Management of Environmental Risks arising from mining operations in Kitwe and Mufulira, Zambia

Prisca Nachalwe [†]* and Bridget Bwalya Umar [†]
[†] University of Zambia, School of Natural Sciences, Geography and Environmental Studies Department, P. O. Box 32379, Lusaka, Zambia.
*Corresponding author e-mail: zewelanji33@gmail.com

Abstract

Mining as an extractive industry has both positive and negative impacts. The positive impacts are economic growth and job creation whereas the negative impacts pose risks to the general environment and human health. On this premise, this study was carried out to: i) identify risks posed by mining operations to the environment and human health in two mine adjacent communities in Zambia, and ii) determine the extent to which the risk management strategies used by mining operators adequately address environmental and health risks in the study areas. Data was collected through water sampling, a questionnaire survey, desk analysis, and key informant interviews. Data was analysed using a Two-Independent Sample T-test, frequencies, means and standard deviations. Findings showed that the risks from mining in Nkana West residential area were minimally reduced whereas Kankoyo Township was impacted by serious pollution from the nearby Mopani Copper Mines. Kankoyo and Nkana West are characterised by pollution of air, water, and land with Kankoyo being more affected by air and land pollution. The prominent health problem was respiratory tract infections resulting from smelting activities. Tests carried out on water samples collected from Uchi and Mwekera Streams in Kitwe indicated that Uchi had above limit concentrations of cobalt, manganese, and iron which were attributed to the effluent discharged from the proximate Nkana mines. The relevant authorities lack vital pollution monitoring equipment and human resource for ensuring that mining companies were in compliance with the statutory environmental regulations.

Keywords: Risk, pollution, impact, health, environment, Kankoyo, Nkana West

Introduction

Mining has been the mainstay of Zambia's economy owing to the variety of mineral wealth that presents opportunities for the sector to continue contributing to the economic growth of the country (GRZ, 2013). However, the mining industry has adversely impacted 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). Analysis of air emissions data from a large scale mine in Chingola Zambia found elevated levels of dust, cadmium, copper and lead pollutants (Kolala and Umar, 2019). 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 (EMPs). Through monitoring and evaluating pollution and waste from their operations mining companies can act to reduce impacts (IFC, 2014). The impacts of mining and mineral processing activities on the environment pose environmental risks to human health and the environment. 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 which 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 important due to the cumulative nature of the risks associated with the environmental impacts of mining (Australian Government, 2008). Thus, this study was carried out to identify risks posed by mining operations to the environment and human health in two mine adjacent communities in Zambia, and to determine the extent to which the risk management strategies used by mining operators adequately address environmental and health risks in the study areas.

Materials and Methods

The study was carried out in Kitwe and Mufulira Districts of the Copperbelt Province of Zambia (Figure 1). The two districts were selected as study sites due to the mining operations carried out by Konkola and Mopani Copper Mines therein. 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 District. Key facilities at the mine are an underground mine and concentrator. Mopani Copper Mines operates in Mufulira District and consist of an underground mine, a leach plant and a smelter.

