MANAGEMENT OF ENVIRONMENTAL RISKS ARISING FROM MINING OPERATIONS IN KITWE AND MUFULIRA

By

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A dissertation submitted to the University of Zambia in partial fulfilment of the requirements for the Degree of Master of Science in Environmental and Natural Resources Management

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DECLARATION

I, Prisca Nachalwe, declare that this dissertation is solely my work and all sources of information have been duly acknowledged. This dissertation has not been submitted to the University of Zambia or any other university for any degree or examination.

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CERTIFICATE OF APPROVAL

This dissertation by Prisca Nachalwe is approved as partial fulfilment of the requirements for the award of Master of Science in Environmental and Natural Resources Management degree by the University of Zambia.

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ABSTRACT

Mining as an extractive industry has both positive and negative impacts. The positive impacts include economic growth and job creation whereas the negative impacts are environmental degradation and human health risks. On this premise this study was carried out in order: To i) identify risks posed by mining operations to the environment and human health in Kankoyo and Nkana West, ii) determine the extent to which the risk management strategies used by mining operators adequately address environmental and health risks in the study areas and, iii) examine the adequacy of institutional arrangements that govern environmental risk management in the mining sector. Data collection methods used in the study were a questionnaire survey, interviews, water sampling and testing. The results show that Kankoyo and Nkana West are characterised by pollution of air, water and land with Kankoyo being more affected. The prominent health problem was respiratory tract infections resulting from smelting activities at the mines with sulphur dioxide being the main air pollutant. Tests carried out on 30 water samples collected from Uchi Stream and Mwekera Stream (the control) respectively indicated that Uchi had above limit concentrations of cobalt, manganese and iron which were attributed to effluent discharged from the Nkana Mines. Uchi Stream had significantly higher ($p<0.05$) concentrations of copper, cobalt, manganese, iron and zinc than Mwekera Stream. Therefore, Uchi Stream was polluted by cobalt, manganese and iron from the Nkana Mines at the time of the research. The risk management strategies used by the mines were found to be inadequate for addressing environmental and health risks and the EMPs were not revised and audited as required by law. The institutional arrangements for management of mining environmental risks were not adequate as evidenced by the relevant authorities' lack of vital monitoring equipment and human resource for ensuring that mining companies were in compliance with the environmental regulations. The study concludes that environmental risk management in the mining sector is not effectively addressing the risks posed by mining activities in Kitwe and Mufulira to the environment and human health. Therefore, there is need for Mopani Copper Mines and Konkola Copper Mines to implement proactive risk management strategies that will minimize mining and mineral processing risks from their operations.

DEDICATION

This dissertation is dedicated to my Heavenly Father, parents and siblings for their support throughout my academic journey.

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ACRONYMS

EMA	Environmental Management Act
EMPs	Environmental Management Plans
CTPD	Center for Trade Policy and Development
CSO	Central Statistical Office
DF	Degrees of Freedom
ECZ	Environmental Council of Zambia
GRZ	Government of the Republic of Zambia
HAZOP	Hazard and Operability
HSE	Health Safety and Environmental
IFC	International Finance Corporation
KCM	Konkola Copper Mine
MCM	Mopani Copper Mine
MMDA	Mines and Minerals Development Act
MSD	Mines Safety Department
TCo	Total Cobalt
TFe	Total Iron
TDS	Total Dissolved Solids
TMn	Total Manganese
WHO	World Health Organization
ZABS	Zambia Bureau of Standards
ZEMA	Zambia Environmental Management Agency

CHAPTER ONE: INTRODUCTION

1.1 Background

Mining has been a significant economic activity in Zambia since the development of the first copper mines in the late 1920s. The sector has been the mainstay of the country's economy owing to the variety of mineral wealth which presents opportunities for the sector to continue contributing to the economic growth of the country (GRZ, 2013). However, the mining industry not only contributes to economic growth, it also adversely impacts the environment and human health. Every phase of a mining operation poses risk of adverse environmental impacts (European Environmental Bureau, 2000). Among the environmental impacts from mining activities are air pollution, soil contamination, pollution and siltation of water, geotechnical problems and land degradation (Lindhal, 2014). Furthermore, environmental effects of mineral resource activities affect flora and fauna, human health and safety, local lifestyles and economic wellbeing (Choudhary, 2015; Fraser and Lungu, 2006; Lindahl, 2014; Makondo *et al* (2015).

In Zambia, mining and mineral processing presents environmental pollution hazards from current and historical production (Aongola *et al*., 2009). Environmental problems that arise from historical mining operations are related to the geotechnical integrity of waste dumps which comprise waste rock and slag dumps and tailings dams in the Copperbelt Province. Additionally, tailings ponds used for water supply, fishing and crop growing have potential to cause health problems. Mine waste which contains sulphide materials is potentially a source for acid mine drainage in the event of its exposure to oxygen and water (Lindahl, 2014).

According to IFC (2014) mining companies have environmental management systems under which they carry out environmental impact studies and develop environmental management and monitoring plans. Through monitoring and evaluating pollution and waste from their operations mining companies may act to reduce impacts. Clear pollution reduction targets in a well-designed environmental management system will ensure continuous improvement upon pollution and waste management strategies by mining companies (IFC, 2014). These strategies could include recycling, reusing, treatment, recovery, minimization, mitigation, prevention, controls and remediation. The Australian Government (2011:112) notes that 'environmental risk can be defined in terms of the impact of exploration, mining or mineral processing activities on the environment.' These risks have potential to impact community health, cost of closure and rehabilitation, and on-going legacy risks following mine closure (Australian Government, 2011). To address the risks associated with environmental impacts of mining, environmental risk management is used. Environmental risk management according to Okonkwo (1998, in Nwite, 2014) is the identification, evaluation and economic control of risks that are a threat to lives and property in an environment. Environmental risk management incorporates strategies such as risk avoidance, risk reduction, risk retention, risk transfer, risk diversification and risk combination (Nwite, 2014) among others. Risk management is the foundation of a successful mining operation and techniques such as hazard analysis, hazard and operability (HAZOP) studies assist mining companies to identify risks from operations and design controls to eliminate the risks (Willis Limited, 2014). Risk registers and risk management systems are useful when combined with effective implementation, robust reviews and audit systems to ensure they are working. Risk management is important due to the cumulative nature of the risks associated with environmental impacts of mining (Australian Government, 2008).

In this regard, the study seeks to critically assess how the environmental risk management strategies of mining companies in Kitwe and Mufulira are safeguarding the health of the local people and the environment.

1.2 Statement of the problem

Mining is Zambia's largest source of foreign exchange earnings. However, the sector also adversely impacts the environment through pollution of environmental media such as air, land and water, consequently affecting human health. Because of the potential environmental and health effects of mining, the Environmental Management Act of 2011 requires mining companies in Zambia to prepare Environmental Management Plans (EMPs) aimed at mitigating environmental risks as per Section 23. The implementation of EMPs is monitored by the Zambia Environmental Management

Agency (ZEMA) which is tasked with the responsibility of monitoring and auditing environmental performance of mining companies under the Zambia Environmental Management Act. This is important as it helps ensure that mining companies do not exceed the pollution limits prescribed by law and in their mine license conditions. Problems that may arise due to the strategies being ineffective are environmental pollution incidences. In Kitwe and Mufulira, Konkola Copper Mine and Mopani Copper Mines are equally required to develop environmental risk management strategies. The strategies are used to mitigate the environmental impacts of the mining and mineral processing activities and prevent incidences of serious environmental impacts on the environment and human health. However, it is not known how effective the risk management strategies used by mining companies in Kitwe and Mufulira are with respect to managing environmental risks posed by the mining operations. Furthermore, communities living near the mine sites face the negative impacts of mining and their knowledge of the risks of mining has not been ascertained. The study sought to examine how the risk management strategies adopted by mining companies adequately address environmental risk in the mining sector.

1.3 Aim of the study

The aim of the study was to determine the effectiveness of environmental risk management systems in the mining sector in Kitwe and Mufulira.

1.4 Objectives

The study had the following specific objectives:

i. To identify risks posed by mining operations to the environment and human health in Kankoyo and Nkana West
ii. To determine the extent to which the risk management strategies used by Konkola and Mopani Copper Mines address environmental and health risks in the study areas
iii. To examine the adequacy of institutional arrangements that govern environmental risk management in the Zambian mining sector

1.5 Research Questions

The research questions addressed by the study were the following:

i. What types of environmental risks emanate from mining operations in Kitwe and Mufulira?
ii. How are the risk management strategies used by Konkola and Mopani Copper Mines addressing environmental and health risks in the study areas?
iii. How adequate are institutional arrangements for management of environmental risk in the mining sector?

1.6 Research Hypotheses

H_1: There was no significant difference between mean copper concentrations in Uchi Stream and mean copper concentrations in Mwekera Stream

H_2: There was no significant difference between mean cobalt concentrations in Uchi Stream and mean cobalt concentrations in Mwekera Stream

H_3: There was no significant difference between mean manganese concentrations in Uchi Stream and mean manganese concentrations in Mwekera Stream

H_4: There was no significant difference between mean iron concentrations in Uchi Stream and mean iron concentrations in Mwekera Stream

H_5: There was no significant difference between mean zinc concentrations in Uchi Stream and mean zinc concentrations in Mwekera Stream

1.7 Significance of the study

The impacts of mining pose risks to the wellbeing of the environment and human beings daily. It is therefore, imperative that the nature of these risks is understood for the purpose of safeguarding the environment and human health through their effective management. The results from the study may potentially be used for improving risk management strategies by mining companies, development of policies by ZEMA to enhance its monitoring and close loopholes in mining legislation. Furthermore, the study will provide fresh insight into scholarship on environmental risks of mining and add to the stock of knowledge on the issue.

1.8 Scope of the study

The study focused on the mining risks posed by mining operations of Mopani and Konkola Copper Mines in Kitwe and Mufulira to the environment and human health and the risk management strategies used to address them. Water sampling was only conducted in Kitwe and not Mufulira due to budget constraints.

1.9 Organization of the dissertation

This dissertation comprises six chapters as follows: Chapter one is an introduction of the study. Literature review is presented in Chapter two. Chapter three describes the study areas. The methodological approaches employed in the study are outlined in Chapter four. Chapter five is a presentation and discussion of the research findings. The conclusions and recommendations of the study are presented in Chapter six.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter reviews literature about risk management and mining focusing on the characteristics of mining risks, risk management in mining as well as relevant institutional arrangements pertaining to mining.

2.2 Characteristics of environmental risks of mining

The risks related to mining activities are diverse and the associated environmental aspects have been documented by various authors (World Bank, 2002; Fraser and Lungu, 2006; Lindahl, 2014; Rembuluwani *et al*., 2014; Aboka *et al.*, 2018). On a global scale the two major ecological footprints of mining according to Carvalho (2017) are mine tailings and acid mine drainage. Banza *et al* (2009) argue that in developing countries environmental risks are mainly viewed in terms of natural systems degradation, global warming or risks of infection without considering man-made pollution.

Some common environmental risks associated with mining in Africa are well reported. Aboka *et al* (2018) report of environmental risks such as acid mine drainage, heavy metal contamination and leaching and mercury contamination from the gold recovery process in Ghana. Ngole-Jeme and Fantke (2017) note high doses of radionuclides, metals and metalloids in tailings of abandoned and active gold mines in South Africa. In Zambia, a notable risk is that of tailings dams from metallurgical processing of ores for extraction of copper and cobalt covering a total surface area of 1579.9 hectares with 224.82 million tonnes of sulphide ore waste (Weissenstein *et* a*l*., 2000). Mine tailings dumps that are not vegetated facilitate extensive spreading of tailings and heavy metals to the environment through erosion (Limpitlaw, 1998; Ngole-Jeme and Fantke, 2017).

