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COPPER MINE DEVELOPMENT AND ENVIRONMENTAL SUSTAINABILITY: A STUDY OF NCHANGA OPEN PIT MINE IN CHINGOLA TOWNSHIP OF ZAMBIA

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Abstract: *The pursuit for environmental sustainability is not only a global journey but a national goal. The study's aim was geared towards examining the impact of copper mine development on environmental sustainability in Chingola. The study's objective was to demonstrate how copper mine development affects environmental sustainability. The study incorporated both system theory and ecological modernization theory. A mixed study research approach was used to describe the study methodology. Questionnaires were used in collection of qualitative and quantitative data. The study target population consisted of all the individuals living in Chingola Mining Area. Non-probability sampling was used by the researcher due to the specificity of the study participants who were aware of mining processes. A sample matrix of 366 participants was drawn with four categories namely miners, students, civil servant members and local civil society members. The response rate consisted of 266 participants. The research presented the following key findings; copper mining was identified as a key driver of the economy in Chingola. The inhabitants of Chingola commented that environmental sustainability is essential for the current and future generations. The study findings were that Copper mine development has a negative impact on environmental sustainability. Recommendations drafted based on the findings to promote environmental sustainability are that: during exploration there should be minimal impact on the environment, people and certification of practice in exploration of minerals should be granted based on clear mining plans from the exploration stage to the reclamation stage. The study also recommends that environmental protection practices for water, air and soil components must be highlighted clearly, as constant assessments are done. The following are areas of research are recommended by the study: Importance of assessment routines in management of natural resource by the government; contribution of community participation in proper management of mining companies; impact of mine reclamation stage on environmental protection and determination of sustainable waste management mechanisms practiced by mining companies.*

Key Terms: *Copper, Mine Development and Environmental Sustainability*

1.1 Background to the study

Copper Mining is one of the most important industrial activities in the world. There are 10,000 mining companies and more than 20,000 mining sites, mineral processing plants, and smelting plants in the world today (Ata-Era, 2016). Mining industry is a profitable activity; however, it has a high environmental impact in its different stages: exploration, extraction, and processing. Copper Mining generates numerous adverse effects, as well as residues, which could cause water, soil, and sediment pollution (Hudson, 2012). The generation of residues is one of the most notorious environmental impacts in mining activity, even though it is the source of important metals such as cadmium, chromium, copper, lead, zinc, and metalloids. The generation of residue by the Mines represent a risk for both human health and biota (ecological) living in the mining areas.

Throughout the world, mining activities strip off 28 billion tons of material from the earth each year; this is more than what is moved by the natural erosion of all the earth's rivers (Dasgupta,2012). Mining and smelting generate 2.7 billion tons of processing waste every year, much of it, is hazardous to the environment. Smelting of minerals pumps an estimated 6 million tons of Sulphur Dioxide into the atmosphere every year; Sulphur Dioxide contributes to acid rain. Smelter pollution has created biological wastelands as large as 10,000 hectares and added some 8 percent of total worldwide emissions of Sulphur Dioxide. Copper smelters in Chile, for instance, emit 12.5 times the amount of Sulphur Dioxide as those in the United States. In the United States of America, the land stretching 220 kilometers and 47 other superfund sites are former minerals operations. Smelters at a single iron mine in Brazil requires enough fuelwood to deforest 50,000 hectares of tropical forest each year; the mine is expected to operate for 250 years (Dasgupta, 2012)

Africa is rich in natural resources ranging from arable land, water, oil, natural gas, minerals, forests and wildlife. The continent has a large share of the world's natural resources, renewable as well as non-renewable. It is home to 30% of the world's mineral reserves, 8% of the world's natural gas, 12% of the world's oil reserves, 40% of the world's gold, and up to 90% of its chromium and platinum. Africa is home to the world's biggest reserves of cobalt, copper, diamonds, platinum and uranium. Africa holds 65% of the world's arable land, 10% of the internal source of clean fresh water (Atlas, 2016).

The continent (Africa), which depends on its natural resources to achieve economic growth, is daunting the challenge of sustainable development that is environmentally friendly. Current non-renewable resource extraction patterns have had untold environmental impacts (Mondal, 2014). For many years now, mining activities have significantly polluted the environment. Abandoned mine sites have been a threat to the environment in many African countries (Yankson, 2010). The loss of productive land, surface and ground water pollution and soil contamination are part of mineral exploration legacies. Consequently, Africa is unable to afford the current resource extraction approach. If the pattern of destructive mineral mining is allowed to continue, Africa's environmentally sustainable growth will remain a major challenge (Francis, 2013).

Large-scale mining of copper and other materials in Zambia have resulted in severe environmental impacts, including water and air pollution, soil contamination from dust and slag particles, and land degradation. Pollution is highest on the Copperbelt Province, where most mines are located.

About 10,000 hectares of land in this province is estimated to be contaminated by mineral waste, constituting an environmental risk to the water, air and soil in surrounding areas. Water pollution linked to mining in Zambia is mainly caused by the discharge of toxic and acidic water and spills into water bodies, leaving elevated levels of dissolved copper and other elements (Jackson,2014). Siltation is yet another problem reported in the mines, it is caused by dewatering of mines and the discharge of tailings into streams, which damages aquatic life and agricultural land for the farmers. Highly toxic leakages from mining operations have reportedly polluted groundwater, impacting negatively hundreds of people's health. Air pollution is another major concern and there are reported examples of release of Sulphuric Acid, causing severe respiratory problems, damage to buildings and soil pollution. Pollution of the air and drinking water have continued to claim both human and animal life. Metal elements constituting a health hazard have also been found in the soil on the Copperbelt of Zambia. For instance, the soil in Chingola Mining areas is heavily polluted by arsenic and other metals (Stephen,2014).

The Nchanga Mine on the copper belt province is one of the largest open-pit mines in Africa, it stretches 6.5 kilometers across the land and 500metres below the ground. It has an underground mine, an open-pit mine and satellite pits. The processing plants include concentrators, a refinery, a smelter and a tailings leach plant in which copper is extracted (Stephen,2014).

