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Assessment of Heavy Metal Concetration in Maize Grown in the Proximity of Kalulush Mine Area (Copper, Lead, Cadmium and Zinc)

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Abstract
In the vicinity of the kalulushi copper smelter and farm areas were studied in order to assess the special distribution of metals or metalloids contaminates of (Cd, Cu, Pb, Zn). However, several studies mines like Kalulushi mine area have revealed that the area has been adversely affected by mining activities as the result of that, areas that are adjacent to the copper mining showed highest levels of heavy metal contamination in the soil samples of kalulushi farms areas near the smelter stack.
The main aim of this research was to assess the Terence of the soil in correlation to contamination of heavy metals in the soils with different settlements in the areas of Kalulushi farms near mines, Zambia. Cadmium, Lead, Copper and Zinc were analyzed. A total of 8 samples were collected at a depth of 0-30cm and 0-20cm. Of the samples collected, 5 were from farm areas, 2 from the Maine area smelter and 1 from kalulushi primary school, just a few kilometers away from the old mines. The heavy metal analysis was done using the Atom Absorption Spectrometer at the university of Zambia lab. The study used a sampling intensity of 100 m. From the soil samples analyzed, Lead had the highest concentration followed by Zink. Copper was next then Cadmium showing no traces. Average concentrations were as follows Zink 1405.200 mg/kg, Lead 1249.700 mg/kg, Copper 50.00 mg/kg and less than Cadmium 0.002 mg/kg respectively. However, in line with that standard as regards the maximum contamination levels of heavy metals, results of this study shows that the average, soils of Kalulushi farm areas are heavily polluted with heavy metals. Recommendations on remediation techniques were such that Lemon grass and Sunflower could be used in a process known as phytoextraction as cited in other similar studies and literature.

Keywords: Assessment of Heavy Metal Concentration in Maize Grown in the Proximity of Kalulushi Mine Area, Lead, Zink, Cadmium, and Copper Kalulushi Farm Areas and Mine Smelter, Absorption Spectrometer

1. Introduction

The scholar Food and Agriculture Organization (FAO) (2004) defined heavy metal as any metallic element that possess a relatively high density and is toxic or very poisonous even at low concentration when exposed to any living thing. Kribek, B., Nyambe, I. A., Njamu, F., Chitwa, G., Ziwa, G. (2014) [16]. Heavy metal contamination refers to the excessive toxicity deposition of toxic heavy metals in the Soils that can result in anthropogenic activities such as mining. On the other hand the significant heavy metals of biological toxicity present in the soil include Lead (Pb), Cadmium (Cd), Zinc (Zn), Copper (Cu), Nickel (Ni), Stannum (Sn), Vanadium (V) etc. Pettersson UT, Ingri J (2011) [19] the presence in High concentration of heavy metal in soils of kalulushi and in groundwater threatens agricultural Maize crop production in so many ways. The desirable Terence level of accumulation of metals in plants eg Maize causes phytotoxicity especially in root crops like Onions, potatoes and Cassava are more severe and toxicity to the humans and animals that consume them as food. Akiwumi FA, Butler DR (2018) [4].

According to Imasiku A.N. & Chirwa M., (2013) [15] stated that Pollution is explained as any substance introduced into the environment that adversely affects the usefulness of resources. Pollution can be in the form of solid, liquid or gaseous substance and it always causes damage to humans, plants and the Cole symbiotic of the animal lives. According to Kribek, B., Nyambe, I. (Eds) (2015) [17]: The nature and concentration of pollutant determine the severity or badness of effect of that particular type of pollution. Pollution is grouped in the pollutant substance such as Degradable pollutants, non – degradable pollutants slowly degradable pollutants. Several studies have shown that metals such as [Pb, Cd, Zn, and Cu] amongst others are responsible for certain diseases that have lethal effects on man, animals and plant.