With regard to air pollution, Banza *et al* (2009) report that while this problem is disproportionately experienced in developing countries, research is mainly conducted in developed countries where risks posed to humans have been reduced through legislation and technical measures. Air pollution in Zimbabwe is characterised by sulphur dioxide emissions (Gwimbi, 2017) while studies in Zambia indicate that air pollution from the

Kitwe Nkana smelters is characterized by emissions of sulphur dioxide (Fraser and Lungu, 2006; Ncube *et al*., 2012) which directly affect biota (Environmental Council of Zambia, 2008). Some effects are leaf necrosis in vegetation (Ncube *et al,* 2012) and acid rain damage to trees (Dixon *et al.,* 2001; Simutanyi, 2008, Center for Trade Policy and Development (CTPD), 2012). Furthermore, vegetable gardens in the vicinity of the Nkana Mines are presumed not to thrive as a result of sulphur dioxide emissions (Ncube *et al*., 2012). Similarly, CTPD (2012) note that a result of acidic rains in areas downwind of the Mufulira smelters result in growth of few plants such as mangoes (*Mangifera indica)*, avocadoes (*Persea americana*) and cactus (*Euphorbia tirucalli*).

Water pollution from mine effluents from mineral processing activities is widely reported in African mining countries. In Ghana there is evidence of water contamination with mercury and arsenic (Aboka *et al.,* 2018) whereas South African mineral processing activities have contaminated water resources with heavy metals, acid mine drainage and other chemicals (Ebenebe *et al,* 2018). In Zambia a report by Fraser and Lungu (2006) showed that water resources were polluted with effluents from mineral processing activities of mines.

In addition to the well-known environmental risks related to mining, new risks are emerging that need to be carefully considered and managed. These include risks associated with growing regulatory controls to manage impacts of mining and the potential for climate change to increase the risk level (Parrish, 2016). This means that mining's contribution to climate change may result in new regulations that mining companies have to comply with in order to manage the impact of their operations on the environment.

2.3 Characteristics of health risks of mining

It has been noted by Australian Government (2016) that the health risks associated with mining may result from single or multiple exposures consequently leading to acute or chronic illness or disability. Furthermore, these outcomes only manifest after a long time which makes it easy to overlook them and focus on managing more immediate concerns. Literature shows that a significant health risk of mining is illnesses such as pneumoconioses which are dust-induced lung diseases (Stewart, 2019) and prominent in most types of mining. Donoghue (2004) reported that silicosis was a problem in developing countries and that silico-tuberculosis was of importance in Africa. Gold mining in countries such as Ghana (Aboka *et al*., 2018), cobalt and copper mining in Zambia (Ngosa and Naidoo 2016), and coal mining in USA and Australia (Stewart, 2019) have recorded respiratory diseases such as silicosis and tuberculosis. In South Africa, the health complaints reported among members of Krugersdorp mining community include dermatitis, flu, chronic cough and wheezing chests (Ngole-Jeme and Fantke, 2017). With regard to mining in northern Chile, asthma and rhinoconjunctivitis were perceived to result from gold and copper mining activities (Herrera *et al*, 2016).

In Zimbabwe, sulphur dioxide emissions from smelting were associated with ischemic heart disease, heart failure and stroke, reduced lung function, asthma, emphysema and bronchitis (Gwimbi, 2017). Similar literature on Zambian mining and health have shown an association between sulphur dioxide emissions and respiratory diseases (Dixon *et al.*, 2001; Fraser and Lungu, 2006; Environmental Council of Zambia, 2008; Simutanyi, 2008; Ncube *et al*., 2012). Furthermore, oxides of sulphur are known to irritate respiratory passages and aggravate asthma, emphysema and bronchitis (Lindahl, 2014). Those at risk include children, the elderly and people who suffer from respiratory ailments such as asthmatics (Ncube *et al*., 2012). According to Gwimbi *et al*., (2017), toxicological data on sulphur dioxide collected around the world suggest that short-term exposure to sulphur dioxide concentrations in the air above 1,000μg/ m^3 may be fatal for humans.

2.4 Risk Management in the Mining Sector

2.4.1 Concept of risk

The mining industry is considered one of the most uncertain and hazardous industries in the world (Badri *et al*., 2012) and is associated with several sources of risk (Kowalska, 2019) that are present throughout the life cycle of a mining project (Australian Government, 2016; Galvin, 2017). It is important to understand mining risks before they can be managed. There is no easy definition for risk (Australian Government, 2016) and thus, various definitions have been proposed. Renn and Sellke (2011) define risk as uncertainty about the consequences of an activity and the severity of the consequences with respect to something valued by humans such as their health and the environment.

Aven (2016) defines risk as the possibility of an unfortunate occurrence whereas ISO (2009) defines risk as the effect of uncertainty on objectives.

In this study the definition of risk that was adopted was by Renn and Selke (2011) as it encompasses the effect of risks on human health and the environment which are valued by humans.

"Uncertainty refers to difficulty in predicting the occurrence of events and/or their consequences based on incomplete or invalid databases" (Renn and Sellke, 2011: pg. 357) whereas Luckmann (2015) defines uncertainty as total or partial deficiency of information related to understanding an event with its consequence or likelihood. An event may refer to an accident or incident (ISO, 2009). Badri *et al* (2012) noted that several types of risks exist during the life cycle of a mine and these tend to change in frequency and severity. Consequently, management of these risks is dependent on several factors such as issues of responsibility, culture of prevention as well as the companies' level of tolerance.

2.4.2 Risk Management Theoretical Framework

Risk management has several definitions that Kozarevic *et al* (2014) attribute to the specific nature of risks. Risk management according to Galvin (2017) refers to the principles, framework and processes for effective risk management. Wissem (2013) defines risk management as the strategies, methods and tools for identification and control of risk to a level that is acceptable. A variety of risks and hazards sources in the mining industry have been identified such as occupational health and safety, environment, operations, regulations, politics, finance and economy (Badri *et al*., 2012) including social and ecological risks (Kowalska, 2019). Kowalska (2019: pg.170) notes that social and ecological risks associated with mining production are extremely complex to effectively and efficiently manage 'due to the non-reversible, long-term, serious social and environmental risks associated with mining production, such as mining-related damage, water contamination and air pollution'. Furthermore, the mutually exclusive dynamic aspects of risk sources are said to complicate risk management since it demands a very flexible approach to risk identification and assessment including the selection of management and control instruments (Kowalska, 2019).

Domingues *et al* (2017) propose that risk management should have a strategy-based project approach that is developed to identify as many potential risks as possible in order to reduce risk. On the other hand, Kozarevic *et al* (2014) identify a scientifically based approach that sees risk management as a process involving several stages. ISO 31000 outlines the risk management process as follows: establishing the context of the risk management process, risks identification, risk analysis, risk evaluation, risk treatment followed by monitoring (ISO, 2009). ISO 31000 is an international standard that provides principles and generic guidelines on risk management and these can be used by any industry or sector. The standard can also be applied to any type of risk and to strategies, decisions, operations and processes throughout the life of an organization.

In reference to the literature reviewed, risk management is an essential tool in the mining industry that enables mining companies to identify potential environmental and health risks and effectively manage them according to their severity. Effective management of risks is vital for the prevention of acute pollution incidences that may contamination the environment or affect human health.

2.4.2.1 Establishing the context

This involves defining external and internal parameters to be taken into account when managing risk as well as setting the scope and risk criteria for the risk management policy. External parameters are concerned with legal and regulatory requirements, stakeholder perceptions and aspects of risk that are specific to the risk management process. Internal parameters refer to the culture, processes, structure and strategy within the organization that may influence the manner in which risk will be managed. Essentially the objectives and concerns of external stakeholders have to be considered in the process. External context can refer to social, political, legal, regulatory, financial, technological, economic environment at international, national, regional or local level. On the other hand, the internal context can refer to governance, organizational structure or policies, objectives and strategies in place for addressing them (ISO, 2009).

2.4.2.2 Risk identification

According to ISO (2009) the risk management process involves identification of risk sources, their causes and their potential consequences. Kowalska (2019) suggests that the approach during risk identification and assessment should be specific. However, this is no easy task according to Badri *et al* (2012) who assert that the complex interactions between humans and various technical processes complicate the setup of a risk management policy during hazard risk identification and assessment.

Most literature on risk management focuses more on identification of threats or negative risks However, Evans *et al* (2007) contend that risk identification should also place emphasis on identification of opportunities. In this case focus is on identification of activities and changes which will increase the likelihood of the opportunity being realised and/or maximise the benefit to be derived from this.

2.4.2.3 Risk analysis

The process enables risk managers to comprehend the nature of risk in order to determine the level of risk (ISO, 2009). According to Kozarevic *et al* (2014) risks are analysed in order to understand their causes, likelihood of occurrence and possible consequences. Risk analysis is important because some risks require a specific approach regarding their management and control (Kowalska, 2019). A specific approach means the selected management and control instruments will result in effective management of the risks. It also provides input for risk evaluations through identifying the risks that must be treated based on appropriate treatment strategies (Australian Government, 2008; Krzemien *et al*., 2016).

2.4.2.4 Risk evaluation

According to Krzemien *et al* (2016) this process involves evaluation of risks through comparing estimated levels of risk with risk criteria. Furthermore, all identified environmental risks are categorised according to potential or insignificant risk and focus is placed on risks of utmost importance. However, Choudhary (2014) posits that risk evaluation sorts identified risks into groups such as extreme risk, high risk, substantial risk, moderate risk and low risk. Thereafter, the level of management response and effort required is then determined. Literature shows that in Zambia risks from mining activities are classified as high, moderate and low (KCM, 2009; MCM, 2013). Overall, the goal of risk evaluation is to determine risks that should be given high priority when developing responses for risk treatment (Choudhary, 2014).

2.4.2.5 Risk treatment

This is the process where risk is modified. Some of the options can involve avoidance of the risk by deciding not to proceed with the activity that gives rise to the risk or removal of the source of risk among others (ISO, 2009). This process also involves formulation of controls for the elimination or reduction of risks to an acceptable level.

Galvin (2017) stresses the need for the controls to be risk assessed to determine their likelihood of being effective. Once controls are implemented, monitoring for changes is imperative in order to identify deviations from the risk management process and to intervene quickly before a hazard materializes (Galvin, 2017). However, Willis Limited (2014) asserts that risk identification and design of suitable controls in the absence of effective implementation is worthless. Despite mining operations having highly developed risk registers and risk management systems, there is a divide between what occurs in the field and what is planned to be in place. Often, there is poor understanding of risk controls, poor implementation and a lack of reviews and audit systems that are robust for ensuring that controls are working.

2.4.2.6 Monitoring and review

This is the frequent checking, performance supervision, critical observation or determining of the status for the purpose of identifying change from the performance level required or expected (ISO, 2009). Risk management according to Galvin (2017) is a continuous process that according to Donoghue (2004) requires vigilance to maintain effective control. If this is not done, risks may increase. However, due to the uncertainty that is inherent in risk, Australia has experienced a recent increase in incidences of coal miner’s pneumoconiosis which has been attributed to lack of regulation of engineering dust controls as well as the economic drive to sustain or increase profit margins

(Stewart, 2019). This is despite controls such as dust suppression, ventilation and respiratory protection being utilized in developed nations according to Donoghue (2004).

It is therefore imperative to review the suitability, adequacy and effectiveness of the controls or treatments in order to meet the objectives of the risk management process.

Galvin (2017) proposes that in order to succeed, risk management requires knowledge of fundamental scientific and engineering principles, knowledge of mining systems, practices and hazards including an understanding of risk management principles , reinforced by experience and skill. Galvin (2017) further states that effectiveness of risk management is based on provision of fit-for purpose equipment, supporting management plans, standard operating procedures and training on safe working procedures and competency assessment in these plans and procedures including effective supervision.

Another key aspect in risk management is that of adapting to the dynamic mining sector. In line with this, Badri *et al* (2012) contend that rapid adaptation to changes in regulations and laws, improvement of technologies, methods and attitudes are necessary for addressing risks throughout the life cycle of mine operations.

2.5 Risk management strategies

The risks presented by mining activities vary depending on the type of mining operations. It has been pointed out by Scot (2000) that mining in any part of the world has a set of specific risks that enable the developer to design strategies to deal with the risks. The diversity of such risks requires that risk management strategies give specific attention to the nature of environmental risks in an area before evaluating such strategies. Furthermore, IFC (2014) states that risk management strategies must be implemented based on valid data and sound science.

