THE UNIVERSITY OF ZAMBIA

SCHOOL OF MINES

EFFECTS OF MINING OPERATIONS ON AIR AND WATER QUALITY IN MUFULIRA DISTRICT OF ZAMBIA: A CASE STUDY OF KANKONYO TOWNSHIP

BY

DARIUS MUMA

Lusaka

December, 2019

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DARIUS MUMA

A dissertation submitted to the University of Zambia in partial fulfillment of the requirements of the degree of Masters of Mineral Science in Sustainable Mineral Resource Development.

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Declaration

I, **Darius Muma,** declare that this dissertation was written in accordance with the rules and regulations governing the award of Master of Science of the University of Zambia. I further declare that the dissertation has neither in any part nor in whole been presented as a substance for award of any degree, either to this University or any other University.

Signature: ______________________

Date: ______________________

Dedications

To my late grandfather Dr. Henry Langazye Kaluba, Reverend Nelson Jilowa, my father Mr. Greenwell Chibulu Muma, my wife Priscilla, my children- Martin Kazandwe, Precious Mwaba Gracious Kunda and Joseph Kaindu for their encouragement and valuable support.

Certificate of Approval

This dissertation of **Darius Muma** is approved as partial fulfillment of the requirements for the award of Master of Mineral Science in Sustainable Mineral Resource Development of the University of Zambia.

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Abstract:

Air and water pollution in the Zambian Copper Mining Industry is considered to be one of the most significant environmental problems facing the communities living in and around the mining operation areas. It is quite a complex issue which cuts across various environmental, social, economic and political dimensions.This thesis highlights the effects of mining operations on air and water quality in Kankoyo area of Mufulira district. Recent investments and technological improvement in the copper mining and copper processing plants have had a significant positive impact on the capture of sulphur dioxide emissions as well as minimizing mine effluent discharges into the natural streams. However, numerous reports still cite air and water pollution in Kankoyo as one of the major environmental problems.

The investigation involved sampling of the ambient air, mine effluent discharge and domestic water samples and the subsequent determination of sulphur dioxide and various water quality parameters respectively. The results obtained indicate significant reductions in terms of sulphur capture and sulphur dioxide emissions from the Copper Smelter. The average sulphur capture was 48% from 2007 to 2013 and about 94% from 2014 to 2018. The average annual sulphur dioxide emissions for 2017/2018 at 144.5μgm^3 in Kankoyo Township were 15.6% above the statutory limit of 125μgm^3 in ambient air (μgm^3 /24hrs). The general water quality meets the allowable statutory limits despite that the water quality in this area may not only be attributed to the mining activities but also from the dilapidated water infrastructures which may be the likely source of alternative contamination.

Key Words: SDGs, scientific, environment, pollution, effluent, emissions.

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List of Acronyms

Abbreviation	Description
CSO	Central Statistical Office
CSR	Corporate Social Responsibility
CTPD	Centre for Trade Policy and Development
ECZ	Environmental Council of Zambia
EEA	European Economic Area
EMF	Environmental Management Facility
EPPCA	Environmental Protection and Pollution Control Act
IFC-World Bank	International Finance Corporation-World Bank
ISASMELT	Smelting technology based on the use of a simple furnace design which is readily enclosed to eliminate emissions to the surrounding environment
LDL	Low Detection Limit
MCM	Mopani Copper Mines
MMD	Ministry of Mines and Mineral Development
MNRD	Ministry of Natural Resources Development
MLNRD	Ministry of Lands and Natural Resources Development
MWSC	Mulonga Water and Sewerage Company
OECD	Organisation for Economic Co-operation and Development
PFCs	Poly fluorocarbons
PM	Particulate Matter
PNA	Poly-Nuclear Aromatics
RSA	Republic of South Africa
SO_2	Sulphur Dioxide
SO_x	Oxides of Sulphur
UK	United Kingdom
UN	United Nations
UNEP	United Nations Environmental Programme
UN WAAP	United Nations Water Assessment Programme

USA	United States of America
UV	Ultra Violet
WEED	World Economy, Ecology and Development
WHO	World Health Organisation
ZABS	Zambia Bureau of Standards
ZCCM	Zambia Consolidated Copper Mines
ZEMA	Zambia Environmental Management Agency

CHAPTER ONE
BACKGROUND TO THE STUDY

1.0 Overview - Structure of the Dissertation

The study consists of six Chapters. The first Chapter introduces the study and presents the background to the problem under investigation, the statement of the problem, the significance of the study and the purpose of the study and the Environmental Sustainability context of the study. The Chapter also outlines the objectives, the research questions, operational definitions as well as the scope of the study. The second Chapter presents a review of literature related to the topic. The methodology of the study is described and outlined in Chapter three. Chapter four presents the results of the study while Chapter five discusses these results. Finally Chapter six draws the conclusion and makes some recommendations.

1.1 Introduction

The complexity and contextual nature of the problem of air and water pollution in Kankoyo Township emanates from the early times of the inception of two initial copper reverbatory smelting furnaces in 1937 (Ross & Vries, 2005) and also from the increase in the mining operation activities in the early 1940's followed by subsequent mining operation developments up to the present day. Apparently, this has been partly a historical and current environmental problem that has attracted serious concern from the local and international community. However, the mining operations in this area have undergone several technological and administrative changes that have recorded significant operational transformations over the past decades.

1.2 Description of study area

1.2.1. Overview

This section looks at the description of the study area where the research was conducted. It specifically focuses on the geographical location, physical characteristics, social economic characteristics and the area selection criteria. It also gives detailed conceptual and theoretical framework of the study.

1.2.2 Demographic background

Kankoyo is an old township located on the western side of Mufulira District in the vicinity of Mopani Copper Mine operations. It is the low cost area and one of the most densely populated areas in Mufulira District. Kankoyo township is one of the major settlements in Kankoyo constituency which has a population of about 45, 258 people (22,754 males and 22,504 females) (CSO, 2013). This represents a percentage population of 50.3% and 49.7% of the male and female population respectively. According to (Action Aid Zambia, 2015) study report, 'apart from a few people in Kankoyo working for the mines, the greater population is unemployed and a few people are engaged in informal trading of assorted merchandise. Since many women of Kankoyo have low formal education, most of them are not in formal employment but are engaged in informal trading activities as described above.

1.2.3 Geographical location

Kankoyo Township is generally a high densely populated community on the western side of Mufulira district. It was created as a settlement for the majority black general mine workers in the early 1930's. Kankoyo Township is located on the downwind of the smoke spewing out of Mufulira Copper Mine's smelting plant. "The Township lies between 28^{o}13' 49^{o}57'' E and 12^{o}31' 55'' S of Mufulira town on the Copperbelt province of Zambia" (SPK Consulting, 2003). It is located on the downwind of the Mopani Copper Mine (MCM) Copper Smelter at the altitude of about 1,288 meters and topography between elevations of 1,250 and 1,400 meters (Mopani Copper Mine, 2004). Kankoyo area is drained by a number of streams such as Luansobe, Butondo, Mupambe and Kansuswa which eventually discharge into the Kafue River located about 15 km to the west of the Township (Mopani Copper Mine, 2004). Figures 1.1 on the next page shows the geographical location of Kankoyo in Mufulira district.

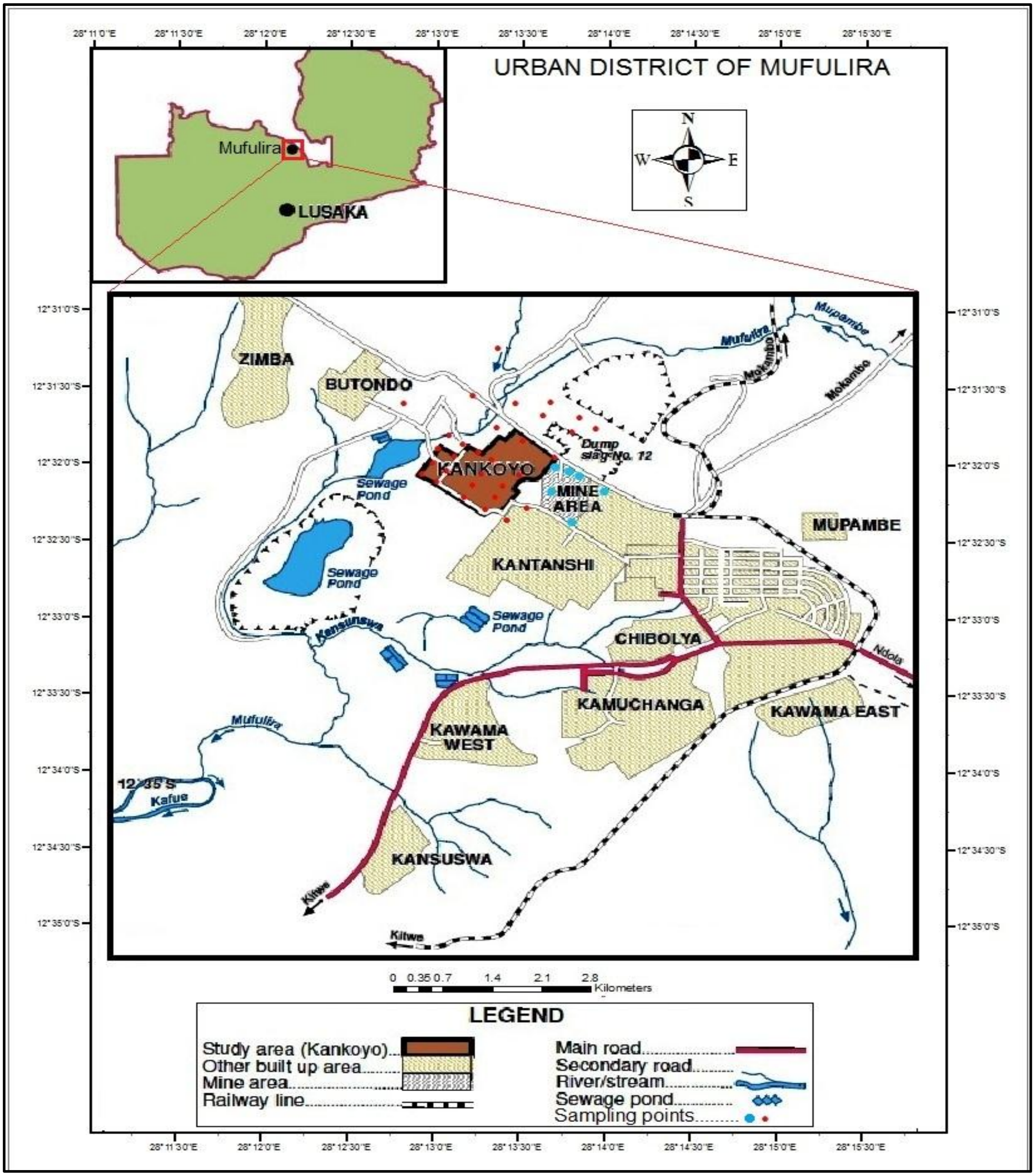

Figure1.1: Map showing location of Kankoyo in Mufulira district

Source: Adapted from (Chipatu, 2011)

1.2.4. Physical characteristics of Kankoyo as a study area

This information was extracted from the previous environmental studies and from the investigations and observations carried out as part of this study.

1.2.4.1 Climate

There are three distinct seasons, namely Cold and dry season; May to July Hot and dry season; August to October and Wet season; November to April. The climate is tropical with maximum rainfall between 1200mm and 1400mm and mean temperature of 24^{o}C. This relatively high precipitation occurs mainly in the summer months, between November and March and falls principally as intense thunderstorms. Generally the rainfall on the Copperbelt has low variability. The 30-year maximum 24-hour precipitation has been calculated as 126 mm and the 100 year maximum 24-hour event as 149 mm (Mopani Copper Mine, 2004). The meteorological station in Mufulira is Kafironda station located 10km from Kankoyo Township. Data from this station indicate that the predominant wind direction is from North west and south west. According to Mopani (Mopani Copper Mine, 2004), wind speed ranges from 2.4m/s and 2.9m/s. However, wind gusts can reach 30m/s.

1.2.4.2 Soils and vegetation

The Copperbelt province, Kankoyo Township inclusive, has red lateritic soils with sandy top soils overlaying more loamy clayed subsoil. The soil profile is thickest over the high ground and gradually thins towards the dambos and stream valleys. These soils are susceptible to erosion by rainwater if soil conservation practices are not used. The soils are acidic but acidity is aggravated by the mining activities. Christophe (Christophe, 2009) observes that on some days, the township is smothered in a choking fog making soils acidic and also affecting plant growth. He further argues that the release of nearly 700,000 tonnes of sulphur dioxide per year into the air has left the Kankoyo Township a canker on an otherwise fertile verdant landscape. Consequently, only two things grow and these are avocado trees and cactus.

1.2.4.3 Social Economic Characteristics

The mining industry is the principal employer for people on the Copperbelt Province. However, (Mopani Copper Mine, 2004) reports that labour shocks brought about by the privatisation of the mining industry in 1991 triggered high unemployment levels in Kankoyo Township. High unemployment levels have further translated into high poverty levels among the people. Consequently, most residents do not have access to social services such as good sanitation and clean water supply. In most places, dilapidated housing structures with iron roofing sheets corroded by acid rain exist. Besides, open sewers and broken down water network run parallel together posing a great risk for water contamination. Christophe also shrewdly observes that due to the open sewers, cholera is common in the area (Christophe, 2009).

1.2.5. Purpose of the study

The purpose of the study was to carry out an investigation into the effects of mining operations on the air and water quality in Kankoyo Township of Mufulira District, in order to generate information that can be used by the mining industry and the government including other interested parties to help resolving the resultant problem of air and water pollution.

1.3 Environmental Sustainability context of the study

The study of environmental and sustainable issues in the mining industry has gained prominence within the academic community during the last decade. Environmental degradation in the exploited areas, noise, dust, air pollution and surface and groundwater pollution are usually the main environmental hazards produced by mining operations. Likewise, Lindahl also shrewdly observes that “the main environmental problems associated with mines in Zambia are pollution of air, soil and water, geotechnical issues and land degradation (Lindahl, 2014)”. The mining sector has strong and direct social, environmental and economic impacts (Lins & Horwitz, 2007). Therefore, mining companies must be aware of the potential impacts of their activities, and plan how to execute strategies to have positive net outcomes that are sustainable in the long term. This study summaries some important sustainability issues in the mining industry, illustrates the sector’s best practices, and suggests sustainable practices for mining in Zambia. Environmental stewardship is the keystone to sustainability in mining and industry (Zvarivadza, 2015).

Mining companies by virtue of their complexity, have always sought ways of improving production, while reducing operating costs through adoption of various strategies, such as labour reduction, implementing of austerity cost and safety measures. A mine must be profitable in order to be sustainable (IFC-World,Bank, 2014). The mining industry is a great contributor to the global revolution of electronic vehicles and renewable sources of energy.

A sustainable mining venture takes cognisance of its impacts on the environment and adopts appropriate measures to address such impacts (Zvarivadza, 2015). Sustainable mining is about balancing financial, social and environmental issues, to ensure the success of the company, as well as the sustainable livelihoods of the communities. It involves community engagement and investments, respecting human rights and protecting the environment, being transparent and acting with integrity (IFC-World,Bank, 2014). It is a tool for balancing economic, social, and environmental considerations. Although the mining industry in Zambia has contributed greatly to the economic growth of the country, it has also contributed to the increase of environmental impact. Some of the Environmental hazards associated with mining activities are listed in Table 1.1 below:

Table 1.1: Environmental Hazards Associated with Mining Activities

MINE CREATION	EXTRACTION	SMELTING AND REFINING
• Deforestation and destruction of animal habitats, particularly in the process of making charcoal from wood. • Use of native land and officially protected natural areas • Creation of potentially toxic waste rock	• Creation of mine waste with toxic emissions • Water table contamination: • Tailing dam failures • Disposal and rivers and oceans • Deep water disposal • Acid mine drainage: sulfides in waste rock react with water to produce sulfuric acid • Linked high skin cancer and tumors, liver disease, nerve damage, and growth retardation in children • Damages water supply and marine life • Considered irreversible and few treatment options exist	• Major energy consumer • Major air polluter - Primarily releases nitrogen and sulphur, major components of smog and acid rains. - Releases greenhouse gases including CO_2 and PFCs - Also emits lead, arsenic, cadmium and zinc - Contributes to lead poisoning, respiratory illnesses and possibly other diseases.

Source: Adapted from: *(Lins & Horwitz, 2007)*

Government regulations and licenses to operate mining companies also demands that for mining companies to be economically viable they need to operate in an environmentally and socially responsible manner. Zambia's environmental legal regime with regard to the operation of the mining industry is clearly provided for in the Environmental Protection and Pollution Control Act (EPPCA) of 1990 which was repealed in 2011 by the Environmental Management Act No. 12. In 2013, all the EPPCA regulations were upgraded by SI No.112-Environmental Management (Licensing) Regulations with yet stiffer penalties upon conviction of environmental violation. The information in Table 1.2 on the next page gives a brief summary of Zambia's key pieces of Environmental Legislation and Regulations.

Table 1.2: Zambia's Key Pieces of Environmental Legislation and Regulations

Year	Environmental Component Target /Objective
1970	*Natural Resources Act/Nature Conservation.
1971	*Game Parks and Birds Act/Wildlife Conservation.
1974	National Fisheries Act/ Protection
1978	*Public Health Act/ Waste Management & Environment
1982	Ratified the 1972 World Culture and Heritage/Eco-tourism Statutes of International Union for the Conservation of Nature and Natural Resources (IUCN).
1985	Petroleum Exploration & Production Act/Pollution Control National Conservation Strategy/Sustainable use of resources
1986	*Local Administration Act (Trade Effluents)/ Pollution Control.
1987	Zambezi River Authority Act/ Water Resources Management.
1988	National Heritage Act/Conservation Tourism.
1990	*Enacted Environmental Protection and Pollution Control Act/Integrated Pollution Control and leads to the establishment of Environmental Council of Zambia in 1992. *Forestry Act (Amended in 1999) and currently under review Ratified Montreal Protocol and Vienna Convention
1991	*Zambia Wildlife Act (Amended 1998).
1993	Ratified Ramsar and Bonn Convention; and the Endangered Species of Wild Fauna and Flora (CITES) Convention on Biodiversity. **Water Pollution Control Regulations (Effluent and Waste SI No. 72).
1994	Ratified Basel Convention/Trans boundary hazardous waste; and Pesticides and toxic substances Regulations (SI No. 20)/Agriculture and Environment.
1995	Town and Country Planning Act 1995 (approval and revocation of development plans). The Energy Regulations Act (Cap 436; SI No. 16 of 1995)/Energy and Environment.
1996	**Air Pollution Control (Licensing and Emissions Standards) Regulations (SI No. 141). Ratified UN Framework Combating Desertification.
1997	Environmental Impact Assessment Regulations (SI. 28).
2000	**Hazardous Waste Management Regulations (SI No. 125).
2001	**Ozone Depleting Substances Regulations (SI No. 27)
2003	*Water Act: applies to water rights, impounds for irrigation.
2006	Ratified Kyoto Protocol-UNFCCC.
2008	Launched the first Environmental Policy
2011	2011 Environmental Management Act No.12/ Repeals Environmental Protection and Pollution Act of 1990. More and stiffer penalties to violators. Water Resources Management Act/Repeals Water Act of 2003.
2013	2013 Environmental Management (Licensing Regulations) SI. No. 112/ Repeals all Regulations except for regulations 1997, SI No 28. To make stringent all environmental regulations.

*Repealed Acts or regulations. ** Repealed specifically by Environmental Management (Licensing Regulations) SI. No. 112 of 2013

Source: International Journal of Environmental Protection and Policy 2015; 4(3): 79-87

Mining companies are not only required by law to ensure sustainable water use, but have their own initiatives like reuse and recycling as a means of avoiding over-abstraction of water from natural water sources. For example, water from underground is pumped to surface reservoirs where it is settled and the clear water is pumped back into the mine again in a cycle (Wimberley, 2008). The mining sector has strong and direct social, environmental and economic impacts. Table 1.3 below summarizes the stakeholder expectations for sustainable Mining in Africa.

Table 1.3: Stakeholder expectations for Sustainable Mining in Africa

GOVERNMENT	COMPANIES	CIVIL SOCIETIES / COMMUNITIES
• Local economic development • Address capacity needs of the local government • Poverty reduction • More prosperous and resilient communities • Better infrastructure • Shared prosperity • Clean environment	• Mitigate risks • Reputational issues • Social license to operate • Increased development impact • Responding to shareholder concerns • Reduce negative impact	• Improve well being • Build capacity • Reduce poverty • Respect for human rights • Access to improved infrastructure and services (water, energy, educations, health, security) • Access to jobs and income generation activities • Clean environment

Source: IFC-World Bank (2014) Sustainable and Responsible Mining in Africa

1.4 Problem statement

The environmental effects of mining activities on air and water are in Kankoyo township are very noticeable. Although some studies on the impact of mining on air and water on the environment have done on the Zambian copper mining towns (World Bank, 2002), there is still inadequate and updated information on the air and water quality in Mufulira District. For example; The Centre for Trade Policy and Development report cites air and water pollution in Kankoyo as one of the major environmental problems (Centre for Trade Policy and Development, 2012) but does not adequately quantify the extent of the pollution in Kankoyo Township. The persistent consumer complaints on the quality of water (i.e. bad taste, scent, stomach pains, heavy suspended solids etc.), the general discontent of the residents on the air quality (e.g. presence of sulphur dioxide (SO_2), acid fumes and dust) and the complaints from the local farmers on the destruction of their crops including fish and animals (Centre for Trade

Policy and Development, 2012) as a result of the air and water quality from the mining activities are some of the indicators of the seriousness of this problem. “This situation has resulted in poor health conditions on both the physical environment and the Mufulira residents of Kankoyo Township” (Christophe, 2009). In relation to environmental problems that emanated from copper mining, Kankoyo residents specified pollution of land, water and air. Others were chest infections, corrosion of roof for houses and cracked buildings that were close to the mine. (Chipatu, 2011). According to the (World Bank, 2002) up to 75,000 people are potentially affected in Kankoyo and Kantanshi townships due to atmospheric emissions of SO_2. Sulphur dioxide is a noxious gas that can cause respiratory damage as well as impairing visibility when in high concentrations. Sulphur Dioxide also has the potential to form Acid rain (H_2SO_4) which causes health, environmental and infrastructural problems to human society (Ecotech, 2011).

Industrial air pollution in the Zambian mining regions is a localized problem, and occurs in areas where industrial activities take place, however the effects of air pollution in Mufulira District affects much of the area especially the western and south-western regions of the District which lies on the windward side road away from the copper smelting plant. Some of the effects of air pollution includes: headaches, nausea, allergic reactions, acid rain and respiratory related diseases such as bronchitis and lung cancer (Mohammad, et al., 2018). “Problems associated with the control of emissions include lack of financial resources to put in place emission control equipment, old worn-out infrastructure which results in fugitive emissions, old and out-dated technologies which were put in place without much consideration for environmental protection, general negligence or lack of concern for the protection of the environment, as well as ignorance” (Abad, 1993).

Besides, enhanced Hydro geochemical processes due to large-scale mining activities, mine effluents discharges and sulphuric acid spillages have greatly contributed to the poor quality of both underground and surface water resources in Kankoyo Township. There have been serious incidences of underground and surface water contamination with severe health effects in the district. For instance, “in January 2008, acidic water struck Mufulira again and close to 800 people had to be hospitalized after drinking the water (Simpere, 2010)”. The British Broadcasting Corporation reports, “at least 13 people in Northern Zambia have been admitted to hospital after drinking water alleged to have been contaminated by a nearby mine. Officials from

Mufulira, who visited the site, claim acidic effluents from Mopani Copper Mines accidentally entered the water supply system." (Chibale, 2008).

