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Assessment of Heavy Metals in Urban Soils of Kabwe (Copper , Lead , Cadmium and Zinc)

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Danny Chisanga Musenge
Department of Agriculture and Environmental Sciences,
Information and Communications University
Zambia Research and Development Centre
Lusaka Zambia
musengedanny@gmail.com

Nanyangwe Silvia
Department of Agriculture and Environmental Sciences,
Information and Communications University
Zambia Research and Development Centre
Lusaka Zambia
silviananyangwe@gmail.com

Abstract - Several studies on Kabwe have revealed that the area has been adversely affected by previous mining activities. As a result, areas that are adjacent to the old Zinc and Lead mines showed high levels of heavy metal contamination in the soils samples. The aim of this research was to assess the levels and magnitude of contamination of heavy metals in the soils of different settlement areas of Kabwe, Zambia. Cadmium, Lead, Copper and Zinc were analyzed. A total of 15 samples were collected at a depth of 0-30 and 0-20. Of the samples collected, 11 were from Chowa, three from Lukanga and 1 reference sample near Mulungushi University, north of the old mines. The heavy metal analysis was done using the Atom Absorption Spectrometer. The study used a sampling intensity of 100 m. From the soil samples analyzed, Zinc had the highest concentration followed by Lead. Copper was next then Cadmium showing no traces. Average concentrations were as follows; *1405.243 mg/kg, 1249.775 mg/kg, 50.17 mg/kg* and less than *0.002 mg/kg* respectively. Going in line with WHO and FAO standards as regards the maximum contamination levels of heavy metals, results of this study show that on average, soils of Kabwe Urban are heavily contaminated 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.

Key Words*: Urban Soil, Heavy Metal, Lead, Cadmium, Pollution, Kabwe, Mine, Smelter, Absorption spectrometer*

Introduction

A heavy metal is defined, by (Lennetech, 2004) as any metallic element that has a relatively high density and is toxic or poisonous even at low concentration. Heavy metal contamination refers to the excessive toxic deposition of toxic heavy metals in the Soils as a result of anthropogenic activities such as mining (Borg, 1989). Some of the significant heavy metals of biological toxicity present in the soil include Lead (Pb), Cadmium (Cd), Zinc (Zn), Copper (Cu), Arsenic (As), Chromium (Cr), Nickel (Ni), Stannum (Sn), Vanadium (V) etc. High concentration of heavy metal in soil and groundwater threatens agricultural production in a number of ways. An unacceptable level of accumulation of metals in plants causes phytotoxicity especially cauliflower and potatoes are toxic to the humans and animals that consume them (Ibid).

Pollution is a worldwide problem and its potential in influencing health of the human population is great (Khan and Ghouri, 2011). The most common environmental pollutants in the world are heavy metals (Papatilippaki et al., 2008). Most heavy metals in high concentrations have an adverse effect on human health, especially on the health of young children, who have a higher rate of absorption of heavy metals because of their active digestion systems and sensitivity to hemoglobin. Heavy metals may accumulate in our body and affect the central nervous system, causing heavy metal poisoning and acting as cofactors in many other diseases (Hammond, 1982; Nriagu, 1988; Thacker et al., 1992; Schwartz, 1994; Bellinger, 1995).The accumulation of heavy metals in agricultural soils is of increasing concern due to food safety issues and potential health risks as well as its detrimental effects on soil ecosystems (Qishlaqi and Moore, 2007). The chronic problems associated with long term heavy metals exposure include; Serious hematological and brain damage, anaemia and kidney malfunctioning (Sonayei et al., 2009)

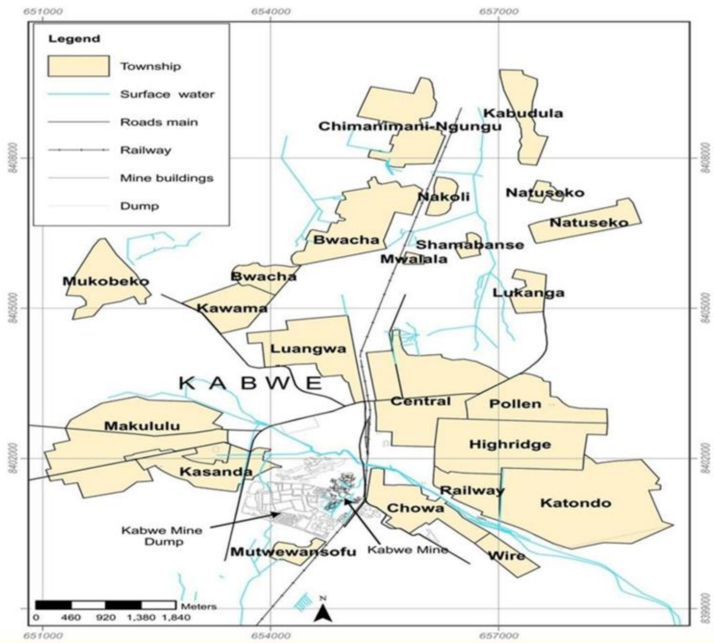
Heavy Metals such as Pb and Cd are lethal even in very small doses. Lead has a negative influence on the somatic development, decreases the visual acuity and auditive thresholds (Simeonov et al., 2010). Acute exposure to lead causes brain damage, neurogical symptoms, brain damage and could lead to death (Simeonov et al., 2010).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 (Kumar, 2009). 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 pain (Al-Weher, 2008).

