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# Bio concentration of Heavy Metals in Cabbage and Tomato Growing near Copper Polluting Facilities on the Copperbelt Province, Zambia

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## ABSTRACT

The current study was undertaken to evaluate the degree of pollution and bioaccumulation of heavy metals; Cu, Cd, Zn, Ni and Pb from the soils of the Copperbelt Province to the edible parts of cabbage (*Brassica oleracea var. Capita l.)* and tomato (*Lycopersicum esculentum Mill)* using the Bioaccumulation Factor (BAF), Contamination Load Index (CLI) and Nemerow Integrated Pollution Index (NIPI). Cu, Cd, Ni, Pb and Zn in soils, cabbage and tomato leaves and fruits from industrial and non-industrial areas in Kitwe, Mufulira and Chingola districts of Copperbelt Province, Zambia were determined after acid digestion by using atomic absorption spectrophotometry (AAS). Very high metal transference from soil to cabbage and tomatoes observed, it is a concern for public health particularly for urban population which consumes the roots, stems, stalks, leaves or fruits of these vegetables. The result showed that BAF in both species were below 1 except for cabbage which accumulate Cd to the critical limit of BAF=1 in areas close to the mine polluting facility. The CLI was above 1 for the studied metals in soil samples collected near the mine polluting facility while in the control site, only Cd, Ni in cabbage and Cd, Pb in tomato were found above the threshold value of 1. The NIPI indicated an extreme soil contamination by all the studied elements in samples collected around the mining generated wastelands. In the control sites only, Cu and Cd exceeded NIPI ≥ 3, indicating that even in the control sites, soils and crops are seriously contaminated by Cu and Cd, slightly contaminated by Zn and Pb and at alert level for Ni. This high level of contamination shows that sufficient attention should be given to the soils of the Copperbelt and to the crops grown in those areas. Consuming such crops may pose increased health risks to the local population.

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## 1. INTRODUCTION

Contamination of soils with heavy metals is one of the current environmental problems in the world (Gratão *et al.,* 2015). The contamination may occur due to either, industrial or natural activities that result in the deposition of heavy metals in the environment (Khan *et al.,* 2008; Zang *et al.,* 2010; Liu *et al.,* 2016). This has an effect on the food chain in that it terms to contaminate some organisms that are consumed by other organisms in the lower trophic levels.

A number of studies on leafy vegetables and fruits grown in locations close to industries and roadsides have reported elevated levels of heavy metals in their edible parts (Grant and Dobbs, 1977; Xiong, 1998;Kachenko and Singh, 2006; Yang *et al.*, 2007; Lăcătuşu, 2008; Siame *et al.,* 2016), observed that tissues of cabbage *(Brassica oleracea)*and tomato *(Lycopersicum esculentum)* accumulate significantly heavy metals such as Zn in its edible parts. According to Sawidis, (2001), the uptake and accumulation of heavy metals by plants follows two different paths, which are the root system and the foliar surface.

Evidence of soil pollution arising from presence of heavy metals associated with mining activities in the mining agro-ecosystems of Zambia's Copperbelt Province has been documented researchers working on those agro-ecosystems, among others Kříbek *et al*., (2010) and Kapungwe*et al*., (2013). However, even with documented evidence of contamination of soils on the Copperbelt province, studies on the degree of vegetables contamination by heavy metals have not yet been conducted although cultivation goes in the vicinity of the polluting facilities such as tailings dams and smelter plants. Therefore, the aim of this study was to investigate the degree of contamination and bioaccumulation of heavy metals in vegetables grown within the polluted environment of the Copperbelt province of Zambia. Additionally, the study was designed to determine the extent of pollution in sites within vicinity of potential polluting facilities.

The objectives of the study were (i) to correlate the concentrations of metals (Cu, Cd, Zn, Ni, and Pb) in soils and vegetables grown in heavy metal polluted environment and the control sites;(ii) to compare the potential pollution indices of soil of the mining areas and the control sites using Pollution index (Pi), and Nemerow Integrated Pollution index (NIPI); and (iii) to compare the Bioaccumulation factor (BAF) and Contamination Load index (CLI) between cabbage and tomato cultivated in the mining areas and those of the control sites.