Mining on the Copperbelt has recently undergone a lot of operation and infrastructural changes (e.g. technological upgrade in the extraction and refining processing of copper including advanced mechanization of mineral extraction in the mining operations including mine ownership changes (Beene, 2015) in the recent past, coupled with significant technological innovations, robust community social and corporate responsibility programs, strategic social and stakeholder engagements and environmental educations awareness. Some of the mitigation measures against environmental pollution from the mining activities includes: introduction of mine effluent discharge, routine audit of Environmental Management Plans (EMPs) for all mines and the setting up of an Environmental Management Facility (EMF) by the government of the republic of Zambia to take up ownership of all environmental liabilities that were created by ZCCM operations and were not taken by new mine owners; this is estimated to cost about US$ 200million (WEED, 2008). A comprehensive investigation into this problem could be a source of valuable qualitative and quantitative information that can be used to help resolving this problem effectively and hence, the significance of this present study.

1.5 Research question

The research was focused on the following questions:

A. General Research Question

What are the causes and effects of air and water pollution resulting from mining and mineral processing?

B. Specific Research Questions

1. What are the effects of mining operations on the air quality in Kankoyo area?
2. What are the effects of mining operations on the water quality in Kankoyo area?
3. What are the current available technologies that can be used to minimize impact of air and water pollution from the mining and mineral processing activities?
4. How can the Zambian copper mines be effectively and responsibly managed with respect to air and water pollution?

1.6 Study objectives

A. General objective

The main objective of the study was to carry out an investigation into the effects of mining operations on air and water quality in the Kankoyo Township of Mufulira District.

B. Specific objectives.

1. To investigate the effects of mining operations on the air quality in Kankoyo area.
2. To investigate the effects of mining operations on the water quality in Kankoyo area.
3. To determine the extent of air pollution in Kankoyo area.
4. To determine the extent of water pollution in Kankoyo area.
5. To propose sustainable solutions to air and water pollution challenges in Kankoyo area.

1.7 Research Methodology

This is a field case study, which is both quantitative and qualitative in scope. The field work involved detailed observations and actual collection of samples from the 30 selected households. Seven (7) Weather sampling stations located in different strategic sites of Mufulira District were used for collection of information on air quality data. Thus, the sample size consisted of 31 water sampling points, seven (7) air monitoring sampling stations. In addition, a few critical sampling points for mine water effluents within and outside the mining operation site were also used to obtain additional information on the effects and extent of water pollution in Kankoyo Township.
With limited time and a constrained financial budget in data collection, the selected target population was specifically Kankoyo Township including other strategic sites (i.e. Market and Police Post) around and within Kankoyo Township. The selection of the target population in this study was randomly and systematically selected based on the established settlement plan. Structured questionnaires were administered to the residents of Kankoyo to help collecting additional information.

To ascertain the effectiveness of air pollution control strategies employed at the mine site, several field visits were conducted to check on the environmental services management control protocols at Mufulira mine site. The checks revealed that, the ISASMELT emissions control technology is able to capture over 90% of sulphur dioxide from the copper smelting and sulphuric acid processing plants. Besides, the effective implementation and incorporation of the Environmental Management system (EMS 14001) into all the process plants also serves as a control strategy to help achieve reductions in air and water pollution incidences.

1.8 Significance of the study

The quality of air and water is at the core of the survival of the human beings. The demand for good air and water quality is at the top of the agenda on governmental programs both at national and international levels. A study of this kind is very important, because it provides up to date and relevant information on the status of air, water quality, in Kankoyo Township, which can be used for making informed decisions in mitigating the impacts of environmental pollution arising from the mining activities.

Further, the findings of this study will not only add value to the general body of knowledge concerning the issues of air and water pollution from mining operations in Kankoyo area, but will also help stakeholders in planning the direction of purpose and policies that defines the operation of the mining company and its business. It will also enhance the knowledge of the researcher on air and water pollution in the mining industry using Mopani Copper Mines in Mufulira as a case study.

1.9 Scope of the study

This study was conducted in Kankoyo Township of Mufulira District in the Copperbelt region of Northern Zambia. The exact location of the study was be the southern and western areas of the District where the pollution effects are very significant; this is the area astride the windward side of the copper smelter and acid plant operations. The primary focus area was the mining communities surrounding the Mopani Copper Mines (MCM) mining operations, as a case study area, with specific attention to air and water quality. The study focuses on MCM mining operation practices, and its effects on the natural and physical environment, so the technical process specifications are not discussed this research. The study was conducted using both primary and secondary data research methods, other data for this study where obtained through review of documents and other related articles of relevance to the study. The duration for the study was approximately eleven months – starting from October 2017 to August 2018.

1.10 Operational definitions

Air pollution: The contamination of the natural air by mixing it with different pollutants such as harmful fumes and chemicals.

Air quality: Refers to the condition of the air within our surrounding. Good air quality pertains to the degree which the air is clean, clear and free from pollutants such as smoke, dust and smog among other gaseous impurities in the air.

Environmental issues: Defined as problems with the planet's systems (air, water, soil, etc.) that have developed as a result of human interference or mistreatment of the planet.

Environmental pollution: Refers to any undesirable change in the physical, chemical, or biological characteristics of any component of the environment (air, water, soil) which can cause harmful effects on various forms of property.

Environmental Sustainability: is defined as responsible interaction with the environment to avoid depletion or degradation of natural resources and allow for long-term environmental quality.

Increment delimitation error – the error that results from incorrect shape of the volume of material extracted from the sampling unit to form the sample.

Water pollution: Any physical, biological or chemical change in water quality that adversely affects living organisms or makes water unsuitable for certain use.

Water quality: Refers to the condition of the water, including chemical, physical, and biological characteristics, usually with respect to its suitability for a particular purpose such as drinking or industrial use.

1.11 Ethical considerations

The principles of autonomy, beneficence, and justice were serious taken into consideration whilst executing this project.

CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

This Chapter presents literature review as related to the subject of the research. The Chapter first shows the importance of studying air and water pollution and thereafter, the different effects of air and water pollution from global, African and Zambian contexts respectively.

2.1 Introduction

Air and water pollution control are necessary for better environment and good health of human beings and other living organisms including non-living things. Therefore the study of air and water pollution is very important in all aspects of our lives. As Zambia continues to industrialise, air and water pollution are some of the most likely environmental problems that will be growing with the national development. The lack of adequate air and water-treatment facilities presents substantial health risks to the growing population especially in the urban areas. This will undoubtedly, not only require government effective intervention to ensure proper use of natural resources to limit environmental degradation but will also require involvement of all stakeholders in the fight against environmental protection.

The Environmental Protection and Pollution Control Act (EPPCA) of 1990 which led to the establishment of the Environmental Council of Zambia (ECZ) is the principal law on Zambian environmental control and protection; it is based on the polluter pays principle. The Act is supported is supported by the following 7 regulations:

1) Waste Management Regulations ,(SI 71 of 1993)
2) Water Pollution Regulations ,(SI 72 of 1993)
3) Air Pollution Control Regulations, (SI 142 of 1996)
4) Pesticides and Toxic Substances, 1994
5) Environmental Impact Assessment Regulations, (SI 28 of 1997)
6) Hazardous Waste Management Regulations, 2001
7) Ozone Depleting Substances Regulations, 2001

Although the EPPCA has reasonable objectives, effective monitoring and execution of this regulation remains a big challenge due to limited financial and institutional capacity.

According to (Hwedie, 1996), "undoubtedly the ECZ has been able to formulate regulations; however, its functions are too numerous while the resource base to support such functions is limited. Therefore, implementation of the provisions of the Act faces a number of difficulties".

2.2 Importance of studying air and water pollution- an environmental perspective

Air and water pollution are some of the most prominent and dangerous forms of pollution in the environment across the globe. The term "air pollution" encompasses any substance which by its presence in the atmosphere impairs the public health and welfare, the use and enjoyment of land, or the economy (Aborn & Axelrod, 1968). Water pollution is the contamination of water bodies (e.g. lakes, rivers, oceans, aquifers and groundwater), very often by human activities. Water is important for all forms of life including its unlimited applications in all economic sectors worldwide. In addition to household uses, water is vital for agriculture, industry, fishery and tourism etc. Air and water are essential for the survival of any form of life. Polluted water poisons plants and animals, and has a direct impact on humans' life. Therefore the importance of studying air and water pollution is very inevitable and deserves special attention in all aspects.

2.3 Effects of air and water pollution: A global perspective

Two major effects of considerable significance are Health and Environmental Effects.

a) Health Effects

Air pollution can cause long-term and short-term health effects. It is found that the elderly and young children are more affected by air pollution. Short-term health effects include eye, nose, and throat irritation, headaches, allergic reactions, and upper respiratory infections. Some long-term health effects are lung cancer, brain damage, liver damage, kidney damage, heart disease, and respiratory disease. Studies have shown that air pollution is strongly associated with respiratory conditions such as pneumonia, bronchitis and asthma, among others (UNICEF, 2016). It can also exacerbate underlying health issues and prevent children from going to school (Jepsen & Richard, 1973), and there is emerging evidence that it can disrupt physical and cognitive development (Thorsteinsson, et al., 2011). If left untreated, some health complications related to air pollution can last a lifetime. Thus, air pollution is one of the causes of deaths in the world. The European Commission (The European Commission for the Environment, 2013) estimates that air pollution caused 420,000 people to die prematurely in the European Union in 2010. Of particular concern are particulate matter (PM) – a type of fine dust – ground-level ozone (O_3) and nitrogen dioxide (NO_2).

b) Environmental Effects

Environmental impacts from mining operations are significant and quite often severe, especially in developing nations which lack adequate management of the sector (Lindahl, 2014). In Mufulira District the major environmental effects from the mining operations are mainly water and air pollution. Water pollution is mainly caused by the mine effluents and acid spillages. According to (Nachiyunde, et al., 2013) "Zambia: MCM Acid Spillage" (2008) reports that Mopani Copper Mines (MCM) in Mufulira has disclosed that part of its ground water table has been contaminated following an acid spillage into the main domestic water supply system that pumps water to households in former mine townships. This has serious consequences to human beings and other living organisms. The main cause of air pollution is sulphur dioxide from the copper smelting plant. Oxides of sulphur (SO_x) can irritate respiratory passages and aggravate asthma, emphysema and bronchitis (Lindahl, 2014).

Air pollution causes damage to crops, animals, forests, and bodies of water. It also contributes to the depletion of the ozone layer, which protects the Earth from the sun's UV rays. Another negative effect of air pollution is the formation of acid rain, which harms trees, soils, rivers, and wildlife. Other major environmental problems associated with air pollution include climate change and the loss of biodiversity through the extinction of many species (Alloway & Ayres, 1997).

2.4 Effects of air and water pollution in USA

Air and water pollution is one of the major environmental problems in the United States. "Air pollution is a significant problem in the United States that affects human health and well-being, ecosystem health, crops, climate, visibility and man-made materials (Nowak, et al., 2014)". The most common air pollutants in USA are: carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), lead (Pb), sulfur dioxide (SO_2), and particulate matter (PM), which includes particulate matter less than 10 microns (PM_{10}) and particulate matter less than 2.5 microns ($PM_{2.5}$) in aerodynamic diameter (Nowak, et al., 2014). Water pollution is a serious threat to in the USA.
Air and water pollution in the United States of America (USA) poses numerous health and environmental threats. Mining, construction, use of fossil fuels and large industrialization in USA has been some of the cause of air and water pollution. The most recent studies by the Environment American Research Centre (Figdor, 2009) show that the "National rate of growth in carbon dioxide pollution has slowed but emissions still remain above the levels of two decades ago and well above the levels needed to prevent the worst impacts of global warming". This is indication that pollution is still a big problem in our global community. The negative effects of air and water pollution on living organism will not only be limited to the human and animal health but also include the whole natural environment. Air pollution can cause serious environmental damages to the groundwater, soil, and vegetation.

2.5 Effects of air and water pollution in UK

Although the United Kingdom (UK) and the much of the Western world have developed monitoring and control systems of air and water pollution, pollution still remains one of the crucial environmental and health problem in some areas of the UK. Recent studies by the Department for Environment, Food and Rural Affairs (UK , 2016) reports that "Medical evidence shows that many thousands of people still die prematurely every year because of the effects of air pollution. Air pollution from man-made particles is currently estimated to reduce average UK life expectancy (from birth) by six months".

Air pollution in the United Kingdom has long been considered a significant health issue especially in major cities like London. A lot of efforts have been done in reducing emissions of air pollutants in the UK but the atmospheric concentrations of the level of pollutants is not always proportionate to the reduction in emissions. This is in part because of the transboundary nature of air pollution which has recently been identified. For example emissions of the pollutants that lead to ozone formation have reduced substantially in the UK, but this is not reflected in the long-term trend in ozone concentrations. This may be partly explained by a proportion of the ozone experienced in the UK originating from releases of precursor pollutants that are transported across from mainland Europe and trends in global hemispheric background concentrations (Defra, 2019).

There is also a wide range of human activities significantly affecting water quality in the UK. According to the (UK Environmental Agency, 2016), the biggest cause of incidents affecting water were containment and control failures (169 of 325 incidents, 52%). This continues the trend of previous years. It includes incidents caused by abnormal process operations, pipe failures, spillages, plant failures, control system or measure failures, sewer failures or overflows and storage tank failures. Containment and control failures on farms were the single largest cause of incidents affecting water (54 incidents) followed by those associated with the water industry (46 incidents). Therefore, air and water pollution still remains a big environmental problem in the UK.

2.6 Effects of air and water pollution in Africa

Air and water pollution continues to be one of the major environmental problems in Africa today. According to the United Nations Environment Programme (UNEP, 2004) report of atmosphere and air pollution, the "increased activity in key social and economic sectors are contributing significantly to air pollution—which has gradually grown into a major environmental concern for African policy makers and gained prominence on the region's political agenda. Unsustainable patterns of consumption and production of energy resources by industry, transport and household sectors have, in particular, been the leading sources of key indoor and outdoor air pollutants. Air emissions are a growing nuisance from Africa's growing industry (UNEP, 2004).Water pollution in Africa is equally a very big environmental problem.

Mining activities have greatly contributed to Water pollution in most African mining countries such as RSA, Zambia, Zimbabwe, Ghana and Nigeria. “Mining by its nature consumes, diverts and can seriously pollute water resources” (Miller, 1999). Some of the identified causes of water problems in most African countries include pollution and depletion of available resources through human activities: about 80% of untreated domestic wastewater in Africa is released into surface water bodies, thus depleting available freshwater (Longe, et al., 2010). This is besides wastewater from agricultural and industrial activities (UN WWAP, 2014).

2.7 Effects of air and water pollution in Zambia

Mining activities in Zambia have been one of the major contributors to air and water problems especially in the copper mining region. The emissions from the copper smelting, lime quarrying and cement plants are among some of the sources of air pollution. The health and environment effects of air pollution are notably the same as those highlighted in section 2.3 above. Previous studies in Zambia shows high concentrations of sulphur dioxide emissions than those required by regulating authorities. According to (Simukanga, et al., 2010) the SO_2 concentration levels, measured as 2-week means, within the copper smelter plant area were well in excess of the World Health Organisation (WHO) and Zambian 24 hour guideline value ($125 \mu g/m^3$). These levels are quite alarming for the health of the communities leaving near the mining operation plants.

2.8 The case of Kankoyo Township

Kankoyo Township makes a good case study on the effects of mining activities on air and water pollution. This is because of the nature of the problem of air and water pollution in this township. Air and water pollution in Kankoyo is very high due to mine effluent discharges and fugitive emissions of sulphur dioxide from the copper smelter respectively. In addition, the area is characterized by tailing dumps and open sewage systems that flow all around the community (Action Aid Zambia, 2015). Apart from air pollution, Kankoyo is also affected by dilapidated roads and poor water supply because of the old water reticulation system that was being maintained by a state enterprise called Zambia Consolidated Copper Mines (Action Aid Zambia, 2015).

2 .8.1 Nature of air pollution problem

The nature of air pollution in Kankoyo Township is somewhat an historical and complex problem which can be traced back to 1937 when the first reverberatory furnaces where installed at Mufulira Mine. Thus, sulphur dioxide emissions have been released into the nearby Kankoyo Township which is located on the windward side of Mopani Copper Smelter for over eight decades. According to (Jones, 2015) “Mopani Copper Mines commissioned their ISASmelt plant at Mufulira in Zambia's Copperbelt during 2006. It was designed to initially smelt 650,000 tonnes per annum of concentrate, with the potential to expand to 850,000 tonnes per annum in the future. Mopani's ISASmelt plant replaced their existing electric smelting furnace, which in turn had been introduced in 1971 to replace the original reverberatory furnaces which had been used for smelting when the plant began in 1937. The plant comprises a new feed preparation system, electric settling furnace, waste heat boiler, electrostatic precipitator, gas cleaning plant, oxygen plant and acid plant. Improvements were also made to the converter aisle and anode plants”. Although the technological improvements have significantly help to reduce sulphur dioxide emissions from virtually 100% to less than 8% by 2018, air pollution due to fugitive sulphur dioxide emissions still remaining the major pollution problem in Kankoyo Township. According to (Chipungu & Kunda, 1994), Kankoyo Township in Mufulira is hardest hit by sulphur dioxide emissions, where residents are reported to suffer from respiratory diseases, are unable to grow vegetables in their backyards, and have paint peeling off from their houses.

2.8.2 Nature of water pollution problem

Water pollution in Kankoyo happens at three parts: the first is due to from heavy metal effluents discharged into rivers (Fraser & Lungu, 2007). The second arises from incidental spillages of acid from mine operations as was the case in January 2008 when acidic water struck Mufulira again and close to 800people had to be hospitalized after drinking the water (Simpere, 2010). The third is caused by the poor and dilapidated water infrastructural network revealed from the field study. The township is supplied with water from old and dilapidated water supply pipes which are a potential source of water contamination especially when there is a massive sewer blockage and floods in rain season. This is potential source of water pollution. Nearly all the township houses are supplied with water from Mulonga Water and Sewerage (MWSC), a local water utility company apart from a few housing units which receive communal supplement water supply from the Mopani Copper Mines. Although the water test parameters from the samples collected in this research study indicates compliance of impurity levels with the international and statutory water limits for domestic and effluent water discharges respectively, there are few incidences of water pollution that have been reported in Kankoyo Township.

2.8.3 Perception of air quality

Hundreds of people in Kankoyo Township have been occasionally exposed to elevated levels of air pollution emitted from the Copper smelting plant which lies on the north eastern side of the township. These levels have health effects on the local communities' health. Air pollution has also been linked to the formation of acid rain which is responsible for the corrosion of houses and other social infrastructures in Kankoyo Township. The Centre for Trade Policy and Development (CTPD) in the Counter Balance Activity Report of 2010 reports that "at Kankoyo the paint on houses is peeling off and their corrugated iron roofs are eroded by the acidity. Acid rain also contributes to the deterioration of the soil, which becomes unfit for farming. In Kankoyo all that grows is cactuses and avocado trees; nothing else survives'' (CTPD, 2010). The data from the questionnaires used in this study showed that at least 80% (See Appendix 23 for details) of the Kankoyo residents interviewed expressly responded that air quality in Kankoyo Township is unhealthy for moderate sensitive groups.

2.8.4 Perception of water quality

Provision of and access to long term sustainability of good quality water are critical to achieving sustained health benefits of human beings in all communities around the world. This is not only emphasized in the 2015 United Nations Sustainable Development goal number 6 (clean water and sanitation) which calls for the availability and sustainable management of water and sanitation for all but also as a human right to have access to safe drinking water. The United Nations (UN, 2010) "recognizes the right to safe and clean drinking water and sanitation as a human right that is essential for the full enjoyment of life and all human rights". However, improved sustainable access to safe drinking water supply remains one of the critical environmental and healthy challenges in Kankoyo Township. Although this study revealed that nine out of ten households have access to tap water, the quality of the tap water supplied by the local utility company was not safe to drink. The community feels that the mining company has not done enough to ensure that the surrounding community receives safe drinking water even though it is clear that Mopani Copper Mine is not responsible for the supply of water to the local community. This perception can be partly linked to the view that the mining company has a social obligation to provide social and community services to the people affected by the mining operations and also partly due to the historical legacy where the former mine owners used to provide free water, housing and recreation facilities to the mining townships. During the time that the mines where owned by the Anglo American Corporation and Roan Selection Trust, employment conditions essentially provided housing, education, health, water and recreation for those who worked in the mines (Lungu, 2008).

2.8.5 Causes of air pollution problem

Sulphur dioxide and acid fumes emissions from the copper Smelting plant and sulphuric acid production plants respectively are the main causes of air pollution in Kankoyo Township. The other cause is the dust blown from the bare un-vegetated land which is susceptible to blowing tropical seasonal winds.

2.8.6 Causes of water pollution problem

The poor and dilapidated water infrastructure and supply network is currently the main cause of water pollution in Kankoyo. The water in Kankoyo Township is supplied from Mulonga Water and Sewerage Company (MWSC) whose source is partly from the Kafue River and the Mopani Copper Mines (MCM) underground operations. The water supply network is badly dilapidated resulting into serious water contamination due to severe pipe leakages and infiltration of contaminants into the water treatment reservoirs and network supply systems.

2.8.7 Measures to address air pollution problem

Measures to address air pollution includes investment in new technology to help capture of sulphur dioxide and emissions and also improve on the also technological improvements in the gas contact and absorption stages in sulphuric acid production in order to improve operation efficiencies. Other measures include the routine monitoring and control of air pollution and strict adherence to statutory emission limits and international best practices and pollution control standards.

2.8.8 Measures to address water pollution problem

Measures to address water pollution include the adoption of best safe working procedures and operation instructions to help control of water contamination. Other measures include the routine monitoring and control of water pollution and strict adherence to statutory effluent discharge limits and international best practices and pollution control standards.

2.9 Conceptual framework

The environmental issues to be addressed are quite complex, and a collective conceptual framework is required to help systematise and prioritise specific issues to correct. The conceptual framework below summaries the broad themes (social, environmental and economic) of responsible mining that the mining companies need to focus on for their sustainable operations. It presents the interactions among the mining operation firms, the community and the natural ecosystems.

2.9.1 Conceptual framework of the study

The figure 2.1 below shows the Conceptual Frame work for the Sustainable Mining Operations and Environmental Management. Sustainable development is, an ongoing process, and not a temporary undertaking. It ensures protection of the natural resources and the environment. It also emphasizes on care for the employee at the workplace and community development in the area of the mining environment.