Pollution from mining operations have been affecting communities in Chingola Township. Communities surrounding Chingola say that toxic spills and discharge of polluted and acidic wastewater have contaminated the Kafue River which flows through the Copperbelt Province and reportedly supplies 40 per cent of the country's population with drinking water and groundwater in boreholes, which is used for cooking, cleaning and irrigating crops. Pollution from the mines has negatively impacted their health, destroyed their farmland and lowered their crop yields. The acid spills and contamination of streams, boreholes and wells have become worse over time as the frequency and severity of spills have increased. Mining operations in Chingola regularly release effluents and discharge that contain copper, cobalt, sulphates, manganese, and other metals and solids that exceeded standard limits. Mining operations cause excessive siltation of the Kafue River and its tributary the Mushishima stream, which flows near Chingola, impacting aquatic ecosystems and agriculture in the area and compromising the domestic water supply of over 100,000 of Chingola's residents (Stephen,2014).

1.2 Statement of the Problem

Mineral extraction is the foundation of the national economies in many developed and developing countries world over. Nonetheless, mineral extraction has negative effects on the environment. Water pollution, loss of biodiversity, soil erosion and air pollution and formation of sink holes are among the worst effects of the mining industry on the environment. Copper mining adversely affects the environment by inducing loss of biodiversity, soil erosion and contamination of surface water, groundwater, and soil (Bulgarelli, 2013). The leakage of chemicals from copper mining sites has detrimental effects on the environment. The creation of landscape blots like open pits and piles of waste rocks due to mining operations lead to the physical destruction of the land at the mining site. Therefore, copper mining has adverse effects on the environment and has led to the general disturbance of the earth's ecological systems.

For the existence and development of human society it is necessary to conserve the environment and to simultaneously meet man's demand for materials through the continuing exploration of mineral resources. Nevertheless, to a varying degree, mining activities have changed the original state of the environment and created potential dangers for both ecological and social systems. Therefore, the continued development of human society depends on the attitude of the mineral industry towards achieving ecologically sustainable development of the mining sector.

Hence, the main challenge for the mining industry is to demonstrate that it contributes to the welfare and well-being of the current generation without compromising the quality of life of future generations. This paper sought to examine copper mine development and environmental sustainability in Chingola Township, which is on the Copperbelt Province of Zambia.

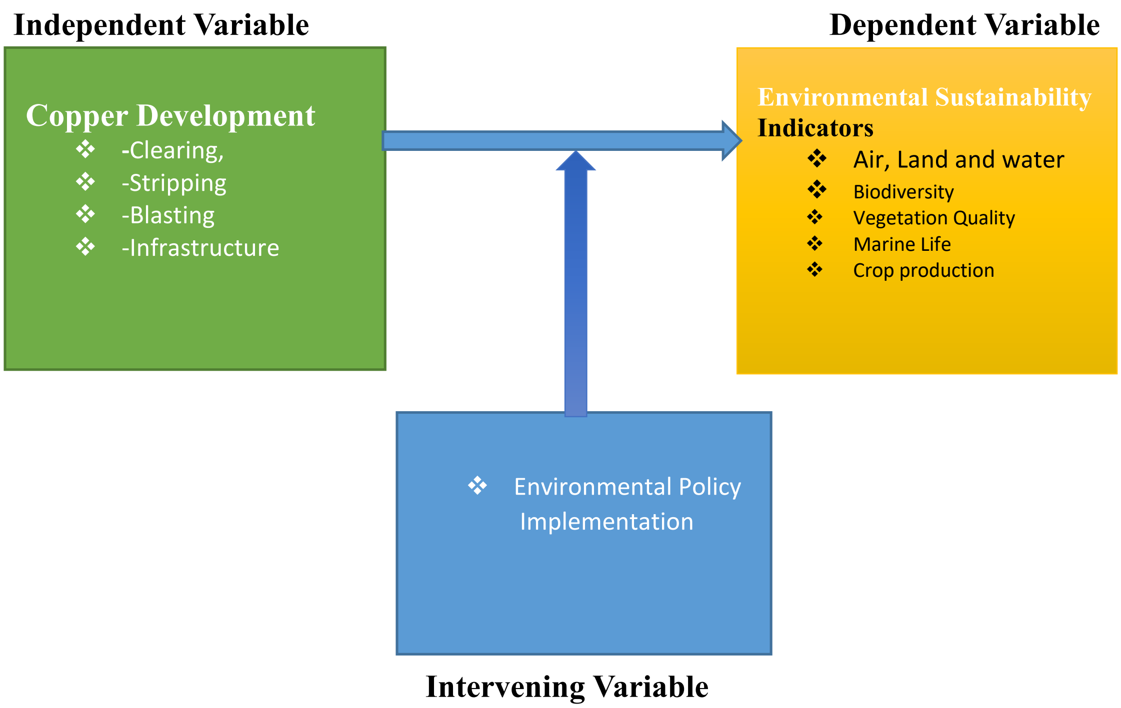
1.3 Objective

Demonstrate how copper mine development affects environmental sustainability in Chingola Township.

1.4 Justification of the Study

Copper Mining is important, it contributes immensely to the economic development of Zambia. In addition, there are economic benefits that are made available to countries that are involved in the extraction of mineral resources. Internally, there is creation of employment and revenue generation. Externally, a substantial foreign exchange is available to such countries. Acknowledging the economic contributions of mining, however, several economies have lost sight of environmental effects associated with mining activities. Research works that have been undertaken on the environmental effects of mining have found mining activities to be more hazardous to economic development than a blessing. A number of mining companies in Zambia claim to have responded to this by instituting and implementing several measures to reduce the negative environmental effects of their activities. Whether some of these measures have or are capable of reducing the negative impact of mining on the environment and surrounding communities is a matter of great concern. The significance of this study lies in the fact that it seeks to undertake a thorough investigation into the environmental effects of Mine development on surrounding communities in Chingola township and recommend policy directives to improve environmental policies as well as reduce the rate of hazardous environmental effects of the mining activities.