In light of this, Aven (2016) identifies three major risk management strategies to manage risks namely risk-informed, cautionary/precautionary and discursive strategies. The risk informed strategy refers to treatment of risk either through avoidance, reduction, transfer and retention by using risk assessment in an absolute or relative manner. This approach can only be used alone when the knowledge is strong and uncertainties are small. The cautionary/precautionary strategy involves; containment, development of substitutes, design of systems with response options as well as improvement of conditions for management of emergencies and system adaptation. Aven and Krohn (2014) assert that the cautionary and precautionary principles play an important role in risk management through ensuring that proper weight is given to uncertainties in decision making. This is particularly important as hidden risks and uncertainties in a project such as mining may lead to poor-decision making (Badri *et al*., 2012).

The discursive strategy utilizes measures to build confidence and trustworthiness to reduce uncertainties and ambiguities, clarify facts and involve affected people.

2.6 Institutional Arrangements for Environmental Risk Management in the Mining Sector

2.6.1 Mining legislation

Mining legislation is enacted for the purpose of regulating pollution from mining and mineral processing activities worldwide. According to Dobbie and Green (2015), pollution is regulated through environmental legislation which contains provisions that create a duty not to cause harm to the environment. However, regulation of pollution using these laws makes it possible for mining companies to defend themselves when harm is caused to the environment in accordance with their license conditions. Dobbie and Green (2015) contend that this may result in only acute acts of air pollution being caught by these regulatory provisions. While legislation is being enacted for environmental protection, there is evidence of the pollution haven hypothesis being borne out in areas without stringent environmental legislation for mining. However, introducing strict environmental regulations may be hindered by institutional resistance and poor enforcement by the mining sector and the relevant government department as is the case in South Africa (Murombo, 2013). The problem of enforcing mining legislation has also been noted in Zambia where enforcement of environmental laws is a challenge. For example, the Ministry of Mines and Minerals Development overruled a decision by the Environmental Council of Zambia (ECZ) (now ZEMA) to suspend Konkola Copper Mine's mining license following pollution of the Kafue River in 2006 (Simutanyi, 2008). Such interference with how the environmental regulatory agency addresses polluting mines hinders the implementation of regulations that are in place to manage environmental impacts of these industries and weakens the regulations. This interference has largely been driven by need to attract foreign investors in the mining sector.

The two policies that guide mining in Zambia are the National Policy on the Environment and the Mineral Resources Development Policy. The National Policy on the Environment was developed by the government in 2009 to try to rationalize and harmonize the scattered environmental policy and legal framework (Lindahl, 2014). The Mineral Resources Development Policy of 2013 replaced the Mining Policy of 1995 and a key objective of the policy is achieving an acceptable balance between mining and the bio-physical environment and ensuring observation of acceptable standards of health and the environment by all mining sector participants (GRZ, 2013). The main laws governing environmental management in the mining sector are the Environmental Management Act No. 12 of 2011 and the Mines and Minerals Development Act No. 11 of 2015. The two Acts are used together with several mining regulations.The Mines and Minerals Development Act of 2015 repealed and replaced the Mines and Minerals Development Act of 2008. A key feature of the Act is that, under Section 75 of the Act, the Director of Mines Safety may suspend mining if it is considered necessary to prevent or mitigate imminent risk to the environment or human health (GRZ, 2015). The Mines and Minerals (Environmental) Regulations of 1997 are a statutory instrument under the Mines and Minerals Act of 2015 for managing pollution from mining activities. The regulations provide the framework for conducting and reviewing environmental impact assessments for the mining sector. Furthermore, these are the most inclusive environmental regulations applicable to mining in Zambia (Lindahl, 2014; Kambani, 2003). According to SADC (2012) in its Environmental Legislation Handbook, available emission standards in Zambia are for water quality, ambient air quality and air emissions. SADC (2012) considers the air emission standards in Zambia to be too stringent.

According to Dixon *et al* (2001) stringent legislation and sulphur dioxide penalties were ways of redressing sulphur dioxide pollution following privatization of mines prior to formulation of environmental management plans by new mine owners. Despite air quality and air emissions being stringent, air emissions from mining still exceed set limits (Ncube *et al*., 2012; GRZ, 2014). This indicates a lack of effectiveness in air quality monitoring and management in Zambia and non-compliance by polluting mines.

With regard to discharge of effluents from mining companies into water bodies, the legislation that covers this is the Water Pollution Control (Effluent and Waste Water) Regulations of 1996 (GRZ, 1996) and Environmental Management (Licensing) Regulations, S.I. No. 112 of (GRZ, 2013). These regulations set limits on the effluents that may be discharged by mining companies into the aquatic environment.

2.7 Chapter Summary

Literature reviewed shows that there is a link between mining and risks to the environment and human health. Furthermore, there is lack of information and on environmental risk management strategies in the mining sector and their effectiveness.

CHAPTER THREE: STUDY AREAS

3.1 Introduction

The study was carried out in Kitwe and Mufulira Districts of the Copperbelt Province of Zambia. The two districts were selected as study sites due to the mining operations carried out by Konkola and Mopani Copper Mines. Konkola Copper Mine Plc operates a refinery at the Nkana Mine Site in Kitwe District. Mopani Copper Mines Plc operates an underground mine at the Nkana Mine Site in the south-west of Kitwe. Key facilities at the mine are an underground mine and concentrator. Mopani Copper Mines operations in Mufulira District consist of an underground mine, a leach plant and smelter.

3.2 Demography

The projected population of Kitwe District for 2019 by the Central Statistical Office is 738, 320, with males numbering 366, 754 and females numbering 371, 566. The projected population of Mufulira District is 196, 401with males giving a total of 98, 860 and females numbering 97, 541 (CSO, 2013).

3.3 Location

Kitwe District is located between latitudes 12^{o} and 13^{o} South and longitude 28^{o} and 29^{o} East. The district lies on a plateau with an altitude of over 1,295 metres above sea level and covers an area of 777km^2 (FAO, 2016). Mufulira District is located between latitudes 12^{o}30' South and 12^{o}40' South and between longitudes 28 ^{o}10' East and 28 ^{o}20' East. The district covers an area of 1, 637km^2 (Mufulira Municipal Council, n.d.).

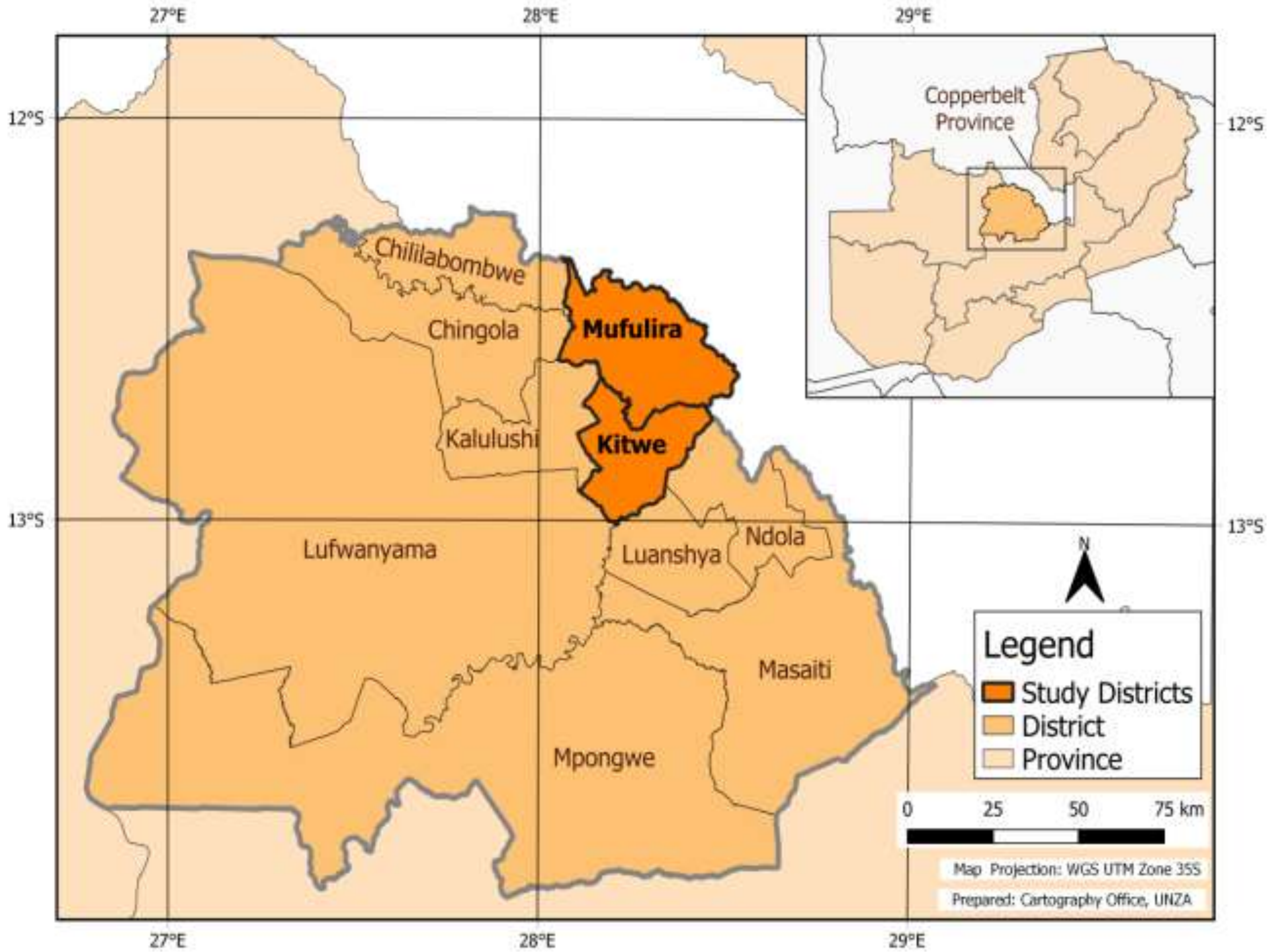

Figure 3.1: Location of study sites

Source: UNZA Department of Geography and Environmental Studies Cartography Office

3.4 Hydrology

The major river that drains the Copperbelt Province is the Kafue River which has numerous tributaries. Kitwe region is drained by several small rivers and streams which include Mindolo, Kitwe, Uchi and Wusakile (Kribek *et al*., 2010b). Effluents from Konkola Nkana Mine facilities which include; Tankhouse operations, Refinery Tankhouse, Slimes Plant and Nkana Anode Furnaces are discharged into the Uchi Stream. At the time of the study only the concentrator and underground mine at Mopani Nkana Mine were operational and effluents from these facilities are discharged into Uchi Stream. Hence, these effluents eventually flow into the Kafue River. Mwekera Stream another tributary of the Kafue is not affected by mining activities. According to FAO (2016), the Kafue River is a source of drinking water and water for industrial activities such as mining which uses the water for mineral processing activities to extract copper and cobalt. Uchi Stream and Kafue River are also used for agriculture irrigation by peri urban farmers. Mufulira District is drained by Mufulira Stream and Kafue River (Mufulira Municipal Council, n.d.).

3.5 Geology

Some of the world's largest copper and cobalt deposits are found in the Copperbelt Province, location of Kitwe and Mufulira. The copper and cobalt deposits are confined to the lower section of the Katanga Supergroup (Kribek *et al*., 2010a). The mineral ores of the Copperbelt form sediment-hosted deposits of strata-bound and/or stratiform type characterized copper-(cobalt)-iron sulphides consisting mostly of chalcopyrite and cobalt-rich pyrite. The host rocks include quartzite, dolomite and shale. The grades of ore average 3 weight percent copper and 0.18 percent cobalt from which both metals are extracted (Kribek *et al*., 2010a).