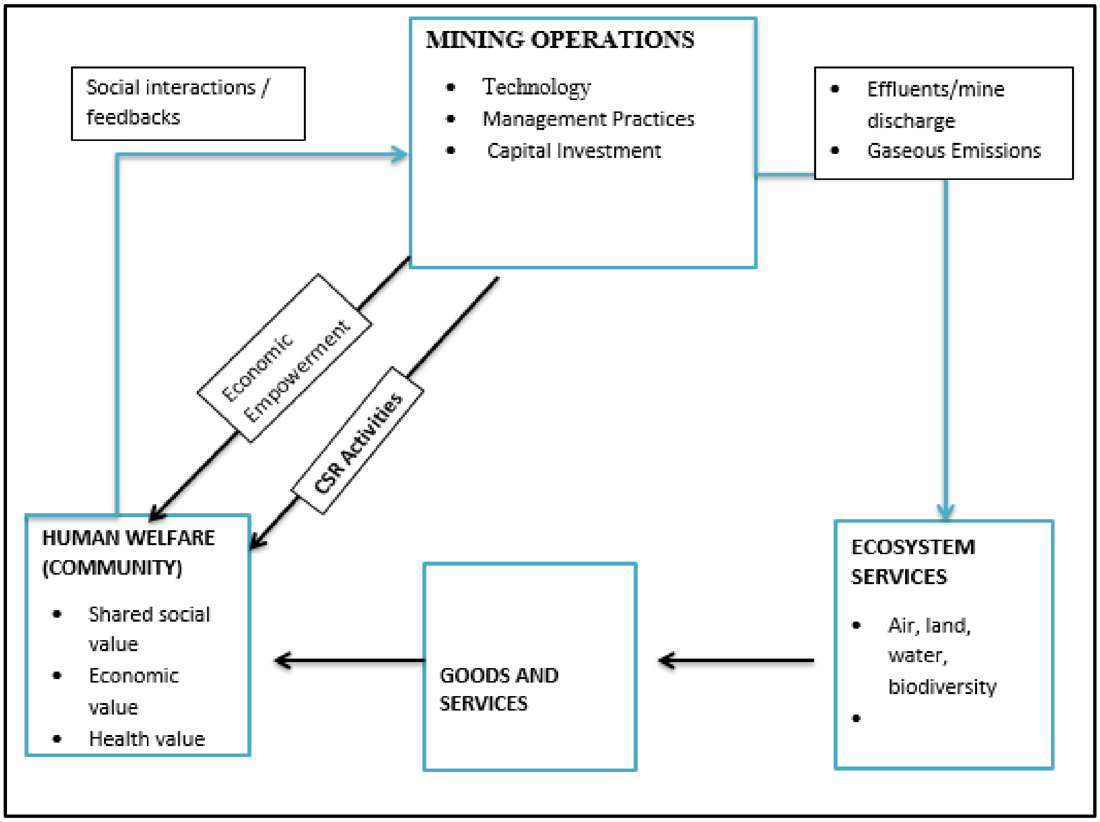

Figure 2. 1 Conceptual framework for the Sustainable Mining Operations and Environmental Management

2.9.2 Cause of air pollution conceptual framework outcomes

Mining activities generate a lot of waste that need to be disposed in more sustainable and environmentally acceptable standards. The gaseous fugitive emissions mainly oxides of sulphur, acid mists and particulate matter from the copper smelter and sulphuric acid plants are the major cause of air pollution in Kankoyo Township. Since the upgrade of the copper smelting process, many improvements have taken place in the process of manufacturing sulphuric acid and also the pollution control technologies. However, technological improvements in the conversion and absorption and cleaning stages have greatly improved the conversion and absorption efficiencies leading to significant improvement in pollution control.

2.9.3 Cause of water pollution conceptual framework outcomes

Water is essential for all mining processes including household use. It is also vital for other industries such as agriculture, industry, fishery and tourism etc. The demand for water in all sectors of the economy is so indispensable that sustainable management of water resources is inevitable. The mining industry in Zambia consumes a lot of water for various process requirements and at the same time generates thousands of cubic liters of mine waste waters and related effluents are hazardous. Konkola mine, which is one of the wettest underground mine in the world pumps an average of 300 000m^3/day of water into the Kafue river (Mulenga, 1993).

The possible sources of water contamination from Mufulira operation include seepage and erosion from old tailings ponds, release of process water from mining operations and metallurgical processing plants. Therefore, there is need for proper management of these point sources to minimize water contamination. Apparently, the tailing pond / dams are further away from Kankoyo township and the likely mine effluent discharge drainages flows outside the township into the Mufulira stream which finally discharges into the Kafue river.

2.10 Theoretical framework

The theoretical framework that was used in this study is the theory of pollution control which is viewed as a choice between a command and control or market- based approach. Environmental regulators and policy makers usually choose ’command and control approaches’ such as the permissible levels of emissions and the required use of standard control techniques while economists mainly prefer to use market based and cost effective approaches to achieve environmental objectives. However, according to (Stavins, 2004) in order to achieve an environmental objective in the cost effective way, the environmental regulator would need to define different standards for each pollution source taking into account the abatement costs that each firm faces. Because of the challenges associated in with such options, the command and control will generally prove to be more costly than the market based approach.

The Organization for Economic Cooperation and Development OECD (OECD, 1991) classify market-based instruments within five categories – emissions taxes, tradable permits, market friction reductions, government subsidy reductions and voluntary agreements. Such instruments could include interventions such as transport taxation or an emissions trading market. Regardless of the application, market based instruments generally operate to create incentives that encourage people acting more or less in their own best interests, simultaneously, to treat the environment in a way that is in the best interests of society. The principle behind this is similar to the polluter pay principle which requires that environmental costs are internalized and reflected in the prices of the goods and services that cause pollution as a result of their production and consumption (EEA, 2005).

Other theory that highlights the subject of environmental pollution among others includes the Conflict theory and some theories of environmental externalities. Conflict theory blames many environmental problems on pollution by multinational corporations that occurs because of weak regulations and a failure to enforce the regulations that do exist. The major assumption of this theory is that Population growth is not a serious problem because the world has sufficient food and other resources, all of which must be more equitably distributed. The practices of multinational corporations and weak regulation of these practices account for many environmental problems. According to (Michaels, 2008), the Conflict theory also assumes that the world's environmental problems are not inevitable and instead arise from two related sources. First, multinational corporations engage in practices that pollute the air, water, and ground. Second, the United States and other governments fail to have strong regulations to limit corporate pollution, and they fail to adequately enforce the regulations they do have.

The (World Bank, 2000) defines Environmental Externalities as a consequence of an action that affects someone other than the agent undertaking that action, and for which the agent is neither compensated nor penalized. Externalities arise when an individual, a firm or a country takes an action but does not bear all the costs (negative externality) or all the benefits (positive externality) of the action. The theory of externalities hinges on overcoming the information barrier concerning the value of social costs, several strategies exist. Much of the discussion about environmental externalities centers not on their existence but rather on their magnitude (Golove & Eto, 1996).

2.11 Summary of literature review

The effects of air and water pollution have very serious health and environmental consequences in our global community. Several studies on air and water pollution have been done in various parts of the world but still more has to be done to help preventing pollution for the better wellbeing of human kind. Pollution preventive and eradication efforts have been done by most governments and interested parties in most countries across the world. The degree and severity of pollution differs from one country or community to the other, and this calls for relevant and appropriate approaches to dealing with pollution problems. Although this air and water pollution is a global problem and it varies from place to place in some cases but the underlying or fundamental principles (causes and effects) remains the same.

CHAPTER THREE
RESEARCH METHODOLOGY

3.0 Overview

This Chapter gives details of the research methodology that was used in this research. It explains the philosophical paradigm, research design or methodology, sample population, sample size, methods of data collection, ethical considerations, data analysis, data validation and trustworthiness. It also highlights the limitations of the study.

3.1 Introduction

The study used a mixed method approach (quantitative and qualitative). Field observations, interview guides and questionnaires were used to record the views from the community. The collected data was analysed using both qualitative and quantitative methods.

3.2 Philosophical Paradigm

The philosophical concept and theory that support this study is the Positivism (also known as logical positivism) which asserts that the scientific method is the only way to establish truth and objective reality (Chilisa & Kawulich, 2015). Thus, a statement is meaningful only if it is either purely formal (essentially, mathematics and logic) or capable of empirical verification (Anon., 2008) Positivism is based upon the view that science is the only foundation for true knowledge. It holds that the methods, techniques and procedures used in the natural sciences offer the best framework for investigating social problems. Positivism believes in the unity of the scientific methods, and natural sciences are generally taken to be the model for all the sciences (Muhammad & Chowdhury, 2015). Thus, the research design for this study includes quantitative approaches, such as experimental and causal comparative research. In this case what really counts as truth is based on precise observation and measurement that is verifiable. This was achieved mainly through questionnaires, observations, tests and experiments, as techniques for data collection.

3.3 Research methodology

A mixed (qualitative and quantitative) research approach was used throughout this study in order to effectively obtain the relevant information that could give the answers to the research questions. This was a typical case study that included quantitative research tools such as laboratory experiments, analytical survey, structured interviews and scientific data as a correlation strategy. The aim for this research methodology was to demonstrate the objectivity and accuracy of the measurements, numerical analysis (statistical) of the data collected through questionnaires, and interviews, including the manipulation of pre-existing statistical data using computational techniques. Thus, quantitative research focuses on gathering empirical data and generalizing it across groups of people or to explain a particular phenomenon (Babbie, 2010). In other words, only a representative part of the population was studied to give the correct information, and the findings from this are expected to be generalized to an entire population within reason.

3.4 Target Population

The target human population for this research is defined to be the residents of Kankoyo Township and the surrounding community, including related public and private institutions located in the community. This includes the local authority representatives, the mining company, and health institutions. In this case a population is all the individuals or units of interest where a specific sample will be collected from. (Hanlon & Larget, 2011).

3.5 Sampling Protocol

The sampling procedure used is defined by the following principles:

3.5.1 Sampling size

A sample is a subset of the individuals in a population; this is typically data available for individuals in samples (Hanlon & Larget, 2011). A sample in this study is, therefore, a smaller group of elements drawn through a definite procedure from an accessible population. The elements making up this sample are those that were actually studied. The sample of the population of this study stands at approximately 30 households from settlement Sections B, C, D, E, F and Kwacha ward, Kankoyo Police Post, 7 weather sampling stations and from 2 civic leader representatives. The 30 households consisted of about 6 households from each of the settlement Sections B, C, D, E, and F respectively as shown in figure 3.1 below:

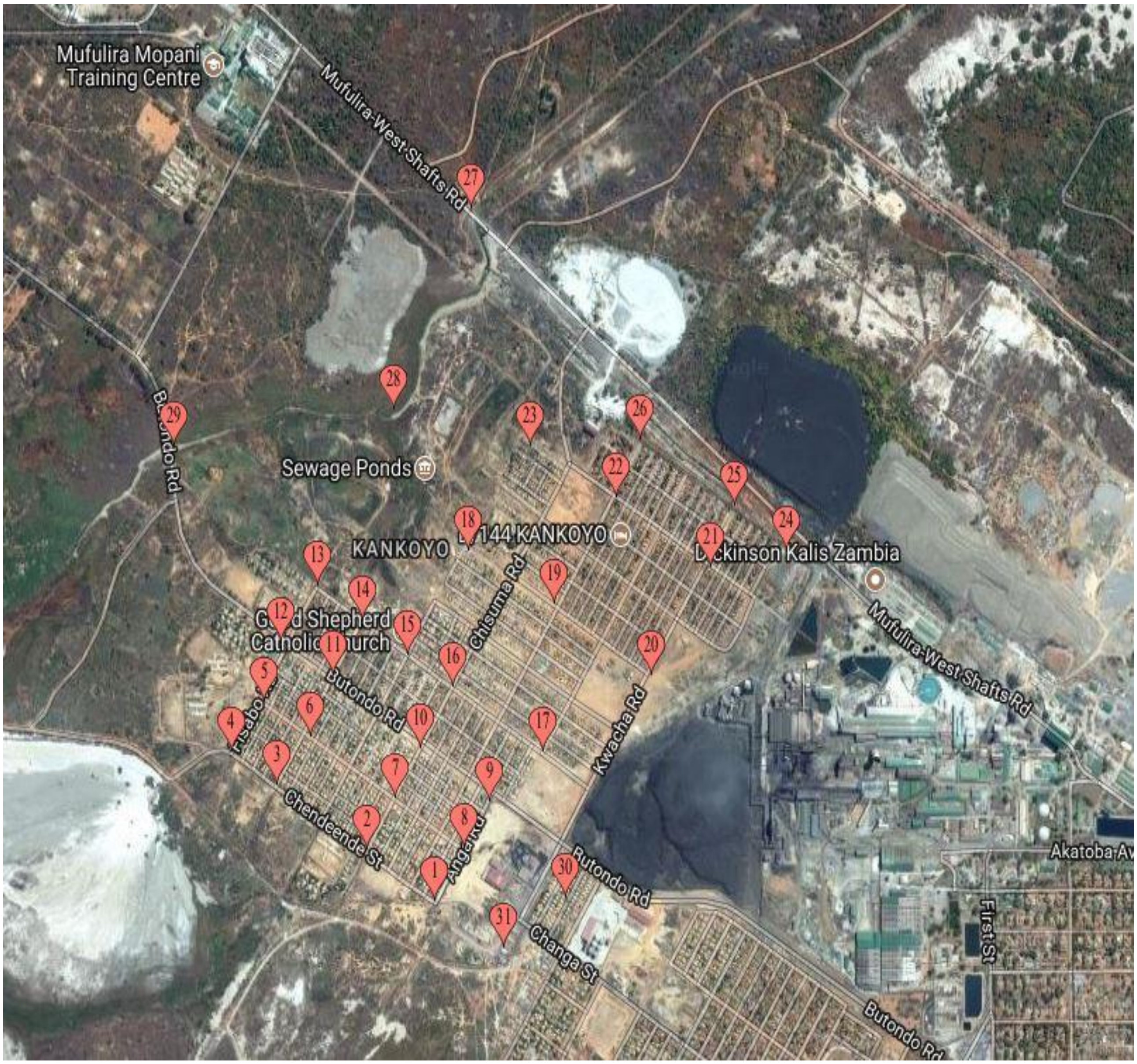

Figure 3 1: Locations of sampling points in 30 households in Kankoyo Township

Source: Field data, 2018. Google map

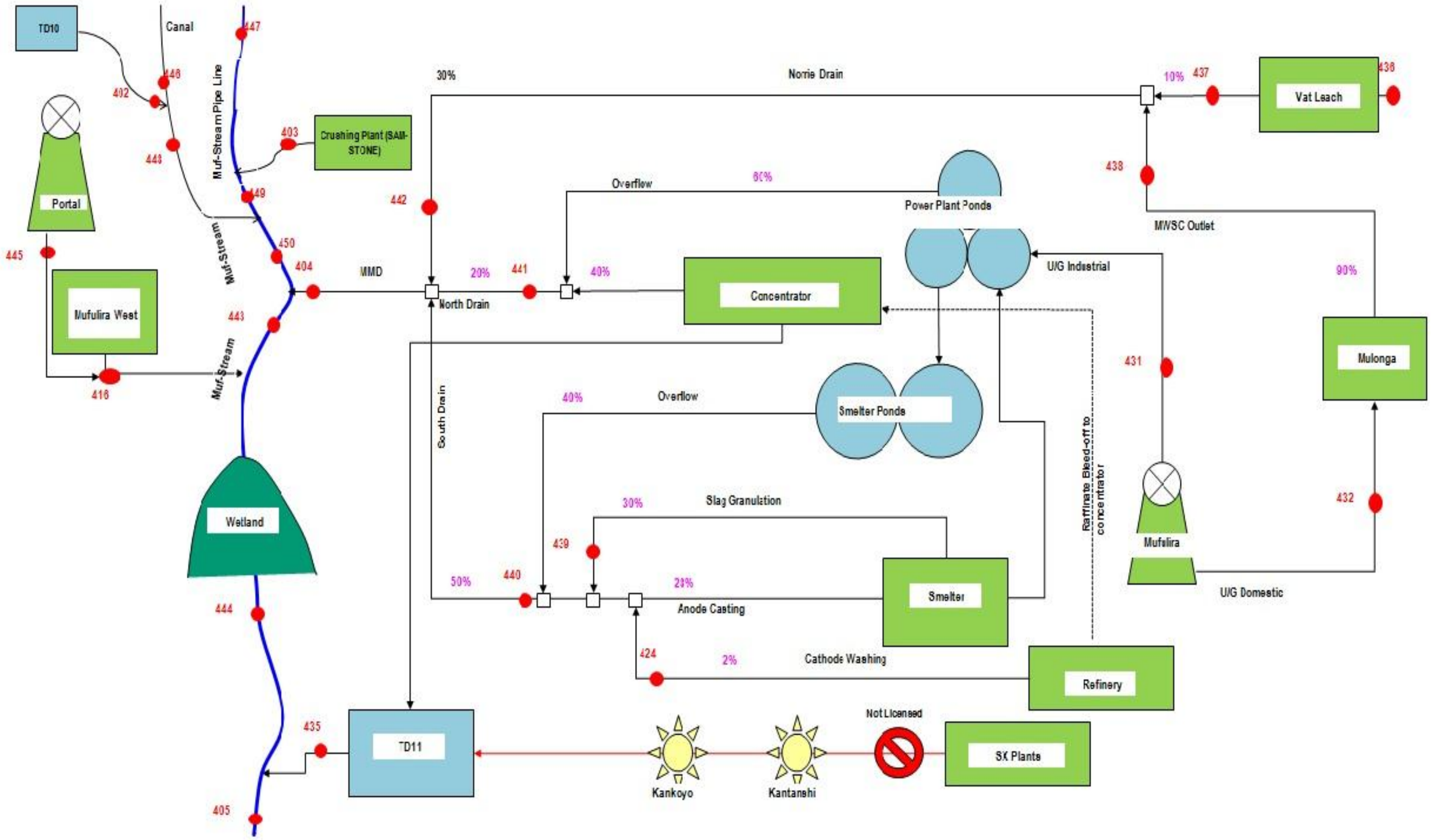

Figure 3.2: Mufulira Mine Effluent Sampling Locations
Source: Adapted from MCM Mufulira Mine Site Bi Annual Environmental Report – January to June 2018

The 7 weather sampling stations are located at the following sites: Butondo clinic, Kankoyo clinic, Kantanshi clinic 3, Kantanshi clinic 6, Eastlea clinic, Kamuchanga Police Station and Malcolm Watson Hospital station.

In additional to the 30 households, the questionnaires were also extended to 2 civic leaders namely; Kankoyo ward counselor and Kwacha market chairperson. These two leaders were strategically chosen to provide accurate social and general information about the community. Kankoyo ward counselor is a more influential person in the community and commands both political and social influence amongst the residents of Kankoyo Township in particular Fibusa and Kwacha wards which are located directly on the windward side of the Mopani Copper Smelter and sulphuric acid processing plants. Kwacha market chairperson was equally an important person because of the influence that he has on the traders who virtually come from all the settlement Sections of Kankoyo Township.

3.5.2 Samples

Only two sample types were collected in this research namely; air and water samples. There were 56 water samples collected from the households, 86 mine effluent samples and over 500 air samples analysed over a period of 18 months on 24hrs basis. Air samples were predominantly ambient air samples from the strategic locations within Mufulira district. Water samples were also mainly domestic water from randomly selected households. Mine effluent samples were also collected from the strategic sampling points located within and around the mining process plant. Besides, thirty (30) Kankoyo residents were also selected as participants for structured questionnaire interviews.

3.5.3. Sampling and analysis procedures

3.5.3.1 To investigate the effects of mining operations on the water quality in Kankoyo Township.

Water samples were collected from selected sampling points (i.e.one sample per sampling point) in Kankoyo using the 1 litre sampling bottles as prescribed in the sampling protocols available. Full chemical (elemental) and physical water quality test analysis were conducted at the BSI ISO 9001 / BSI ISO17025 Certified test laboratories.

3.5.3.2 To determine the extent of air pollution in Kankoyo Township

Samples for air quality were taken at the designated 7 weather sampling stations located in different areas of Mufulira District taking in to consideration the direction of the prevailing winds at the time of sampling.The automatic air samplers model S5001 SO_2 Analyzer shown in plates 3.1 and 3.2 below were used in the determination of sulphur dioxide gas in the ambient air because of their reliability in measurements. The S-5001 is a Non-Pulsed U.V. Fluorescence Sulphur Dioxide Analyzer. The operation of this Analyzer is based upon the well proven technology, of the measurement of fluorescence of SO_2 due to absorption of UV energy. Sulphur Dioxide absorbs in the190 nm - 230 nm region, free of quenching by air and relatively free of other interferences (Ecotech, 2011). Interferences caused by PNA (poly-nuclear aromatics) are reduced and selectively removed through a membrane, without affecting SO_2 sample gas. The UV lamp emits ultraviolet radiation which passes through a 214 nm band pass filter, excites the SO_2 molecules, producing fluorescence which is measured by a PMT with a second UV band pass Filter.

The technology of pulsed UV-fluorescence detectors offer an inexpensive and efficient way to measure SO_2, and are widely used both in ambient air and flue gases. In these instruments SO_2 is electronically excited by the radiation of an UV lamp, yielding an excited species which fluoresces in the UV (EPA, 2017). This technique is very sensitive but other gaseous components may interfere. Decrease in fluorescence intensity also known as quenching (e.g. by O_2 or H_2O) of the excited species can lead to an underestimation of the SO_2 concentration. Quenching was accounted for by calibrating with a standard that contains the same concentration of the quenching compound as the sample. The equations describing the above reactions are as shown on the next page:

$$SO_2 + h\nu \xrightarrow{I\alpha} SO_2* \qquad (1)$$

The excitation ultraviolet light at any point in the system is given by:

$$I\alpha = I_o [I - exp(-\alpha x (SO_2))] \qquad (2)$$

Where I_o is the UV light intensity, α is the absorption coefficient of SO_2, x the path length, and (SO_2) the concentration of SO_2. The excited SO_2 decays back to the ground state emitting a characteristic fluorescence:

$$SO_2{}^* \xrightarrow{kF} SO_2 + h\nu_2 \qquad (3)$$

When the SO2 concentration is relatively low, the path length of exciting light is short and the background is air, the above expression reduces to:

$$F = K (SO_2) \qquad (4)$$

Hence, the fluorescent radiation impinging upon the PMT is directly proportional to the Concentration of SO_2.

Plate 3.1: Air monitoring station at Kankoyo Clinic 5 station (Photo: Muma-2018)

Plate 3.2: SO_2 Analyzer at Kankoyo Clinic 5 Station (Photo: Muma-2018)

3.5.4. Method of analysis:

a) When the collected air sample passes through the absorbing solution, the Sulphur dioxide in the air is converted to sulphuric acid and remained trapped in solution. Stoichiometric calculations from titration was computed to give the average Sulphur dioxide concentration in the air in g/m^3 or any standard concentration unit of choice.

b) The parameter measured is SO_2; this is important because it is the major gas emitted from the copper smelting plant. The second parameter is sulphuric acid mist concentration. The sulphuric acid mists sometimes escapes from the sulphuric acid plants and acid heap leaching areas. Particulate matter - from the fine emissions from the smelter plant
c) Sampling period was approximately nine (09) months from January to September 2018. Sampling period was extrapolated backwards to establish the trends

3.5.4.1. Assessment of the extent of water pollution in Kankoyo area.

a) Use of validated sampling protocols to ensure representative sampling of water in the designated / mapped sampling points throughout Kankoyo Township
b) Basic and appropriate sampling tools such as sampling scoops and bottles were used.
c) The following critical parameters were analyzed:
    1) Total Suspended solids (TSS) – measure of dry particles trapped in water
    2) Total Dissolved Solids (TDS) – measure of particles dissolved in water or particles below two micrometers. The choice of filter also plays a big role in TDS determination. Because total suspended solids (TSS) are defined as the particles retained by a 1.5 μm glass fiber filter, TDS must necessarily be defined as everything that passes through said filter. Use of a common pore size is critical to method adherence and in comparison of results between analyses (David, 2013) .
    3) pH - measure of acidity
    4) Colour - Colour in water may be caused by the presence of minerals such as iron and manganese or by substances of vegetable origin such as algae and weeds. Colour tests indicate the efficacy of the water treatment system
    5) Turbidity - measure of the degree to which the water loses its transparency due to the presence of suspended particulates.
    6) Sulphates – may come from leached soils or sulphuric acid infiltration from the environment.