## 2. MATERIAL AND METHODS

### 2.1 Description of the study area

The study was undertaken within the selected sites in Kitwe, Mufulira and Chingola districts of the Copperbelt Province (Figure 1). The sites that are close and exposed to some mines potential polluting facilities and where farmlands are allotted for growing

cabbage and tomato throughout the year were purposively selected for inclusion in the study.

The control sites were selected at approximately 25 km away any mine polluting facility. The climate of the Copperbelt Province is characterized by three distinct seasons; the warm dry season (August to October), the warm wet season (November to April) and the cold dry season (May to August) (KCC, 2010). The Province receives up to 1600 mm of rainfall annually with temperatures ranging from 18° to 28° C (Sracek, 2015).

The soils are mainly ferrasols (acric, orthic or rhodic ferrasols) (FAO-UNESCO, 1997) with the principal soil forming process in the area being rock weathering; hence, climatic factors influence the rate and depth of weathering and the soil formation.

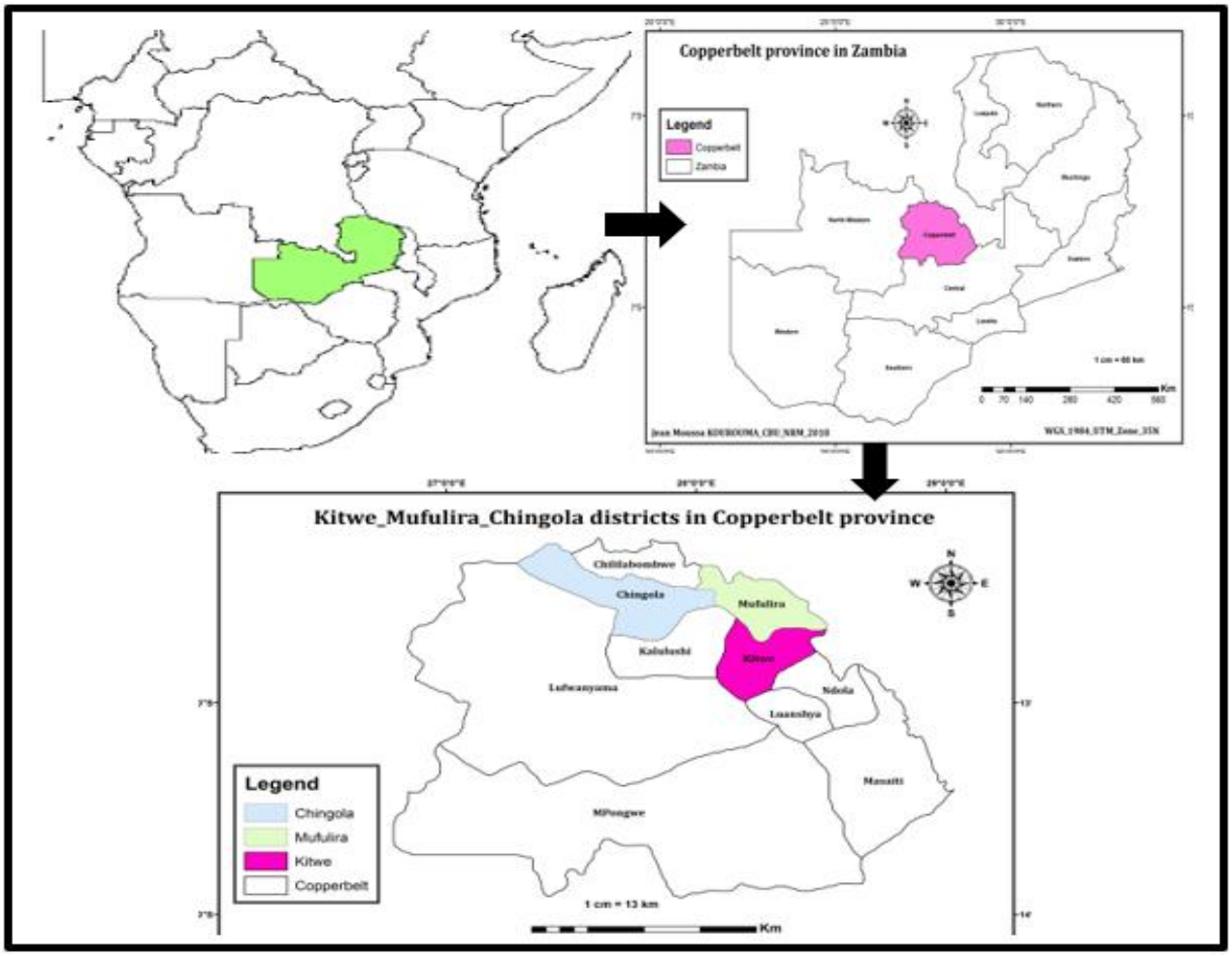



**Fig. 1 Location Map of the Study Area in Copperbelt**

## 2.2 Samples collection

The sampling sites were located within 0.5 km downstream of tailings facilities in each of the selected district. Additionally, a control site on each study site was chosen at 25 km away from theany mine polluting facility but in the area of the same geological formation as the other sampling sites. The sample plots of 400 $m^2$ were systematically established along 25 km transect. Each main plot was divided into 5 sub-plots of 9 $m^2$ from which the sample collection was undertaken. Five soil samples were collected at 0-20 cm depth from each corner and the center of each sub-plot and then mixed together in a bucket to get a composite sample. Fifteen (15) samples each of cabbage and tomato were randomly collected per sample plot. Table 1 shows the total number of samples with respective weights collected on each site.

**Table 1. Informative Table of the Sampling Design and Techniques**

| **Sampling points** | **Treatment 1** (Polluting facility) | **Treatment 2** (Control site) |
|---|---|---|
| | 0.5 km | 25 km |
| Total number of sub-plots / Field block | 15 | 15 |
| Total weight of Soil composite samples/Field block | 15 kg | 15 kg |
| Total of Tomato samples collected /Field block | 15 | 15 |
| Total of Cabbage samples collected /Field block | 15 | 15 |

