standards concluding that the waters are highly polluted.

5.2. Recommendations

According to the findings of this study, the following recommendations are made:

- The study recommends that water monitoring programs should be put in place to monitor frequently the quality of water that is being used in Mchenga area
- Method of purifying high-level contaminated water should be developed as soon as Possible and the measures to avoid the contaminated water impacts should be implemented
- It is also recommended that detailed stream water quality investigations should be carried out before mining operations commence so as to control pollution levels of the stream through proper mining methods. Further studies should be carried out on the seasonal variations of chemical compounds and the health impacts associated with consumption of stream water with high concentration of natural inorganic compounds especially at Mchenga.

6. REFERENCES

Mshali, R. S., (2000), Rank, Quality and Reserves of the Coal Resources of Malawi, Geological Survey Department, pp. 2-9

Malawi Annual Economic Report, (2015), Ministry of Finance, Economic Planning and Development, Department of Economic Planning and Development, pp. 52-55

Nyirenda, G. B., (2009), National Report on Mining to the United Nation's Commission for Sustainable Development (UNCSD), pp. 4, 12, 14, 16-17

Singh R N, Atkins A K and Pathan A G, 2010, "Determination of ground water quality associated with lignite mining in arid climate", International Journal of Mining & Environmental Issues, Vol. 1,pp: 65-78.

Carlos V M, Pompeo M L M, Lobo F L, 2011, "Impact of coal mining on water quality of three artificial lakes in Morozini River Basin", Actd Limnologica Bratsiliensid, Vol. 23, pp: 271-281.

Singh R N, Dharmappa H B, Sivakumar M, 1998, "Study of waste water quality management in Illawara coal mines", Coal Conference, University of Wollongong, pp: 456-473.

Dwivedi P R, Augur M R, Agarwal A, 2014, "Assessment of water quality of Hasdeo river, Korea district, Chattisgarh: with special reference to pollution due to coal mines", International Journal of Engineering Sciences & Research Technology, pp: 854-857.

Khandelwal M and Singh T N, 2005, "Prediction of mine water quality by physical parameters", Journal of Scientific & Industrial Research, Vol. 64, pp: 564-570.

Muthangya M and Samoei D, 2012, "Status of water quality in the coal rich Mui Basin on Kitui county, Kenya", ARPN Journal of Earth Sciences, Vol. 1, pp: 48-51.
Singh G, 1998, "Impact of coal mining on mine water quality", International Journal of Mine Water, Vol. 7, pp: 49-59.

Verma S, Thakur B and Das S, 2012, “To analyse the water sample of pond located near Nandini mines in Durg district, Chattisgarh, India”, Journal of Pharmaceutical and Biomedical Sciences, Vol. 22, pp: 1-3.

Xu L J and Gao Y M, 2009, “Coal mine subsided water quality assessment and subsided water resource comprehensive utilization analysis”, International Conference on Environmental Science and Information Application Technology, pp: 225-228.

Zakir H M, Islam M. M, Arafat M Y and Sharmin S, 2013, “Hydrogeochemsitry and quality assessment of waters of an Open coal mine area in a developing country”, International Journal of Geosciences Research, Vol. 1, pp: 20-44.

American Public Health Association, 2005. Standard Methods for the Examinations of Waters and Waste Waters, 21st ed. APHA AWWA-WEF, Washington, DC. Malawi Bureau of Standards (MBS), 2000. MBS guidelines on constituents of health significance, MBS, Malawi. Association).

BGS (British Geological Survey) (2004). Groundwater quality: Malawi. Natural Environmental Research Council (NERC). Cañedo-Argüelles, M., Kefford, B., C, P., Prat, N., Schäfer, R., & Schulz, C. (2013). Salinisation of rivers: An urgent ecological issue. Environmental Pollution, 173, 157-167.

Chavula, G., & Mulwafu, W. (2007). Hazardous water: An assessment of water quality and accessibility in Likangala catchement area in Malawi. Malawi Journal of Sci & Techn, 8, 30-41.

Mkandawire, T. (2008). Quality of Groundwater from shallow wells of the selected villages in Blantyre, Malawi. Physics and Chemistry of the Earth, 33, 807-811.

Monjerezi, M. (2012). Groundwater Salinity in lower Shire River valley (Malawi). Dissertation for r the Degree of philosophiae Doctor (Ph.D.), 1-188.
Monjerezi, M., & Ngongondo, C. (2012). Quality of Groundwater Resources in Chikwawa, Lower Shire valley, Malawi. Water Qual Expo Health, 39-53.

MoIWD (Ministry of Irrigation and Water Development), 2011. Preparotory survey report on the project of the groundwater development in Mwanza and Neno. CTI Engineering International Co., Ltd.

Msonda, K. M., Masamba, W. L., & Fabiano, E. (2007). A study of fluoride groundwater occurence in Nathenje, Malawi. J. Physics and Chemistry of Earth, 32, 1178-1184.

WHO (World Health Organisation), 2008. Guidelines for drinking-water quality. Third edition. Vol. 1, Recommendations. WHO Press Geneva, Switzerland.

Saka, J.K., 2006. A chemical study of surface and groundwater in the Lake Chilwa Basin, Malawi. Groundwater Pollution in Africa, p.229.

Staines, M. (2002). Water/Wastewater problems and solutions in Rural Malawi. Mphil Thesis. UN Department of Economic and Social Affairs, 2016.

Vellemu, E. C. (2017). The Ecological Risk of Acid Mine Drainage in Salinising Landscape. Thesis, 1-190.