7) Residue Chlorine - low level of chlorine remaining in water after its initial application. It constitutes an important safeguard against the risk of subsequent microbial contamination after treatment
8) Heavy metals (Cu, Pb, Fe, Hg, Cd, As, Zn, Mn, Al) – presence of Heavy metals in drinking water which pose a threat to human health due to bioaccumulation which may induce cancer and other health risks.

d) Various analytical methods were employed in the analysis of these parameters. The pH was measured using a pH meter; sulphates were analysed using analytical classical methods of gravimetric with barium chloride precipitation whereas TSS and iron were determined by gravimetric techniques and wet iron collection by Zinc reduction methods respectively. Heavy metals were analysed by wet chemistry methods with ICP –OES (Inductively Coupled Plasma - Optical Emission Spectrometry) and the Atomic Absorption Spectrometer (AAS) finish. (Plate 3.3)
e) The sampling period was approximately nine months from January to September 2018.

Plate 3.3: Chemical analysis of water samples using the Atomic Absorption Spectrometer (AAS) at Mufulira Laboratory. (Photo: Muma-2018)

3.6 Sampling Techniques

Stratified random sampling procedure was used for selecting the participants in this study. This technique was employed to ensure equal representation of the chosen variables for the study. The stratification was based on local government definition of the settlement (township) and other public institutions including privately owned institutions, in Kankoyo Township. Within each residential section, selection of samples was by simple random sampling. (Plate 3.5). This was prepared with the help of Google imaging techniques. Proportionate stratified random sampling technique was employed to select 33 households, 7 weather monitoring stations located at various health institutions and a state police post located within the township. The proportionate stratification was based on the fact that Kankoyo is a well-established and planned settlement. Sampling of mine effluents was done at defined ZEMA licensed sampling points. Plate 3.4 shows the researcher collecting the mine effluent sample the Mufulira Mine South Drain Sampling point. Plate 3.5 shows sampling of domestic tap water from the broken pipeline at house No. 54 Section E Kankoyo Township.

Plate 3.4: Sampling of Mine effluent at the Mine South Drain sampling Point. (Photo: Muma-2018)

Plate 3.5: Sampling of Tap water at House No. 54 Section E. Kankoyo Township. Photo: Muma-2018)

3.7 Methods of Data Collection

Different ways of collecting primary and secondary data were used in this study. The reason for this was to ensure correct data capture and a comprehensive interpretation of the research findings. Some of the methods used include: Laboratory experiments, documents and records review, field observations, interviews and questionnaires.

3.7.1. Primary Data

Primary data was obtained through field observations, interviews and questionnaires.

3.7.1.1 Field Observations

The observations on the effects of mining operations on the air and water quality in Kankoyo Township involved a prolonged engagement of field activity which lasted for a period of over eight months. Field observation notes were used to help understand the perceived caused and effects of air and water pollution among the Kankoyo residents. The observations helped the researcher to fully understand and capture the context within which people interact with the mining operations. It provided firsthand experience to the ongoing community experience. It therefore, provided an opportunity to learn about issues that people may be unwilling to discuss in an interview, setting.

3.7.1.2 Interviews

Interviews were conducted on officials from ZEMA whilst on internship at the same time the study was been conducted. The other interviews were conducted with community/market leaders and selected of Kankoyo Township. All the interview responses were recorded and filed for formal and critical analysis.

3.7.1.3 Questionnaires

Questionnaires were used to collect qualitative information from the Kankoyo residents. A total of 30 questionnaires were applied in this study. These questionnaires comprised of open-ended and closed questions with clear instructions on how to complete them. Questionnaire protocols were observed as per sample questionnaire in Appendix 4.

3.7.2. Secondary Data

The study made use of publications and information available on the Internet, from different organizations in Zambia which included Zambia Environmental Management Agency (ZEMA), Ministry of Natural Resources and Environment (MENR), Ministry of Mines and Mineral Development (MMD), Centre for Trade Policy and Development (CTPD), academic journals and publications, newsletters, magazines and reports issued by research institutions. Internet resources were also extensively used. The idea was to collect information from as many different sources as possible and then be able to counter check the information so as to further validate the findings. This multiple and integrated data collection approach is preferred in order to ensure the validity, quality and reliability of the research data.

3.8. Ethical Considerations

Ethical norms in research promote the aims of research, such as knowledge acquisition and dissemination, and avoidance of inaccuracy data collection. Further, ethical standards promote the values that are essential to collaborative work, such as trust, accountability, mutual respect, and fairness. According to (Hennink, et al., 2011), "ethical standards promote the values that are essential to collaborative work, such as trust, accountability, mutual respect, and fairness". Some of the important ethical concerns that were taken into consideration while carrying this study are: providing the right to withdraw, avoiding deceptive practices, minimizing the risk of harm, anonymity, confidentiality and informed consent.

3.9. Method of Data Analysis / characterization

The water samples collected from the field were analysed using recommended international methods of analysis namely; Inductively Coupled Plasma (ICP) spectroscopy for trace impurities in water samples, gravimetric and related wet chemistry methods for some selected parameters of interest in water samples such as suspended solids, total dissolved solids and total sulphates. Infra-red techniques for ambient air were used. Further, Statistical methods of analysis were applied using Minitab for correct statistical data treatment and interpretation.

3.10 Data Validation and trustworthiness

According to the United Nations Economic Commission for Europe (UNICE) glossary on statistical data editing (UN, 2000), data validation is defined as an activity aimed at verifying whether the value of a data item comes from the given (finite or infinite) set of acceptable values. Thus, the experimental data collected in this research was authenticated by use of laboratory certified reference material standards, including validated laboratory work procedures at all times.

The questionnaire designed for the study was subjected to a validation process for face and content validity. Face and content validity have been defined by (McBurney & White, 2009) as follows: Face validity is the idea that a test should appear superficially to test what it is supposed to test; and Content validity is the notion that a test should sample the range of behaviour represented by the theoretical concept being tested. In the validation process of this study, copies of the questionnaire and copies of the research questions were given to the residents of Kankoyo Township who were selected to be interviewed.

3.11 Limitations of the study

Lack of sufficient updated past literature on environmental studies in Kankoyo Township made the study quite challenging despite the pollution problem being on record for the past seven decades. However, the limited available literature did provide some pertinent information to help in identifying the scope of works that have been undertaken so far in Kankoyo Township; this helped the researcher to build a base upon which to achieve his research objectives. Besides, insufficient funds to do more laboratory test works for water and air quality (bacteriological test in domestic water and particulate matter determination in ambient air) was also another research constraint. The researcher used the limited laboratory facilities provided by the Mopani Copper Mines to conduct much of his research.

3.12 Summary

The main purpose of this study design was to collect reliable and accurate data to determine the effects of mining operations on the air and water quality of Kankoyo Township by employing both qualitative and quantitative research methods. The research findings obtained were carefully recorded and statistically collated to get a meaningful interpretation of the data. The next chapter presents the research findings and results.

CHAPTER FOUR
PRESENTATION OF THE FINDINGS

4.0 Introduction

This chapter presents the research findings in terms of the study objectives and research questions.

The results of the study are further presented under the following subheadings:

4.1 Types of samples

4.1.1 Water Samples

a) Industrial / mine effluents

Eleven (11) mine effluent samples were collected from the already existing mine effluent sampling points, eight of which are located within the mine site and three (03) are located outside the mine site. The reason for sampling these points was to establish the levels of pollutants (sulphates, copper cobalt, iron, manganese etc.) leaving the mine area and entering the natural water bodies. The sampling frequency for these samples once a day. The ZEMA licensed sampling points includes the Main Mine Effluent (Sampling Point number 404), Main Mine Boundary (Sampling Point number 405) and the TD 11 Spill Way (Sampling Point number 435).

b) Domestic water

Twenty nine (29) sampling points located in the core of Kankoyo Township were strategically and systematically defined for the collection of domestic water samples, to determine the water quality availed to the Kankoyo community. The samples were collected from water supplied by the Mulonga Water and Sewerage Company (MWSC).

4.1.2 Air Samples

The air samples referred to in this study is the ambient air in Kankoyo Township and from another six selected sites outside Kankoyo Township, which were used as a reference for comparison. Figure 4.1 on the next page shows the geographical location of the 7 air sampling stations.

Figure 4.1: Location of monitoring stations for SO_2 in ambient air

Source: Adapted from MCM Mufulira Mine Site Bi Annual Environmental Report – January to June 2018

Table 4.1 below shows the 7 sampling stations and their respective locations.

Table 4.1: Location of the 7 Air Sampling Stations

Sampling Station	**Location**
Kankoyo Station	<1km on the Western side of the Copper Smelting Plant
Kantanshi Clinic 3	<1km on the Southern side of the Copper Smelting Plant
Kantanshi Clinic 6	<2km on the South Eastern side of the Copper Smelting Plant
Eastlea Clinic 9	High Cost residential area
Kamuchanga Station	>6 km on the Southern side of the Copper Smelting Plant
Malcolm Watson Hospital Station	Central Town area within 2km radius from the Copper Smelting Plant
Butondo Station	>4 km on the Western side of the Copper Smelting Plant

4.2 Characteristics of Questionnaire respondents

The characteristic of the respondents interviewed in this study are given below:

4.2.1 Gender of respondents

The gender consideration of the respondents was important in this study to help get balanced views of the residents, considering that the population distribution of male to female residents in Kankoyo Township is almost 1:1 as shown, in Section 1.2.2 i.e. 50.3% to 49.7% male to female ratio. The 31 respondents were 18 females and 13 males representing 58% and 42% respectively. Figure 4.1 below shows the graphical presentation of the people sampled.

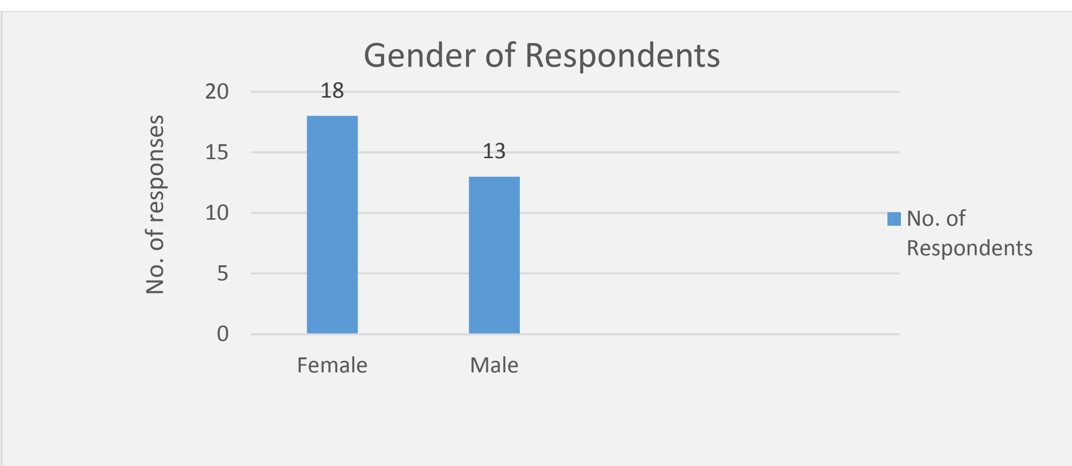

Figure 4.2: Gender of respondents (Source: Field Data, 2018)

4.2.2 Age of respondents

The age of the respondents was important in terms of appreciating the answers given by the respondents. Two of the respondents were from the age group 21-25yrs representing 6.5%; seven respondents came from the age group 26-30yrs representing 22.6%; five of the respondents came from the age group 31-35yrs and another five came from the age group 36-40yrs representing 16.1% respectively. Three respondents were from the age group 41-45yrs representing 9.7%; four respondents were from the age group 46-50yrs representing 12.1%; five other respondents were from the age group 51yrs and above representing 16.1%. The age group of the respondents are shown in Table 4.2 and Figure 4.2 below.

Table 4.2: Age of respondents

Age (years)	Frequency	Percentage (%)
21-20	2	6.5
26-30	7	22.6
31-35	5	16.1
36-40	5	16.1
41-45	3	9.7
46-50	4	12.9
51 & above	5	16.1
Total	**31**	**100**

Source: Field Data, 2018

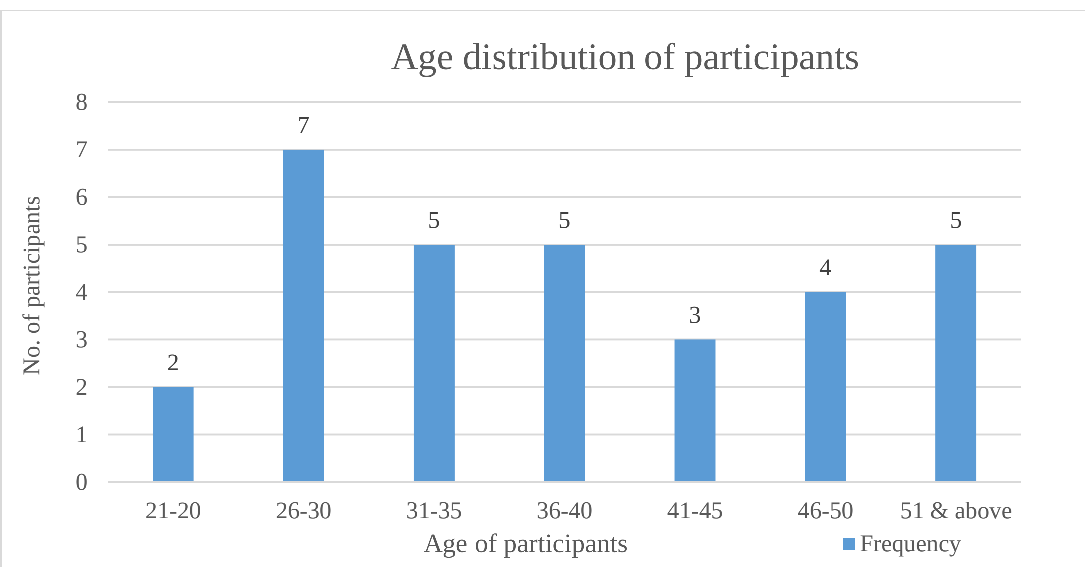

Figure 4.3: Age distribution of participants
Source: Field Data, 2018

4.2.3 Educational level of respondents

The education levels of the respondents from primary, secondary and tertiary levels were at 25.8%, 51.6% and respectively 22.6%. The educational levels of the respondents were very important because it helped the researcher to know education background of the respondents during the data collection process. All the respondents were able to freely contribute during the interview sessions. Table 4.3 below shows the education level of the respondents.

Table 4.3: Education level of respondents

Level of Education	Frequency	Percentage (%)
Primary	8	25.8
Secondary	16	51.6
Tertiary	7	22.6
Total	**31**	**100.0**

Source: Field Data, 2018

4.2.4 Perceptions of respondents

Perceptions of adversity caused by copper smelting have reached an extent that seriously threatens the existence of copper industry in Zambia. Copper mining is destructive to the environment. Zambian copper smelters gives off excessive quantities of SO_2 and particles, which are rich in copper content. Therefore the mining industry needs to arm itself with clear responses to these and similar misconceptions, and to communicate those responses loudly and clearly, if it is to survive. Apparently, despite the significant reductions in the air pollutions that have been achieved in the last decade, residents of Kankoyo still believe that very little has been done in addressing the air and water quality (notable environmental problems) issues in this township. The community put all the blame for economic hardships, unemployment environmental degradation, air and water pollution on the mining industry. Perhaps this may be attributed to the historical background that the previous miner owners used to clean up the mine townships and provide social amenities in additional to employment opportunities which is no longer the case.

4.3 Comparison of laboratory results from different sampling points

The air quality comparison for the 7 different weather sampling stations shows the highest average SO_2 concentration of 159.73 μg/m^3/24hrs to be at Kankoyo clinic 5 while the lowest average concentration of 11.51 μg/m^3/24hrs is at Malcolm Hospital over the 18 months sampling period. The overall average comparisons of SO_2 emissions from the seven weather sampling stations for the 18 months period from January 2017 June 2018 are shown in Table 4.4 and Figure 4.3 below.

Table 4.4:

Month	Kankoyo-Clinic 5	Butondo Clinic 7	Kantanshi Clinic 3	Kantanshi Clinic 6	Eastlea Clinic 9	Kamuchanga	Malcolm Hospital
18 Months Ave.	**159.73**	**9.49**	**81.77**	**19.81**	**14.19**	**12.05**	**11.51**
Statutory (ZEMA) Limit	**125.00**	**125.00**	**125.00**	**125.00**	**125.00**	**125.00**	**125.00**

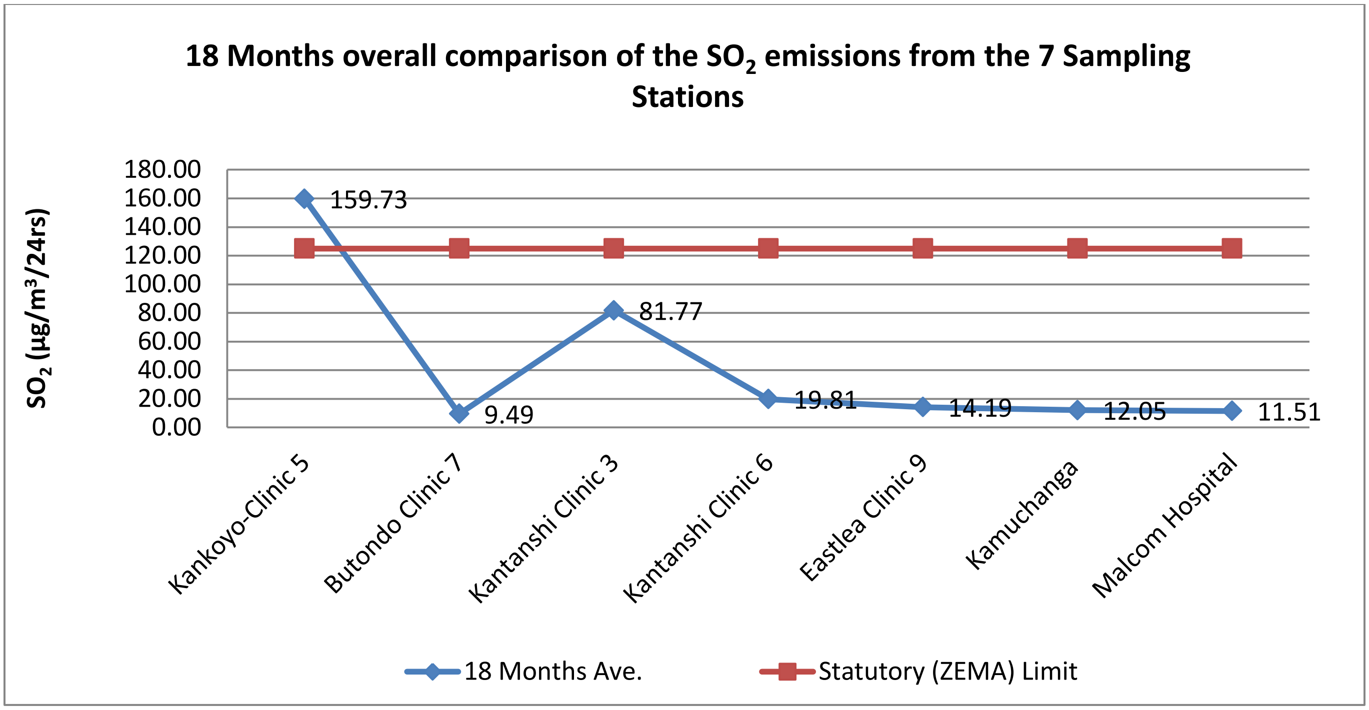

Figure 4.4: 18 Months overall average comparisons of SO_2 emissions from the 7 sampling Stations

4.4 Trends in ambient air quality at the 7 different weather stations from January 2017 to May 2018

The figures 4.4 to 5.10 below show the trends in air quality at 7 different weather stations from January 2017 to May 2018