3.6 Economic activities

The district of Kitwe is highly urbanized and quite advanced in terms of industry. Mining and mining-related activities dominate the economy of Kitwe (FAO, 2016). Agriculture in Kitwe District is diverse in line with the Seventh National Development Plan. The types of farming practiced are small-scale, medium-scale and large-scale farming. Major crops grown are maize, cassava, sweet potatoes, groundnuts and vegetables (Kitwe District Investment Profile, 2019). Industries produce beverages, metal products, batteries, chemicals, wires and cables and textiles. Copper and cobalt are exported as raw materials, mainly to industrialized countries (FAO, 2016).

Economic activities in Mufulira constitute copper mining and agriculture. Agriculture is a growing sector involving cash crop and irrigation farming (Mufulira Municipal Council, n.d.).

CHAPTER FOUR: METHODOLOGY

4.1 Introduction

This chapter outlines the research design, methods of data collection and sampling including the analytical methods that were utilized in the study.

4.2 Research Design

The research was carried out using a case study approach which offered in-depth information about risk management in the mining sector. According to Yin (2003), a case study is advantageous in explaining and describing complex issues. The case study used both qualitative and quantitative research methods. Qualitative data from the interviews and document review was complemented by quantitative data from a questionnaire survey and field assessments. Therefore, the study provided a deeper and broader understanding of the study through use of both.

4.3 Data Collection

4.3.1 Qualitative Data Collection Methods

Qualitative data was collected through interviews with key informants and through document analysis.

4.3.1.1 Key informant interviews

Qualitative data was collected using key informant interviews. Key informants were selected based on the knowledge they possessed on environmental management in the mining sector. Purposive sampling was used in the selection of the seven key informants for interviews which are presented in Table 4.1.

Interviews were conducted with informants from Zambia Environmental Management Agency, Mines Safety Department, Misenge Environmental and Technical Services and Mufulira District Health Management Office. The interviews used open-ended questions that provided a degree of flexibility to the interviewees. Questions asked mainly focused on; the environmental and health risks of mining, the strategies used by mining companies to manage risks as well as the adequacy of institutional arrangements pertaining to mining. The interviews were unstructured to allow for in-depth understanding of the viewpoints of the informants on environmental risk management in mining in Kitwe and Mufulira districts. Furthermore, using unstructured interviews enabled collection of detailed data on aspects relating to environmental risk management in mining.

Table 4.1: Key Informants

Key Informant	**Number of participants**
ZEMA	01
Misenge Environmental and Technical Services	01
Mufulira District Health Office	03
Mines Safety Department	01
	06

Source: Field data, (2018/2019)

Informants from ZEMA, MSD and Misenge Environmental and Technical Services respectively provided information on known risks from Mopani and Konkola Mine operations in Kitwe and Mufulira. The informants from Mufulira District Health Office gave information on the health issues in Kankoyo.

4.3.1.2 Document Analysis

Document analysis involved a review of environmental Management Plans (EMPs) for Mopani Kitwe and Mufulira Mines, EMP for Konkola Nkana Mine including policies and procedures. Further, policy and legal frameworks related to mining were also examined for the purpose of evaluating the adequacy of the institutional framework governing environmental risks management in the mining sector.

4.3.2 Quantitative Data Collection Methods

The quantitative data collection methods employed were structured interviews and field assessments.

4.3.2.1 Structured Interviews

The structured interviews were conducted through the use of a questionnaire that contained open and closed ended questions. It was administered in Nkana West residential area in Kitwe city and Kankoyo Township in Mufulira district. Out of a total of 456 households in Nkana West, forty six participated in the survey. In Kankoyo the number of households interviewed was sixty two out of 193 households. The goal was to conduct interviews with 82 households representing 1 percent of the target population. However, due to disinterest in the survey by possible respondents the goal could not be met. There was disinterest from Kankoyo residents as they were fatigued from too many researchers going there. Thus, a total of 108 questionnaires were administered in the two residential areas. The households were selected using simple random sampling and respondents above the age of 18 were interviewed. The knowledge sought was the respondents' perception of mining risks in their community. The interviews were administered by the researcher and conducted in English and Bemba. Convenient sampling was carried out by selecting respondents who were willing to participate in the survey.

4.3.2.2 Water Sampling

To understand the nature of risks emanating from mining and their impact on the environment, laboratory tests were conducted on water samples collected from Uchi and Mwekera Streams. Water from Uchi Stream was assumed to be polluted because it is a licensed discharge stream for Mopani Nkana Mine whereas water from Mwekera Stream is not polluted and therefore was selected as a control. The purpose of the tests was to analyse the quality of water from the two streams. The parameters tested were heavy metals. Heavy metals that were considered were copper, cobalt, manganese, zinc and iron. The heavy metals were selected because they are chemical parameters of concern that are monitored for compliance with effluent limits outlined in the Environmental Management and Licencing Regulations of 2013. Water quality was chosen because water is a significant pathway through which people may be exposed to contaminants from mine waste water released into streams and rivers.

4.3.2.3 Sampling Strategy

Sampling of the Uchi and Mwekera Streams was conducted between 12th September and 2nd October 2018. Water samples were collected over a number of days to observe the trends in concentrations of heavy metals in the streams. Six samples were collected per day from Uchi Stream. Thus in five days a total of 30 samples were collected. The mean concentration of each heavy metal at each of the 6 sampling points collected over the 5 days was calculated (Appendix 2).

From Mwekera Stream, five samples were collected per day. Thus in two days a total of 30 samples were collected. The mean concentration of each heavy metal at each of the 3 sampling points collected over the 2 days was calculated (Appendix 2). The concentration of heavy metals in each sample was compared with the Zambia Bureau of Standards (ZABS) 2010 standards for drinking water. These standards were used because they were more stringent than standards in the Water Pollution Control (Effluent and Waste Water) Regulations of 1996. Though people do not drink water from the two streams, vegetables are irrigated using water from the streams. Uchi Stream was selected for sampling due to the effluent discharged into the stream from the Nkana Mines and Mwekera Stream was selected as a control site on the assumption that it was free of mining impacts. Sampling was carried out at 6 purposively selected sampling points along the Uchi Stream (Figure 4.1) and at 3 points along Mwekera Stream as the stream was easier to access at these points for collection of water samples (Figure 4.2). The samples were collected in 1000ml plastic bottles that were rinsed three times with water from the stream before collection of the water sample (USEPA, 1996).

Figure 4.1: Sampling points along Uchi Stream

Source: Google Earth

Figure 4.2: Sampling points along Mwekera Stream

Source: Google Earth

4.4 Data Analysis

This section presents the methods that were used to analyse the data collected in the study.

4.4.1 Content Analysis

Content analysis was used to analyse qualitative data from the key informant interviews. Content analysis as defined by Krippendorf (2004:18) is 'a research technique for making replicable and valid inferences from texts to the contexts of their use'. Content analysis is useful for collection and organization of non-structured information into a standardized format from which inferences about the characteristics and meanings of written or recorded material can be made (Kulatunga *et al.*, 2007). The study analysed key informant interview data using conceptual content analysis where the text was analysed to check the existence and frequency of concepts or themes (Kulatunga *et al.*, 2007). Themes were categorized to enable description of the phenomenon under study. Content analysis was also used for document review of bi-annual reports, EMPs, policies and legal frameworks in the mining sector as it is a prevalent approach to qualitatively analysing documents (Bryman, 2012). The text from the documents was transcribed and categorized into themes which were then interpreted.

4.4.2 Statistical analysis

Quantitative data from the questionnaires was coded and then analysed using frequencies and percentages to determine the locals' understanding of environmental risks of mining.

Thirty (30) water samples from Uchi and Mwekera Streams were analysed for concentrations of copper, cobalt, manganese, iron and zinc using Atomic Absorption Spectrometry at the Copperbelt University School of Mines Laboratory. Following this analysis, the mean concentration of each heavy metal collected from each point on all the days was calculated (Appendix 2). The levels of the heavy metals were compared with Zambian standards for drinking water quality to determine whether the concentrations of the elements were within acceptable thresholds. Descriptive statistics gave the mean concentrations of the heavy metals (copper, cobalt, manganese, iron and zinc) in the water samples.

A Two-independent sample T-test was used to test for significant differences between the heavy metal levels in Uchi and Mwekera Streams respectively. The test was performed with the aid of Minitab 18 software (Minitab Inc., 2017) at 5% level of significance.

4.5 Ethical considerations

Before undertaking the research, clearance from the University of Zambia, School of Natural Sciences through the Department of Geography and Environmental Studies was obtained in form of an introductory letter. The letter explained the purpose of the research and was used to conduct interviews and obtain information from ZEMA, MSD, Misenge Environmental and Technical Services and Mufulira District Health Office. Informed consent was obtained from the respondents before interviews and administration of the questionnaire and after they were informed of the purpose for the research. Respondents were also informed that their participation was voluntary, and they were not coerced into participating in the study. Audio recording of the interviews was conducted with the permission of the respondents who were assured of anonymity and confidentiality. Hence, their names and positions have not been included in the dissertation.

4.6 Limitations of the study

The study encountered a few challenges during data collection. Questionnaire survey was a challenge as some residents in Nkana West declined to participate in the survey reportedly because air pollution is no longer a problem in the area. Furthermore, some residents in Kankoyo expressed their disinterest in the survey. They complained that nothing had been done to address the air pollution problem in the area despite numerous visits from Mopani mines, government officials and researchers. Obtaining a copy of the EMPs and related documents on risk management procedures for Mopani Copper Mines from ZEMA proved difficult reportedly due to filing challenges at the institution. The Agency explained that relevant documents pertaining to the research was in storage and had not been sorted. Therefore, the study had to rely on the EMP commitments contained in the bi-annual reports.

The legal department at Konkola Copper Mine stated that the research was too sensitive and as such interviews and access to pertinent information could not be granted. At Ronald Ross General Hospital in Mufulira, the legal department did not grant access to records on mining-related illnesses in Mufulira as the information was considered confidential. The Kitwe District Health Office did not have information on mining-related illnesses and referred the researcher to Kitwe Teaching Hospital where the contact person was found to be on leave from work. Furthermore, due to lack of ethical clearance, information from the Institute for Occupational Health and Safety was not accessed. Hence, the study relied on the responses from the questionnaire survey. Permission to interview personnel from the Environmental Department was granted by the CEO of Mopani Copper Mines. However, meeting with the contact person proved to be unsuccessful despite several phone calls and visits to Mopani Head Office. Hence, the study utilised information contained in the EMPs for Konkola and Mopani Mines, MSD and bi-annual reports for Mopani Copper Mines. Consequently, the effectiveness of the risk management strategies utilised by the two mining firms could not be assessed for compliance with mining regulations.

CHAPTER FIVE: FINDINGS AND DISCUSSION

5.1 Introduction

This chapter is a presentation of the results of the study and a discussion of the findings. It includes the risks to the environment and human health that result from mining, health and environmental mining risks, strategies for managing mining risks and the legal framework that guides mining in Zambia.

5.2 Environmental and health risks from mining in the study areas

The study characterised the environmental and health risks posed by mining in terms of pollutants of concern (i.e. hazards), the environmental media affected and pathways of exposure for humans. Further, laboratory tests were used to determine the levels of concentration of heavy metals and the extent to which these exceeded Zambia Bureau of Standards thresholds.

From the results of the study the main pollutants of concern in the study areas include emissions and effluents from mineral processing activities of the mines in Kitwe and Mufulira.

Table 5.1 presents pollutants emanating from mine operations and the environmental media affected including their pathways of exposure.

Table 5.1 Pollutants of concern in Nkana West and Kankoyo

Area	Type of Hazard (Pollutant)	Environmental media in which pollutant occurs	Pathway(s) of exposure
Nkana West	Fumes from Mopani Concentrator	Air	Inhalation
	Dust from Uchi Slag Dump	Air/Land	Inhalation and dermal intake
	Effluent from Konkola and Mopani Nkana Mines	Surface and Ground Water	Ingestion
Kankoyo	Sulphur dioxide emissions from Mopani Smelter	Air/Land	Inhalation/dermal intake
	Dust from Mopani Slag Dump	Air/Land	Inhalation or dermal intake
	Effluent from Mopani Mine	Surface and Ground Water	Ingestion or dermal intake

Source: Field data (2018)

5.2.1 Air pollution

From interviews with key informants in the mining sector, other hazards in the areas were copper and sulphur dioxide fallout from the smelters and dust from tailings containing silica that may cause chest infections. Stack emissions, noxious fumes, arsenic, nitrous fumes and dust were risks noted by the MSD. These risks are distributed in the environment through air and consequently deposited on the soil and vegetation. With regard to air pollution, the spatial distribution of the pollutants depends on wind direction, size of particulates emitted by the smelter as well as the chemical and mineralogical composition of the particulates (Ettler, 2016).