1.5 Conceptual Framework



1.6 Mine Development

Taskinen (2001) stated that mining development phase usually takes four to twelve years to open an ore deposit for production, and may cost substantial amount of money to complete depending on the type of mine. Production requires extensive planning and documentation in advance of construction. Budget and financial reports are being prepared and licenses are being requested. Reports are generated on potential impacts on the environment and surrounding communities. Additionally, Horton (2017) argued that plans are being assessed for: mining process and technology to be used, building transportation access roads, identifying resources such as power and water sources, and building ore processing facilities and waste material disposal areas. A lot of money may have been invested in the project at this point, but it may fail to open if the requirements for pre-development are not met, including community acceptance. According to Kelly, (2017) at this stage, the mine site is undergoing sufficient development to ensure that it is productive without subsequent interruption.

Mudd (2010) discovered that there are three major types of mining, surface mining, underground mining, and solution mining; their use depends on the type and location of the mine, as well as health, technology, economics, and environmental impacts. Surface mining, including strip mining, open-pit mining, and erosion of hills, extracts soil and rock on top of the mineral deposit. It can start as soon as it completes the pre-development steps. The underground mining uses shafts and tunnels to enter deep-buried mineral deposits while the underlying rock remains in place (Bai, 2012). This method of mining is usually more expensive and complicated, and for convenience and security requires a lot of additional preparation. Solution mining, also referred to as in Situ

Leaching, is carried out by pouring into the soil a leaching solution like an acid, where the solution dissolves the solid minerals into a liquid. This water containing the minerals is then drained out of the soil and different techniques can then extract the mineral (Gruber et al., 2011).

Wang et al. (2016) noted that mine site preparation, removal of trees and other vegetation, and site levelling may lead to sedimentation problems in the nearby water bodies due to release of suspended solids in surface water run-off. Furthermore, it is possible to affect sensitive plants or animals. Such behaviors can also affect the site's dust. At most of today's mines, removed soil is kept for later reuse in reclaiming the site, and care is taken to limit environmental effects (Hiskey, 2012). The roads and buildings needed for the mine site will be built once the preparation is complete. Building activities can result in air pollution from trucks and other construction equipment. Roads may impact wildlife, and when roads cross rivers or are constructed too close to shorelines, lakes and streams can be impaired. Mine operations are also being built during construction (Nakajima, 2011).

The main environmental concerns associated with the setting up a mine are waste rock and mine water disposal. Mine water is groundwater that streams into mine operations and must be drained out to avoid mine flooding. Depending on the type of rock, mine water can contain metals and be acidic. Unless properly collected and treated before disposal, water can be polluted by pumping mine water from mine operations. The facilities for the disposal of waste rock, tailings and other mine waste are also installed during the construction of the mine. These facilities were rudimentary in the past; they may exist in a simple structure of a wooden dam to contain the tailings. These facilities are carefully designed and built at modern mines to prevent or minimize the pollution of water from these mine waste.

1.7 Theoretical Framework

This research work anchors on two theories: The Ecological Modernization theory developed by Joseph Huber and Martin Janicke and System Theory developed by Bertalanffy. Joseph Huber a German Social Scientist who developed Ecological Modernization theory was in the 1982 and improved on by Martin Janickein 1985. The argument of Ecological Modernization theory is that central institutions of modern societies can be transformed in order to avoid ecological crisis. Joseph Huber (1982) argued that there is need for ecological switchover, that is a transition of industrial societies towards an ecologically rational organization of production, based upon the theory of a changed relationship between the economy and ecology. Ecological Modernization has more in common with strong versions of sustainability in that it envisages a process of the progressive modernization of the institutions of modern societies, as opposed to their destruction (Spaargaren, 1993)

Ecological modernization proposes that structural change must occur at the macro-economic level through broad sectoral shifts in the economy and at the micro-economic level, through the use of new and clean technologies by individual firms (Gouldson and Murphy 1997). Ecological Modernization Theory, seeks to explain the dynamics and effects of modernization on the environment. Its proponents admit that even when modern societies have caused substantial environmental problems, further modernization can solve those problems. This argument is based on the logic that, in modern nations, companies come to recognize the importance of environmental sustainability for their own long-term survival. Consequently, they take measures to reduce environmental impacts by restructuring production systems along ecological lines. From the initial contributions onwards, the aim of Ecological Modernization Theory is to analyze how contemporary industrialized societies deal with environmental crisis.

Ecological Modernization theory is not sufficient to emphasize the importance of environmental sustainability. For instance, modernization theory does not discourage environmental exploitation rather it stresses on the use of clean technology. This entails that Mining Companies can continue exploiting the environment as long as they are using clean technology. This is where system theory comes in; which totally discourages environmental exploitation.

According to the System Theory developed by Bertalanffy (1950), nature is an intricate arrangement of systems, which are interdependent. Therefore, the environment is understood as a network of systems; modification of one system causes a change to the whole set of systems. In this research work the environment is perceived as a complete set made up of both living and non-living things, in such a way that alteration of any one or more sub-sets, interferes with the functioning of the entire system. The physical environment is currently under immense exploitation to the extent that human, animals and plants have been endangered (Waber,2008).

Bertalanffy restated that good systems interrelate with their surroundings unreservedly and that they can subjectively gain new properties. Based on this theory, degradation is theorized as a result of mining activities, which upsets the physical and biological subsets of the whole environmental unit (Schaffer and swilling,2013).

1.8 Research Methodology

A mixed method research approach has been adopted by the study. The mixed methods approach involves parallel processing and evaluation of both qualitative and quantitative data (Williman, 2011). Mixed approach is the use of mixed data (numerical and text) and alternative methods (statistics and analysis), but using the same method (Creswell, 2015). It is a type of research in which a researcher uses the qualitative research paradigm for one phase of the study and a quantitative research paradigm for another phase of the study (Ranjit, 2011).