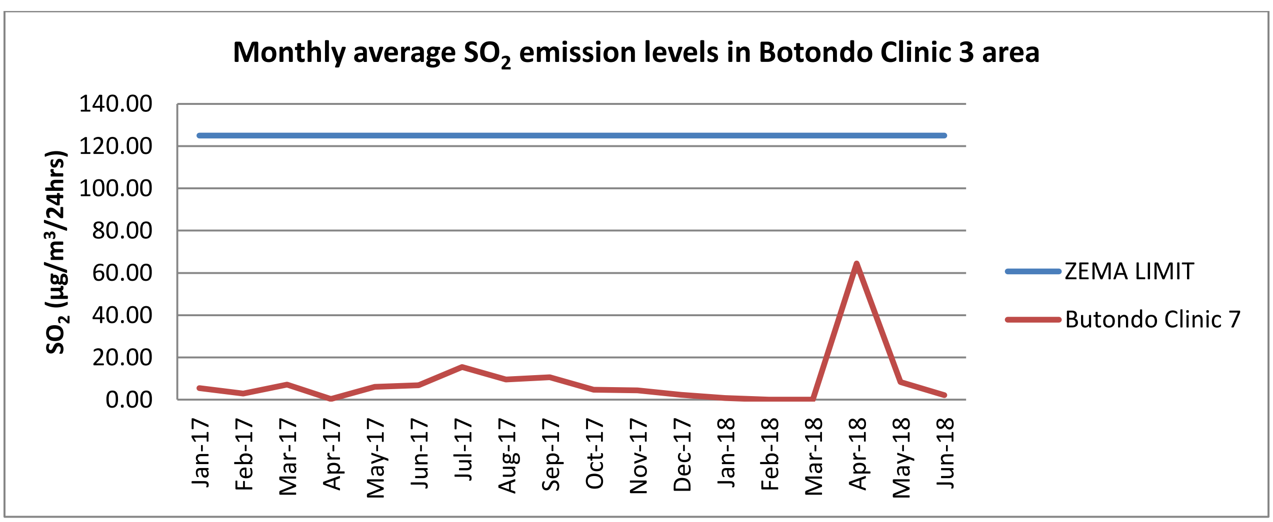

Figure 4.5: Butondo Clinic 3- Monthly SO_2 emission levels

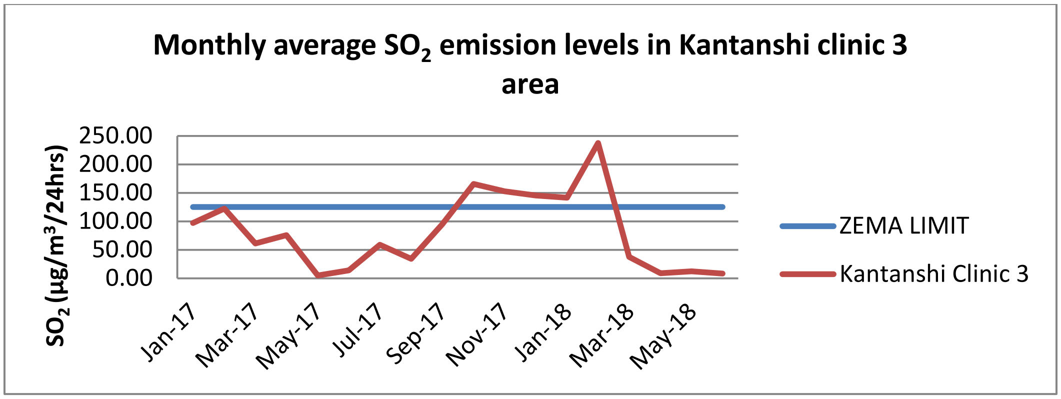

Figure 4.6: Kantanshi Clinic 3- Monthly SO_2 emission levels

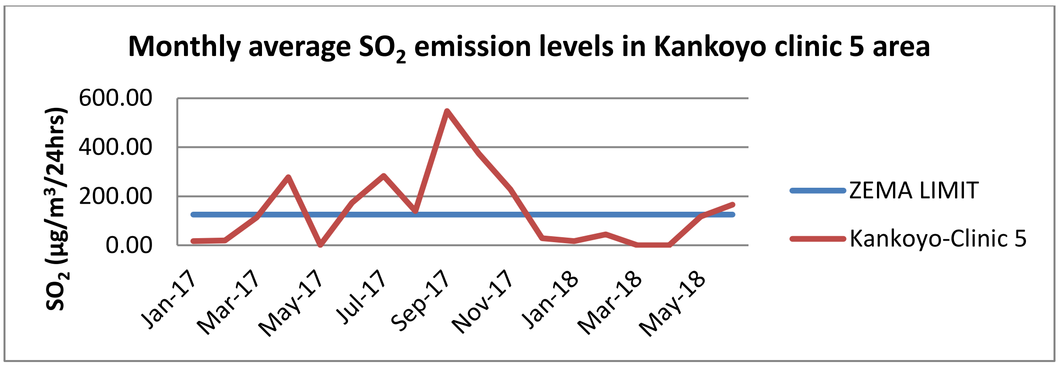

Figure 4.7: Kankoyo Clinic 5- Monthly SO_2 emission levels

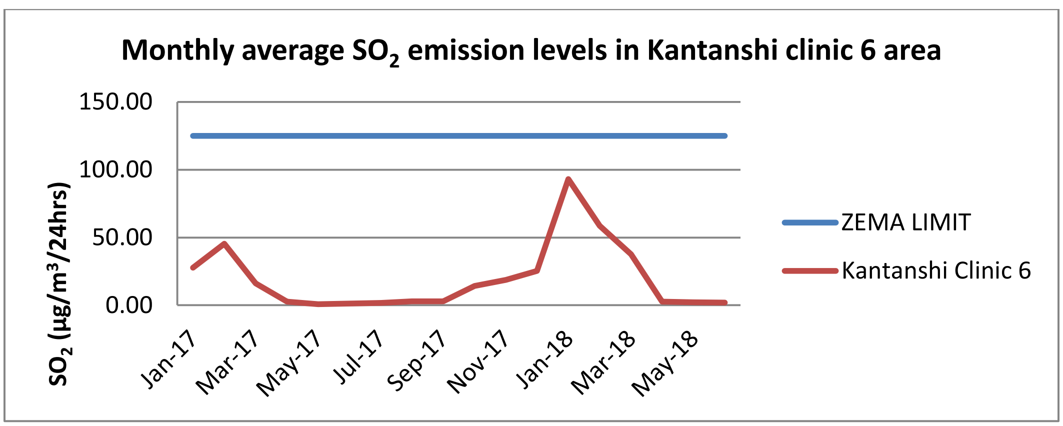

Figure 4.8: Kantanshi Clinic 6- Monthly SO_2 emission levels

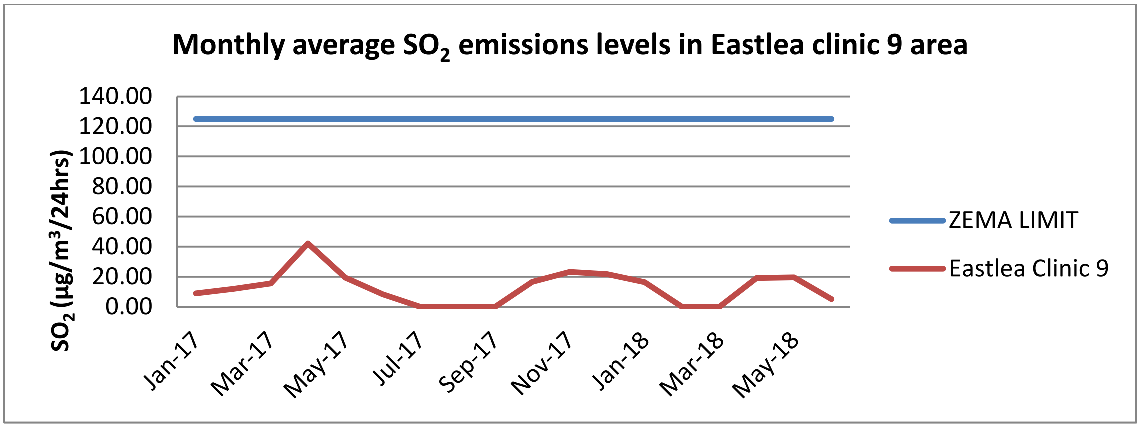

Figure 4.9: Eastlea Clinic 9- Monthly SO_2 emission levels

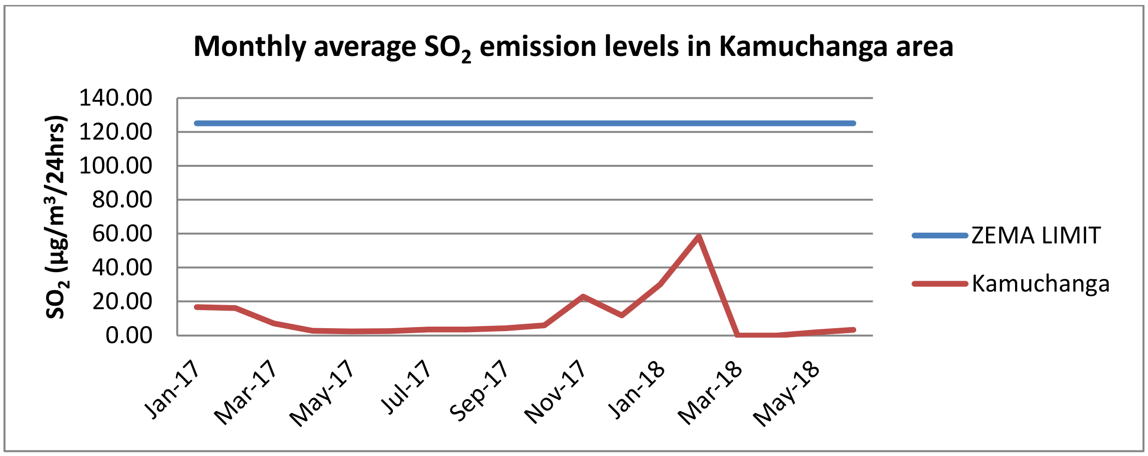

Figure 4.10: Kamuchanga Station- Monthly SO_2 emission levels

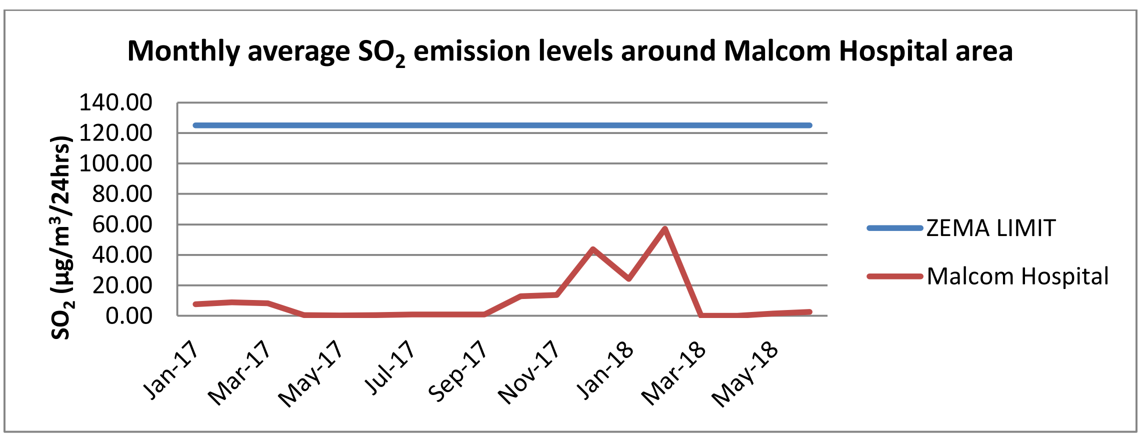

Figure 4.11: Malcolm Watson Hospital Station- Monthly SO_2 emission levels

4.4.1 Kankoyo - average annual ambient Sulphur dioxide level for the past two Decades

The available sulphur dioxide concentration information for the last two decades for Kankoyo (as shown in table 4.5 and figure 4.11 below) shows a significant decrease in sulphur dioxide emission levels from over 400 µg/m^3/24hrs to less than 110 µg/m^3/24hrs from 1995 to June 2018. The results are supported by the massive technological investments in sulphur dioxide capture in the copper smelting plants after the year 2010. The SO_2 emission data for Kankoyo clinic 5 station from 2001 to 2016 was not available from reliable sources.

Table 4.5: SO_2 emissions for Kankoyo clinic 5 station from January 1995 to June 2018

Year	Zambian 24-hr SO_2 guideline (µg/m^3)	Clinic 5 - Kankoyo Station
1995	125	427
1996	125	485
1997	125	342
1998	125	407
1999	125	480
2000	125	247
2017	125	184
**2018	125	105

Key: Shaded areas indicate concentrations above the Zambian statutory guidelines limit.
**2018: The 2018 results are from January to June 2018
Source: Mopani Copper Mines Environmental Impact Statement Volume 1 Page 33. Assessments of Impacts for Mufulira Mine. Report No. 283142/4 July 2003. SRK Consulting Engineers and Scientists

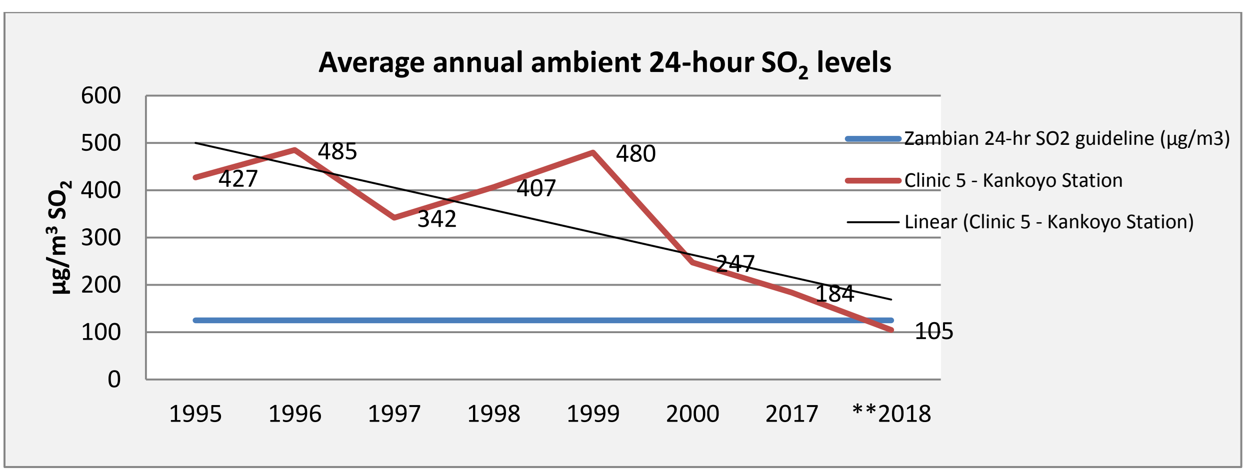

Figure 4.12: SO_2 emissions for Kankoyo clinic 5 station from January 1995 to June 2018

4.5 Sulphur Capture

The capture of sulphur dioxide from the copper smelting plants has greatly improved due to new and improved technologies which play are vital for reducing or even preventing smelter air and water pollution. Traditional or old smelters used to emit most of the sulfur dioxide generated, and now almost all of it is captured prior to emission using new technologies, such as the complex gas absorption towers in the sulphuric acid plants and the use of electrostatic precipitators, which capture dust particles and return them to the process. The results obtained indicate significant reductions in terms of sulphur capture and sulphur dioxide emissions from the Copper Smelter. The average sulphur capture was 48% from 2007 to 2013 and about 94% from 2014 to 2018. The average annual sulphur dioxide emissions for 2017/2018 at 144.5μgm^3 in Kankoyo Township were 15.6% above the statutory limit of 125μgm^3 in ambient air (μgm^3 /24hrs).

Figure 4.13 on the page below shows the Smelter sulphur capture trends for the period March 2007 to March 2018. The average increase of about 44% in sulphur capture from March 2008 to 2014 was due to technology improvement. The additional sulphur capture increase of over 90% from mid- 2018 to early 2019 is attributed to significant process improvements in the ISASMELT technology.

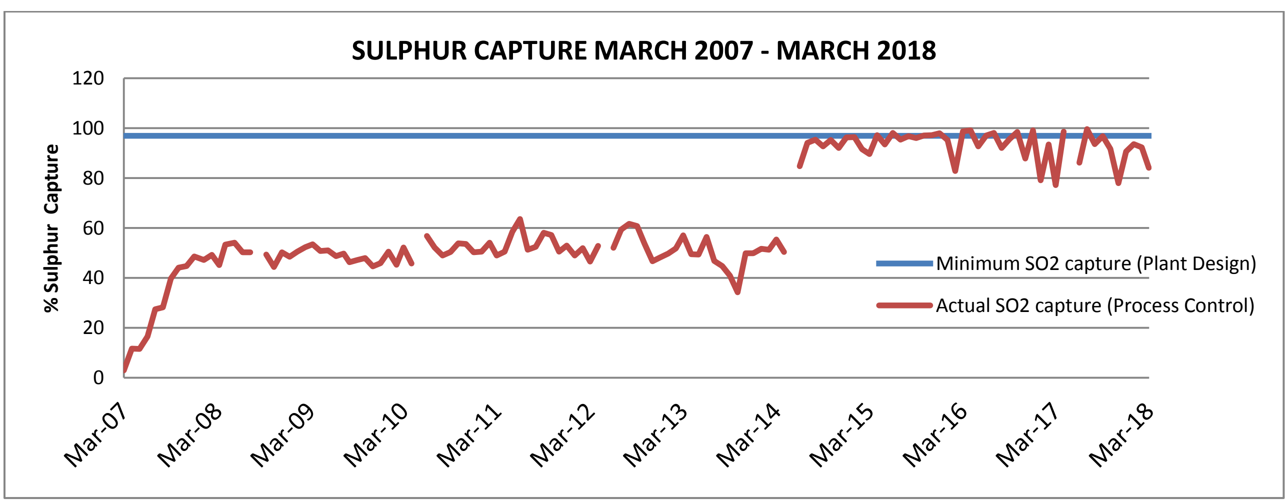

Figure 4.13: Sulphur Dioxide Capture Trend - March 2007 to March 2018

4.6 Trends in water quality

The results from the selected five sampling points are given in Table 4.6 below. More detailed explanations on the trends and implications of the data are given in the later subsections. These results are the typical averages of the analyses obtained for each quality test parameters for the period from January to July 2018 except for the household or domestic water from the taps which were sampled between March and August 2018. The prefix 'T' and 'D' for Cu, Co, Fe and Mn stands for total and dissolved Cu, Co, Fe and Mn respectively.

Table 4.6: Averages of water quality parameters for selected critical sampling points

Test Parameter	Statutory (ZEMA) Limits	Concentration Units	Kafue River Water	Industrial Water from Underground	Mine Effluent
Conductivity	-	µS	250.90	1485.19	1467.58
TCu	1.5	mg/l	0.07	0.70	1.24
DCu	-	mg/l	0.02	0.13	0.44
TCo	1.0	mg/l	0.02	0.03	0.05
DCo	-	mg/l	0.02	0.01	0.04
TFe	2.0	mg/l	0.42	1.03	1.42
DFe	-	mg/l	0.17	0.04	0.58
TMn	1	mg/l	0.19	0.11	0.27
DMn	-	mg/l	0.17	0.04	0.19
TDS	3000	mg/l	126.65	740.56	725.68
Sulphates	1500	mg/l	63.23	367.44	349.03
TSS	100	mg/l	21.55	45.94	49.10
pH	6.5-9.0	-	7.89	7.84	8.02
Pb	-	mg/l	0.04	0.03	0.05
Cd	-	mg/l	0.01	0.01	0.01

4.6.1 River water

The river water refers to Kafue river water which is the source of water supply for both domestic and industrial use. The average water quality parameters were all within the statutory limits. The Kafue River is the major natural water catchment in this region.

4.6.2 Tap water / Domestic water from underground

Drinking water supply to the people of Mufulira is from three main sources. The municipal residential area has a piped water from the Kafue River. The mine townships are supplied by water from the network that partly comes from the dewatering operations in the underground mine and from the Kafue River. The water supply is solely managed by local utility water company called Mulonga Water and Sewerage Company (MWSC). The third source of water is the boreholes and shallow water wells for those people who are not connected to the piped network. Kankoyo Township is a mine residential area which is exclusively supplied with water from underground treated piped network. The average water quality parameters were all within the statutory limits. However a comprehensive table of test parameters in Appendix 5 and 6 shows a number of parameters above the ZABS and WHO maximum permissible limits for drinking water. The relatively high levels of turbidity, iron, and sulphates can be attributed to the heavily dilapidated water network infrastructure since these are not lower than those from the mine effluents which are the possible sources of contamination. The tap water in most households was collected from broken down water connections which are much more prone to contamination (plate 3.5).

Table 4.7: Typical quality parameters of Domestic water from underground and Household Water from water taps

Test Parameter	Statutory (ZABS) Limits	Statutory (WHO) Limits	Concentration Units	Domestic Water from Underground	Household Water from Taps
Conductivity	1500	-	µS	1567.75	1193.00
TCu	1.0	1.5	*mg/l*	0.31	0.20
DCu	-	-	*mg/l*	0.10	-
TCo	0.5	-	*mg/l*	0.01	0.04
DCo	-	-	*mg/l*	0.01	-
TFe	0.3	0.3	*mg/l*	0.31	0.49
DFe	-	-	*mg/l*	0.08	-
TMn	0.1	0.05	*mg/l*	0.07	0.26
DMn	-	-	*mg/l*	0.03	-
TDS	1000	1000	*mg/l*	792.63	662.00
Sulphates	400	400	*mg/l*	393.31	325.00
TSS	-	1500	*mg/l*	31.44	10.00
pH at 25^oC	6.5-8.0	6.5-8	-	7.84	7.60
Pb	0.01	0.01	*mg/l*	0.02	<0.1
Cd	0.003	0.01	*mg/l*	0.01	<0.1

4.6.3 Mine process water / Industrial water from underground

All the test parameters in the mine process or industrial water show the parameters that are beyond the drinking water limits, and the long term effects of the same in appendix 10 were all within the ZEMA limits for Industrial effluents.

4.6.4 Mine Effluents

All the test parameters in the mine effluent discharges shown in appendix 8 were within the ZEMA limits for Industrial effluent discharge.

4.7 Perceived cause and extent of air pollution

The perceived cause of air pollution in Kankoyo Township is deemed to be entirely mining operations and this is deeply inherent in the residents of this old mining township. Perhaps this has been an inherited problem for the current generation of the people in this township. Significant air pollution at Mufulira results from gaseous emissions from the Smelter. Other sources of air pollution but of lesser significance are bare surfaces on the plant site and tailings dumps. (Mopani Copper Mine, 2004). Environmental pollution is the key concern for the humanity. The extent of air pollution in Kankoyo is quite devastating and requires immediate, reliable and solutions to minimise its impact on the natural and physical environment.

4.8 Perceived cause and extent of water pollution

The perceived cause of water pollution in Kankoyo Township is deemed to be total negligence from the water utility company, and the lack of concern from the mining company. This is also a long outstanding view for the inhabitants of this old mining township. The extent of water pollution is actually quite threatening especially that some contaminants such as suspended solids are clearly seen from all the household taps in the morning when the tap water is opened. In most households that were visited, the tap water is usually left to run open to allow for the suspended solids (usually sand and soil particles) to clear from the pipe for some few minutes and then collect and store water for domestic consumption. Thus, the cause and extent of water pollution is perceived to be failure from the water utility company and the mining company to provide clean water to Kankoyo Township. This problem requires a practical and sustainable solutions to mitigate the impact of water pollution on the healthy and social wellbeing of this township.

4.9 Impacts of air and water pollution on the local environment

Kankoyo Township has a long standing legacy of sulphur dioxide in the air starting from the time the Mufulira Smelter was initially commissioned in 1937. The effects of air and water pollution on the local environment in Kankoyo Township have been very devastating as evidenced by the general land degradation. According to (Musonda, 2015) “Mining in Zambia has led to devastating environmental and health impacts on the nearby communities”. He further argues that “while mining still remains the main stay of the Zambian economy, it is inherently devastating to the environment in two main ways: Physical pollution result from the ingress of particulates into the atmosphere (as dust and aerosols), into water or onto land. Chemical pollution can occur by the release to the environment of reagents added during mineral processing and by oxidation of naturally occurring minerals in the ore as a result of exposure to air. Despite the huge technological investments in the reduction of sulphur dioxide emissions from the copper smelting plant, there is still a presence of fugitive gas emissions which put miners and residents at a greater risk of contracting serious respiratory illnesses. According to the (Fahrbach & Watenphul, 2011), at Mufulira Glencore metallurgical smelters, SO_2 and PM are typically emitted as either stack or fugitive emissions. Similarly, water pollution from the mining discharges and runoffs if not properly contained can cause serious health and environmental effects in the residents of Kankoyo Township. Filed observations in figures 4.14 and 4.15 on the next page shows that the air pollution in Kankoyo Township has negatively affected the physical environment as evidenced by excessive corrosion of iron roofing sheets, and paint degradation including the serious deterioration of the soils and vegetation due to acid rains.

Figure 4.14: House with Corroded iron roof sheet caused by acid rain
Source: Field Data , August 2018

Figure 4.15: Bare land with literally no vegetation grown
Source: Field Data , August 2018

4.10 Summary

This Chapter expressly presented the findings for this research in several subheadings in order to systematically provide the recent information on the effects of the mining operations on the air and water quality in Kankoyo Township. The subsequent Chapter will focus on the discussion of these findings and relate the results to the objectives of the study and answer the research questions of this study.

CHAPTER FIVE

DISCUSSION OF THE FINDINGS

5.0 Introduction

This is a discussion of the research findings in relation to the research objectives as a way of answering the general and specific research questions. It focuses on the finding of the causes and extent of air and water pollution in Kankoyo Township as a means of understanding the social views of people about the causes and effects of air and water pollution in Kankoyo Township. The discussion provides suggestions for minimising air and water pollution in the MCM operations and the surrounding communities.

5.1 Types of Samples

Two types of samples were considered for the purpose of this study; namely water and air samples. The definition and collection of the correct, representative and reliable samples was very inevitable. Standard sampling protocols were followed to ensure proper sample collection and reliability of analytical results was taken care of by using the BSI ISO 19001:2015 certified laboratory.

5.1.1 Water samples

Three categories of water samples were considered in order to fully understand the causes and extent of water pollution in Kankoyo Township. These are domestic water, industrial waste water (mine effluents) and the Kafue river water. The average analytical results for domestic water were generally within the Zambian Bureau of standards (ZABS) and the World Health Organisations (WHO) allowable limits of drinking water quality as shown in Appendix 5 and 6. However, at certain times, some water quality parameters (Turbidity, Iron, sulphates and conductivity) exceeded the ZABS and WHO maximum permissible allowable limits for drinking water. This can be attributed to the dilapidated state of the pipe water network and water treatment infrastructure which are the likely cause of water pollution. Turbidity is a measure of the degree to which the water loses its transparency due to the presence of suspended particulates. The ingress of suspended solids and sulphates in the dilapidated pipelines may lead to increase in turbidity levels and increase in iron and sulphates levels in water respectively. Dissolved metal salts are responsible for high conductivity of water. The typical analytical results for Kafue river water were within the ZABS and WHO maximum permissible allowable limits for drinking water as well the ZEMA effluent statutory limits.