5.2.2 Land pollution

The Uchi Slag Dump in Nkana West and the slag dump at Mopani Mufulira Mine may contain traces of chemicals from mineral processing activities that may contaminate the surrounding environment.

5.2.3 Water pollution

In Kankoyo, an effluent drain from Mopani Mine poses the risk of contaminating groundwater and the Mufulira West Stream into which effluent reports. With regard to distribution of heavy metals in water, surface water sampling found evidence of copper, cobalt, manganese, iron and zinc being present at different points of Uchi and Mwekera Streams in Kitwe.

5.2.3.1 Heavy metal trends at different sampling points and days

Laboratory tests results indicated that the Uchi Stream water samples had above threshold concentrations of cobalt, manganese and iron at all the 6 sampling points (Table 5.2). Copper concentration increased at sampling points 1 and 2 and declined at sampling point 3. An increase in copper concentration was observed at sampling point 4and a gradual decline was observed from sampling point 5 to 6. Copper concentrations fluctuated over the days of sampling.

There were fluctuations in cobalt concentrations at all the 6 sampling points over the days of sampling and the highest concentration was observed on the fifth day of sampling. Fluctuations in manganese concentrations were observed at all sampling points and the highest concentration was recorded on the fifth day of sampling. Concentrations of manganese increased from sampling points 1 to 4 where peak concentrations were observed. There was a gradual decline at sampling points 5 and 6. Zinc concentrations fluctuated at all the sampling points and over the duration of sampling. Fluctuations in iron concentrations were observed at all sampling points over the days of sampling. The highest concentrations of zinc were observed at sampling point 4. A gradual decline was observed from sampling point 5 to 6.

The low copper concentrations may be attributed to efficient extraction of copper at the Nkana Mines. The high levels of cobalt, manganese and iron may be attributed to the historical Uchi Slag Dump (‘black mountain’) depositing the heavy metals into the Uchi Stream through erosion and runoff. Though other sources may account for the presence of heavy metals in the Uchi Stream such as raw sewage and natural sources, inefficient processes of smelting and refining at the Nkana Mines may generate the cobalt. The high concentrations of manganese may be attributed to the natural occurrence of manganese in the crust of the Earth (WHO, 2011). Manganese is known to be present in cobalt-copper ores in significant quantities and this may account for the concentrations above the acceptable limit at all the sampling points. The high iron content may be due to the natural occurrence of iron in fresh water (WHO, 2011).

Iron is one of the two most abundant minerals in the earth’s crust which accounts for the high concentrations at all the sampling points. Effluent such as raw sewage is known to contain traces of heavy metals and this may also explain the high levels of some of the metals as raw sewage was found flowing at sampling points 1 and 2.

5.2.3.2 Comparison of heavy metal mean values for Uchi and Mwekera Stream with ZABS drinking water standards

The comparison of mean values for heavy metals in Uchi and Mwekera Streams are presented in Table 5.2.

Copper in Uchi was higher than Mwekera ($p<0.05$). Copper mean value in Uchi (0.11mg/l) and Mwekera (0.08mg/l) was below the ZABS limit (1.00mg/l). Cobalt in Uchi was higher than Mwekera ($p<0.05$). Cobalt mean value in Uchi (1.40mg/l) was above ZABS limit (0.50mg/l) but low in Mwekera (0.01mg/l). Manganese in Uchi was higher than Mwekera ($p<0.05$). Manganese mean value in Uchi (0.31mg/l) and Mwekera (0.13mg/l) was above the ZABS limit (0.10mg/l). Zinc in Uchi was higher than Mwekera ($p<0.05$). The zinc mean value in Uchi (0.14mg/l) and Mwekera (0.06mg/l) was below the ZABS limit (3.00mg/l). Iron in Uchi was higher than Mwekera ($p<0.05$). Iron mean value in Uchi (0.63mg/l) and Mwekera (0.48mg/l) was below the ZABS limit (0.30mg/l).

Table 5.2: Two-Sample T-Test between Uchi and Mwekera Stream heavy metal concentrations

Heavy Metal	**Uchi Mean Concentration (mg/l)**	**Mwekera Mean Concentration (mg/l)**	**ZABS Limit (mg/l)**	**Test statistic**
Copper	0.11 (S.D ± 0.0845)	0.08 (S.D ± 0.0293)	1.00	T=1.73, p=0.044
Cobalt	1.40 (S.D ± 0.992)	0.01 (S.D ± 0.0036)	0.50	T=7.66, p=0.0001
Manganese	0.31 (S.D ± 0.202)	0.13 (S.D ± 0.089)	0.10	T=4.44, p=0.0001
Zinc	0.14 (S.D ± 0.0878)	0.06 (S.D ± 0.0237)	3.00	T=4.96, p=0.0001
Iron	0.63 (S.D ± 0.449)	0.48 (S.D ± 0.175)	0.30	T=1.74, p=0.044

Source: Field data (2018)

These results show that the liquid pollutants that come from the Nkana Mines in the Uchi Stream are cobalt, manganese and iron which exceeded ZABS thresholds for heavy metals in drinking water. The study did not find evidence of people drinking water from Uchi Stream. However, the stream is a tributary of the Kafue River which is a source of drinking water.

5.2.3.3 Problems with excess Cobalt, Manganese and Iron

Toxicity of cobalt is generally low compared to other metals but exposure to very high levels can cause health problems overtime. These problems include cardiomyopathy, nerve problems, thickening of blood and thyroid related problems (Kayika *et al.*, 2017). Inhalation of dust containing cobalt may result in rhinitis, bronchitis, bronchial asthma and, in some circumstances lung fibrosis (Nemery, 2011).

Humans can be exposed to toxic levels of manganese through ingestion, dermal exposure skin contact and inhalation of particulates containing manganese. Ingesting contaminated water or soils and skin contact with elevated levels of manganese are major risks to humans. Compounds of manganese are neurotoxic substances that may cause a severe neurological disorder known as manganism, which is characterized by slowly progressive neurological psychiatric dysfunction (Caruso *et al*., 2011; Nemery, 2011). High occupational exposure to manganese by miners, steelworkers and welders can lead to diseases of the respiratory tract and central nervous system (Nemery, 2011).

Excess uptake of iron increases the risk of cancer and iron toxicity may result from high exposure of iron (Jaishankar *et al.*, 2014).

Two studies found evidence of heavy metal pollution in mining towns on the Copperbelt.

Makondo *et al* (2015) reported above limit levels of cobalt, manganese and lead in the Uchi Stream while copper was found to be below the stipulated threshold. A study by Nachiyunde *et al* (2013) of surface water in Mufulira, Chingola, Kitwe, and Ndola revealed that stream/river water in these areas had high concentrations of manganese that were attributed to lack of control and remediation measures during and after mining operations.

Sracek *et al* (2012) contended that the major source of heavy metal pollution in all environmental media on the Copperbelt is fallout from copper and cobalt smelting activities, untreated mine effluent discharged into streams and tailings discharge. Heavy metals in the environment have become a source of concern due to the threats they pose to the quality of human life when they exceed allowable limits *(*Okoro *et al,* 2012). Kapungwe (2013) similarly noted that consumption of food crops grown with heavy metal laden irrigation water in peri-urban areas had potential health risks to humans.

Figure 5.1: Vegetable garden near sampling point 6 along Uchi Stream

Source: Field data (2018)

5.3. Residents' perception of health problems resulting from mining

The findings show that the main health problems perceived to result from mining in Kankoyo and Nkana West were respiratory tract infections (RTIs) according to 88% of the respondents (n=83). Respiratory infections noted include; tuberculosis, bronchitis, silicosis, pneumoconiosis, colds and influenza.

Table 5.3 Perception of health problems in Kankoyo and Nkana West

Health problem	**Nkana West**	**Kankoyo**	**Combined No.**	**Combined % of sample**
Respiratory	31 (33%)	52 (55%)	83	88%
Eye	-	5 (5%)	5	5%
Skin	-	1 (1%)	1	1%
Hearing	3 (3%)	-	3	3%
Heart	1 (1%)	-	1	1%
Injuries	2 (2%)	-	2	2%

Source: Field data, (2018/2019)

These findings were echoed by an officer at the Mufulira District Health Office who revealed that RTIs were common health problems believed to be due to sulphur dioxide pollution in Mufulira. Another officer stated that tuberculosis re-infections among Kankoyo residents were common and the reason was not clear. Eye problems were reported by 5 percent of the respondents in Kankoyo whereas skin problems were noted by one respondent from Kankoyo. Kankoyo and Nkana West are located on the windward side of the slag dumps. Thus, winds blowing into these areas carry with them dust particles resulting in inhalation and deposition of dust particles on the skin of the residents. The responses of respondents in Nkana West pertaining to air pollution were based on past experiences with sulphur dioxide pollution. However, their perception was that these illnesses resulted from sulphur dioxide pollution However, respondents from Kankoyo reported on-going air pollution at the time of the study.

Similar studies in Chile (Herrera *et al.*, 2016) and Zimbabwe (Gwimbi, 2017) found that members of the community perceived that respiratory illnesses in their community were a result of sulphur dioxide emissions from smelting operations at the mines.

According to Mulenga (1999), pneumoconiosis is common among industrial workers (which include mine workers) as the type of rock found on the Copperbelt is rich in silica.

According to Mujuru *et al* (2012), when sulphur dioxide is absorbed in the upper respiratory system it reacts with water forming acidic sulphates and long term exposure to high doses of the gas result in a higher frequency of respiratory infection among children. The authors also indicated that a link between air pollution and health effects such as eye and respiratory irritation, asthma, chronic bronchitis and death rates had been shown by studies. Simukanga (1999) noted that sulphur dioxide is a health hazard that causes respiratory, skin and eye diseases. Despite the occurrence of illnesses among residents living near operations, an officer at ZEMA asserted that linking health ailments in communities to mining is a challenge. However, based on the responses from the respondents, the study found evidence of health problems in Kankoyo and Nkana West being the result of mine pollution. Hence, this suggests a link between mining and health problems.

5.4 Residents' perception of environmental problems resulting from mining

According to 34% (n=32) of the respondents, poor growth of vegetation was an environmental problem perceived to be the result of sulpur dioxide emissions from the mines. Vegetables were purportedly difficult to grow and this was attributed to soil degradation by sulphur dioxide emissions. This problem was particularly severe in Kankoyo where some plants turn yellow or dry up due to frequent emissions of sulphur dioxide. Air pollution was noted by 26 % (n=25) of the respondents as an environmental problem. Land degradation was noted by 21% (n=19) of the respondents some of whom stated that they had had trouble growing vegetation as they believed the soil had been degraded by sulphur dioxide emissions. Mulenga (1999) noted that Kankoyo Township had no vegetation except for a few plant species such as *Lantana camara* and avocado (*Persea americana*).

Table 5.4 presents the perception that residents of Kankoyo and Nkana West have regarding environmental problems related to mining.