This study used descriptive research design. The design assisted in collecting data without manipulating the research variables. According to Kothari (2016) descriptive approach illustrates the ideologies of a population. It tries to illustrate systematically the structured instances, phenomenon, problem, service or data related to living conditions meant for the community. The process of descriptive research design is liable of generating perfect interrelationships among the notable variables (Creswell, 2015). Some of the collected data was quantitative in nature and was analyzed through numbers and percentages, while the other data was qualitative. Descriptive research design identifies and justifies practical conditions. It is capable of making assessments and comparing factual data depicting relevant phenomena (Sahaya, 2017)

1.9 Site description, Study Population and Target Population

A population refers to any group of institutions, people or objects that have common characteristics. The target population for this study composed of all the individuals living in Chingola mining area on the Copperbelt Province. This study was done in Chingola, which is one of the cities on the Copper belt province of Zambia. Chingola Township is a mining area, with a population of 210,073, this is according to the 2010 Census conducted by Central Statistical Office of Zambia. Chingola is home to Nchanga Open-Pit Mine which is the actual study area and it is the second largest Open Pit mine in the world. Nchanga Open Pit mine lies in an arc 11-kilometre-long around the west and north of the town. At present, mining is concentrated on the main Nchanga Open Pit, with satellite planned for future extensions, as economic and processing technological developments unfold. Together they are termed generically as the Nchanga Open Pits (Stephen,2014).

1.10 Sample and Sampling Techniques

Non probability sampling is a strategy in which the chance that an individual will be selected is unknown. It is the sampling method which offers no basis for estimating the probability that each element in the population will have a chance to be included in the survey. Non-probability sampling is also known by various names such as intentional sampling, purposeful sampling, and sampling of decisions. The researcher actively chose items for the test in this form of sampling; his decision about the items remains supreme. In other words, the organizers of the inquiry deliberately choose the specific units to be included in the sample under non-probability sampling (Creswell, 2012).

Purposive sampling (also known as decisive, selective or arbitrary sampling) is a sampling technique in which researchers rely on their own judgment when selecting population members to participate in the sample. Purposive sampling is an unusual sampling process that happens when the researcher's decision selects the elements chosen for the sample. This involves identifying and selecting individuals or groups of individuals who are particularly familiar with a phenomenon of interest or are experienced with it. Researchers often think that by using a sound judgment, they can obtain a representative sample, which will save time and money. As such this study used purposeful sampling to select its participants because of the following reason: it is cost and time effective sampling method (Creswell, 2015).

A sample is a smaller number of the population that is used to make conclusions regarding the whole population. The objective is to estimate the unknown population characteristics. Therefore, sampling is the systematic method of selecting a number of individuals to represent a larger group from which they are chosen for a sample. The sampling process takes different issues into account and will depend on the type, purpose, complexity, time constraints and previous field research (Creswell, 2015).

The sample size is calculated as follows:
Known population size N = 210,072

The study has used 95% confidence interval, the error level is 0.05. The minimum sample size is calculated by using the Yamane method (1967):

Yamane = $\frac{N}{1+Ne^2}$

The calculation follows:

$\frac{210{,}073}{(1 + 210{,}073(0.0025)}$ =336

Table 1: Sample Matrix

Sample Matrix		
	Population	Sample
Miners		112
Students		100
Civil servant members		100
Civil society		24
Total	**210,073**	**336**

Source: Researcher, 2019

1.11 Description of Instruments and Methods for Data collection

Data for this study was collected from both primary and secondary sources. Primary data include administering of questionnaires to the residents of surrounding community of Nchanga Open Pit mine and some miners. The questionnaires were administered to the participants by trained research assistants. The participants were given a time frame within which they were required to respond to the questionnaire. Upon completion, the research assistants collected the questionnaires and ensured high completion rate and return of completed questionnaires.

The questionnaire instruments comprised of two sets of questions; open ended and close ended. The questionnaire was organized according to the study's objectives. The study considered using questionnaires because of its low cost; it is free from bias and gives research participants adequate time to give appropriate answers. Secondary data was sourced from books, relevant articles from journals and reports of researches conducted on the effects of mining operations on the environment. They were obtained from library of the University, Internet and other relevant sources.

1.12 Research Findings

1.12.1 Mine Development and Environmental Sustainability

Mine development impact on the environmental sustainability is handled in the following data presentation forms and participant responses below. This section will handle the effect of mine development on vegetation, air quality, ecosystem, water quality, biodiversity, landscape and soil quality respectively.

Mine Development on Vegetation in Chingola

Table 2 Mine Development on Vegetation

Effects of Mine Development on vegetation in Chingola			
		Frequency	Percent
Valid	Extremely	106	39.8
	Moderately	79	29.6
	Slightly	40	15.0
	Not at all	38	14.2
Total		266	100.0

Source: Researcher, 2019

Mine development in the area is presented as very scarce and almost close to non-existent. Table 2 presents that 39 % (106) of the participants attest that there is extreme effect on vegetation under mining development. Moderate effect is felt on vegetation in terms of mine development as presented by 29% (79) responses. Slight response is seen among 16% (43) of the participants. 14% (38) of the participants present that 'not at all' mining development has no effect on vegetation whatsoever.
Participants who attested that they had experienced extreme change in vegetation present so in line of the following responses:

> *Vegetation existence is not present at all since their life cannot be sustained. Existing vegetation are used as dumping spots for mining waste and their existence is eroded. There is very high depletion of vegetation*
>
> *S*ource: participants (mine development on vegetation), 2019

Participants who attested that they have experienced moderate change in vegetation based on mine development presented the following responses;

> *The vegetation left behind after exploration tends to be of low quality. Vegetation around the mine is very scarce to non-existent. Extinction of some vegetation in the area is observed.*
>
> *S*ource: participants (mine development on vegetation), 2019

Participants who support that vegetation had changed slightly presented the following responses:

> *This mining phase affects vegetation since its waste is left bare on the surface, there is lack of enough nutrients for vegetation around the mines, the vegetation are not able to grow in such conditions at all.*

*S*ource: participants (mine development on vegetation), 2019

Participants who support that vegetation has not changed at all presented the following responses:

> *No effect is felt on vegetation at all, mine development in the area is not seen at all thus the vegetation remains as it was in the previous phase.*

*S*ource: participants (mine development on vegetation), 2019

Mine Development on Air Quality in Chingola

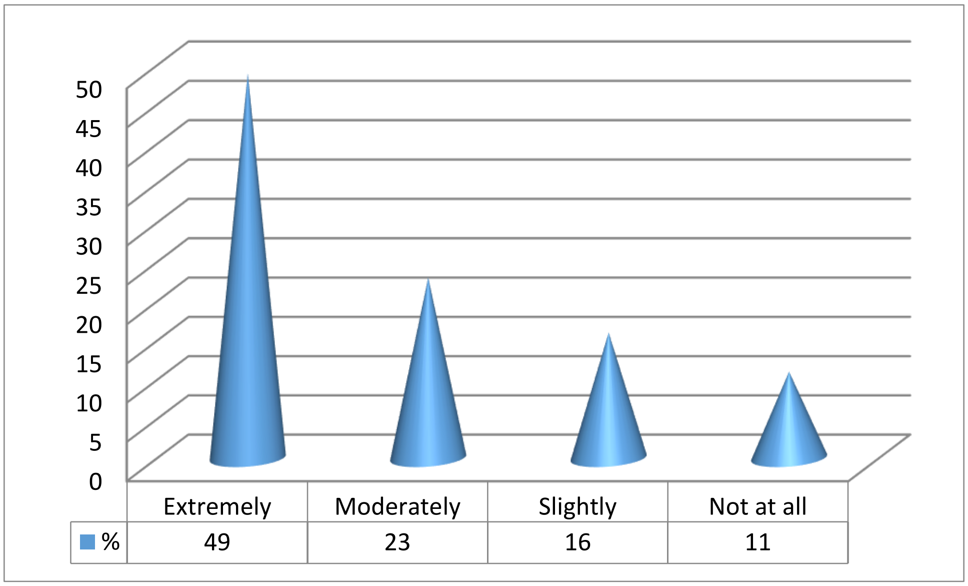


Figure 1 Mine Developments on Air Quality

The figure 1 above presents the impact of mine development on air quality in mines around Chingola. The mines are seen as destructive on-air quality as shown by 49% (131) responses from the participants. Moderate effect is felt on air quality by 23% (62) of the participants, slight effect is observed by 16% (44) of the participants and 11% (29) of the participants present a 'not at all' response on the effect of mine development on air quality.

Extreme effect is seen to affect air quality in Chingola as demonstrated by 49% of the participants who said that:

> *Production of copper reduces air quality, air is contaminated through open-pit mines which emit a lot of carbon, gases exposed from the mines emit a lot of carbon and areas close to the mines are heavily saturated with dust.*

*S*ource: participants (mine development on air quality), 2019

Moderate effect is observed by 23% of the participants who believe that:

> *Fumes emitted affect those who reside in the mining areas. Quality of air is reduced drastically. The smelters used in the mining process give rise to production of a lot of harmful gases*

Source: participants (mine development on air quality), 2019

Slight effect is observed by 16% of the participants who believe that:

Pollution produced is slightly felt; only air near the mines is mostly affected

Source: participants (mine development on air quality), 2019

The air quality has not changed at all during the mine development phase among residents in Chingola

No development has taken place in the mines; air quality is reduced and lost; the phase is not visible among the residents thus the air quality is lost.

Source: participants (mine development on air quality), 2019

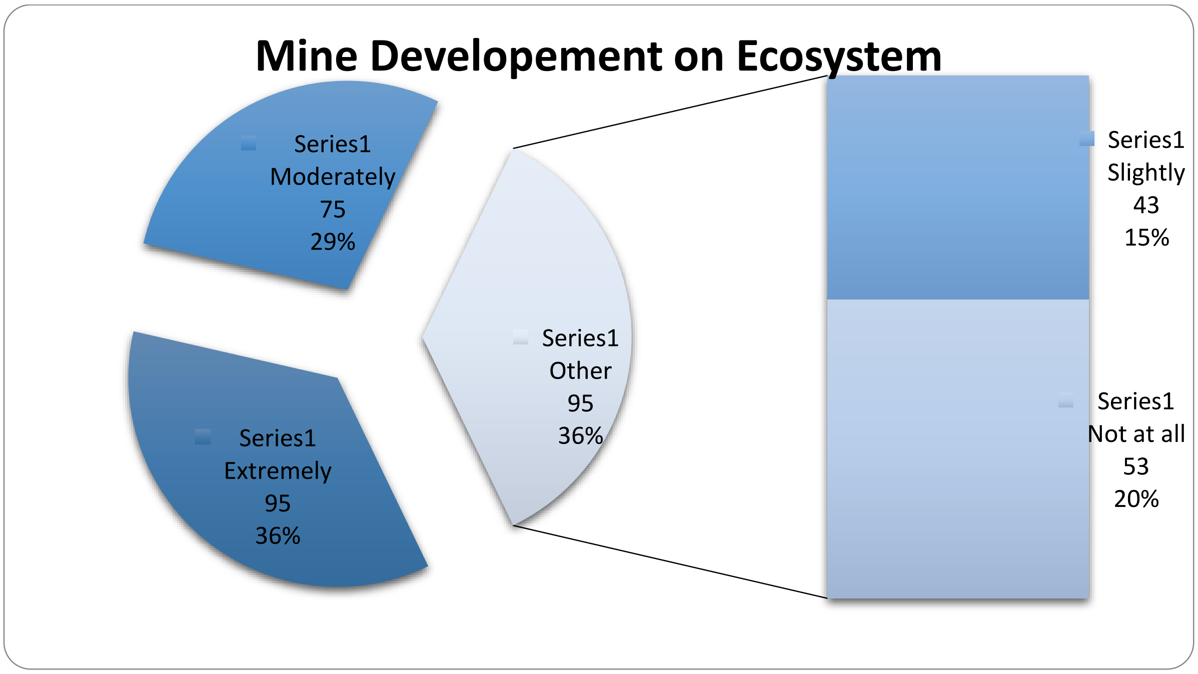


Figure 2 Mine Developments on Ecosystem

The figure 2 above presents mine development effect on ecosystem among the residents of Chingola. The ecosystem appears to be affected extremely at a response rate of 36% (95) as presented by the participants. Moderate effect follows at a response rate of 29% (75). 20% (53) of the participants present that there is no effect on the ecosystem as a result of mine development. The ecosystem is slightly affected as presented by 15%(43) of the participants under the mine development phase.