5.1.2 Air samples

The air quality discussed in this study is the ambient air in Kankoyo Township and other selected parts of Mufulira District. The air samples were collected and analysed at the seven air sampling stations located in different sections of Mufulira District as shown in Table 4.1 in section 4.1.2 in Chapter 4. These air sampling and monitoring stations are the state of art equipment which use the S5001 SO_2 analyzer series to determine sulphur dioxide content in air over a range of 0-2ppm with a lower detection limit (LDL) of 0.5 ppb. The determination of sulphur dioxide is based on classical fluorescence spectroscopy principles. Sulphur dioxide exhibits a strong ultraviolet (UV) absorption spectrum between 200 and 240nm, when SO_2 absorbs UV from this, emission of photons occurs (300-400nm). The amount of fluorescence emitted is directly proportional to the SO_2 concentration. (Ecotech, 2011). The S5001 follows these principles and measurement techniques:

- Sample air is passed through a hydrocarbon kicker a device which removes hydrocarbons from sample air.
- A zinc discharge lamp and a UV band pass filter is used to produce radiation at 214nm.
- The radiation (214nm) is focused into the fluorescence cell where it interacts with SO_2 molecules and emits photons uniformly in all directions.
- A portion of the fluorescence is collected and filtered.
- Wavelengths at 310-350nm pass through the filter where they reach the photomultiplier and record a signal.
- A reference detector monitors the emission from the zinc lamp and is used to correct for fluctuations in lamp intensity.

- Air drawn from the Background Port is scrubbed via charcoal and then passed through a particulate filter. This air is then available for use by the Hydrocarbon Kicker and is also used to perform zero background adjustments.

5.2 Characteristics of respondents

5.2.1 Gender of respondents

The findings collected from the 31 respondents show that there were 18 females and 13 males representing 58% and 42% respectively. This was a reasonable representation despite the expectation of almost equal percentages of male and female participants as stated in section 4.2.1 in chapter 4.

5.2.3 Age of respondents

The age of the respondents was equally important in ensuring correct representation of the age group participating in the research. This had a great effect on the nature of responses provided. The highest number of the participants were the youths from the age group ranging from 26-30years representing 22.6% while the adult members from the ages of 31-35yrs; 36-40yrs and those above 51yrs were each 16.1%. The age distribution of the participants from 21yrs to above 51yrs old was deemed to be good enough to provide reasonable information to be used in this study. It is noted that the age distribution of the respondents is well spread to give confidence in the information given by the participants. The information collected on the age distribution of the participants shows the need to engage the youth as part of the concerned or affected stakeholders who can play an important role in helping providing sustainable solutions to prevent pollution caused from the mining and mineral processing activities.

5.2.4 Educational level of respondents

The education levels of the respondents from primary, secondary and tertiary levels were at 25.8%, 51.6% and 22.6% respectively. The educational levels of the respondents were very important because it helped the researcher to appreciate the knowledge level of the respondents during the data collection process. Table 4.3 in section 4.2.3 shows the education level of the respondents.

5.2.5 Perception of respondents

The analysis of the perceptions of the residents of Kankoyo on air and water pollution is that much as they appreciate the importance of the mining industry to the economy of Zambia, they still believe Kankoyo Township has not benefited much in terms of employment opportunities, environmental protection and Corporate Social Responsibility (CSR) from the mining industry. They feel the mining company has no care for the community in which it operates from.

However, most residents interviewed did not look at the problem of pollution with the positive or justifiable holistic approach, apart from blaming the mining company for every environmental problem. Despite the significant reductions in sulphur dioxide emissions that Mopani has recorded in the recent past, the some residents of Kankoyo still believe that very little has been done in addressing the air and water quality (notable environmental problems) issues in this township.

5.3 Trends in ambient air quality

Ambient air quality is defined as the physical and chemical measure of pollutant concentrations in the ambient atmosphere to which the general population will be exposed. In most developing countries, ambient air quality is reported to have deteriorated seriously, especially in urban areas, exposing populations to pollutant levels above the recommended limits (UNEP, 1998).The trends in air quality in Mufulira and Kankoyo Township in particular shows some remarkable improvements. The available sulphur dioxide concentration information for the last two decades for Kankoyo (as shown in table 4.5 and figure 4.12 in chapter 4) shows a significant decrease in sulphur dioxide emission levels from over 400 $\mu g/m^3$/24hrs to less than 110 $\mu g/m^3$/24hrs from 1995 to June 2018. The results are supported by the massive technological investments in sulphur dioxide capture in the copper smelting plants after the year 2010.

Although there are seasonal and operational variations in terms of sulphur dioxide emissions as shown in Appendix 23, the general trend still shows that Kankoyo Township is more affected than other townships. Out of the forty eight times that Mufulira recorded average and maximum SO_2 emissions above the 125 μg/m^3/24hrs ZEMA maximum allowable limit for the period January 2017 to June 2018, Kankoyo recorded twenty three times representing 48% of total counts. Kantanshi clinic 3 and clinic 6 Stations recorded thirteen and six times representing 27% and 13% respectively. Butondo and Eastlea stations recorded no incidences of SO_2 emissions of during the same period. Kamuchanga Station and Malcolm Hospital Station recorded four and two times representing 8% and 4% respectively.

The study reveals significant information towards the effects of mining operations on the air and water quality in Kankoyo Township. Although there are a number of air quality criteria pollutants (carbon monoxide, ozone, nitrogen dioxide, particulate matter, dust, and sulphur dioxide), this study concentrated only on SO_2 because of the unavailability of equipment to measure other pollutants. There was only seven automatic air samplers' model S5001 SO_2 analyser available with restricted access.

The results in figure 4.12 shown in section 4.5 of chapter 4 shows significant reductions in terms of sulphur capture and sulphur dioxide emissions from the Copper Smelter. The average sulphur capture was 48% from 2007 to 2013 and about 94% from 2014 to 2018. The 46% sulphur capture improvement in four years period from 2014 to 2018 is a remarkable improvement attributed to technological upgrade and good operating practices implemented at Mopani Mufulira Copper Smelter. Since the inception of the Mufulira Copper Smelter in 1937, there was no sulphur dioxide abatement facility (Ross & Vries, 2005). Quite apart from the metallurgical benefits of the ISASmelt process, an ISASmelt furnace used in a converting operation that undoubtedly recover more sulphur than conventional converters, sulphur is converted into sulphuric acid which is sold to other mines. The average annual sulphur dioxide emissions for 2017/2018 at 144.5μgm^3 in Kankoyo Township were 15.6% above the statutory limit of 125μgm^3 in ambient air (μgm^3 /24hrs).

5.4 Trends in water quality

The typical results of water quality parameters for Kafue River, industrial water from underground, domestic water from underground, household water from the taps and mine effluents are given in table 4.6. More detailed explanations of the implications of data are given in the later subsections. These results are the averages of the analyses obtained for each water quality parameter for the period March to August 2018. Laboratory results in table 4.6 in the previous chapter shows that the test parameters for the samples were within the ZABS allowable limits for drinking water. However the case of pH, the standard is given as a range from 6.5 to 9.0. All the pH range for the water samples were less than 9.0. There is not much pH variations in the different water samples tested from the period January to July/August 2018. This shows that the alkalinity of the water provides a good pH buffering.

Although the impact of mining and other human activities might not push the toxic levels of some elements beyond the set limits, the results show that these activities do have a great impact as can be seen from the results of the pollutant concentrations in the main mine drain and underground water as seen in Appendix 8 and 9 respectively.

Industrial and domestic water from underground (See Appendix 10 and 11) shows higher conductivity levels including total iron (TFe) and sulphates compared to other water sources. Trend for iron ranges from 0.01mg/L to 1.11mg/L and 0.01mg/L to 6.88mg/L for domestic and Industrial underground water respectively. The trends for sulphates ranges from 214mg/L to 577mg/L domestic water from underground. The relatively high level of copper in the month of January, February and July 2018 can however be attributed to some copper concentrates from the smelter being washed to the drain by rain water and process water respectively (Mopani, 2018).

The trend for Water quality parameters for industrial water from underground is mixed-up with some months showing high levels of contaminants, others showing a relatively constant and the rest showing a decrease. Kafue River water shows a fairly low levels of contaminants apart from the high levels for iron and manganese in April 2018 which can be accounted for by experimental errors arising mainly from the sampling techniques applied. Environmental; water samples are manually scooped from the flowing streams with high possibilities of increment delimitation errors.

5.5 Perceived causes and extent of air pollution

Clean air is considered to be a basic requirement of human health and well-being. Air pollution has continued to be perceived as a serious environmental problem in Kankoyo Township. The main causes of air pollution are the sulphur dioxide and particulate matters emitted from the copper smelting plant. The extent of air pollution in some cases has reached higher levels than those recommended by ZEMA as can be seen from the destructive effects on the physical and natural environment in the surrounding community of Kankoyo and also from the field data shown in Appendix 18: i.e. the number of times SO_2 emissions exceeded ZEMA maximum emission limit for the eighteen months period from period January 2017 to June 2018 was about 48% in Kankoyo Township. This show that despite the technological interventions by upgrading the copper smelting and the sulphuric acid plants to improve the capture of SO2, there is still fugitive emissions that need serious attention. According to (Chanda, 2017), the pollutants from the copper Smelting plant continue to be periodically released in the atmosphere, mostly during periods of electronic control and monitoring system failure during unplanned power outages. As a result 91% of the residents interviewed in this study repeatedly stated that air pollution has degraded their quality of life. Further details of the field responses on the perceived causes and extent of air pollution in Kankoyo Township are shown in Appendix 23.

5.6 Perceived causes and extent of water pollution

There is limited published evidence available on public perceptions of water quality in Kankoyo Township, even though a number of reports that focuses on perceptions of air quality do exists. In the case of Mopani Mufulira site, the use of in situ leaching (ISL) is all open to criticism because the acid is injected into a deposit adjacent to the underground water that supplies the town of Mufulira (CPTD, 2010). Such criticisms as this are still prevalent today in Kankoyo Township and the surrounding communities despite the fact that Mopani Copper Mine stopped in situ leaching way back in 2015. Even though previous reports show pollution incidences of acid contamination in Mufulira's water network (CPTD, 2010), the majority of the population in Kankoyo have this conception that Mopani mine has permanently polluted the water supply to this township. Thus, the perceptive extent of water pollution is far beyond rectification to the ordinary majority residents. The majority of the residents (about 70%) interviewed perceive the quality of water to be unhealthy for human consumption. See appendix 24 for details.

5.7 The impact of air pollution on the local environment

Environmental impacts from mining operations are significant and quite often severe, especially in developing nations which lack adequate management of the sector. In Zambia, impacts from mining results from both historical and ongoing mining operations, and the majority of them is located in the Copperbelt district (Lindahl, 2014). Impacts of air pollution on the local environment has been very devastating. The buildings and the surrounding environment have been degraded due to corrosive effects of acid rains. Residents complain of headaches, coughing, itching eyes and ears and bronchitis.

5.8 The impact of water pollution on the local environment

The mining operations in the Mufulira district are within the catchment area of the Kafue River and other natural water bodies such as the Mufulira and Kansuswa streams. Several studies have shown that concentrations of many dissolved elements (i.e. ions) are clearly elevated in the Kafue and its tributaries within the Copperbelt (Lindahl, 2014). The dissolved element contaminants are mainly from the run off mine (ROM) and untreated effluent discharges including the domestic and industrial water from underground and process plants effluents. Results from this study shows significantly reduced water pollutants in the local environment as opposed to previous studies. The mining company has shown some commitment to pollution control and environmental management as evidenced by vigorous routine environmental monitoring and massive investments in process operations technological upgrade to improve on process efficiency and minimize environmental pollution. However, results from this study shows that the general dilapidation of the water pipeline and network system is another potential source of water pollution.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This chapter gives a summary of the conclusions of the study findings based on the data obtained from the field and laboratory test works. It also presents some recommendations.

6.2 Conclusions

From the study, results have shown that significant reductions in terms of sulphur capture and sulphur dioxide emissions from the Copper Smelter have been progressively achieved since implementation of the Smelter technological upgrade in 2014. The average sulphur capture was 48% from 2007 to 2013 and about 94% from 2014 to 2018. The average annual sulphur dioxide emissions for 2017/2018 at 144.5μgm^3 in Kankoyo Township were 15.6% above the statutory limit of 125μgm^3 in ambient air (μgm^3 /24hrs). This is a remarkable achievement considering that, there was no sulphur dioxide abatement facility at the Mufulira Copper Smelter since its inception in 1937.The upgrade of the new smelter and acid plant in the recent years has worked well in the reduction of sulphur dioxide emissions, however periodical fugitive emissions do occur and cause pollution but not to significant or alarming quantities. It was also observed that the air pollution has negatively affected the physical environment as evidenced by excessive corrosion of iron roofing sheets, wall plaster and paint degradation including the serious deterioration of the soils due to acid rains. See detailed evidence of environmental degradation from figure 4.14 and figure 4.15 in Chapter 4.

The general water quality meets the ZEMA and ZABS allowable statutory limits for effluent discharge and domestic drinking water quality respectively. It is worth noting that the water quality in this area may not only be attributed to the mining activities but also from the dilapidated water infrastructure and pipe network which may be the likely source of alternative contamination of water.

However, the negative impact of air and water pollution that has been in existence for the past six decades are still eminent and represents serious environmental concerns to Kankoyo residents and other interested parties. It therefore, suffice to state that the Kankoyo community is faced with tremendous environmental problems due to the legacy of the past and this needs urgent sustainable abatement solutions for the healthy and social wellbeing of the people and natural environment of Kankoyo Township.

6.3 Recommendations

The mining company should seriously consider investing in environmental protection programmes that will help mitigate some of the environmental concerns raised by the communities around the mine site and various other stakeholders. It should also consider continuous technological improvements to maximise sulphur capture; the captured sulphur should not only end up at sulphuric acid production but also other value additional by-products such as phosphoric acid and sulphates/phosphate containing fertilizers.

To ascertain the effectiveness of air and water pollution control technologies employed in the mining industry, the mining company should ensure robust equipment maintenance and strict environmental routine monitoring of all pollution control points. The government of Zambia (GRZ) through the Ministry of Lands and Natural Resources must ensure that ZEMA and the local authority are adequately equipped with sufficient capacity and information to provide the various stakeholders on the state of the environment and various sources of pollution that a community may be experiencing.

6.3.1 Recommendations for further research

The effects of mining operations on air and water quality in Kankoyo Township should be looked at in more detail by future researchers and scholars. Preferably, future projects should involve the whole year round sampling of water samples from all the critical water sources / bodies. The correlation between the variable parameters such as pH of rain water and other types of water, local soils and vegetation should also be investigated. Besides, the air quality study should also include the particulate matter (PM) also known as particle pollution as a critical parameter for serious consideration.

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APPENDICES

Appendix 1: Information Sheet

Name of Student: Darius Muma

Student Number: 2017011824

Institution: University of Zambia School of Mines

Field of Study: MSc. Sustainable Mineral Resource Development

Area of Research: Air and Water Pollution arising from mining activities in Kankoyo Township of Mufulira District in the Zambian Copperbelt Province

Research Target group: Kankoyo community, local authority, mine owners / investors, Interested Stakeholders.

General Research parameters: Air and Water Quality

Research Sponsors: Education for Sustainable Development in Africa (ESDA)/ African Development Bank (ADB)

Duration of Research: Eleven months – starting from October 2017 to August 2018

Appendix 2: Consent Form

My name is Darius Muma and I am a postgraduate student from the School of Mines at the University of Zambia (UNZA) in Lusaka. As part of my degree course, I am undertaking a research project for Master of Science dissertation. The title of my project is: ***Effects of Mining Operations on Air and Water Quality in Mufulira District of Zambia: A Case Study of Kankoyo Township.***

The main objective of this study is to carry out an investigation into the effects of mining operations on air and water quality in the Kankoyo area of Mufulira district. The findings of the project will be useful to the community of Kankoyo Township and all the concerned stakeholders because it will provide the relevant updated information on the effect of mining activities on the air and water pollution. The research is being conducted under the supervision of Dr. Bunda Besa, Dean School of Mines at the University of Zambia.

I am looking for volunteers to participate in this project. There are no criteria (e.g. gender, age, or health status) for being included or excluded – everyone is welcome to take part. Your participation in this research study is voluntary. You may choose not to participate and you may withdraw your consent to participate at any time. You will not be penalized in any way should you decide not to participate or to withdraw from this study. If you agree to participate in the study, you will be asked to sign this consent form. There are no a risks that is associated with this research.

All data collected will be strictly for academic purpose and will be confidentially treated as such. Your identity will not be revealed in any publication resulting from this study. The results may be published in a journal or presented at a conference.

If you would like to contact an independent person, who knows about this project but is not involved in it, you are welcome to contact Dr Bunda Besa on +260 979351754 / +260 965373644 or Dr. Jewette Masinja on +260 977134622 / +260 978704972.

If you have read and understood this information sheet, any questions you had have been answered, and you would like to be a participant in the study, please now see the consent form.

Appendix 3: Effects of Mining Operations on Air and Water Quality in Mufulira District of Zambia: A Case Study of Kankoyo Area

The University of Zambia requires that all persons who participate in research studies give their written consent to do so. Please read the following and sign it if you agree with what it says.

1. I freely and voluntarily consent to be a participant in the research project on the topic of environmental pollution to be conducted by Mr. Darius Muma who is a postgraduate student at the University Of Zambia School Of Mines.

2. The broad goal of this research study is to explore the effects of mining operations on air and water quality in Kankoyo Township. Specifically, I am required to provide information on perceived and actual effects of gaseous emissions and effluent discharge from the mining operations in Kankoyo Township, which should take no longer than estimated eleven months to complete.

3. I have been told that my responses will be anonymised. My name will not be linked with the research materials, and I will not be identified or identifiable in any report subsequently produced by the researcher.

4. I also understand that if at any time during the survey/interview/session I feel unable or unwilling to continue, I am free to leave. That is, my participation in this study is completely voluntary, and I may withdraw from it without negative consequences. However, after data has been anonymised or after publication of results it will not be possible for my data to be removed as it would be untraceable at this point.

5. In addition, should I not wish to answer any particular question or questions, I am free to decline.

6. I have been given the opportunity to ask questions regarding the interviews and or research sampling procedure and my questions have been answered to my satisfaction.

7. I have read and understand the above and consent to participate in this study and have been given the opportunity to ask questions. I give my consent to participate in this study.

Furthermore, I understand that I will be able to keep a copy of the informed consent form for my records if needed.

Participant’s Signature Date

I have explained and defined in detail the research procedure in which the respondent has consented to participate. Furthermore, I will retain one copy of the informed consent form for my records.

Researcher’s Signature Date

For further information, including a copy of the results of this study, please contact: Mr. Darius Muma; Mobile numbers: +260 977 696128 / +260 66312198 / +260 962484705
Email: darius.muma@gmail.com

Appendix 4: Interview guide for research participants

A semi structured interview guide on the effects of mining activities on water and air quality in Kankoyo Township of Mufulira district.

A. Basic Information

1. Gender:
   - Male/Female (Circle or tick where applicable)
2. Age of respondent: (Circle or tick where applicable)
   - 15-20yrs
   - 21-25yrs
   - 26-30yrs
   - 31-35yrs
   - 36-40yrs
   - 41-45yrs
   - 46-50yrs
   - 50yrs & above
3. Educational level of respondent: (Circle or tick where applicable)
   - Primary
   - Secondary
   - Tertiary

B. Perceived effects of air pollution

Air Quality Perception Guide; to be answered with reference to pollution effect in the past seven days.

No.	Over the past week, as a result of air pollution, did you:	Never	Sometimes	Often	Always
1	Smell unpleasant smell indoors?				
2	Smell unpleasant smell outdoors?				
3	Have difficulty in breathing?				
4	Have eye irritations?				
5	Have chest of related pains?				
6	Suffer from nose irritation?				
7	Physically see / observe fume or gas emissions in your location?				
8	Suffer from headaches?				
9	See medical attention on cases related to air pollution?				
10	Feel worried about your health?				
11	Think that your quality of life was being degraded?				
12	Think about shifting to another place?				
13	Use perfume or an air freshener in your home?				
14	How do you rate the quality of air in your community with reference to the following ratings: 1) Good 2) Moderate 3) Unhealthy for sensitive groups i.e. active children / old people 4) Unhealthy				

Thank for your responses.

C. Perceived effects of water pollution

As part of the survey I am also looking at the quality of household drinking water that is usually used by your household members. Your household has been randomly selected for this part of the survey and I would like to perform some simple water quality test using samples of your usual drinking water.

No.	Question	Answer	Filed Observations / Comments
1	What is your House Number?		
2	What is the source of your drinking water?		
3	Can you please show me the actual source where you collect your drinking water from so that I can take a water sample from this source? [***If 'no' probe to find out why this is not possible***]		
4	May you show me the vessel you use for water collection?		
5	May you also show me the vessel you use for water storage?		
6	How do you rate the quality of water in your community with reference to the following ratings: 5) Good 6) Moderate 7) Unhealthy for sensitive groups i.e. active children / old people 8) Unhealthy		

May I ask you the following questions?

Thank for your responses.