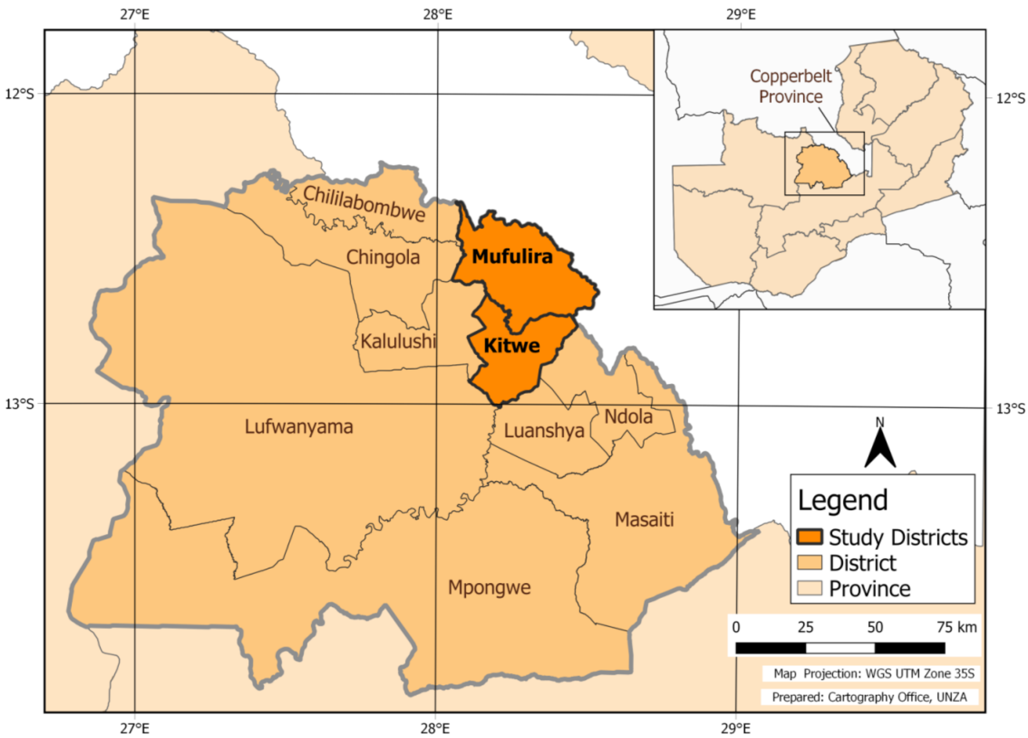

Figure 1: Location of study areas

Source: UNZA Department of Geography and Environmental Studies Cartography Office, 2018.

The data collection methods employed were a questionnaire survey administered to residents of Nkana West in Kitwe and Kankoyo in Mufulira to gain an understanding of their experiences with the impacts of mining operations. Water sampling was conducted on the Uchi and Mwekera Streams in Kitwe over several days during the hot dry season, between September and October, 2018. Uchi Stream was selected for sampling due to its proximity to the Nkana Mines and the high likelihood that the mines discharged effluent into the stream, while Mwekera Stream was selected as a control site on the assumption that it was free of mining effluents. Water sampling was carried out at 6 purposively selected sampling points along the Uchi Stream and at 3 points along Mwekera Stream (Figure 2).

Quantitative data from the questionnaires was coded and then analysed using percentages to determine the residents' understanding of environmental risks of mining. The water samples were analysed for concentrations of heavy metals using Atomic Absorption Spectrometry at the Copperbelt University School of Mines Laboratory. The average concentrations of selected heavy metals were compared with the Zambia Bureau of Standards (ZABS) thresholds for drinking water quality to determine whether the parameters were within acceptable limits. 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 per cent level of significance.

Figure 2: Sampling points along Mwekera and Uchi Streams
Source: Google Earth, 2018

Results and discussion

Characteristics of health and environmental risks from mining

In this section, the health and environmental problems associated with mining in Kankoyo and Nkana West were examined. The study characterised the environmental and health risks posed by mining with regard to pollutants of concern (i.e. hazards), the environmental media affected, and pathways of exposure for humans. Study results showed that the main pollutants of concern in the study areas were emissions and effluents from mineral processing activities of the mines in Kitwe and Mufulira.

Table 1 presents pollutants emanating from mine operations and the environmental media affected including their pathways of exposure.

Table 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 Mine 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 Mine Smelter	Air/Land	Inhalation/dermal intake
	Dust from Mopani Mine Slag Dump	Air/Land	Inhalation or dermal intake
	Effluent from Mopani Mine	Surface and Ground Water	Ingestion or dermal intake

Air pollution

Interviews with key informants from the Mines Safety Department revealed that other common hazards in the areas were copper and sulphur dioxide fallout from the smelters; dust from tailings containing silica that may cause chest infections; stack emissions; noxious, arsenic, and nitrous fumes. These risks are distributed in the environment through air and consequently deposited on the soil and vegetation. Ettler (2016), noted that the spatial distribution of air pollutants depends on wind direction, size of particulates emitted by the smelter, as well as the chemical and mineralogical composition of the particulates. In a review of dust in the mining environment focused on workers and communities, Chiluba (2018) found that the most notable dust emissions were Particulate Matter (PM), Sulphur Dioxide (SO_2), Nitrogen Dioxide (NO_2) and heavy metals and these are mostly suspended as dust in the mining environment.