According to Nwankwo JN, Elinder CG (2019) [18], 20 million children worldwide suffer from mine pollutions which has become more critical to environmental health as human activities began to undergo industrialization and for most of the amount of waste thrown in the environment is increasing at a faster rate and Heavy metals can accumulate in soils to toxic levels as a result of untreated waste. Syakalima M, *et al* (2011) [21]. The extent of soil pollution by heavy metals is very alarming because of their toxicity which leads to adverse effects on crops such as maize (zea may) and ecosystem health.

Picture 1

The scholar Aguilar A, Borrel A, Reijnders PJH (2016) [3] defined heavy metal as any metallic element that possess a relatively high density and is toxic or very poisonous even at low concentration when exposed to any living thing. Aguilar A, Borrel A, Reijnders PJH (2016) [3]. Heavy metal contamination refers to the excessive toxicity deposition of toxic heavy metals in the Soils that can result in anthropogenic activities such as mining. On the other hand the significant heavy metals of biological toxicity present in the soil include Lead (Pb), Cadmium (Cd), Zinc (Zn), Copper (Cu), Nickel (Ni), Stannum (Sn), Vanadium (V) etc. Akiwumi FA, Butler DR (2018) [4] the presence in High concentration of heavy metal in soils of kalulushi and in groundwater threatens agricultural Maize crop production in so many ways. The desirable Terence level of accumulation of metals in plants eg Maize causes phytotoxicity especially in root crops like Onions, potatoes and Cassava are more severe and toxicity to the humans and animals that consume them as food.

According to Barceloux GD (2020) [5]. Stated that Pollution is explained as any substance introduced into the environment that adversely affects the usefulness of resources. Pollution can be in the form of solid, liquid or gaseous substance and it always causes damage to humans, plants and the Cole symbiotic of the animal lives. The nature and concentration of pollutant determine the severity or badness of effect of that particular type of pollution. Pollution is grouped in the pollutant substance such as Degradable pollutants, Non – degradable pollutants slowly degradable pollutants. Several studies have shown that metals such as [Pb, Cd, Zn, and Cu] amongst others are responsible for certain diseases that have lethal effects on man, animals and plant. According Food and Agriculture Organization (FAO) (2014) about 20 million children worldwide suffer from mine pollutions which has become more critical to environmental health as human activities began to undergo industrialization and for most of the amount of waste thrown in the environment is increasing at a faster rate and Heavy metals can accumulate in soils to toxic levels as a result of untreated waste. The extent of soil pollution by heavy metals is very alarming because of their toxicity which leads to adverse effects on crops such as maize (zea may) and ecosystem health.

Nevertheless, Trace element of pollution in mining areas is always a huge environmental challenge for the global mining industry Bradl HB (2015) [7]. With the weathering of pyrite waste, a large amount of harmful trace elements enter the soil, water, and surrounding environment used for crop production, Syakalima M, *et al* (2011) [21]., Pollution hazards of some trace metal elements could be acute or one experiencing a rapid onset and short but severe course due to the serious toxicity that they present even in low concentrations, such as zinc (Zn), cadmium (Cd), and lead (Pb), Pettersson UT, Ingri J (2011) [19]. Their sustainable and long-term bioaccumulation poses a huge threat to human health Anderson, M., (2014) [2] Understanding the sources and relevant characteristics of trace metals can provide useful information for decision makers on the purpose of effectively developing mine remediation policies Gaetke ML, Chow KC (2015) [11]. Previously, many studies emphasized the trace element contamination and ecological in Zambia are risks caused by large-scale mining operations Yelpatyevsky VP, Elpatyevskaya PV, Spalinger MS (2014) [22]. Especially, most of them analyzed the differences of soils in waters surrounding the mining area with aspects to the water composition, geological conditions, mineralization type, rock style, and microbial distributions in soils. For example, Gawthorne, J., (2018) found that the biggest Cu mining area in Konkola produced high levels of soil contamination, poising human non-carcinogenic risk or Causing cancer. Anija-Obi, F. N. (2001) [1] reported that toxic metals such as Cu, Zn, and Cd, are associated with anthropogenic or a study of the origins and development of human beings in contributions caused by mining activities in the Copperbelt province in chililabombwe of Zambia. Pb could be related with both anthropogenic and natural geochemical processes and Metals/metalloids are either absorbed by plants e.g. zae maize or deposited in soil and sludge, which consequently affect the growth of animals and plants Food and Agriculture Organization (FAO) (2014) Acute exposure to lead causes brain damage, neurogical symptoms, brain damage and could lead to death Imasiku A.N. & Chirwa M., (2013) [15]. Cd exposure on the other hand, causes renal dysfunction, calcium metabolism disorders and also increased incidence of some forms of cancer possibly due to the inhibition by Cd of DNA mismatch remediation Kribek, B., Nyambe, I. (Eds) (2015) [17]: Zinc toxicity is rare, but at concentrations in water up to 40 mg/l, may induce toxicity characterized by symptoms of irritability, muscular stiffness and Kribek, B., Nyambe, I. (Eds) (2015) [17]: The main research objective was to:

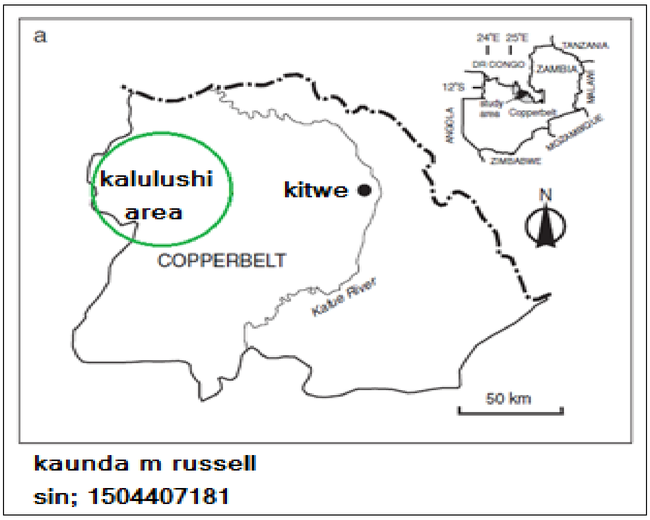
1. Assess the content and magnitude of contamination of Heavy Metals in Kalulushi mine and farm area.

In order to archive the main objective, the study had the following specific objectives:

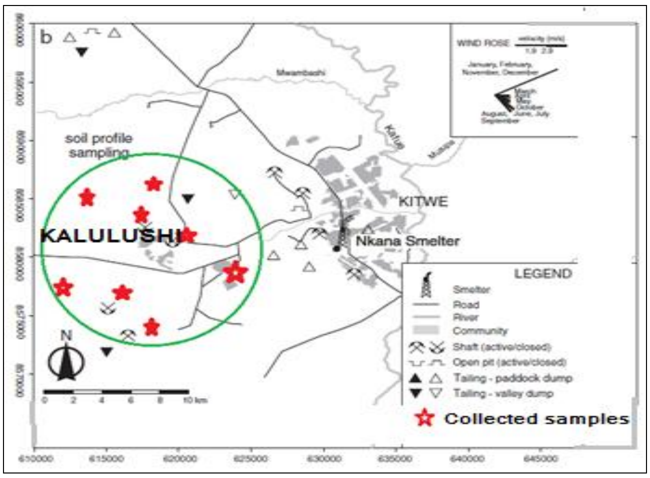
1. Determine extent and magnitude of contamination by heavy metals.
2. Characterize main pathways of lead exposure to Maize or farm crops.
3. Unerstand the effect of heavy metals on soil pollution.