## 2.3 Preparation of soils and vegetables for analysis

Samples were air-dried for several days before passing them through a 2 mm nylon sieve to remove sand and any other debris that may have been collected. These were then repacked in transparent plastic bags and 0.5 g of the powdered sample was digested. For convenience in the analysis, two different digestion procedures were employed to prepare samples for all metal analyses. Each soil sample was placed in the 250 $cm^3$ conical beakers and 30 ml of 0.5 M nitric acid was added. The mixture was stirred and heated at 200°C for 30 minutes on a hot-plate, then, 3 ml of Hydrofluoric acid (HF) was added and reheated to extract the total metal content in the soil samples. The digestion liquids were evaporated to near dryness to remove HF. The residuals were then diluted with triple distilled water and filtered through ashless Whatman filter paper No.40. The atomic Absorption Spectrophotometer (AAS) was used to measure the concentration of heavy metals in the final solutions. The heavy metals analyzed by the AAS included nickel, zinc, copper, lead and cadmium.Plant samples were washed with distilled water to eliminate air-borne pollutants and those that may have been on the surface of the plants. The samples were sliced and then air dried. Thereafter, the samples were oven-dried at 80°C for 24 hours. Each oven-dried sample was ground using a mortar until and then sieved using a 0.18 mm sieve.

The ground samples were then weighed and 2g of each sample was also placed in a clean dry 250 $cm^3$ conical flasks and then 30 ml of 0.5 M nitric acid was added. The

mixture was heated at 200°C for 30 minutes using hot-plate after which 10 ml of Perchloric acid ($HCLO_4$) was added on the plant samples to extract total metal concentration. The samples were then diluted into 100 $cm^3$ of distilled water and filtered through ashless Whatman filter paper 40. The concentration of heavy metals in the final solutions was measured by Atomic Absorption Spectrophotometer (AAS).

### 2.4 Data analysis

All the data were checked for homogeneity of variance (Levene test) and normality tests of Shapiro wilk ($p<0.05$) was applied to investigate the normal distribution of the data at a confidence level of 95%. Independent t-test was conducted to detect if there is a significant difference between the means of soil, tomato and cabbage grown within the mining area (0.5 km from the mine) and the control site (25 km away from the mine). All the analyses were performed with R (Inc., Chicago. IL, USA) and SPSS. Then each specific aspect of the collected data was analyzed separately as shown in the subsections below.

#### 2.4.1 Heavy metals accumulation assessment

The mean values for Zn, Ni, Cu, Cd and Pb concentration in the three (3) districts were used to represent the concentrations of the Copperbelt urban towns. The degree of accumulation of each metal was calculated based on Zhang *et al.*, (2015) Eq. (1) as follow:

$$A_m = C_m - B_m \qquad \text{Equ.1}$$

Where $A_m$ is the metal accumulation in province m, $C_m$ and $B_m$ are the metals concentration and background value respectively in province m.