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.

Water pollution

In Kankoyo, an effluent drain from Mopani Mine poses the risk of contaminating groundwater and the Mufulira West Stream into which the effluent flows. With regard to the 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 (Table 2).

Table 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 (SD ± 0.0845)	0.08 (S.D ± 0.0293)	1.00	T=1.73, p=0.044*
Cobalt	1.40 (SD ± 0.992)	0.01 (S.D ± 0.0036)	0.50	T=7.66, p=0.0001*
Manganese	0.31 (SD ± 0.202)	0.13 (S.D ± 0.089)	0.10	T=4.44, p=0.0001*
Zinc	0.14 (SD ± 0.0878)	0.06 (S.D ± 0.0237)	3.00	T=4.96, p=0.0001*
Iron	0.63 (SD ± 0.449)	0.48 (S.D ± 0.175)	0.30	T=1.74, p=0.044*

*significantly different between Uchi and Mwekera at α=0.05. SD = standard deviation

Laboratory tests results indicated that the concentrations of the five heavy metals tested were statistically significantly higher in Uchi than in Mwekera Stream. Furthermore, water samples from Uchi Stream had above ZABS threshold concentrations of cobalt, manganese, and iron at all the 6 sampling points (Table 2). 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 Uchi Stream through erosion and runoff. Although 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 cobalt and contribute to the observed concentrations. The high concentrations of manganese may be attributed to both the natural occurrence of manganese in the crust of the Earth (WHO, 2011) and to cobalt-copper ores, resulting

in the above acceptable limit concentrations 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 could account for the high concentrations at all the sampling points. Further, effluent such as raw sewage is known to contain traces of heavy metals and this may contribute to the high levels of the metal as raw sewage was found flowing at sampling points 1 and 2.

Figure 3: Raw sewage flowing at sampling point 2

Noteworthy is that manganese and iron concentrations were above ZABS thresholds in the water samples from the control points while the rest were below the limits.

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 per cent of the respondents (n=83). Respiratory infections noted include tuberculosis, bronchitis, silicosis, pneumoconiosis, colds, and influenza (Table 3).

Table 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%

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. This finding is backed by Simukanga (1999). Another officer stated that tuberculosis re-infections among Kankoyo residents were common but the reason was not clear. Eye problems were reported by 5 per cent 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 continuing air pollution at the time of the study.

Similar studies in Chile (Herrera *et al.*, 2016) and Zimbabwe (Gwimbi, 2017) reaveled 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. Mujuru *et al.* (2012), explained that 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 infections 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 Zambia Environmental Management Agency (ZEMA) asserted that linking health ailments in communities to mining is a challenge. However, based on the responses from the respondents, the study averred that health problems in Kankoyo and Nkana West partly resulted from mine pollution.

Residents' perceptions of environmental problems resulting from mining

According to 34 per cent (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 because of sulphur dioxide emissions had degraded the soil. 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 4 presents the perception that residents of Kankoyo and Nkana West have regarding environmental problems related to mining.

Table 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%

Risk management at Mopani Copper Mines and Konkola Copper Mine

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 minimising 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 is 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. 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 stabilisation 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.

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 neutralisation 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.

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 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.

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 the treatment of effluent before it is discharged 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) similar to those found in the study (Table 2).

Table 5: 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

The EMPs for Mopani was last revised in the year 2013 whereas for Konkola it was last 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 No. 12 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 harmonisation between the two regulatory agencies with regard to the frequency of auditing and revising of EMPs. Desk review of the *Environmental Management Act* 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 organisations 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.

Conclusions

The study identified heavy metals as a risk of concern as it found above limit concentrations of cobalt, manganese, and iron in Uchi Stream. Furthermore, air pollution characterised by sulphur dioxide emissions from Mopani Copper Mines in Kankoyo, Mufulira, was perceived to be the cause of respiratory tract infections in the area. In Nkana West, Kitwe, 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 the release of pollutants into the environment. This was attributed to inefficient technology for limiting the concentration of pollutants released into the environment. Furthermore, risk management strategies were not effective as demonstrated by heavy metals exceeding the prescribed thresholds and incidences of air pollution. Failure to manage environmental risks by mining companies can have large adverse impacts on humans and the environment if not addressed. The study recommends more stringent penalties for failed environmental risk management strategies to be charged on mining operations by environmental regulatory authorities.