Death of animals and microorganisms are experienced, due to release of fumes and harmful chemicals.

Source: participants (mine development on ecosystem, extremely response), 2019

Fumes emitted from the mine affect ecosystems. Mine development causes displacement thus misbalancing the ecosystem

Source: participants (mine development on ecosystem, moderate response), 2019

Decrease in number of animals and organisms are experienced, habitats to animals/ microorganisms seizes. Death of animals and microorganisms is experienced as well

Source: participants (mine development on ecosystem, slightly response), 2019

Development is not taking place and the mines are still the same, the ecosystem in the area was said as having no change at all in this phase.

Source: participants (mine development on ecosystem, not at all response), 2019

Mine Development on Water Quality in Chingola

Table 3 Mine development on water quality

Effects of Mine Development on Water Quality in Chingola

		Frequency	Percent
Valid	Extremely	117	43.9
	Moderately	58	21.8
	Slightly	39	14.6
	Not at all	51	19.1
Total		266	100.0

Source: Researcher, 2019

The table 3 above presents mine development effect on water quality among the residents of Chingola. The water quality appears to be affected extremely at a response rate of 44% (117) as presented by the participants. Moderate effect follows at a response rate of 21% (58). 19% (52) of the participants present that there is no effect on the water quality as a result of mine development. 15% (39) of the participants present that there is a slight effect on the water quality as a result of mine development.

Water quality is poor it has been polluted by the chemicals. Development means more waste production where these waste disposals will end up in water bodies such as river Kafue

Source: participants (mine development on water quality, extremely response), 2019

Disposal mechanisms are diversifying and less waste being dumped into water bodies. Minimal effect is felt on water quality

Source: participants (mine development on water quality, slightly response), 2019

Water does pass through mines; no mine development is taking place, mine development phase in the area is non-existent

Source: participants (mine development on water quality, not at all response), 2019

Table 4 Mine Development on Biodiversity

Effects of Mine Development on Biodiversity in Chingola

		Frequency	Percent
Valid	Extremely	79	29.6
	Moderately	85	31.9
	Slightly	41	15.4
	Not at all	59	22.1
Total		266	100.0

Source: Researcher, 2019

Biodiversity change due to mine development in Chingola is experienced in different forms by the participants. 29% (79) affirm that copper extraction is extremely affected. Moderate effect on biodiversity is attested to by 31% (85) of the participants. Biodiversity change has been observed slightly by 16% (43) of the participants and 22% (59) of the participants have not experienced any biodiversity change in light of mine development.

Biodiversity is extremely degraded as presented by a proportion of 29% of the participants, the following being their key supporting statements:

Noise from mines affects animals in the area, extinction of some trees and animals is seen, displacement of animals and man to other habitats.

Source: participants (mine development on biodiversity), 2019

Moderate response at a rate of 31% is presented by the participants, the following being their supporting statements:

Destruction of biodiversity experienced once only a single part is affected, mine development affects growth of animals and plants

Source: participants (mine development on biodiversity), 2019

Mine development is not seen as having any effect on biodiversity as supported by 22% of the participants who present the following responses:

Mine development is not presented, employment opportunities will increase due to mine development, mine development is not evident in the area (not at all)

Source: participants (mine development on biodiversity), 2019

Effect of Mine Development on landscape

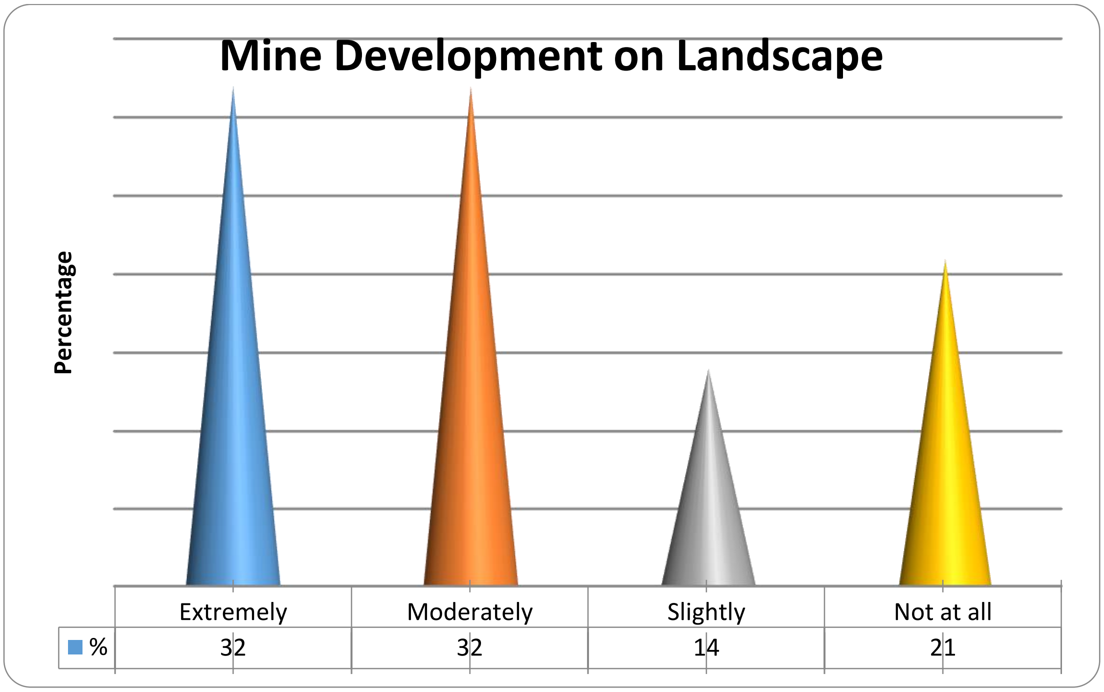


Figure 3 Mine Developments on Landscape

The figure 3 above presents mine development effect on landscape. According to the participants responses 32 % (85) (86) are extremely and moderately certain that the landscape has been greatly affected respectively. The impact of mine development on landscape has not been affected at all as presented by 21 % (57) of the participants. 14 % (38) of the participant's responses are that the effect on landscape in light of mine development has been slight.