The main research objective was to:

1. Assess the content and magnitude of contamination of Heavy Metals in urban soils of Kabwe town.
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 residents
3. Understand the effect of heavy metals on soil pollution

Materials and Methods

Kabwe Town is located in the Central Province of Zambia about 136 km north of Lusaka, the capital of Zambia. It is located at 28^{0} 26`E and $14^{0}$27`S with a population of approximately 250,000. According to Kribek et al. (2010), it has a terrain that is slightly undulating, with Kalulu Hill at 1223 m as the highest point in Kabwe, and the rest lying between 1100 – 1200 m above sea level. The town is characterized by Acrisols although Podsols and Vertisols are also found. Vegetation is mainly characterised by Miombo woodlands (Kribek et al., 2010).



Mbuki. R & Mbewe G (2017: 3, fig 1)

Study Area

Figure 1 above shows the Map of Kabwe town showing the areas of study, Chowa and Lukanga as well as Mulungushi University area North of Kabwe. Kabwe town which is the provincial headquarters of central province is located at 28^{0} 26`E and $14^{0}$27`S.Chowa township hosts the former Kabwe Lead Mine which has been the main key source of Contamination of Chowa and other parts of Kabwe.

The 15 samples were labeled and bagged on site in clean black polyethylene bags to avoid

Contamination and the chemical Analysis was done at Geo Chemical laboratory at the University of Zambia, School of Mines.

Collection of Soil Samples

To initiate the researcher's investigation of the assessment of soil contamination by heavy metals in Kabwe, the researcher collected 15 soil samples from 2 townships Chowa and Lukanga including one reference sample north of Kabwe near Mulungushi University Area. At each sampling point approximately 0.5 kg of soil was collected 0 – 30 depth using a stainless-steel sampler and a hand-held pick.

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 sample division was done in order to decrease the mass of the samples that were analysed. The sample division step was governed by the particle size and the mass of the material. The cardinal rule of crushing before you divide the sample was observed.

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
Table 1

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

Results and Discussions

Table 2. The gross content of heavy metals in Urban Soils of Kabwe, mg / kg

Table 2

Soil Sample	Horizon, depth, cm	Cu	Cd	Pb	Zn
01	0 - 30	82.81	<0.002	3103.9	4528.3
02	0 - 20	93.92	<0.002	4979.7	6342.2
03	0 - 30	51.06	<0.002	2501.4	3404.0
04	0 - 30	23.60	<0.002	1184.9	1079.6
05	0 - 30	28.54	<0.002	1052.4	2026.3
06	0 - 30	102.54	<0.002	256.9	869.6
07	0 - 30	45.56	<0.002	748.6	1959.4
08	0 - 30	43.52	<0.002	352.9	195.14
09	0 - 20	20.32	<0.002	139.5	88.79
10	0 - 30	4.96	<0.002	249.8	72.90
11	0 - 20	38.55	<0.002	293.5	235.9
12	0 - 30	12.57	<0.002	<0.01	45.81
13	0 - 30	42.98	<0.002	<0.01	9.84
14	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 Chowa, 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 Chowa, 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 was *4979.7 mg/kg*, *2559.6 mg/kg* was the average and *139.5 mg/kg* was 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 Lukanga, 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.

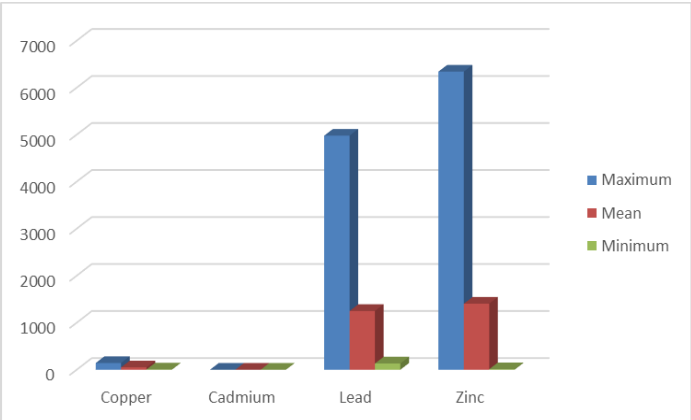


Fig 2. Minimum, Maximum and average Concentration of Heavy Metals in mg/kg

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*.