References

Australian Government (2008) Risk Assessment and Management: Leading Practice Sustainable Development Program for the Mining Industry. Department of Resources Energy and Tourism.

Australian Government. (2011) Risk Management: Leading Practice Sustainable Development Program for the Mining Industry.

Chiluba, B. Critical Review of Dust in the Mining Environment: A Focus on Workers and Community Health. *Preprints* 2018, 2018110602 (doi:10.20944/preprints201811.0602.v1).

Choudhary, R.P (2015) 'Environmental Audit: A Need for Sustainable Development of Mining Industry,' *International Journal of Innovative Research in Engineering and Management,* 2 (4), pp. 35-39.

Ettler, V. (2016) 'Soil contamination near non-ferrous metal smelters: A review', Applied Geochemistry, 64, pp. 56-74.

European Environmental Bureau (2000) 'The Environmental Performance of the Mining Industry and the Action Necessary to Strengthen European Legislation in the wake of the Tisza-Danube Pollution,' European Environmental Bureau, Brussels.

GRZ (2013) Mineral Resources Development Policy, Government Printers, Lusaka.

Gwimbi, P. (2017) 'Monitoring SO2 emission trends and residents' perceived health risks from PGM smelting at Selous Metallurgical Complex in Zimbabwe', *International Journal for Equity in Health*, pp. 1-11.

Herrera, R., Radon, K., von Ehrenstein, O.S., Cifuentes, S., Munoz, D.M. and Berger, U. (2016) 'Proximity to mining industry and respiratory diseases in children in a community in Northern Chile: A cross-sectional study', Environmental Health, pp. 1-10.

IFC (2014) Sustainable and Responsible Mining in Africa – A Getting Started Guide. International Finance Corporation. Washington, D.C.

KCM (2009) Final Environmental Management Plan, Konkola Copper Mines Public Limited Company, Kitwe.

KCM (2018) Environmental Protection fund Audit Report for Nkana Mine. Citizens for a Better Environment, Kitwe.

Kolala, C. and Umar, B. B. (2019), National benefits, local costs? Local residents' views on environmental and social effects of large-scale mining in Chingola, Zambia. *Natural Resources Forum*, 43: 205-217.

Lagnika, S.B.M, Hausler, R and Glaus, M (2017) Modeling or Dynamic Simulation: A Tool for Environmental Management in Mining? *Journal of Integrative Environmental Sciences,* 14 (1), pp. 19-37.

Lindahl, J. (2014) 'Environmental Impacts of Mining in Zambia: Towards better Environmental Management and Sustainable Exploitation of Mineral Resources,' Geological Survey of Sweden, Uppsala.

MCM (2015) Nkana Bi-Annual Environmental Report January to June, Mopani Copper Mines, Kitwe.
MCM (2015) Nkana Bi-Annual Environmental Report July to December, Mopani Copper Mines. Kitwe.
MCM (2016) Nkana Bi-Annual Environmental Report January to June, Mopani Copper Mines. Kitwe.
MCM (2017) Nkana Bi-Annual Environmental Report July to December, Mopani Copper Mines. Kitwe.
Mujuru M., McCrindle R.I., Gurira R.C., Zvinowanda C.M., Maree, J. (2012) 'Air Quality Monitoring in Metropolitan Harare, Zimbabwe', *Journal of Environmental and Analytic Toxicology*, 2 (3), pp. 1-7.
Mulenga, M.C. (1999) 'Air pollution regulations new to Zambia', The Environmentalist, 19, pp. 197-201, Boston: Kluwer Academic Publishers.
Nwite, S.C. (2014) 'Strategies of Environmental Risk Management in Nigeria', *Global Advanced Research Journal of Management and Business Studies*, 3(1) pp. 11-15.
Simukanga, S. (1999) Status of Air Pollution in Zambia. School of Mines, University of Zambia.
World Health Organisation (2011) Guidelines for drinking water quality, 4th ed. Geneva, World Health Organisation.