2. Literature Review
2.1 Overview
The idea is set out to examine and to process assessment of the Heavy metal pollutions such as [Cu, Zn, Pb, Cd,] on the environment and its attendant consequences on the Zambian society. The aim of this study is to evaluate the distribution of heavy metals in agricultural farms to where the maize (zea may) is concern in copper-belt particularly in KALULUSHI area of Zambia and to understand the characteristics of the Heavy Metals pollution in each area of the farms.

3. Materials and Methods
3.1 Study Area
Kalulushi is a town in the Copper belt Province in north central Zambia. Municipal (district) population 75,806 at the 2000 Census. Kalulushi was established in 1953 as a company town for workers at the nearby Chibuluma copper and cobalt mine, and it became a public town in 1958. It is located 14 km (9 mi) west of Kitwe, the nearest rail station, at an altitude of 1,260 m (4,130 ft). The city's major employer is Chambishi metals Anderson, M., (2014) [2].



(2020: 3, fig 1 above)



Source: Kaunda m Russell (2020)

Figure 1 and 2 above shows the Map of copper belt province and kalulushi in a green circle showing the areas of study, Kitwe and kalulushi are just neighbor towns in the copper belt province. Kitwe is the provincial headquarters of kalulushi located at 14 km (9 mi) west of Kitwe. Kalulushi Township hosts the Mine which has been the main key source of Contamination of farms and crops grown in the area and other parts of Kalulushi.

3.2 Collection of Soil Samples
To initiate the researcher's investigation of the assessment of soil contamination by heavy metals in Kalulushi, the researcher collected 8 soil samples, 5 from the farm areas and 3 from the mine area, 1 from the kalulushi primary school. At each sampling point approximately 0.5 kg of soil was collected 0 – 20cm depth using a stainless-steel sampler and a hand-held pick.

(Picture 4 below)

3.3 Laboratory Soil Analysis Procedure
Stages in Sample Preparation
During the Laboratory analysis, each sample bag was mixed thoroughly so as to obtain homogeneity and then the sample division was done in order to decrease the mass of the samples that to be analyzed. The sample division step was governed by the particle size and the mass of the material. The cardinal rule of crushing before dividing the sample was observed.

3.4 Conning and Quartering
This study used the conning and quartering lab procedure. Contents of each sample were mixed thoroughly on a clean surface to ensure zero disruptions and non-biased results. A large steel plate was used in this instance. Mixing was done by transferring the sample from one point to another by a hand-held shovel, the hand-held shovel of the material was always put on top of the cone. This process was done three times. The cone was flattened with the shovel and divided into four even quarters then reject opposite quarters leaving half the sample. Further, the retained quarters were removed and a repetition of the procedure was done until the required amount of material was reached.

Elemental Analysis of Soil Samples

About 1 gram of the soil sample was weighed from each sample then mixed with about 30ml of Aqua Regia (a mixture of one part concentrated Nitric acid and three parts of concentrated Hydrochloric Acid). Then the samples were heated on a hot plate with a temperature of above 400 degrees Celsius for 15 minutes or removed when the samples near dryness. There after the conical flask was thorough washed in the inside then filtered 100 ml volumetric flask up to the mark of the volumetric flask. Filtrate was thoroughly mixed then let it to settle. The Atomic Absorption Spectrophotometer was calibrated with known working standards and ensured that a linear curve was obtained. Lastly the samples were run on the Atomic Absorption Spectrophotometer with the elements and their conditions of analysis as shown in Table 1 below.