Appendix 5: Laboratory results for tap (household) water from Kankoyo Township

Sample Date	Sampling Point	Sample Code	Parameters															
			Conductivity	**Turbidity**	**TCu**	**DCu**	**TCo**	**DCo**	**TFe**	**DFe**	**TMn**	**DMn**	**TDS (ppm)**	**Sulphates**	**TSS**	**pH**	**Pb**	**Cd**
			µS/cm	**NTU**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**ppm**	**mg/l**	**mg/l**		**mg/l**	**mg/l**
ZABS- Maximum Permissible Limits in drinking water			**1500**	**5**	**1.0**		**1.0**		**0.3**		**1.0**		**1000**	**400**	**100**	**6.5-9.0**		
WHO- Maximum Permissible Limits in drinking water			**1500**	**5**	**1.0**		**1.0**		**0.3**		**1.0**		**1000**	**250**	**100**	**6.5-9.0**		
31.03.2018	1	DKM 01	1184	4	<0.10	-	<0.10	-	0.50	-	<0.1	-	589	53	2	7.4	<0.1	<0.1
31.03.2018	2	DKM 02	1189	4	<0.10	-	<0.10	-	0.19	-	<0.1	-	663	37		7.5	<0.1	<0.1
31.03.2018	3	DKM 03	1182	5	<0.10	-	<0.10	-	0.57	-	<0.1	-	588	60	8	7.5	<0.1	<0.1
31.03.2018	4	DKM 03	1201	5	<0.10	-	<0.10	-	0.34	-	<0.10	-	666	39	21	7.1	<0.1	<0.1
06.04.2018	5	DKM 04	1330	5	<0.10	-	0.03	-	0.31	-	0.22	-	662	25	4	7.7	<0.1	<0.1
06.04.2018	6	DKM 05	1438	8	0.05	-	0.04	-	0.49	-	0.23	-	718	398	5	7.6	<0.1	<0.1
06.04.2018	7	DKM 06	1375	8	0.14	-	0.04	-	0.54	-	0.25	-	687	359	3	7.6	<0.1	<0.1
06.04.2018	8	DKM 07	1389	12	0.35	-	0.06	-	0.58	-	0.42	-	694	333	7	7.5	<0.1	<0.1
06.04.2018	9	DKM 08	1404	5	0.51	-	0.06	-	1.14	-	0.38	-	702	375	4	7.6	<0.1	<0.1
06.04.2018	10	DKM 09	1424	32	0.33	-	0.05	-	1.69	-	0.35	-	712	247	36	7.8	<0.1	<0.1
06.04.2018	11	DKM 10	1334	5	0.32	-	0.06	-	0.88	-	0.29	-	666	323	5	7.7	<0.1	<0.1
16.04.2018	12	DKM 11	1260	8	0.05	-	<0.10	-	0.33	-	<0.10	-	631	263	2	7.9	<0.1	<0.1
16.04.2018	13	DKM 12	1275	<1.0	<0.10	-	<0.10	-	<0.10	-	<0.10	-	638	446	3	7.8	<0.1	<0.1
16.04.2018	14	DKM 13	1237	6	<0.10	-	<0.10	-	0.23	-	<0.10	-	621	323	5	7.7	<0.1	<0.1
16.04.2018	15	DKM 14	1249	17	0.11	-	<0.10	-	0.57	-	<0.10	-	624	221	3	7.6	<0.1	<0.1
16.04.2018	16	DKM 15	1273	2	0.03	-	<0.10	-	0.12	-	<0.10	-	637	392	4	7.7	<0.1	<0.1
02.06.2018	17	DKM 16	1311	3	<0.1	-	<0.10	-	0.50	-	<0.1	-	589	403	2	7.4	<0.1	<0.1
02.06.2018	18	DKM 17	1271	3	0.12	-	<0.10	-	0.19	-	<0.1	-	637	263	9	7.6	<0.1	<0.1
02.06.2018	19	DKM 18	1320	5	<0.1	-	<0.10	-	0.57	-	<0.1	-	588	431	8	7.5	<0.1	<0.1
02.06.2018	20	DKM 19	1301	6	<0.10	-	<0.10	-	0.34	-	<0.10	-	663	465	7	7.6	<0.1	<0.1
02.06.2018	21	DKM 20	1279	5	0.14	-	0.03	-	0.31	-	0.22	-	662	279	4	7.7	<0.1	<0.1
02.06.2018	22	DKM 21	1303	7	0.05	-	0.03	-	0.49	-	0.23	-	718	317	5	7.6	<0.1	<0.1
02.06.2018	23	DKM 22	1375	9	0.14	-	0.04	-	0.54	-	0.25	-	687	297	3	7.6	<0.1	<0.1
02.06.2018	24	DKM 23	1318	11	0.06	-	<0.10	-	0.58	-	0.42	-	694	201	7	7.5	<0.1	<0.1

*Shaded areas indicates parameters above the Maximum permissible limits of Zambian Standard for Drinking Water

Appendix 6: Laboratory results for tap (household) water from Kankoyo Township

Sample Date	Sampling Point	Sample Description	Parameters															
			Conductivity	Turbidity	TCu	DCu	TCo	DCo	TFe	DFe	TMn	DMn	TDS (ppm)	Sulphates	TSS	pH	Pb	Cd
			µS	NTU	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	ppm	mg/l	mg/l		mg/l	mg/l
ZABS- Maximum Permissible Limits in drinking water			**1500**	**5**	**1.0**		**1.0**		**0.3**		**1.0**		**1000**	**400**	**100**	**6.5-9.0**		
WHO- Maximum Permissible Limits in drinking water			**1500**	**5**	**1.0**		**1.0**		**0.3**		**1.0**		**1000**	**250**	**100**	**6.5-9.0**		
02.06.2018	25	DKM 24	1321	6	0.31	-	0.06	-	1.14	-	0.38	-	702	316	4	7.6	<0.1	<0.1
23.06.2018	26	DKM 25	1397	29	0.12	-	0.07	-	1.23	-	0.31	-	682	299	26	7.6	<0.1	<0.1
23.06.2018	27	DKM 26	1349	4	0.11	-	0.05	-	0.49	-	0.18	-	775	198	6	7.7	<0.1	<0.1
23.06.2018	28	DKM 27	1289	6	0.02	-	<0.10	-	0.12	-	<0.10	-	641	54	1	7.8	<0.1	<0.1
23.06.2018	29	DKM 28	1292	2	<0.10	-	<0.10	-	<0.10	-	<0.10	-	645	63	3	7.7	<0.1	<0.1
23.06.2018	30	DKM 29	1364	5	0.14	-	<0.10	-	0.11	-	<0.10	-	710	23	3	7.6	<0.1	<0.1
23.06.2018	31	DKM 30	1398	22	0.31	-	<0.10	-	0.61	-	0.2	-	640	661	4	7.8	<0.1	<0.1
23.06.2018	1	DKM 31	1290	2	0.08	-	<0.10	-	0.14	-	<0.10	-	671	643	2	7.7	<0.1	<0.1
02.08.2018	3	DKM 01	8088	5	<0.1	-	<0.10	-	0.17	-	<0.10	-	719	649	15	7.1	<0.1	<0.1
02.08.2018	5	DKM 02	7843	3	<0.1	-	<0.10	-	0.13	-	<0.10	-	645	323	23	6.9	<0.1	<0.1
02.08.2018	7	DKM 03	7219	11	0.11	-	0.01	-	0.53	-	0.39	-	721	295	4	8.1	<0.1	<0.1
02.08.2018	9	DKM 03	3368	13	0.21	-	0.02	-	0.48	-	0.26	-	634	388	14	7.3	<0.1	<0.1
02.08.2018	11	DKM 04	5893	25	0.33	-	0.02	-	1.30	-	0.13	-	742	389	5	7.9	<0.1	<0.1
02.08.2018	13	DKM 05	5527	14	0.12	-	0.06	-	1.20	-	0.19	-	636	225	17	7.4	<0.1	<0.1
02.08.2018	15	DKM 06	10009	20	0.23	-	0.09	-	0.17	-	0.13	-	696	428	31	7.6	<0.1	<0.1
02.08.2018	17	DKM 07	8026	12	0.11	-	0.05	-	0.13	-	0.10	-	737	459	5	7.6	<0.1	<0.1
11.08.2018	19	DKM 08	6877	9	0.10	-	<0.10	-	0.11	-	<0.10	-	679	281	3	7.8	<0.1	<0.1
11.08.2018	21	DKM 09	9606	2	<0.10	-	<0.10	-	0.12	-	<0.10	-	727	393	20	7.7	<0.1	<0.1
11.08.2018	23	DKM 10	6830	13	0.21	-	0.03	-	0.48	-	0.31	-	723	415	33	7.6	<0.1	<0.1
11.08.2018	25	DKM 11	8192	7	0.08	-	<0.10	-	0.19	-	<0.10	-	632	265	24	7.4	<0.1	<0.1
11.08.2018	27	DKM 12	5219	7	0.09	-	<0.10	-	0.15	-	<0.10	-	608	491	4	7.6	<0.1	<0.1
11.08.2018	29	DKM 13	12319	11	0.12	-	0.02	-	1.20	-	0.37	-	693	413	19	7.9	<0.1	<0.1
19.08.2018	DKM 1A	DKM 14	1245	10	0.20	-	<0.01	-	0.27	-	0.02	-	663	233	7	7.8	<0.01	<0.01
19.08.2018	DKM 1B	DKM 15	1300	5	0.21	-	<0.01	-	0.15	-	<0.01	-	651	470	3	8.0	<0.01	<0.01
19.08.2018	DKM 1C	DKM 16	1303	10	0.18	-	<0.01	-	0.24	-	0.03	-	652	479	13	7.9	<0.01	<0.01
19.08.2018	DKM 1D	DKM 17	834	30	1.63	-	<0.01	-	1.16	-	1.03	-	417	487	40	6.8	<0.01	<0.01
19.08.2018	DKM 1E	DKM 18	1262	11	0.17	-	<0.01	-	0.27	-	0.04	-	631	659	11	7.6	<0.01	<0.01
19.08.2018	DKM 1F	DKM 19	1259	9	0.15	-	<0.01	-	0.23	-	0.03	-	630	329	8	7.8	<0.01	<0.01

*Shaded areas indicates parameters above the Maximum permissible limits of Zambian Standard for Drinking Water

Appendix 7: ZEMA Statutory limits for industrial effluents and waste water discharges

Parameters	Conductivity	Turbidity	TCu	TCo	TFe	TMn	TDS	Sulphates	TSS	pH	Pb	Cd
Statutory Limits	-	-	1.50	1.00	2.00	1.00	3,000	1,500	100	6.5-9.0	-	-
ZEMA LIMITS	<4300mS/cm	<15Nephelometer	1.50	1.00	2.00	1.00	<3000	<1500	<100	6.0-9.0	0.50	0.50

Appendix 8: Sampling Point 404 (Main Mine Drain Discharge)

Date	MEASUREMENT PARAMETERS															
	Conductivity	Turbidity	TCu	DCu	TCo	DCo	TFe	DFe	TMn	DMn	TDS	Sulphates	TSS	pH	Pb	Cd
	μS	NTU	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	-	mg/l	mg/l
31-Jul-18	1,471.00	30.00	0.97	0.32	0.02	0.02	0.11	0.01	0.27	0.25	736.00	368.00	26.00	8.60	0.10	0.00
24-Jul-18	1,554.00	22.00	3.62	0.68	0.04	0.03	1.52	0.01	0.21	0.15	777.00	389.00	70.00	7.10	0.10	0.00
17-Jul-18	1,631.00	35.00	1.31	0.42	0.01	0.01	0.77	0.16	0.18	0.13	816.00	408.00	34.00	8.30	0.00	0.00
10-Jul-18	1,564.00	43.00	0.39	0.06	0.01	0.01	0.20	0.01	0.10	0.06	782.00	391.00	36.00	8.30	0.00	0.00
03-Jul-18	1,644.00	61.00	0.66	0.11	0.01	0.01	0.42	0.01	0.10	0.07	822.00	411.00	67.00	8.20	0.00	0.00
26-Jun-18	1,530.00	29.00	0.73	0.10	0.10	0.01	1.02	0.01	0.08	0.03	766.00	383.00	34.00	8.20	0.00	0.00
19-Jun-18	1,515.00	4.00	0.23	0.07	0.01	0.01	0.05	0.01	0.08	0.06	758.00	377.00	8.00	8.40	0.00	0.00
12-Jun-18	1,685.00	44.00	0.89	0.22	0.01	0.01	0.74	0.01	0.16	0.14	826.00	393.00	63.00	8.20	0.20	0.00
05-Jun-18	1,713.00	64.00	0.07	0.07	0.01	0.01	1.69	0.01	0.25	0.18	840.00	400.00	90.00	7.90	0.00	0.00
29-May-18	1,689.00	18.00	0.65	0.08	0.01	0.01	0.36	0.04	0.21	0.20	845.00	414.00	28.00	8.70	0.00	0.00
22-May-18	1,718.00	17.00	2.18	0.21	0.01	0.01	0.01	0.01	0.29	0.21	860.00	426.00	50.00	8.00	0.00	0.00
15-May-18	1,692.00	17.00	0.60	0.03	0.01	0.01	0.44	0.01	0.25	0.16	845.00	425.00	41.00	8.80	0.00	0.00
08-May-18	1,698.00	28.00	0.45	0.08	0.01	0.01	0.54	0.01	0.14	0.11	840.00	416.00	40.00	8.00	0.00	0.00
01-May-18	1,657.00	24.00	1.06	0.01	0.01	0.01	0.98	0.10	0.13	0.13	835.00	421.00	61.00	8.30	0.00	0.00
24-Apr-18	1,668.00	10.30	1.18	0.01	0.01	0.01	0.88	0.01	0.32	0.19	834.00	399.00	77.00	8.50	0.10	0.00
17-Apr-18	1,651.00	26.00	1.94	0.30	0.03	0.03	0.74	0.03	0.21	0.20	813.00	400.00	5.00	7.90	0.20	0.00
10-Apr-18	1,641.00	2.00	0.50	0.01	0.02	0.01	0.13	0.13	0.21	0.20	819.00	40.00	34.00	8.30	0.00	0.00
03-Apr-18	1,104.00	29.00	0.37	0.16	0.06	0.05	0.53	0.23	0.57	0.23	550.00	272.00	16.00	7.50	0.00	0.00
27-Mar-18	1,611.00	12.00	0.51	0.34	0.01	0.01	0.61	0.33	0.11	0.01	805.00	405.00	19.00	7.80	0.00	0.00

20-Mar-18	1,270.00	16.00	0.32	0.15	0.01	0.01	0.13	0.01	0.07	0.03	634.00	320.00	100.00	8.00	0.10	0.10
13-Mar-18	1,417.00	14.00	0.72	0.44	0.09	0.06	0.59	0.31	0.99	0.61	713.00	355.00	34.00	7.70	0.00	0.00
06-Mar-18	1,489.00	24.00	1.58	0.01	0.03	0.02	0.88	0.01	0.01	0.09	756.00	379.00	52.00	8.00	0.00	0.00
27-Feb-18	1,602.00	37.00	3.55	2.43	0.08	0.05	4.48	2.93	0.16	0.09	800.00	398.00	47.00	7.30	0.00	0.00
20-Feb-18	1,415.00	34.00	0.42	0.01	0.01	0.01	0.01	0.21	0.08	0.06	711.00	359.00	22.00	8.30	0.00	0.00
13-Feb-18	1,776.00	113.00	6.12	5.63	0.55	0.49	19.82	11.62	0.49	0.34	658.00	333.00	79.00	5.30	0.10	0.10
06-Feb-18	1,481.00	30.00	0.31	0.07	0.03	0.01	0.33	0.05	0.20	0.18	740.00	375.00	35.00	8.30	0.00	0.00
30-Jan-18	953.00	24.00	0.35	0.13	0.01	0.01	0.52	0.05	0.25	0.18	483.00	247.00	30.00	8.40	0.10	0.10
23-Jan-18	933.00	31.00	0.27	0.11	0.02	0.01	0.33	0.16	0.21	0.18	480.00	243.00	54.00	8.10	0.00	0.00
16-Jan-18	874.00	59.00	1.48	0.82	0.05	0.01	2.97	0.66	0.26	0.11	443.00	227.00	72.00	7.90	0.00	0.00
09-Jan-18	983.00	70.00	3.84	0.64	0.23	0.20	1.90	0.50	1.54	1.11	472.00	232.00	172.00	8.20	0.40	0.00
02-Jan-18	866.00	5.00	1.06	0.01	0.10	0.08	0.38	0.24	0.22	0.20	437.00	214.00	26.00	8.10	0.10	0.00

Average	**1,467.58**	**31.36**	**1.24**	**0.44**	**0.05**	**0.04**	**1.42**	**0.58**	**0.27**	**0.19**	**725.68**	**349.03**	**49.10**	**8.02**	**0.05**	**0.01**
Min	**866.00**	**2.00**	**0.07**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**437.00**	**40.00**	**5.00**	**5.30**	**0.00**	**0.00**
Max	**1,776.00**	**113.00**	**6.12**	**5.63**	**0.55**	**0.49**	**19.82**	**11.62**	**1.54**	**1.11**	**860.00**	**426.00**	**172.00**	**8.80**	**0.40**	**0.10**
Statutory Limits	**-**	**-**	**1.50**	**-**	**1.00**	**-**	**2.00**	**-**	**1.00**	**-**	**3,000**	**1,500**	**100**	**6.5-9.0**	**-**	**-**

High levels of total copper and total iron were due to:

1. Slag pond being full. The slag pond has since been de-sludged and the water quality has improved
2. Concentrate from the smelter being washed to the drain by rain water. Area outside the concentrate shed has been concreted and sumps constructed to trap concentrate

Appendix 9: Sampling Point 454 (Kafue River Water)

Date	MEASUREMENT PARAMETERS														
	Conductivity	TCu	DCu	TCo	DCo	TFe	DFe	TMn	DMn	TDS	Sulphates	TSS	pH	Pb	Cd
	µS	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	-	mg/l	mg/l
31-Jul-18	217.00	0.22	0.01	0.01	0.01	0.20	0.08	0.01	0.01	109.00	54.00	7.00	8.30	0.00	0.00
24-Jul-18	133.00	0.04	0.02	0.01	0.01	0.14	0.08	0.01	0.01	67.00	33.00	19.00	6.80	0.00	0.00
17-Jul-18	2,414.00	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	1,207.00	603.00	7.00	8.30	0.00	0.00
10-Jul-18	235.00	0.05	0.01	0.01	0.01	0.25	0.09	0.01	0.01	118.00	59.00	6.00	8.20	0.00	0.00
3-Jul-18	257.00	0.13	0.01	0.01	0.01	0.51	0.10	0.10	0.01	129.00	64.00	26.00	7.90	0.00	0.00
26-Jun-18	184.00	0.01	0.01	0.01	0.01	0.72	0.34	0.01	0.01	95.00	48.00	9.00	7.60	0.00	0.00
19-Jun-18	245.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	123.00	61.00	18.00	8.30	0.00	0.00
12-Jun-18	153.00	0.34	0.01	0.01	0.01	0.74	0.11	0.01	0.01	75.00	36.00	72.00	7.50	0.00	0.00
5-Jun-18	177.00	0.15	0.14	0.01	0.01	1.01	0.25	0.15	0.01	87.00	41.00	14.00	7.50	0.00	0.00
29-May-18	129.00	0.01	0.01	0.01	0.01	0.95	0.13	0.08	0.01	65.00	32.00	59.00	8.50	0.00	0.00
22-May-18	134.00	0.19	0.01	0.01	0.01	0.17	0.01	0.04	0.01	68.00	34.00	9.00	8.10	0.00	0.00
15-May-18	167.00	0.09	0.01	0.01	0.01	0.25	0.02	0.01	0.01	84.00	40.00	10.00	8.10	0.00	0.00
8-May-18	250.00	0.09	0.01	0.01	0.01	0.24	0.12	0.01	0.01	125.00	61.00	66.00	7.40	0.00	0.00
1-May-18	129.00	0.01	0.01	0.01	0.01	0.30	0.01	0.01	0.01	65.00	36.00	24.00	7.60	0.00	0.00
24-Apr-18	138.00	0.01	0.01	0.01	0.01	0.63	0.43	0.01	0.01	70.00	33.00	35.00	7.80	0.00	0.00
17-Apr-18	114.00	0.16	0.03	0.02	0.02	0.80	0.01	0.13	0.01	56.00	28.00	19.00	7.90	0.10	0.00
10-Apr-18	239.00	0.02	0.01	0.01	0.10	0.01	0.01	0.01	0.01	119.00	59.00	11.00	8.00	0.00	0.00
3-Apr-18	126.00	0.01	0.01	0.11	0.10	2.38	0.94	4.68	4.52	66.00	33.00	6.00	7.80	0.00	0.00
27-Mar-18	231.00	0.01	0.01	0.01	0.01	0.06	0.01	0.01	0.01	116.00	61.00	39.00	7.90	0.00	0.00
20-Mar-18	125.00	0.01	0.01	0.01	0.01	0.17	0.02	0.01	0.01	63.00	33.00	73.00	7.90	0.10	0.10
13-Mar-18	170.00	0.01	0.01	0.01	0.01	0.89	0.50	0.01	0.01	86.00	43.00	17.00	7.60	0.00	0.00
6-Mar-18	215.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	111.00	58.00	12.00	7.60	0.00	0.00

27-Feb-18	207.00	0.01	0.01	0.01	0.01	0.59	0.38	0.01	0.01	104.00	52.00	17.00	7.70	0.00	0.00
20-Feb-18	146.00	0.01	0.01	0.01	0.01	0.01	0.16	0.01	0.01	73.00	39.00	11.00	7.70	0.00	0.00
13-Feb-18	232.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	116.00	59.00	4.00	8.60	0.10	0.10
6-Feb-18	172.00	0.02	0.01	0.00	0.01	0.30	0.26	0.01	0.01	103.00	53.00	5.00	7.80	0.00	0.00
30-Jan-18	78.00	0.03	0.01	0.01	0.01	0.09	0.01	0.01	0.01	39.00	21.00	12.00	8.50	0.00	0.10
23-Jan-18	354.00	0.11	0.01	0.01	0.01	0.21	0.09	0.01	0.01	174.00	89.00	15.00	7.80	0.00	0.00
16-Jan-18	143.00	0.01	0.01	0.05	0.01	0.08	0.01	0.01	0.01	71.00	35.00	12.00	8.30	0.00	0.00
9-Jan-18	127.00	0.31	0.30	0.13	0.13	1.01	0.89	0.37	0.34	73.00	33.00	5.00	7.70	0.80	0.00
2-Jan-18	137.00	0.01	0.01	0.07	0.05	0.17	0.10	0.04	0.01	69.00	29.00	29.00	8.00	0.10	0.00
Average	**250.90**	**0.07**	**0.02**	**0.02**	**0.02**	**0.42**	**0.17**	**0.19**	**0.17**	**126.65**	**63.23**	**21.55**	**7.89**	**0.04**	**0.01**
Min	**78.00**	**0.01**	**0.01**	**0.00**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**39.00**	**21.00**	**4.00**	**6.80**	**0.00**	**0.00**
Max	**2,414.00**	**0.34**	**0.30**	**0.13**	**0.13**	**2.38**	**0.94**	**4.68**	**4.52**	**1,207.00**	**603.00**	**73.00**	**8.60**	**0.80**	**0.10**
Statutory Limits		**1.50**		**1.00**		**2.00**		**1.00**		**3,000**	**1,500**	**100**	**6.5-9.0**		

Appendix 10: Sampling Point 431 (Industrial water from underground)

Date	*MEASUREMENT PARAMETERS*														
	Conductivity	***TCu***	***DCu***	***TCo***	***DCo***	***TFe***	***DFe***	***TMn***	***DMn***	***TDS***	***Sulphates***	***TSS***	***pH***	***Pb***	***Cd***
	µS	***mg/l***	***mg/l***	***mg/l***	***mg/l***	***mg/l***	***mg/l***	***mg/l***	***mg/l***	***mg/l***	***mg/l***	***mg/l***	**-**	***mg/l***	***mg/l***
31-Jul-18	1,300.00	0.63	0.13	0.01	0.01	0.53	0.01	0.09	0.04	650.00	325.00	57.00	8.30	0.10	0.00
17-Jul-18	1,538.00	0.84	0.26	0.01	0.01	0.90	0.06	0.15	0.08	769.00	384.00	57.00	7.90	0.00	0.00
3-Jul-18	1,482.00	3.75	0.01	0.01	0.01	6.88	0.01	0.67	0.01	741.00	371.00	182.00	7.90	0.00	0.00
19-Jun-18	1,650.00	0.19	0.02	0.01	0.01	0.01	0.01	0.01	0.01	825.00	410.00	13.00	7.80	0.00	0.00
5-Jun-18	1,789.00	0.81	0.19	0.01	0.01	0.82	0.19	0.14	0.09	877.00	418.00	56.00	7.70	0.00	0.00
22-May-18	1,683.00	0.29	0.03	0.01	0.01	0.01	0.01	0.09	0.04	842.00	417.00	13.00	7.90	0.00	0.00
8-May-18	1,707.00	0.34	0.06	0.01	0.01	0.51	0.01	0.03	0.01	854.00	418.00	81.00	8.10	0.00	0.00
24-Apr-18	1,638.00	0.19	0.01	0.01	0.01	0.17	0.01	0.01	0.01	819.00	392.00	56.00	7.80	0.10	0.00
10-Apr-18	1,663.00	0.24	0.05	0.04	0.01	0.16	0.06	0.04	0.01	808.00	404.00	11.00	7.80	0.00	0.00
27-Mar-18	1,609.00	0.28	0.06	0.01	0.01	0.20	0.06	0.01	0.01	806.00	409.00	29.00	7.40	0.00	0.00
13-Mar-18	1,589.00	0.01	0.01	0.01	0.01	0.07	0.01	0.01	0.01	793.00	395.00	47.00	7.70	0.00	0.00
27-Feb-18	1,577.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	789.00	393.00	20.00	7.80	0.00	0.00
13-Feb-18	1,640.00	2.95	0.92	0.24	0.01	6.03	0.08	0.25	0.21	824.00	415.00	43.00	7.90	0.10	0.10
30-Jan-18	1,049.00	0.22	0.19	0.01	0.01	0.06	0.01	0.08	0.01	524.00	265.00	30.00	8.00	0.00	0.10
16-Jan-18	964.00	0.50	0.16	0.01	0.01	0.02	0.01	0.10	0.06	483.00	243.00	29.00	7.80	0.00	0.00
2-Jan-18	885.00	0.01	0.01	0.08	0.07	0.12	0.07	0.08	0.05	445.00	220.00	11.00	7.60	0.10	0.00