Table 5.4 Perception of environmental problems in Kankoyo and Nkana West

Health problem	**Nkana West**	**Kankoyo**	**Combined No.**	**Combined % of sample**
Air pollution	14 (15%)	11 (12%)	25	26%
Poor vegetation growth	6 (6%)	26 (27%)	32	34%
Land degradation	9 (10%)	10 (11%)	19	21%
Environmental degradation	-	3 (3%)	3	3%
Water pollution	6 (6%)	1 (1%)	7	7%
Damage to houses	3 (3%)	3 (3%)	6	6%
Noise	1 (1%)	2 (2%)	3	3%

Source: Field data, (2018/2019)

5.5 Risk management at Mopani Copper Mines and Konkola Copper Mine

5.5.1 Risk management strategies used to manage mining risks

Findings of the study show that risk management at Mopani Copper Mines and Konkola Copper Mine is conducted using internal controls such as policies, procedures, Environmental Management Plans (EMPs) and engineering controls. Policies and procedures are documents that outline strategies for minimizing or mitigating the risks posed by mining activities. EMPs support effective management of the environment thereby enhancing the safety, health and socio-economic impacts of mine operations (KCM, 2009: pg.8). The internal controls are used to manage risks presented by on-going operations at the mine sites and also guide the management of risks related to emergencies.

The policy that guides environmental management at Mopani Copper Mines and Konkola Copper Mine is the Health, Safety and Environmental (HSE) Policy. At Mopani Copper Mines, the policy is used to set standards for maintaining a safe and healthy environment that are measured against the Environmental and Social Management Plan which is the standard for the environmental management system at the mine sites. With regard to the HSE Policy, Konkola Copper Mine has promised a commitment to preventing or minimising the adverse impacts arising from operations. Various procedures are also used by Mopani Copper Mines and Konkola Copper Mine to manage risks from operations. Some of the procedures used at Konkola Copper Mine are presented in Table 5.5. These procedures are reviewed periodically to ensure that they are in line with best practices for mining. Engineering controls such as dust suppression are also used at the mine sites to manage dust according to an interview with MSD.

The EMPs outline management actions for risks identified by the mines and these are addressed using the EMP for Operations, EMP for Progressive Rehabilitation and the EMP for Monitoring. The EMP for Operations focuses on the operations involved in running various mining activities at the mine sites whereas the EMP for Progressive Rehabilitation is concerned with rehabilitation of areas such as tailings dams and dumps that have been decommissioned. Rehabilitation measures involve revegetation and stabilization of dam walls. The EMP for Monitoring involves monitoring air quality, stack emissions, subsidence, noise, vibration, effluent discharges, surface and groundwater. Further, an interview with ZEMA revealed that a new furnace had been installed at Mopani Mufulira Smelter and was reported to be capturing 96 percent of sulphur dioxide gas which was used to manufacture sulphuric acid.

Table 5.5 Key policies and procedures for risk management at KCM, Nkana Site

Policy/Procedure	**Purpose of Procedure/Policy**	**Last revision date**
Waste Management Policy	Provides guidance on management of all categories of waste as required under Section 54 of the EMA of 2011(GRZ, 2011: pg. 134)	27.04.2017
Hazardous Waste Management Procedure	Procedure for treatment, temporary storage and disposal of hazardous waste as stipulated in the Hazardous Waste Management Regulations of 2001	22.03.2013
Spills Prevention, Control and Countermeasure Procedure	Prevention of the discharge of petroleum products or other hazardous liquids	05.05.2017
Safety Procedure for Emergency Preparedness	Outlines actions for minimization or containment of effects of an incident on the environment and human health	15.08.2017

Source: KCM, 2018

Other strategies in place are limiting emissions and effluents released to the environment as per limits set in the Environmental Management (Licensing) Regulations, S.I. No. 112 of 2013. Other compliance standards subscribed to by the mines were International Finance Corporation Standards, Occupational Health and Safety Standards (OHSAS) and ISO 14001 Standards. Compliance by the mines was found to comprise monitoring of operations and testing of mine pollution which is then reported to ZEMA and MSD. Preventive measures in place involve treatment of effluent before discharge such as neutralization of acidic effluent using lime and good housekeeping practices to prevent environmental incidents.

Overall, the findings show that there are management strategies in place for the management of risks from mining activities in Kitwe and Mufulira.

5.5.2 Adequacy of risk management strategies used by mining companies

Despite the strategies for risk management being in place, the results of laboratory analysis conducted during the current study show that Uchi Stream in Kitwe had high concentrations of cobalt, manganese and iron exceeding ZABS limits as presented in Table 5.2. Furthermore, residents in Kankoyo revealed that air pollution from Mopani Copper Mine was still a problem. This suggests that the strategies are currently failing to address heavy metal and air pollution and are therefore inadequate.

5.5.3 Reasons for ineffectiveness of risk management strategies

Based on the findings of the study, there are a number of reasons for the strategies not adequately addressing heavy metal pollution in Kitwe's Uchi Stream and air pollution in Kankoyo. Among them is the lack of competent staff as per regulation number 102 of the Guide to the Mining Regulations. From an interview with MSD, mining firms lack well trained staff to manage environmental risks. Furthermore, technological failure may be the cause of continuous air pollution problems in Kankoyo with regard to inefficient capture of sulphur dioxide emissions. Monitoring reports submitted by Mopani Copper Mines and Konkola Copper Mine to MSD that were reviewed during the study indicated ineffective internal controls with regard to treatment of effluent before discharge to the environment. The quarterly reports for 2015, 2016 and 2017 on effluent discharge into Uchi Stream for Mopani Nkana Mine gave evidence of cobalt, manganese and iron exceeding ZABS thresholds (Table 5.6) similar to those found in the study (Table 5.2).

Table 5.6: Uchi Stream effluent discharge from Mopani Nkana Mine

Sampling Date	TCo (mg/l)	TMn (mg/l)	TFe (mg/l)
18.05.2015	0.70	3.30	0.50
23.06.2015	1.80	2.60	46.10
14.07.2015	1.30	0.80	1.20
21.07.2015	1.10	5.00	1.60
17.05.2016	0.70	0.20	0.40
26.07.2017	2.00	2.80	0.50
09.10.2017	6.40	0.80	0.40
ZABS Limit	**0.50**	**0.10**	**0.30**

Source: MCM, 2015; MCM, 2016; MCM, 2017

Furthermore, the adequacy of the internal controls with regard to compliance with license conditions and prescribed pollution thresholds was found to be inadequate. Evidence of this was provided by review of emissions and effluents reports that showed exceedance of some pollutants with regard to prescribed limits. Therefore, on this basis the study gave the Mine a rating of 3 (Table 5.7). Table 5.7 depicts ratings pertaining to compliance with statutory benchmarks. The benchmarks include: risk assessment involving identification of risks posed by non-compliance with license conditions; process compliance relating to adequacy of internal controls; outcome compliance relating to adequacy of license conditions; output compliance pertaining to procedures being followed and controls being maintained; integrity of performance reporting relating to performance of reporting systems to the authorities and; compliance with any individual license conditions for specific performance at particular operations. Operations at the Mopani Copper Mines were rated at 3 (Table 5.7) based on evidence of exceedance of effluent discharges and emissions limits as per bi-annual reports for 2015, 2016 and 2017. The results reflected in the bi-annual reports could not be verified by ZEMA or MSD. Hence, there was a possibility of the results not reflecting a true picture with regard to compliance with pollutants released into all environmental media.

Table 5.7: Description of Compliance Rating for Environmental Risk Management

Name	Rating	Description
Fully Compliant	5	This rating is for operations that have fulfilled the commitments fully. In other words, the license or permit holder has implemented actions according to plan, and has consistently maintained compliance
Compliant	4	This rating is for operations that are generally compliant apart from minor issues
Partially Complaint	3	This rating is for operations that meet minimum requirements in most areas but improvements are required to achieve full compliance
Non-Compliant	2	This rating is for operations that do not meet minimum requirements as set out in the Environmental Impact Statement (EIS) or Environmental Project Brief (EPB) as well as environmental law
Significantly Non-Compliant	1	This rating is for operations that have demonstrated significant weaknesses and/or where serious remedial action is required

Source: KCM, 2018

The EMPs for Mopani had last been revised in the year 2013 whereas for Konkola it had last been revised in 2009. This was despite the Environmental Management Act requiring revision after a five year period. With regard to auditing and revision of the EMPs divergent responses were provided by the regulatory authorities. MSD contended that the Environmental Management Act of 2011 requires revision and audit of EMPs annually. However ZEMA stated that EMPs are to be reviewed when the need arises. This indicated a lack of harmonization between the two regulatory agencies with regard to the frequency of auditing and revising of EMPs. Desk review of the EMA regarding revision of the EMPs did not yield any result. However, review and audit of EMPs by both ZEMA and MSD was found to be poor. Key informants from the two organizations observed that inadequate institutional capacity resulted in very few reports from the mines being reviewed. Inadequate institutional capacity refers to few members of staff who have been trained in environmental management pertaining to mining as well as equipment and facilities in need of upgrading.

Similarly, Lagnika *et al* (2017) consider internal environmental policies used by the mines as not being quite adequate for addressing environmental problems due to the high number of problems and ongoing processes that negatively affect or destroy ecosystems.

5.6 Adequacy of institutional arrangements

5.6.1 Environmental and Legal Framework

The findings show that there have been several laws and regulations formed over the years since the enactment of the Mines and Minerals Act of 1969. The principal laws governing mining in Zambia are the Environmental Management Act No.12 of 2011 (EMA) and Mines and Minerals Development Act No. 11 of 2015 (MMDA). Interviews with MSD and ZEMA offered different views on the adequacy of mining legislation pertaining to environmental risk management. MSD was of the view that the mines generally had not shown adherence to relevant mining regulations. On the other hand, ZEMA had observed some commitment to mining laws by mining companies in general. However, the study found evidence of cobalt, manganese and iron polluting the Uchi Stream in Kitwe which was a violation of the Water Pollution Control Regulations of 1996 and the Environmental Management (Licensing) Regulations of 2013. Furthermore, the study found that sulphur dioxide pollution was a significant environmental problem in Kankoyo from interviews with the residents. Thus, air pollution in Kankoyo by Mopani Mine was a violation of the Air Pollution Control Regulations of 1997. Based on this, a conclusion was drawn that adherence to mining pollution laws in Kankoyo and Kitwe was still lacking and there was need to ensure that environmental management in the mining sector was prioritised as opposed to economic development and profit making. The implication of lack of adherence is that mines may not comply with their license conditions and pollution limits.

A number of regulations are used in conjunction with the EMA and MMDA (Table 5.8).

Table 5.8: Key mining regulations in the mining sector

Regulations	**Purpose**
Mining (Amendment) Regulations (Amalgamation of S.I No. 107 and S.I No. 95)	The Mining (Amendment) Regulations offer guidance on how a mine should operate and incorporates aspects such as appointment of mine managers, working conditions for mine workers. The regulations address aspects such as setting of discharge limits for pollutants *that are not established by other regulations*.
Water Pollution Control (Effluent and Waste Water) Regulations, S.I. No.133 of 1996	These regulations set limits on the effluents that may be discharged by mining companies. Effluents refer to waste water originating from an industry that is treated or untreated and directly discharged into the aquatic environment
Air Pollution Control (Licensing and Emission Standards) Regulations, S.I. 141 of 1996 & 24 of 1997	Provide licensing requirements for gaseous waste emissions to the environment and prescribe ambient air quality guidelines and emission limits for respective parameters. It provides for licensing of point source polluters.
Environmental Protection and Pollution Control (Environmental Impact Assessment) Regulations, S.I. No.28 of 1997	These regulations provide guidelines for conducting environmental impact assessments and require project developers to prepare an environmental and social management plan.
Mines and Minerals (Environmental) Regulations, S.I. No. 29 of 1997	These regulations cover aspects such as mine residue deposits, air quality, emission and water standards, and the storage, handling and processing of hazardous material
Environmental Protection Fund Regulations, S.I. No.102 of 1998	Provide protection to the Government against the risk of having the obligation to undertake the rehabilitation of the mining area where the holder of the mining license fails to do so.

Hazardous Waste Management Regulations, S.I. No. 125 of 2001	Provide for the control and monitoring of generation, collection, storage, transportation, pre-treatment, treatment, disposal, export and import of various hazardous wastes.
Environmental Management (Licensing) Regulations, S.I. No. 112 of 2013	These regulations provide for licensing requirements for air emissions, effluents and wastewater discharge into the environment, toxic substances and ozone depleting substances. The regulations also set out guidelines and limits where applicable.