#### 2.4.2 Nemerow integrated pollution index (NIPI)

A sub-index (NIPI) of each contaminant was calculated by comparing the measured value of each heavy metal in the soil sampling area with the evaluation standard. The integrated pollution index of Nemerow was determined in order to show the degree of contamination of soil quality and the likely impact on crops or plants growing on such soils. The Nemerow integrated pollution index was calculated using Equation 2 below:

$$NIPI = \sqrt{\left[\left(\frac{C_m sample}{B_n}\right)^2_{aver} + \left(\frac{C_m sample}{B_n}\right)^2_{max}\right]} \qquad \text{Equ.2}$$

Where NIPI is the Nemerow integrated pollution indexof the soil, $(C_m/B_n)_{aver}$ is the average value of the concentration factor and $(C_m/B_n)_{max}$ is the maximum value of the single pollution index. The soil pollution grade standard for Environmental Quality Assessment and Green Food Growing Areas compiled in 1994 was used in this study (see below table 2).

**Table 2: Classification criteria for the Comprehensive Soil assessment**

| Grade division | NIPI | Contamination level | Contamination degree |
|---|---|---|---|
| 1 | NIPI ≤ 0.7 | Safe | Clean |
| 2 | 0.7 ≤ NIPI ≤ 1 | Alert | Still clean |
| 3 | 1 < NIPI ≤ 2 | Light contamination | Soil slightly contaminated |
| 4 | 2 < NIPI ≤ 3 | Moderate contamination | Soil and crops moderately contaminated |
| 5 | NIPI > 3 | Severe contamination | Soil and crops seriously contaminated |

Pi was calculated to assess soil contamination level of heavy metals; a pollution index (Pi) of each metal was attributed to each metal using Equation 3 (Wei , *et al.*, 2015) below:

$$Pi = \frac{C_m Sample}{B_n} \qquad \text{Equ.3}$$

Where $C_m$ (mg/kg) is the concentration of each heavy metal and $B_n$ is background value for each metal (mg/kg). The higher the Pi the greater the soil contamination (Table 3).

**Table 3: Contamination categories based on Pollution index (Pi)**

| Pollution index (Pi) | Contamination level |
|---|---|
| Pi < 1 | refers to low contamination; |
| 1 ≤ Pi <3 | means moderate contamination; |
| 3 ≤ Pi≤ 6 | indicates considerable contamination |
| Pi > 6 | indicates very high contamination |

## Background value consideration

The Background values have been considered as a basis for assessment of anthropogenic pollution in many parts of the world in environmental sciences, Reimann & Garrett, (2005) defined the background value, as the concentration of an element in a sample far away enough from an eventual contaminant source. For the purpose of this study, the world soil background values ofHooda, (2010) were used as the reference concentration for the studied elementsof Copperbelt soils,Cu =25 mg/kg, Cd= 0.3 mg/kg; Zn= 70 mg/kg; Pb= 29.2 mg/kg; Ni= 75 mg/kg. This is in line with the common practice adopted by many other researchers (see Martin and Meybeck, 1979; Rath *et al.*, 2005). Several authors around the world (Hooda, 2015; Wu *et al.*, 2015) have considered average concentrations of individual metals of world surface rocks as the background values.

### 2.4.3. Bioaccumulation and Contamination determination method

Bioaccumulation Factor (BAF) and Contamination Load Index (CLI) of Wilberforce, (2015) were used to assess the degree of contamination in tomato and cabbage for the selected study sites.

### 2.4.4Bio-accumulation factor (BAF)

The BAF is used to estimate potential human health risks posed by heavy metals occurring in edible parts of the plant. It is calculated using equation (4) as follows:

$$BAF = \frac{Cplant\left(\mu g g^{-1}(edible\ parts)\right)}{Csoil\ (\mu g g^{-1})\ Concentration} \qquad \text{Equ.4}$$

Where $C_{plant}$ and $C_{soil}$ represent heavy metal concentration in edible parts of vegetables and soil, respectively.BAF of 0.1 indicates that plant is excluding the element from its tissues while the BAF of 0.2 for vegetables indicate the chances of metal contamination by anthropogenic activities and high metal uptake from soil by the edible plant(Khan, *et al.,* 2009)and so the need for environmental monitoring of the area will be required (Sponza & Karaoglu, 2002).