Average	**1,485.19**	**0.70**	**0.13**	**0.03**	**0.01**	**1.03**	**0.04**	**0.11**	**0.04**	**740.56**	**367.44**	**45.94**	**7.84**	**0.03**	**0.01**
Min	**885.00**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**445.00**	**220.00**	**11.00**	**7.40**	**0.00**	**0.00**
Max	**1,789.00**	**3.75**	**0.92**	**0.24**	**0.07**	**6.88**	**0.19**	**0.67**	**0.21**	**877.00**	**418.00**	**182.00**	**8.30**	**0.10**	**0.10**
Statutory Limits	**-**	**1.50**		**1.00**	**-**	**2.00**	**-**	**1.00**	**-**	**3,000**	**1,500**	**100**	**6.5-9.0**	**-**	**-**

Appendix 11: Sampling Point 431 (Domestic Water from underground)

Date	MEASUREMENT PARAMETERS														
	Conductivity	***TCu***	***DCu***	***TCo***	***DCo***	***TFe***	***DFe***	***TMn***	***DMn***	***TDS***	***Sulphates***	***TSS***	***pH***	***Pb***	***Cd***
	µS	***mg/l***	***mg/l***	***mg/l***	***mg/l***	***mg/l***	***mg/l***	***mg/l***	***mg/l***	***mg/l***	***mg/l***	***mg/l***	***-***	***mg/l***	***mg/l***
31-Jul-18	1,812.00	0.33	0.17	0.01	0.01	0.16	0.01	0.08	0.07	906.00	453.00	13.00	8.40	0.10	0.00
17-Jul-18	1,562.00	1.02	0.22	0.01	0.01	1.11	0.05	0.17	0.06	781.00	391.00	51.00	7.90	0.00	0.00
3-Jul-18	1,603.00	0.38	0.08	0.01	0.01	1.07	0.90	0.03	0.01	802.00	401.00	46.00	7.90	0.00	0.00
19-Jun-18	2,320.00	0.16	0.04	0.01	0.01	0.01	0.01	0.01	0.01	1,160.00	577.00	19.00	7.70	0.00	0.00
5-Jun-18	1,793.00	0.61	0.05	0.01	0.01	0.66	0.01	0.13	0.10	879.00	419.00	53.00	7.70	0.00	0.00
22-May-18	1,696.00	0.40	0.17	0.01	0.01	0.05	0.01	0.28	0.08	848.00	420.00	16.00	7.90	0.00	0.00
8-May-18	1,728.00	0.37	0.07	0.01	0.01	0.64	0.03	0.04	0.01	864.00	424.00	65.00	8.00	0.00	0.00
24-Apr-18	1,642.00	0.26	0.01	0.01	0.01	0.31	0.01	0.01	0.01	820.00	392.00	67.00	8.10	0.00	0.00
10-Apr-18	1,671.00	0.18	0.07	0.01	0.01	0.01	0.01	0.03	0.01	813.00	409.00	7.00	7.80	0.00	0.00
27-Mar-18	1,646.00	0.23	0.07	0.01	0.01	0.11	0.02	0.01	0.01	823.00	415.00	20.00	7.40	0.00	0.00
13-Mar-18	1,588.00	0.01	0.01	0.01	0.01	0.45	0.01	0.01	0.01	792.00	394.00	6.00	7.60	0.00	0.00
27-Feb-18	1,578.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	988.00	491.00	8.00	7.80	0.00	0.00
13-Feb-18	1,644.00	0.22	0.16	0.00	0.01	0.06	0.03	0.05	0.01	822.00	413.00	59.00	7.80	0.10	0.10
30-Jan-18	924.00	0.20	0.09	0.02	0.01	0.16	0.09	0.10	0.03	462.00	233.00	28.00	8.00	0.00	0.10
16-Jan-18	970.00	0.53	0.34	0.01	0.01	0.06	0.01	0.11	0.04	487.00	247.00	32.00	7.80	0.00	0.00
2-Jan-18	907.00	0.01	0.01	0.08	0.07	0.10	0.06	0.07	0.06	435.00	214.00	13.00	7.70	0.10	0.00
Average	**1,567.75**	**0.31**	**0.10**	**0.01**	**0.01**	**0.31**	**0.08**	**0.07**	**0.03**	**792.63**	**393.31**	**31.44**	**7.84**	**0.02**	**0.01**
Min	**907.00**	**0.01**	**0.01**	**0.00**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**435.00**	**214.00**	**6.00**	**7.40**	**0.00**	**0.00**
Max	**2,320.00**	**1.02**	**0.34**	**0.08**	**0.07**	**1.11**	**0.90**	**0.28**	**0.10**	**1,160.00**	**577.00**	**67.00**	**8.40**	**0.10**	**0.10**
Statutory Limits	**-**	**1.50**	**-**	**1.00**	**-**	**2.00**	**-**	**1.00**	**-**	**3,000**	**1,500**	**100**	**6.5-9.0**	**-**	**-**

Appendix 12: Kankoyo household water quality-Summary of typical assay parameters

Test Parameter	Parameters											
	Conductivity	Turbidity	TCu	TCo	TFe	TMn	TDS	Sulphates	TSS	pH	Pb	Cd
	uS	NTU	mg/l	mg/l	mg/l	mg/l	ppm	mg/l	mg/l		mg/l	mg/l
ZEMA Maximum Specification Limits			1.5	1.0	2.0	1.0	3000	1500	100	6.5-9.0		
Average	3193	9	0.20	0.04	0.49	0.26	662	325	10	7.6	<0.10	<0.10
Minimum	834	2	0.02	0.01	0.11	0.02	417	23	1	6.8	<0.10	<0.10
Maximum	13219	32	1.63	0.09	1.69	1.03	775	661	40	8.1	<0.10	<0.10

Appendix 13: Air quality data for the 7 weather sampling stations- Monthly average readings

Month	ZEMA LIMIT	Kankoyo-Clinic 5	Butondo Clinic 7	Kantanshi Clinic 3	Kantanshi Clinic 6	Eastlea Clinic 9	Kamuchanga	Malcom Hospital
Jan-17	125.00	17.09	5.53	97.13	27.73	8.82	16.67	7.52
Feb-17	125.00	20.17	2.96	122.50	45.47	11.78	16.13	8.85
Mar-17	125.00	114.21	7.21	61.20	16.25	15.39	7.06	8.25
Apr-17	125.00	277.84	0.42	75.74	2.77	42.17	2.68	0.43
May-17	125.00	1.59	6.05	5.00	0.92	19.23	2.40	0.23
Jun-17	125.00	173.83	6.78	14.09	1.23	8.22	2.56	0.42
Jul-17	125.00	282.72	15.42	58.60	1.79	0.00	3.47	0.93
Aug-17	125.00	140.55	9.65	34.09	2.90	0.00	3.43	0.81
Sep-17	125.00	547.75	10.65	94.89	2.83	0.00	4.20	0.91
Oct-17	125.00	374.68	4.67	165.36	14.31	16.61	6.01	12.84
Nov-17	125.00	228.51	4.39	152.68	18.64	23.15	22.89	13.77
Dec-17	125.00	29.60	2.35	145.32	25.41	21.57	11.72	43.77
Jan-18	125.00	18.19	0.73	141.37	93.01	16.43	29.99	24.25
Feb-18	125.00	44.34	-	237.45	58.73	-	58.37	57.18
Mar-18	125.00	-	-	37.53	37.61	-	-	-
Apr-18	125.00	-	64.47	8.56	2.76	19.03	-	-
May-18	125.00	118.09	8.34	12.07	2.23	19.63	1.82	1.53
Jun-18	125.00	166.54	2.24	8.26	2.04	5.02	3.34	2.50
Average	**125.00**	**159.73**	**9.49**	**81.77**	**19.81**	**14.19**	**12.05**	**11.51**

Appendix 14: Air quality data for Kankoyo Clinic 5 Station- Monthly Maximum readings

Concentration of SO_2 in ambient air (μg/m^3/24 hrs.)		
Month	**ZEMA LIMIT**	**Kankoyo-Clinic 5**
Jan-17	125	123.47
Feb-17	125	183.27
Mar-17	125	433.83
Apr-17	125	1183.45
May-17	125	3.85
Jun-17	125	861.42
Jul-17	125	1010.29
Aug-17	125	709.17
Sep-17	125	1318.07
Oct-17	125	1417.36
Nov-17	125	1580.49
Dec-17	125	200.39
Jan-18	125	116.64
Feb-18	125	523.31
Mar-18	125	-
Apr-18	125	-
May-18	125	364.53
Jun-18	125	639.17
Average	**125.00**	**666.79**
Minimum	125.00	3.85
Maximum	125.00	1580.49
Max. times over ZEMA limit		**13**
Ave. times over ZEMA limit		**5**

Appendix 15: Sulphur dioxide Concentrations (average annual concentrations) for Selected Weather Stations from 1995 to 2000

Year	Clinic 3- Kantanshi Station	Clinic 5 - Kankoyo Station	Clinic 7 - Butondo Station	*Clinic 8/9 – Eastlea Clinic
Zambian 24-hr SO_2 guideline	**125µg/m^3**	**125µg/m^4**	**125µg/m^5**	**125µg/m^6**
1995	*145*	*427*	63	29
1996	*189*	*485*	74	41
1997	*149*	*342*	41	22
1998	103	*407*	50	34
1999	*141*	*480*	74	45
2000	76	*247*	44	35
Notes: * The data for clinic 8/9 is not representative as the sampler was not in operation for more than %0% of the time during 2000.				
Shaded text indicates an exceedance of the 24-hour guideline- for comparison purposes the SO_2 24hr guide lines (µg/m^3) for other international countries are:				
European Union = 100-150; US-EPA = 365; RSA = 265; World Health Organisation = =150.				
Source: Mopani Copper Mines Environmental Impact Statement Volume 1 Page 33. Assessments of Impacts for Mufulira Mine. Report No. 283142/4 July 2003. SRK Consulting Engineers and Scientists				

Appendix 16: Typical monthly air quality data for the seven air monitoring stations the period January 2017 to June 2018

Month	Range	Kankoyo Station (Clinic 5)	Butondo Station (Clinic 7)	Kantanshi Station (clinic 3)	Kantanshi Station (clinic 6)	Eastlea station (clinic 9)	Kamuchanga Station	Malcolm Station
Jan,2017	Min	0.59	0.21	5.16	0.37	4.35	3.77	0.25
	Ave	17.09	5.53	97.13	27.73	8.82	16.67	7.52
	Max	123.47	79.64	*394.86	*177.85	26.12	82.14	37.33
Feb, 2017	Min	0.55	0.15	8.11	0.96	4.83	2.1	0.02
	Ave	20.17	2.96	122.5	45.47	11.78	16.13	8.85
	Max	*183.27	10.55	*328.03	260.77	29.76	*134.74	48.6
Mar, 2017	Min	0.66	0.17	5.4	0.28	7.58	1.21	0
	Ave	114.21	7.21	61.2	16.25	15.39	7.06	8.25
	Max	*433.83	58.31	*301.85	*180.26	26.1	37.85	57.14
Apr,2017	Min	3.91	0	5.87	0.13	7.43	1.21	0.02
	Ave	*277.84	0.42	75.74	2.77	42.17	2.68	0.43
	Max	*1183.45	9.85	*264.95	24.1	91.78	7.27	3.4
May,2017	Min	0.46	0	-	0.18	0.02	1.15	0.02
	Ave	1.59	6.05	5	0.92	19.23	2.4	0.23
	Max	3.85	49.43	10.89	2.3	49.9	4.65	0.79

Jun, 2017	Min	0.63	1.1	3.72	0.34	0.67	1.58	0.12
	Ave	*173.83	6.78	14.09	1.23	8.22	2.56	0.42
	Max	*861.42	20.4	61.97	2.73	20.92	3.69	1.16
Jul,2017	Min	40.48	5.39	-8.45	0.47	0	2.18	0.25
	Ave	*282.72	15.42	58.6	1.79	0	3.47	0.93
	Max	*1010.29	47.43	*166.77	8.37	0	12.66	4.4
Aug, 2017	Min	0	1.85	17.89	0.36	0	1.85	0.16
	Ave	*140.55	9.65	34.09	2.9	0	3.43	0.81
	Max	*709.17	40.64	102.91	35.84	0	5.86	1.63
Sep, 2017	Min	1.1	2.74	12.03	0.93	0	1.96	0.24
	Ave	*547.75	10.65	94.89	2.83	0	4.2	0.91
	Max	*1318.07	65.75	*393.05	14.68	0	9.29	4.33
Oct,2017	Min	1.73	0.28	8.91	0.27	0.22	1.43	0.35
	Ave	*374.68	4.67	*165.36	14.31	16.61	6.01	12.84
	Max	*1417.36	13.45	*473.07	85.4	67.49	24.01	76.51
Month	**Range**	**Kankoyo Station (Clinic 5)**	**Butondo Station (Clinic 7)**	**Kantanshi Station (Clinic 3)**	**Kantanshi Station (Clinic 6)**	**Eastlea station (Clinic 9)**	**Kamuchanga Station**	**Malcolm Hospital Station**
Nov,2017	Min	0.24	0	14.06	0.26	7.09	1.51	0.75
	Ave	*228.51	4.39	152.68	18.64	23.15	22.89	13.77
	Max	*1580.49	25.99	*539.29	96.39	75.61	*154.68	73.58
Dec, 2017	Min	0.06	0.19	31.62	0.87	1.33	1.08	0.72
	Ave	29.6	2.35	145.32	25.41	21.57	11.72	43.77
	Max	*200.39	11.54	*308.75	124.23	80.74	51.7	*346.35
Jan, 2018	Min	0.06	0.18	5.11	1.09	1.68	1.51	0.71
	Ave	18.19	0.73	141.37	93.01	16.43	29.99	24.25
	Max	116.64	1.25	*679.91	*438.8	57.54	*137.95	105.73
Feb, 2018	Min	0.17	-	2.49	0.76	-	2.35	1.18
	Ave	44.34	-	*237.45	58.73	-	58.37	57.18
	Max	*523.31	-	*1828.67	*374.81	-	*205.95	*223.66
Mar, 2018	Min	-	-	4.94	1.11	-	-	-
	Ave	-	-	37.53	37.61	-	-	-
	Max	-	-	93	*141.86	-	-	-
Apr, 2018	Min	-	61.3	8.1	0.23	16.48	-	-
	Ave	-	64.47	8.56	2.76	19.03	-	-
	Max	-	70.89	9.48	39.7	24.39	-	-
May, 2018	Min	2.68	1.49	2.35	0.93	4.62	0.3	0.68
	Ave	*118.09	8.34	12.07	2.23	19.63	1.82	1.53
	Max	*364.53	77.89	33.31	4.79	108.76	4	3.14

	Min	6	1.03	0	0.77	0.1	0.84	0.49
Jun, 2018	Ave	*166.54	2.24	8.26	2.04	5.02	3.34	2.5
	Max	*639.17	3.31	26.6	3.67	45.8	8.69	5.78

*Shaded text indicates an exceedance of the 24-hour guideline- for comparison purposes the SO_2 24hr guidelines ($\mu g/m^3$) for other ZEMA statutory limit of 125 $\mu g/m^3$

Appendix 17: No. of times SO_2 emissions exceeded ZEMA maximum emission limit for the period Jan. 2017 to June 2018

Air Monitoring Station	**Kankoyo Station (Clinic 5)**	**Butondo Station (Clinic 7)**	**Kantanshi Station (clinic 3)**	**Kantanshi Station (clinic 6)**	**Eastlea Station (clinic 9)**	**Kamuchanga Station**	**Malcolm Hospital Station**
No. of times emissions exceeded ZEMA limit	23	0	13	6	0	4	2
Total No. of times emissions exceeded ZEMA limit	48	48	48	48	48	48	48
% Exceedance	48	0	27	13	0	8	4

Appendix 18: Description of water sampling points

Sampling Point No.	GPS- Coordinate	Point Description
1	-12.5381765, 28.2215196	Junction - Chendeende and Anga Road
2	-12.5369030, 28.2194430	Junction - Chendeende and Chisuma Road (Opposite Makole Primary School)
3	-12.5352529, 28.2167077	Junction - Chendeende and Esha Road (Opposite CMML Church)
4	-12.5344030, 28.2153180	Junction - Chendeende and Fisabo Road (Opposite Chankwa Secondary School)
5	-12.5331559, 28.2163373	Junction - Fisabo and Makwala Road
6	-12.5340200, 28.2177340	Junction - Esha and Makwala Road
7	-12.5355805, 28.2202975	Junction - Chisuma and Makwala Road
8	-12.5368611, 28.2224379	Junction - Anga and Makwala Road
9	-12.5356701, 28.2231816	Junction - Anga and Butondo Road (Near Kankoyo Primary School)
10	-12.5343165, 28.2210911	Junction - Chisuma and Butondo Road
11	-12.5324965, 28.2184093	Junction - Esha and Butondo Road
12	-12.5316410, 28.2168330	Kankoyo UCZ Church - along Butondo Road
13	-12.5302136, 28.2179416	Junction - Fisabo and Mpezeni Road
14	-12.5311081, 28.2193387	Junction - Esha and Mpezeni Road
15	-12.5319888, 28.2207099	Junction - Dzuwa and Mpezeni Road -near Good Shepherd Catholic Church
16	-12.5327596, 28.2220645	Junction - Chisuma and Mpezeni Road
17	-12.5344091, 28.2248003	Along Mpezeni Road astride the open play ground
18	-12.5293610, 28.2225271	Junction - Dzuwa and Kalulu Road -opposite Muleya Winter Primary School
19	-12.5306892, 28.2251594	Junction - Kalulu and Buseko Road
20	-12.5324732, 28.2281289	Junction - Kalulu and Kwacha Road
21	-12.5297495, 28.2299149	Junction - Kankoyo and Kwacha Road
22	-12.5280041, 28.2270560	Junction - Kankoyo and Buseko Road
23	-12.5267175, 28.2244228	Kankoyo road near the sewer ponds
24	-12.5293512, 28.2322498	Mufulira West Shaft Roads - near CEC Kankoyo Electrical Power Sub Station
25	-12.5282201, 28.2306505	Junction -Mufulira West Shaft Roads and Kwacha Road (Mine drain)
26	-12.5265267, 28.2277833	Junction -Mufulira West Shaft Roads and Buseko Road (Mine drain)
27	-12.5207007, 28.2226311	Mufulira Stream -upper
28	-12.5258040, 28.2202623	Mufulira Stream - middle (near the sewer ponds)
29	-12.5267152, 28.2135689	Mufulira Stream - Lower (at Butondo road bridge)
30	-12.5380806, 28.2255077	Section K (Kwacha Township)
31	-12.5393488, 28.2236014	Kwacha Market (Kankoyo)

Appendix 19: Map of showing the water sampling points

Source: Field Data 2018, Google map.

Appendix 20: General physical characteristic of drinking water

Parameters	Maximum permissible limit	Method of Test
Odour	Unobjectionable to most consumers	ZS 312 Part 1
Colour (True colour units TCU)	1.5	ZS ISO 7887
Taste	Unobjectionable to most consumers	SM 2160B
pH	6.5-8.0	ZS ISO 10523
Hardness (total) as Calcium carbonate $CaCO_3$ (mg/litre)	500	ZSASTM D 1126
Dissolved solids (total) mg/l	1,000	ZS 312 Part 19
Turbidity (NTU)	5	ZS ISO 7027
Conductivity (µs/cm)	1,500	ZS ISO 7888

Source: ZABS: 2010

Appendix 21: Non-Toxic Chemical Substances in Drinking Water

Substance	Maximum permissible limit (mg/litre)	Method of Test
Calcium (Ca)	200	ZS ISO 6068
Chloride (Cl^-)	250	ZS ISO 9297
Chlorine residue	0.2-0.5	ZS ISO 7393 Part 1
Copper (Cu)	1.0	ZS ISO 8288
Iron (Fe)	0.3	ZS ISO 11885
Magnesium (Mg)	150	ZS ISO 7980
Sulphate ($SO^{2-}{}_4$)	400	ZS 312 Part 3
Zinc (Zn)	3	ZS ISO 8288
Phenolic compounds (as phenol)	0.002	ZS ISO 6439
Detergents (alkyl benzene sulphonate)	1.0	ZS 312 Part 20
Sodium	200	ZS ISO 9964 Part 1

Source: ZABS: 2010

Appendix 22: Zambia's National Effluent Statutory Limits

Air emission (mg/Nm^3)		Water effluent discharge (mg/l)	
Sulphur dioxide	100	Suspended Solids	100
Arsenic	0.5	Arsenic, total	0.5
Cadmium	0.05	Cadmium, total	0.5
Copper	1	Copper, total	1.5
Lead	0.2	Lead, Total	0.5
Mercury	0.05	Mercury, total	0.002
PM 10 Smelters	50	Iron, total	2
PM 10 Other	50	pH	6-9 units

Source: (Joanna Lindahl, 2014-pp19/2)

Appendix 23: Field responses on the perceived causes and extent of air pollution in Kankoyo Township

Over the past week, as a result of air pollution, did you:	Never	Sometimes	Often	Always
	% Respondents			
Smell unpleasant smell indoors?	18	61	21	0
Smell unpleasant smell outdoors?	2	80	15	3
Have difficulty in breathing?	98	2	0	0
Have eye irritations?	0	0	0	0
Have chest of related pains?	95	3	2	0
Suffer from nose irritation?	83	17	0	0
Physically see / observe fume or gas emissions in your location?	22	20	49	9
Suffer from headaches?	90	8	2	0
See medical attention on cases related to air pollution?	0	0	0	0
Feel worried about your health?	0	2	8	90
Think that your quality of life was being degraded?	0	4	91	5
Think about shifting to another place?	50	27	4	19
Use perfume or an air freshener in your home?	83	17	0	0
How do you rate the quality of air in your community with reference to the following ratings:				
1) Good = 2%				
2) Moderate = 3%				
3) Unhealthy for sensitive groups i.e. active children / old people = 80%				
4) Unhealthy = 15				

Appendix 24: Field responses on the perceived causes and extent of water pollution in Kankoyo Township

No.	Question	Answer	Filed Observations / Comments
		Responses	
1	What is your House Number?	Response = 100% (House No. was given upon request)	The numbering of houses is well defined. Some houses have their numbers nicely stack on the wall side
2	What is the source of your drinking water?	All households get water from the water taps within the yard	All the thirty (30) households visited/sampled had tap water provided by MWSC
3	Can you please show me the actual source where you collect your drinking water from so that I can take a water sample from this source? [***if 'no' probe to find out why this is not possible***]	Response = 100% (water source was shown)	Most of the water collection points were in a very deplorable state
4	May you show me the vessel you use for water collection?	Response = 100% (water collection vessel was shown)	Clean and standard water collection vessels were presented
5	May you also show me the vessel you use for water storage?	Response = 100% (water Storage vessel was shown)	Clean and standard water storage vessels were presented
6	How do you rate the quality of water in your community with reference to the following ratings:	Percentage Response	-
	1) Good	4%	-
	2) Moderate	18%	-
	3) Unhealthy for sensitive groups i.e. active children / old people	72%	Most residents fear for the health of the vulnerable children and old people in Kankoyo Township
	4) Unhealthy	6%	-

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