Sources: GRZ, 1996; GRZ, 1997; GRZ, 1998; GRZ, 2001; GRZ, 2013;
Reid and Russell, 2017

The adequacy of institutional arrangements for the mines in Kitwe and Mufulira was measured in terms of their compliance with mining regulations pertaining to permissible pollution limits provided by law and their license conditions. The environmental media that were considered by the study were water and air. The study found lack of compliance with effluent discharge limits by the Nkana Mines in the Uchi Stream where laboratory analysis found above threshold concentrations of cobalt, manganese and iron. This was in direct violation of the Environmental Management (Licensing) Regulations, S.I. No. 112 of 2013 and Water Pollution Control (Effluent and Waste Water) Regulations; S.I. 133 of 1996. Air pollution legislation was found to be inadequate in Kankoyo as residents claimed that they were still experiencing emissions of sulphur dioxide from Mopani Copper Mine operations.

Further evidence of violation of environmental pollution regulations was revealed through desk review of bi-annual reports for Mopani operations only. There was exceedance of various emissions and effluents in the bi-annual reports and EMPs and this indicated lack of compliance with license conditions.

With regard to adequacy of penalties imposed on polluting mines, the penalties provided under the Environmental Management Act were found to be minimal and hence inadequate to motivate the mines to adhere to state laws pertaining to environmental pollution.

Counter Balance (2010) reports that in situ leaching involving injection of sulphur acid solution into the ground to dissolve copper in the deposit led to contamination of underground water in Mufulira. The pollution incident occurred in January 2008 and the acid contaminated water resulted in about 800 people being hospitalized after consuming the water. Mopani Copper Mine was fined a few hundred dollars for the pollution incident.

Another example of a low pollution penalty is that of Konkola Copper Mines' fine for polluting the Kafue River with acidic tailings in 2006. Swedwatch (2019), reports that in 2015, Konkola Copper Mines in Chingola polluted the fields of approximately 1,800 farmers from the villages of Shimulala, Hippo Pool, Kakosa and Helen. This led to loss of livelihoods, illness and poisoning of water sources and farmland. The claimants were awarded approximately USD 1.5 million by a Zambian court which following an appeal by the mining company resulted in compensation that was reduced to essentially nothing.

Interviews with two officers from ZEMA and MSD respectively revealed that the two organisations are understaffed and in serious need of monitoring equipment for the purpose of ensuring that mining companies comply with the mining regulations and the conditions of their mining licenses and permits.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The study identified heavy metals as a risk of concern as the study found above limit concentrations of cobalt, manganese and iron in the Uchi Stream. Furthermore, air pollution characterized by sulphur dioxide emissions from Mopani Copper Mines in Kankoyo was perceived to be the cause of respiratory tract infections in the area. In Nkana West respondents did not report any respiratory tract infections at the time of the study. However, they acknowledged that these infections had been prevalent prior to closure of the smelter.

The study also established that the risk management strategies employed by the two mining firms were not effective with regard to release of pollutants to the environment. This was attributed to inefficient technology for limiting the concentration of pollutants released into the environment. Furthermore, risk management strategies were not being achieved as demonstrated by heavy metals exceeding the prescribed thresholds and incidences of air pollution.

With regard to adequacy of institutional arrangements for mining in Zambia, the study found that the Mopani and Konkola Mines were not complying with the law where pollution limits and environmental reporting were concerned. With regard to infrequent audits of mining operations in Kitwe and Mufulira, the study concluded that gauging the compliance of mines in these areas with mining laws and regulations was difficult. The study further concluded that measurement of compliance with mining laws could be established when the regulatory authorities were fully equipped to monitor compliance by the mines.

6.2 Recommendations

Based on the findings, the following are the recommendations:

i. There is need for Mopani and Konkola Copper mines to employ efficient technology to capture heavy metals and significantly reduce the concentrations released into the environment. Further, the capacity of the smelter at Mopani Mufulira smelter should be upgraded to ensure increased sulphur dioxide capture and conversion to sulphuric acid.

ii. There is need for ZEMA to carry out a bio- monitoring survey along the Uchi Stream to determine the concentrations of heavy metals. This will help to ascertain the risk to human health through consumption of vegetables grown along the stream

iii. Mopani Copper Mines and Konkola Copper Mines should employ environmental risk management strategies that are more proactive than reactive that will ensure effective mitigation of environmental risks

iv. To ensure effective environmental risk management, ZEMA and MSD should be empowered for them to enforce environmental laws and regulations in the mining sector. Furthermore, sufficient resources should be allocated to monitoring of mining operations' compliance with environmental laws and regulations throughout the country

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APPENDICES

APPENDIX A: TWO SAMPLE T-TEST RESULTS

Two-Sample T-Test and CI: Copper Uchi, Copper Mwekera

Method

μ_1 : mean of Cu- Uchi

μ_2 : mean of Cu- Mw

Difference: $\mu_1 - \mu_2$

Equal variances are assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
Copper -Uchi	30	0.105	0.0845	0.015
Copper- Mw	30	0.077	0.0293	0.0053

Estimation for Difference

Difference	Pooled StDev	95% Lower Bound for Difference
0.0283	0.0632	0.0010

Test

Null hypothesis	$H_0 : \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1 : \mu_1 - \mu_2 > 0$

T-Value	DF	P-Value
1.73	58	0.044

Two-Sample T-Test and CI: Co-U, Co-M

Method

μ_1 : mean of Co- Uchi

μ_2 : mean of Co- Mw

Difference: $\mu_1 - \mu_2$

Equal variances are assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
Cobalt-U	30	1.396	0.992	0.18
Cobalt- M	30	0.00785	0.00356	0.00065

Estimation for Difference

Difference	Pooled StDev	95% Lower Bound for Difference
1.388	0.702	1.085

Test

Null hypothesis	$H_0 : \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1 : \mu_1 - \mu_2 > 0$

T-Value	DF	P-Value
7.66	58	0.0001

Two-Sample T-Test and CI: Mn-Uchi, Mn-Mw

Method

μ_1 : mean of Mn-Uchi

μ_2 : mean of Mn-Mw

Difference: $\mu_1 - \mu_2$

Equal variances are assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
Manganese-Uchi	30	0.312	0.202	0.037
Manganese-MW	30	0.133	0.089	0.016

Estimation for Difference

Difference	Pooled StDev	95% Lower Bound for Difference
0.1790	0.1561	0.1116

Test

Null hypothesis $H_0 : \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1 : \mu_1 - \mu_2 > 0$

T-Value	DF	P-Value
4.44	58	0.0001

Two-Sample T-Test and CI: Zn-Uchi, Zn-Mw

Method

μ_1 : mean of Zn-Uchi

μ_2 : mean of Zn-Mw

Difference: $\mu_1 - \mu_2$

Equal variances are assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
Zn-Uchi	30	0.1433	0.0878	0.016
Zn-Mw	30	0.0610	0.0237	0.0043

Estimation for Difference

Difference	Pooled StDev	95% Lower Bound for Difference
0.0823	0.0643	0.0546

Test

Null hypothesis $H_0 : \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1 : \mu_1 - \mu_2 > 0$

T-Value	DF	P-Value
4.96	58	0.0001

Two-Sample T-Test and CI: Fe- Uchi, Fe-Mw

Method

μ_1 : mean of Fe- Uchi

μ_2 : mean of Fe-Mw

Difference: $\mu_1 - \mu_2$

Equal variances are assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
Fe- Uchi	30	0.632	0.449	0.082
Fe-MW	30	0.479	0.175	0.032

Estimation for Difference

Difference	Pooled StDev	95% Lower Bound for Difference
0.1530	0.3409	0.0058

Test

Null hypothesis $H_0 : \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1 : \mu_1 - \mu_2 > 0$

T-Value	DF	P-Value
1.74	58	0.044

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APPENDIX B: WATER SAMPLING RESULTS

SAMPLE DESCRIPTION	WATER (Uchi Stream)	**DATE SUBMITTED**
SERVICES REQUESTED	SP1 Water Quality Analysis	12.09.2018, 13.09.2018, 17.09.2018, 18.09.2018, 21.09.2018

Parameter	Unit	Result	ZABS Limit
pH		7.28	6.5 – 8.0
Turbidity	NTU	-	5
TDS	mg/l	-	1000
Conductivity	µS/cm	-	1500
Total hardness	mg/l	-	500
Cl-	mg/g	-	250
SO^{2}_{-4}	mg/l	-	400
NO_{-3}	mg/l	-	10
Cu	mg/l	0.09	1.0
Co	mg/l	1.75	0.5
Mn	mg/l	0.27	0.1
Zn	mg/l	0.13	3
Fe	mg/l	0.46	0.3
Mg	mg/l	-	150
Pb	mg/l	-	0.01
Cd	mg/l	-	0.003
As	mg/l	-	0.01

Comment: Most of the parameters tested were within acceptable limits. However, Co was above the limit.

Note: The results shown in the table above are averages of 6 samples taken at each sampling point

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SAMPLE DESCRIPTION	WATER (Uchi Stream)	**DATE SUBMITTED**
SERVICES REQUESTED	SP2 Water Quality Analysis	12.09.2018, 13.09.2018, 17.09.2018, 18.09.2018, 21.09.2018

Parameter	Unit	Result	ZABS Limit
pH		7.37	6.5 – 8.0
Turbidity	NTU	-	5
TDS	mg/l	-	1000
Conductivity	µS/cm	-	1500
Total hardness	mg/l	-	500
Cl-	mg/g	-	250
SO^{2}_{-4}	mg/l	-	400
NO_{-3}	mg/l	-	10
Cu	mg/l	0.13	1.0
Co	mg/l	1.02	0.5
Mn	mg/l	0.26	0.1
Zn	mg/l	0.10	3
Fe	mg/l	0.67	0.3
Mg	mg/l	-	150
Pb	mg/l	-	0.01
Cd	mg/l	-	0.003
As	mg/l	-	0.01

Comment: Most of the parameters tested were within acceptable limits. However, Co and Fe were above the limits.

Note: The results shown in the table above are averages of 6 samples taken at each sampling point

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Designation:		

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SAMPLE DESCRIPTION	WATER (Uchi Stream)	**DATE SUBMITTED**
SERVICES REQUESTED	SP3 Water Quality Analysis	12.09.2018, 13.09.2018, 17.09.2018, 18.09.2018, 21.09.2018

Parameter	Unit	Result	ZABS Limit
pH		7.52	6.5 – 8.0
Turbidity	NTU	-	5
TDS	mg/l	-	1000
Conductivity	µS/cm	-	1500
Total hardness	mg/l	-	500
Cl-	mg/g	-	250
SO^{2}_{-4}	mg/l	-	400
NO_{-3}	mg/l	-	10
Cu	mg/l	0.09	1.0
Co	mg/l	1.07	0.5
Mn	mg/l	0.36	0.1
Zn	mg/l	0.18	3
Fe	mg/l	0.71	0.3
Mg	mg/l	-	150
Pb	mg/l	-	0.01
Cd	mg/l	-	0.003
As	mg/l	-	0.01

Comment: Most of the parameters tested were within the acceptable limits. However, Co and Fe were above the limits.

Note: The results shown in the table above are averages of 6 samples taken at each sampling point

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SAMPLE DESCRIPTION	WATER (Uchi Stream)	**DATE SUBMITTED**
SERVICES REQUESTED	SP4 Water Quality Analysis	12.09.2018, 13.09.2018, 17.09.2018, 18.09.2018, 21.09.2018

Parameter	**Unit**	**Result**	**ZABS Limit**
pH		7.62	6.5 – 8.0
Turbidity	NTU	-	5
TDS	mg/l	-	1000
Conductivity	µS/cm	-	1500
Total hardness	mg/l	-	500
Cl-	mg/g	-	250
SO^{2}_{-4}	mg/l	-	400
NO_{-3}	mg/l	-	10
Cu	mg/l	0.18	1.0
Co	mg/l	1.89	0.5
Mn	mg/l	0.54	0.1
Zn	mg/l	0.17	3
Fe	mg/l	0.93	0.3
Mg	mg/l	-	150
Pb	mg/l	-	0.01
Cd	mg/l	-	0.003
As	mg/l	-	0.01

Comment: The parameters that were above acceptable limits were Co, Mn and Fe.