Mine development has destroyed the landscape as stated by 32% of the participants, the following statement support the response:

Presence of discoloration of landscapes to red due to dumped copper ores, explosives used during the process affects the landscape

Source: participants (mine development on landscape), 2019

Moderate landscape destructions have been experienced by 32% of the participants as supported below:

Presence of activities that will lead to landslides, there has been destruction of physical features due to this phase of mining and the landscape has been affected *based on characteristics of dumped soil*

Source: participants (mine development on landscape), 2019

There have been slight landscape effects due to mine development:

Slight effect has been experienced in light of less impact on landscapes, mine development in the area is not existent however the landscape destruction has reduced.

Source: participants (mine development on landscape), 2019

Mine development has not affected landscape in Chingola:

No effect has been experienced, mine development is currently not taking place around the mines and the landscape is not affected at all

Source: participants (mine development on landscape), 2019

Effect of Mine Development on Soil Quality in Chingola

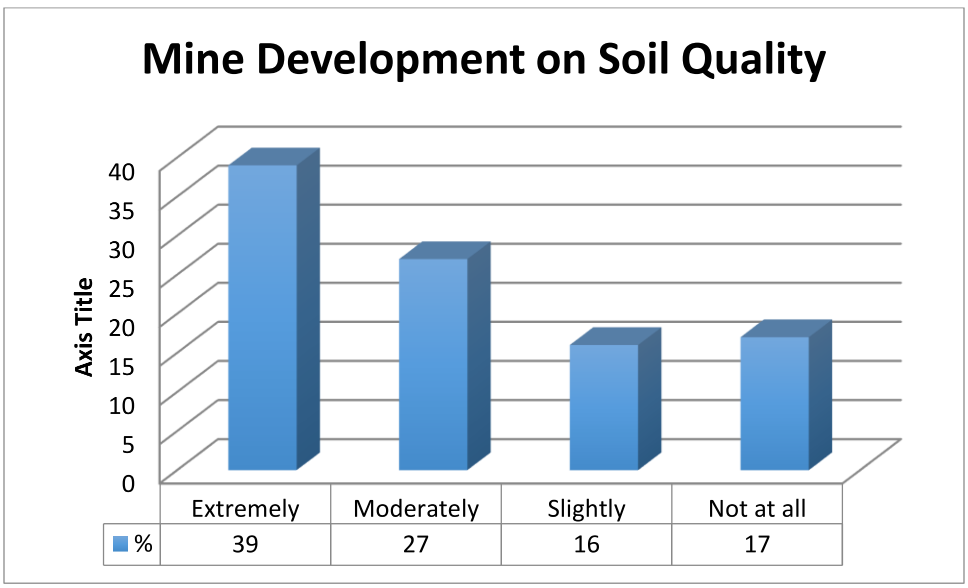


Figure 4 Mine Developments on Soil Quality

Mine development on soil quality is presented by figure 4 above. An extreme effect on soil quality is observed in line with mine development it is observed that 39% (105) of the participants attest that soil quality has reduced abruptly. Moderate effect on soil quality reduction is also observed by the participants at a response rate of 27% (72). Slight effect on soil reduction is observed by the participants at a response rate of 16% (44) and those that presented a ‘not at all’ response are 17% (45).

Effects of mine development are extremely felt on the soil quality due to mine development as stated below:

Soil becomes infertile due to mining products/ chemical and mechanisms, mine

> *development effects are as a result of an accumulation of effects over the previous phases*
>
> Source: participants (mine development on soil quality), 2019

Moderate effects are experienced on soil quality:

> *Toxic chemicals used in the process destroy the soil fertility, soil erosion is observed, areas near the mine lose their fertility*
>
> Source: participants (mine development on soil quality), 2019

There have been slight soil quality effects due to mine development:

> *Soil quality continues to degrade from extraction to this stage since impurities are still added to the soil from the process; soil is believed to be more fertile since it has traces of copper from the mines as praised by some farmers*
>
> Source: participants (mine development on soil quality), 2019

Mine development has not affected soil quality in Chingola:

> *No development is taking place; the effect on soil quality is not present*
>
> Source: participants (mine development on soil quality), 2019

Mine Development affects Environmental Sustainability

The study sought to demonstrate how mine development; affects environmental sustainability in Chingola. Mine development in the area has seen destructive mechanisms being applied on the environment components in order to pave way for copper extraction. Environment components such as vegetation have been cleared/ burned and those that have not are set as disposal areas for mining waste. Soil, water and air face higher levels of pollution from untreated fumes being exposed, untreated mineral waste being disposed and exposure to very corrosive mining chemicals. The landscape is at this level destroyed to pave way for actual extraction, various mechanisms such as open pit mining are used to expose the earth to extraction. The ecosystem and biodiversity at this stage is completely unbalanced since the other components of the environment are polluted. The effect of this phase on the environment is negative; no clear measures are put in place to protect the environment.

Policy Recommendations on the second study objective mine development to enhance environmental sustainability

Constant assessment of mine companies that have done exploration and are in the mine development stage should be done efficiently. The assessment result might benefit the government and the community by ensuring that proper practices are in place during the mining process.

Purification of air and water mechanisms should be put in place. The purification of water and air should be done in a pursuit to protect the community. The mining process entails a lot of waste extracted into the environment; before it is emitted such waste should first be treated.
Only qualified staff should be employed and conservation of the environment emphasized. Qualified staff has gone through the adequate training necessary to handle the mining process in the pre and post stages. Only they are able to ensure the process is done well without unnecessary

destruction. In cases where unqualified staffs are employed necessary supervision should be put in place to avoid destruction.