Table 1: Elements and their conditions of analysis

Element Analysed	*Wavelength of Analysis*
Cu	324
Zn	213.9
Cd	228.8
Pb	217.0

4. Results and Discussions

Table 2: The gross content of heavy metals in kalulushi farm areas, mg / kg

Soil Sample	Horizon, depth, cm	Cu	Cd	Pb	Zn
A1	0 - 30	82.81	<0.002	3103.9	4528.3
A2	0 - 20	93.92	<0.002	4979.7	6342.2
A3	0 - 30	51.06	<0.002	2501.4	3404.0
A4	0 - 30	23.60	<0.002	1184.9	1079.6
A5	0 - 30	28.54	<0.002	1052.4	2026.3
A6	0 – 30	102.54	<0.002	256.9	869.6
A7	0 – 30	45.56	<0.002	748.6	1959.4
A8	0 – 30	43.52	<0.002	352.9	195.14
A9	0 – 20	20.32	<0.002	139.5	88.79
A10	0 – 30	4.96	<0.002	249.8	72.90
A11	0 – 20	38.55	<0.002	293.5	235.9
A12	0 – 30	12.57	<0.002	<0.01	45.81
A13	0 – 30	42.98	<0.002	<0.01	9.84
A14	0 – 30	18.37	<0.002	133.8	196.7
REF	0 – 30	143.2	<0.002	<0.01	24.17

According to the results above, for Kalulushi farms, a total of 11 soil samples were analyzed. Of these, eight samples, with a horizon of 0-30 had the following minimum, average and maximum concentrations of the heavy metals. Maximum for Cu was 102.54mg/kg, the average was 47.82375mg/kg and the minimum was 4.96mg/kg. For Cd, the Maximum, average and minimum values were less than 0.02mg/kg. For Pb, the maximum was 3103.9mg/kg, the average 1181.35mg/kg and the minimum was 249.8mg/kg. The maximum for Zn was 4528.3mg/kg, the average was 1766.905 mg/kg and the minimum was 72.9mg/kg.

Results for Mine area, three samples for a 0-20 horizon were analysed, the maximum value for Cu was 93.92 mg/kg and 57.12 mg/kg was the average while 20.32 mg/kg was the minimum. For Cd, average, maximum and minimum values were null. The maximum values for Pb were 4979.7 mg/kg, 2559.6 mg/kg was the average and 139.5 mg/kg were the minimum. For Zn, the maximum was 6342.2 mg/kg; the average was 3215.495 mg/kg and the minimum 88.79 mg/kg.

For Kalulushi primary school, three samples for 0-30 horizon were analysed. The maximum value for Cu 42.98 mg/kg, 24.64 mg/kg was the average while 12.57 mg/kg the minimum. For Cd, the values were negative values. For Pb, the maximum, average and minimum value was 133.8mg/kg. For Zn, the maximum was 196.7 mg/kg. The average was 84.11667 mg/kg and the minimum was 9.84 mg/kg. Mulungushi, from which a reference sample was collected at a 0-30 horizon, had a maximum, average and minimum value of 134.2mg/kg for Cu. For Cd, the values were at less than 0.002 mg/kg. For Pb, a maximum and average value was less than 0.01mg/kg. For Zn, minimum, maximum and average was at 24.17mg/kg. Figure 2 below summarises the minimum, maximum and average concentrations of the heavy metals of the study.

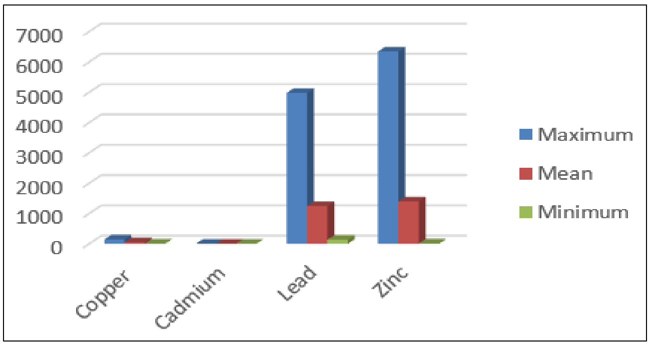


Fig 2: Minimum, Maximum and average Concentration of Heavy Metals in mg/kg

In this study, it can be seen that results for Zinc showed a high content in the soils of the study area in comparison with other heavy metals. Across all samples, Zinc presented itself with high values. Zn had the highest concentration of *21078.65mg/kg*, followed by Pb with *14997.3mg/kg* and then Cu had *752.5mg/kg*. Least was Cd with less than *0.002mg/kg*. According to table 2, the accepted amount of lead concentration in soil is *100 mg/kg* Therefore Rashad S, Barsoum MD (2016) [20] it was noted in this study that the elements exceeded the recommended optimum soil concentrations by WHO. Figure 3 and 4 depicts the study results in comparison to WHO and FAO heavy metal thresholds in urban soils respectively.