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According to table 3, the accepted amount of lead concentration in soil is *100 mg/kg* Therefore 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 3. Optimum concentration values as recommended by WHO

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

Source: Mamtaz and Chowdhury (2006);

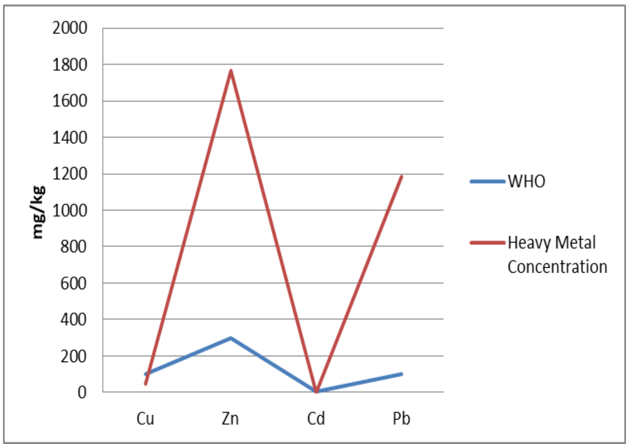

Fig 3. Study Results in comparison to WHO heavy metal thresholds in urban soils

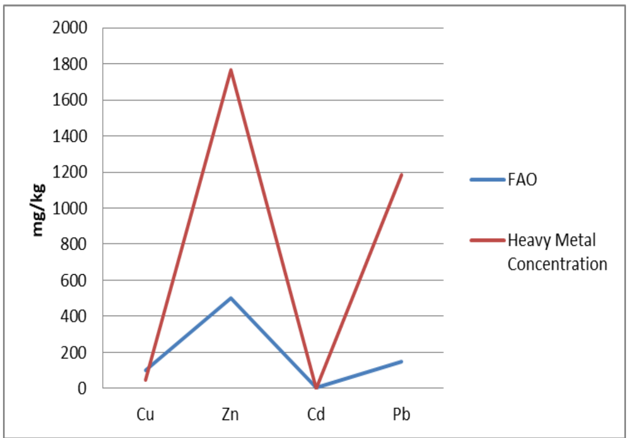

Fig 4. Study Results in comparison to FAO heavy metal thresholds in urban soils

According to the canadian soil quality guideline values in table 4 and the Recommended values for heavy metal concentrations in the Soil in Africa Table 5 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 4. Canadian soil quality guideline values for Lead

Table 4

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)

Heavy Metal Pollution in Africa

Table 5. Recommended values for heavy metal concentrations in the Soil

Table 5

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.

From the results, 3 samples from Lukanga were analyzed, of the three; 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. 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 Zinc and Lead 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 Lead 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 mining area. All metals under investigation showed significant increases with close proximity to the old mining area, however, it should be 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 land 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.

Considering the fact most samples were collected from agricultural lands and in settlement areas, the seriousness of the impacts associated as regards to heavy metal contamination cannot be overemphasized Crops in such areas take up heavy metals from polluted and disrupted agricultural land. However, as part of the recommendations all hope is not lost because Nyambe and Chirwa (2014), stated from their results that Lemon grass was observed to have a higher phytoremediation potential to clean Kabwe of heavy metals. In the same vein Mbuki and Mbewe (2017) attest to the fact that when sunflower was grown in the composite soil mixture with concentration of *3,553* $mg\ kg^{-1}$ *Pb*. In their research work it was noted that sunflower was able to accumulate about *2.3795* $mg\ kg^{-1}$ Pb within a period of 4 weeks. Thus, proving the usefulness of sunflower in accumulation of heavy metals especially Lead from the soil. According to Diane Nelson (2016) in the recommendations the researcher recommends the use of phytoextraction of 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 and

2) 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.

Conclusions

The purpose of this study was to assess the contents and magnitude of heavy metal levels in urban soils of Kabwe in order to assess the anthropogenic impact of previous mining activities on urban soils. Clear accumulations of Cu, Zn and Pb were observed through the analysis of 15 soil samples from 15 representative sites of Kabwe town and it can be concluded that approximately almost all soil samples were heavily polluted by these elements except Cd. This research suggested that the surface soils of Kabwe had been polluted by anthropogenic sources which was mainly mining as other mines like sable Zinc had continued operations in the same abandoned mines.

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