Note: The results shown in the table above are averages of 6 samples taken at each sampling point

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SAMPLE DESCRIPTION	WATER (Uchi Stream)	**DATE SUBMITTED**
SERVICES REQUESTED	SP5 Water Quality Analysis	12.09.2018, 13.09.2018, 17.09.2018, 18.09.2018, 21.09.2018

Parameter	Unit	Result	ZABS Limit
pH		7.55	6.5 – 8.0
Turbidity	NTU	-	5
TDS	mg/l	-	1000
Conductivity	µS/cm	-	1500
Total hardness	mg/l	-	500
Cl-	mg/g	-	250
$SO^2{}_{-4}$	mg/l	-	400
NO_{-3}	mg/l	-	10
Cu	mg/l	0.08	1.0
Co	mg/l	1.14	0.5
Mn	mg/l	0.26	0.1
Zn	mg/l	0.17	3
Fe	mg/l	0.52	0.3
Mg	mg/l	-	150
Pb	mg/l	-	0.01
Cd	mg/l	-	0.003
As	mg/l	-	0.01

Comment: Most of the parameters tested were within the acceptable limits. However, Co was above the limit.

Note: The results shown in the table above are averages of 6 samples taken at each sampling point

Authorizing Officer's Approval:	**Sign:**	**Date:**
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SAMPLE DESCRIPTION	WATER (Uchi Stream)	**DATE SUBMITTED**
SERVICES REQUESTED	SP6 Water Quality Analysis	12.09.2018, 13.09.2018, 17.09.2018, 18.09.2018, 21.09.2018

Parameter	Unit	Result	ZABS Limit
pH		7.53	6.5 – 8.0
Turbidity	NTU	-	5
TDS	mg/l	-	1000
Conductivity	µS/cm	-	1500
Total hardness	mg/l	-	500
Cl-	mg/g	-	250
SO^{2}_{-4}	mg/l	-	400
NO_{-3}	mg/l	-	10
Cu	mg/l	0.06	1.0
Co	mg/l	1.70	0.5
Mn	mg/l	0.18	0.1
Zn	mg/l	0.10	3
Fe	mg/l	0.50	0.3
Mg	mg/l	-	150
Pb	mg/l	-	0.01
Cd	mg/l	-	0.003
As	mg/l	-	0.01

Comment: Most of the parameters tested were within the acceptable limits; however, Co was above the acceptable limit.

Note: The results shown in the table above are averages of 6 samples taken at each sampling point

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SAMPLE DESCRIPTION	WATER (Mwekera Stream)	**DATE SUBMITTED**
SERVICES REQUESTED	SP1 Water Quality Analysis	28.09.2018, 02.10.2018

Parameter	Unit	Result	ZABS Limit
pH		8.29	6.5 – 8.0
Turbidity	NTU	-	5
TDS	mg/l	-	1000
Conductivity	µS/cm	-	1500
Total hardness	mg/l	-	500
Cl-	mg/g	-	250
$SO^{2}{}_{-4}$	mg/l	-	400
NO_{-3}	mg/l	-	10
Cu	mg/l	0.09	1.0
Co	mg/l	0.01	0.5
Mn	mg/l	0.13	0.1
Zn	mg/l	0.04	3
Fe	mg/l	0.39	0.3
Mg	mg/l	-	150
Pb	mg/l	-	0.01
Cd	mg/l	-	0.003
As	mg/l	-	0.01

Comment: All the parameters tested were within the acceptable limits. The pH was slightly above the acceptable limit.

Note: The results shown in the table above are averages of 10 samples taken at each sampling point

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SAMPLE DESCRIPTION	WATER (Mwekera Stream)	**DATE SUBMITTED**
SERVICES REQUESTED	SP2 Water Quality Analysis	28.09.2018, 02.10.2018

Parameter	**Unit**	**Result**	**ZABS Limit**
pH		8.34	6.5 – 8.0
Turbidity	NTU	-	5
TDS	mg/l	-	1000
Conductivity	µS/cm	-	1500
Total hardness	mg/l	-	500
Cl-	mg/g	-	250
SO^{2}_{-4}	mg/l	-	400
NO_{-3}	mg/l	-	10
Cu	mg/l	0.08	1.0
Co	mg/l	0.01	0.5
Mn	mg/l	0.08	0.1
Zn	mg/l	0.07	3
Fe	mg/l	0.43	0.3
Mg	mg/l	-	150
Pb	mg/l	-	0.01
Cd	mg/l	-	0.003
As	mg/l	-	0.01

Comment: All the parameters tested were within the acceptable limits. However, pH was slightly above the acceptable limit.

Note: The results shown in the table above are averages of 10 samples taken at each sampling point

Authorizing Officer's Approval:	**Sign:**	**Date:**
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Designation:		

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SAMPLE DESCRIPTION	WATER (Mwekera Stream)	**DATE SUBMITTED**
SERVICES REQUESTED	SP3 Water Quality Analysis	28.09.2018, 02.10.2018

Parameter	**Unit**	**Result**	**ZABS Limit**
pH		8.35	6.5 – 8.0
Turbidity	NTU	-	5
TDS	mg/l	-	1000
Conductivity	µS/cm	-	1500
Total hardness	mg/l	-	500
Cl-	mg/g	-	250
SO^{2}_{-4}	mg/l	-	400
NO_{-3}	mg/l	-	10
Cu	mg/l	0.07	1.0
Co	mg/l	0.01	0.5
Mn	mg/l	0.18	0.1
Zn	mg/l	0.07	3
Fe	mg/l	0.62	0.3
Mg	mg/l	-	150
Pb	mg/l	-	0.01
Cd	mg/l	-	0.003
As	mg/l	-	0.01

Comment: Most of the parameters tested were within the acceptable limits. However, Fe and pH values were above the acceptable limit respectively.

Note: The results shown in the table above are averages of 10 samples taken at each sampling point

Authorizing Officer's Approval:	**Sign:**	**Date:**
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APPENDIX C: QUESTIONNAIRE ON MINING RISKS IN KITWE AND MUFULIRA

Section A: Personal Information

1. What is your gender?
   a. Male [ ] b. Female [ ]
2. What is your age? …………………………………..
3. What type of employment are you in?
   a. Formal [ ] b. Informal [ ] c. Unemployed [ ]
4. What is your level of education?
   a. Primary [ ] b. Secondary [ ] c. College/ University [ ]
5. Name of residential area……………………………………………………………
6. Number of years lived in the area……………………………………………………

Section B: Perception of risks from mining

1. What types of health problems result from mining?
   ………………………………………………………………………………………
   ……..……………………………………………………………………………………
2. What types of environmental problems result from mining?
   ………………………………………………………………………………………
   ………………………………………………………………………………………
3. How did you come to know about these problems?
   a. Television [ ]
   b. Newspapers [ ]
   c. The mining company [ ]
   d. Information from the government [ ]
   e. Any other (Please specify)
   ……………………..……………………...……………………………………….
4. Have you experienced these problems? Kindly explain

………………………………………………………………………………………..

5. Indicate the risks that you think are serious to you

   a. Air pollution [ ]

   b. Pollution of drinking water [ ]

   c. Pollution of the your vegetable garden [ ]

   d. Pollution of rivers or streams [ ]

6. Has the mining company talked about the risks of its mining operations to you?

   a. Yes [ ] b. No [ ] c. I do not know [ ]

7. Which of the following incidents has/ have taken place in the past in your area?

   a. Chemical spill into stream [ ]

   b. Fish dying in a stream as a result of chemical spill from mine [ ]

   c. Appearance of vegetables changing after a pollution incident [ ]

   d. Change in water quality after water pollution incident [ ]

   e. Any other (Please specify)

   ……………………………………………...…………………………………….

8. Do you feel that mining in your area has led to illnesses?

   a. Yes [ ] b. No [ ] c. I do not know [ ]

9. If answer to **question 8** is yes, what type of illnesses?

   ………………………………………………………………………………………

10. How concerned are you about consuming water with high concentrations of heavy metals?

    a. Not concerned b. Slightly concerned c. Concerned d. Very concerned

11. How concerned are you about consuming vegetables with a high concentration of heavy metals?

    a. Not concerned b. Slightly concerned c. Concerned d. Very concerned

12. What do you feel should be done about the risks of mining in your area?

    ……………………………………………………………………………………

13. Do you feel mining companies are managing their operations effectively?

a. Yes [ ]   b. No [ ]   c. I do not know [ ]

14. Do you feel mines should sensitize your community on threats from their activities?

a. Yes [ ]   b. No [ ]   c. I do not know [ ]

15. Has the mining company informed you of a pollution incident in order for you to take safety measures?

a. Yes [ ]   b. No [ ]   c. I do not know [ ]

16. Have you considered moving away from your area because you are concerned about your health or the environment?

a. Yes [ ]   b. No [ ]

17. Which statement describes your reason to stay despite your concerns?

a. I own the house I live in [ ]

b. I have lived here for a long time [ ]

b. I work for the mine [ ]

d. Any other (please specify) ………………………………………………………….

18. Would you say that the benefits of mining are greater than your concerns?

a. Yes [ ]   b. No [ ]   c. I do not know [ ]

19. Please give a reason for your **yes** or **no** answer to **question 18**

……………………………………………………………………………………

Please pick <u>one</u> number on the scale to show how you agree or disagree with the following statements:

20. I worry about the health of my family because I live near the mine

1…………………...2…………………..3…………………

Agree   Disagree   I do not know

21. I worry about my health because I live near the mine

1…………………...2…………………..3…………………

Agree   Disagree   I do not know

22. I have all the necessary information I need to decide how I feel about risks of mining

1…………………...2…………………..3…………………

Agree Disagree I do not know

23. I am willing to accept most of the risks of mining because of the benefits

1…………………...2…………………..3…………………

Agree Disagree I do not know

THANK YOU FOR YOUR TIME AND RESPONSES

APPENDIX D: MSD/ZEMA INTERVIEW SCHEDULE

1. What are the main environmental risks posed by mining activities?
2. What are the significant health risks posed by mining activities?
3. Have there been serious incidences of environmental mismanagement that have compromised the health of local people?
4. How would you describe management of risks by mining companies?
5. What strategies has the department/agency employed to ensure effective monitoring of mine operations?
6. Have mining companies always appreciated the importance of managing environmental issues effectively?
7. How often are the EMPs reviewed and revised by mining companies?
8. Has the 2015 Mines and Minerals Act strengthened regulatory compliance by mining companies?
9. In your opinion, has changing legislation affected the ability of mines to invest in proactive environmental management measures?
10. Are mining companies incorporating new technologies that are environmentally friendly?
11. What would encourage mining companies to invest in environmentally sound technology?
12. Are the penalties inflicted on mining companies for pollution encouraging better management of their activities?
13. Are there international standards that guide mining operations in order to safeguard the environment and local populations?
14. How can the importance of environmental management in the mining industry be emphasized?

APPENDIX E: ZCCM-IH/MISENGE INTERVIEW SCHEDULE

1. What are the main environmental risks posed by current mining operations in Kitwe and Mufulira?
2. What are the legacy environmental liabilities from the ZCCM era found in Kitwe and Mufulira?
3. How many of these sites are located near communities?
4. What environmental and health hazards do these sites present to the locals?
5. Has any action been taken to address these legacy liabilities in the past?
6. What action do you plan to take to manage the legacy mining liabilities?
7. What are some of the challenges you face in the management of legacy operations?

APPENDIX F: MUFULIRA DISTRICT HEALTH OFFICE INTERVIEW SCHEDULE

1. What are some of the illnesses associated with mining?
2. Which of these illnesses affect communities living near mining operations?
3. Which hospitals treat patients with these illnesses?
4. How often are such cases handled by hospitals?
5. Do you work with the mining company to address these health problems?
6. How are hospitals working with members of the communities to address the health problems?
7. How are you working with communities affected by pollution from the mining company?