Table 2: Optimum concentration values as recommended by WHO

Parameters	*WHO values (mg/ kg)*
Cu	2 – 100
Zn	300.00
Cd	3.0
Pb	100.00

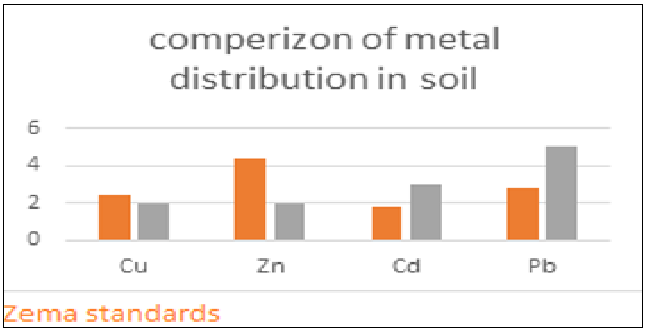


Fig 3: Study Results in comparison to WHO heavy metal thresholds in urban soils

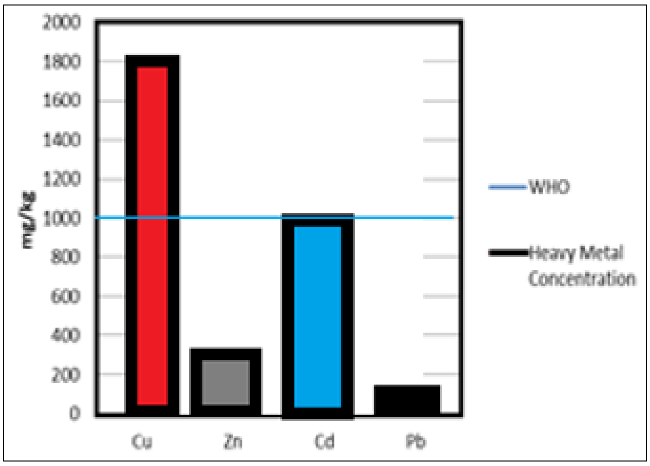


Fig 4: Study Results in comparison to FAO heavy metal thresholds in urban soils

The way the canadian soil quality is on the guideline values in table 3 and the recommended values for heavy metal concentrations in the Soil in Africa Table 4 below. Lead exceeded all the values for residential and agricultural land use except in sample 09,12,13,14 and reference sample which showed no traces of Lead and this could be due to Anomalies and irregularities during the Laboratory analysis for the element but for the reference sample it could be the distance from the mining area as samples that were collected with close proximity to the mine showed higher concentration in comparison to those that were collected further away from the old mining area.

Table 3: Canadian soil quality guideline values for Lead

Canadian soil quality guideline value	Lead (mg/kg)
Industrial land use	600
Commercial land use	260
Residential land use	140
Agricultural land use	70

Source: Imasiku A.N. & Chirwa M., (2013) [15]

Heavy Metal Pollution in Africa

Table 4: Recommended values for heavy metal concentrations in the Soil

pb	Cd	Hg	Cu	Co	Zn	Cr
150	5		100	50	500	250

Source: Food and Agriculture Organization (FAO) and International Soil Reference and Information Centre (ISRIC), 2004 [14].