The third objective of the study aimed at establishing how copper extraction impacts on environmental sustainability in Chingola township. The study findings presented by the participants show that copper extraction has negative effect on environmental sustainability. The following are policy and practical recommendations on how to ensure environmental protection for current and future generations.

Practical recommendations on the second study objective mine development to enhance environmental sustainability

The study recommends a practical recommendation where compensation should be given to agricultural land owners and home owners near the newly developed mines. Mines should be developed with a view of whole empowerment for both people and the economy; there should be a plough back mechanism where the community benefits from the mining resources as well as environmental protection.
This phase entails the drafting, and putting into place plans to ensure the mining phase takes off. The study provides that environment protection practices such as for water, air and soil components must be highlighted in these document plans. This will benefit the government and the community in instances where these protection practices have not been conducted and very key stakeholders can be put to task to fulfil them.

Recommendations for further Research

The researcher investigated the impact of copper mining on environmental sustainability in Chingola Township; the following are recommendations on areas that require further research: Importance of assessment routines in management of natural resource companies by the government; Contribution of community participation in proper management of mining companies and the impact of mine reclamation stage of mining on environmental protection and Sustainable waste management mechanisms practiced by mining companies.

REFERENCES

Ata-Era, A. J. (2016). Assessing the effects of stone quarrying: the case of Wenchi municipality in the BrongAhafo Region of Ghana.

Atlas. (2016). *Mapping Mining to the sustainable development goals*. Retrieved from http://unsd.org/wp-content/uploads/2016/11/ Mapping -mining-sdgs-an atlas.

Bai Y.R. (2012). Water eco-service assessment and compesation in a coal mining region: A case study in the Mentougou district in Beijing. *Ecological Complexity,* 8, 144-155.

Berttalanffy L. (1950) General System Theory: Foundations, Development and Application. New York: George Braziller

Bulgarelli D. K. (2013). Structure and functions of the bacterial microbiota of plants. *Annual Review of Plant Biology,* 64, 807-838.

Creswell J. (2015). A concise Introduction to Mixed Methods Research. Thousand Orks, CA: Sage.

Creswell, J. (2012). *Educational Research: planning, conducting and evaluating quantitative and qualitative research.* London: Prentice Hall.

Dasgupta, A. (2012). Impact of Mining on Rural Environment and economy. A case study of Kota District, Rajasthan. *international journal of remote sensing and geoscience*, 21-26.

Francis C.D. (2013). A framework for understanding noise impacts on wild life: an urgent conservation priority. frontiers in ecology and the environmental 11. 305-313.

Gouldson A. M. (1997). Ecological Modernization and the European Union Geoforum. 27 (1).

Gruber P. W. (2011). Global Lithium Availability: A constraint for electric vehicles? *Journal of Industrial Ecology*.

Hiskey B.J. (2012). Mechanism and Thermodynamics of Floating Slimes Formation;Chen Symposium; Wiley: Hoboken, NJ, USA. 101-112.

Horton A.A. (2017). Large microplastic particles in sediments of the river thames. Uk- abundance, sources and methods for effective quantification. Marine Pollution Bulletin 114 (1) 218-226.

Huber J. (1982). Die verlorene Unschuld der Okologie. Neue Technologien und superindustiellen Entwicklung, Frankfurt am Main: Fisher Verlag.

Hudson, T. (2012). Living earth an introduction to environmental geology. PHI learning private limited.

Jackson R.B. (2014). The Environmental costs and benefits of fracking. *Annual Review of Environmental Resources*, 39, 327-362.

Kelly T.D. (2017). *USGS Copper End-Use Statistics; Historical Statistics for mineral and material commodities in the United States; Data Series 140.* . Retrieved from 140. https: mineral . usgs, gove.mineral, pubs, historical - statistics for mineral.

Kothari, C. (2016). *Research Methodology: Methods and Techniques.* New Delhi: New Age International Printing Press Limited.

Mondal, S. (2014). Scientific Investigation of the environmental impact of Mines using Geospatial Techniques over a small part of Keonjihar District of Orisa. *International journal of Scientific and research Publication*.

Mudd G.M. (2010). The environmental sustainability of mining in Australia: Key mega-trends and looming constraints. *Resource Policy*, 98-115. Retrieved from resource policy.

Nakajima K. T. (2011). Analysis for the controllability of elements in the recycling process of metals. *Environmental Science Technology*, 45, 4929-4936.

Ranjit, K. (2011). *Research Methodology: Step by Step guide for beginners.* New Delhi: Sage Publications.

Sahaya G.S. (2017). *Empirical Research: A study guide.* Nairobi: Pauline Publications.

Schaffler, A. S. (2013). Valuing green infrastructure in an urban environment under pressure. *jOhannesburg case: Ecological Economics, 86, 246*.

Spaargaren G. A. (1993). Sociology, environment, modernity: ecological modernization as a theory of social change. Society and natural resources Volume 5 no.4 . 323.

Stephen C.A. (2014). *Workers and community health impacts related to mining operations: A rapid Review of the literature*. Retrieved from http//www. natural resources. org/minerals/CD/docsmmsd/topics/worker_community_health.

Taskinen, P. S. (2001). Oxygen pressure in te Outokumpu flash smelting furnace: Copper flash smelting settler.

Wang, S. D. (2016). Copper Smelting Data; Paper PY 1-1, The mining and materials processing Institute of Japan. 8.

Weber, C. (2008). *Theory of Technical Systems; its role for design theory and methodology and challenges in the future: Procceeding of AEDS, Workshop Pilsen, Czech Republic*.

Williman N. (2011). *Research Methods: The Basics.* London: Routledge Publisher

Yamane, T. (1973). *Statistics: An introductory Analysis.* New York: Harper and Row.

Yankson W.K. (2010). *Gold Mining and Corporate Social Responsibility in the Wassa West District , Ghana.* Retrieved from https:www.jstor.org/stable/ 27806712.