According to the results, 4 samples from Lukanga were analyzed, of the 4; one shows a very high concentration of Pb and Zn.This is for the particular reason that this sample was collected from a water-logged area. **Rashad S, Barsoum MD** (2016) [20]. This demonstrates that water logged areas are the sinks of heavy metals because of runoff water, at the same time it was noted during sample collection that the residents were collecting the contaminated sand from the abandoned old Coppermine and cobalt mine area into the communities and use it as building sand which might have contributed to the high concentration of Lead in sample 14. One trend that was noticed was that metals showed higher concentrations at sampling locations near the old copper mine. Samples that were collected with close proximity to the mine showed higher concentration in comparison to those that were collected further away from the old copper mining area. All metals under investigation showed significant increases with close proximity to the old mining area, however, it was noted that regardless of proximity, Cadmium showed very low levels of concentration in the sampled soils. When compared to the WHO and FAO acceptable concentrations of the heavy metals under discussion, it was discovered that results showed increased and therefore, unacceptable concentrations in the study area. Except for Cd, all the metal concentrations in soil samples were on average above these standards. The implication is that mining operations polluted agricultural crops like maize basing on the land it may be grown and as such, crops grown on such soils are likely to take up high levels of these heavy metals that may result in health problems for both animal and human beings.

When considering the fact most samples were collected from agricultural lands of maize production and in settlement or catchment areas, the seriousness of the impacts associated as regards to heavy metal contamination cannot be exaggerated Crops in such areas take up heavy metals from polluted areas and disrupt to agricultural land. However, as part of the recommendations all hope is not lost because Bruvold, W. H. (2019) [8] stated from their results that Lemon grass was observed to have a higher phytoremediation potential to clean Kalulushi heavy metals. In the same way Anija-Obi, F. N. (2001) [1] stipulated that the fact that when the ZEA-MAY/Maize was grown in the composite soil mixture with concentration of *3,553* $mg\ kg^{-1}$ *Pb*. In their research work it was noted that the ZEA-MAY/Maize was able to accumulate about *2.3795* $mg\ kg^{-1}$ Pb within a period of 4 weeks. Thus, proving the usefulness of ZEA-MAY/Maize in accumulation of heavy metals especially Lead from the soil. According to Anija-Obi, F. N. (2001) [1] started in the recommendations that the use of phytoextraction on heavy metals which is the uptake of these heavy metals by plants which is then paired with the harvesting of contaminated plant tissue as an attempt to eliminate further accumulation. The researcher recommends two types of phytoextraction that could be applied in order to reduce the contamination:

1) Natural phytoextraction using hyperaccumulating plant species that can absorb or remove heavy metals.

2) Bruvold, W. H. (2019) [8]. Induced phytoextraction using metal tolerant plant species and soil chelating agents. Both types of phytoextraction have their pros and cons which need to be assessed before a remediation method is chosen for a specific site Howe etal Bruvold, W. H. (2019) [8].

5. Conclusions

The concentrations of heavy metals in soil samples collected from the cultivated farms of Zea-MAy in Kalulushi area of the Kitwe Regional State Zambia have been determined. The study indicates that the soils studied has the potential source of the heavy metals in the environment and the farm in particular, therefore the Zea-May/Maize grown is also contaminated and concentration of the heavy metals are in rage concentration: Zn, Cu, Cd, and Pb, cannot be tolerable in foods or agricultural farm.

The purpose of this study was to investigate the contents and percentage of heavy metal levels in the soils of Kalulushi mine and farm areas.

6. Acknowledgements
First of all, I would like to thank the Almighty God for his grace and immeasurable love, giving me strength, ideas and patience to bring out this piece of work in to light. Our deepest gratitude goes to the Zambia Research and Development Centre for funding and supporting this research study from its inception. It is difficult to mention everybody that contributed in a way towards this study but we wish to extend our heartfelt gratitude to Dr. Richard Silumbe, Dr. Meki Chirwa and Mr. Hamakala Derick and the Information and Communications University research team. We also would like to thank the University of Zambia, School of Mines for the geochemical laboratory Analysis of the elements in the soil samples.

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