### 2.4.5 Contamination Load Index (CLI)

Contamination Load Index (CLI) also known as the Pollution Index (PI) is the ratio of metal concentration in a biotic or abiotic medium to that of the regulatory Standard of International bodies such as Food and Agriculture Organization (FAO), the World Health Organization (WHO) and the United States Environmental Protection Agency (USEPA) (Arain *et al.,* 2009). The following equation (5) was used determine CLI level in crops (edible parts of crops).

$$CLI = \frac{C_{crop}}{MPC} \qquad \text{Equ.5}$$

Where $C_{crop}$ is the heavy metal concentrations in the edible portion of plants and MPC is the maximum permitted concentration of heavy metal in crops (FAO, 1984).

## 3. RESULTS

### 3.1 Comparison of Heavy metals content in soils and vegetables between mining areas and control sites

The analysis also revealed significant difference in metal concentration between soil collected at 0.5 km from the polluting facilities and those collected from the control sites (Table 4).Copper has the highest concentration (1172±298.98 mg/kg) followed by Zinc (195.2±15.84 mg/kg). There is a significant difference in metal concentration between soils collected at 0.5 km from the mining areas and those collected from the control sites located at (25 km) from the mines (Table 4).

**Table 4. Heavy metal concentration (mg/Kg) in soil**

| Sampling sites | Statistical indices | Cu | Cd | Zn | Ni | Pb |
|---|---|---|---|---|---|---|
| Mining/smelting areas N=15 | Mean±Se | 1172.80±298.98 | 7.73±1.37 | 195.2±15.84 | 171.33±10.7 | 153.7±14.70 |
| | Skewness | -0.145 | 0.726 | -0.045 | -0.339 | -1.584 |
| | Kurtosis | -0.291 | -1.131 | -0.629 | -0.367 | 3.781 |
| | CV (%) | 83.4 | 92.75 | 59.5 | 50.8 | 54.8 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Control sites N=15 | Mean±Se | 109.47±7.36 | 2.00±0.00 | 38.93±3.48 | 31.53±4.232 | 28.80±2.95 |
| | Skewness | 0.669 | 0.726 | 0.593 | -2.189 | -0.975 |
| | Kurtosis | -0.807 | -1.131 | -0.932 | 5.941 | 1.162 |
| | CV (%) | 105.7 | 64.5 | 86.8 | 45.6 | 50.3 |
| | | | | | | |
| Shapiro wilk test | p-value | 0.235[a] | 0.0001** | 0.241[a] | 0.136[a] | 0.0001** |
| Independent t-test | p-value | 0.0001** | 0.001* | 0.001* | 0.007* | 0.008* |
| FAO/WHO (1984) Safe limit | | 100 | 3 | 300 | 60 | 300 |

'Two. Sided'. Conf. level=.95. * = significant at $p < 0.05$; ** = significant at $p < 0.01$; a= non-significant

**Cabbage:**In terms of heavy metal concentration in vegetables, Cu (51.4±7.63 mg/kg) had the highest concentration followed by Zn (72.2±7.95 mg/kg) in cabbage growing near mining areas compared to the control site (Table 5). Independent t-test showed significant difference between the means of all metals except for Ni and Ni ($p>0.05$) in cabbage collected from the mining areas and the control sites (Table 5).

**Table 5. Heavy metals concentration (mg/Kg) in Cabbage *(Brassica oleracea)***

| Sampling sites | Statistical indices | Cu | Cd | Zn | Ni | Pb |
|---|---|---|---|---|---|---|
| Mining/smelting areas N=15 | Mean±Se | 51.4±7.63 | 7.7±0.79 | 72.2±7.95 | 42.2±2.91 | 10.9±1.06 |
| | Skewness | 0.032 | 0.007 | 0.154 | -0.146 | -0.053 |
| | Kurtosis | 2.984 | -0.978 | 2.386 | 1.531 | 1.698 |
| | CV (%) | 67.9 | 97.5 | 44.5 | 43.3 | 184.8 |
| | Range | 23.5-146 | 2-12 | 34.5-175 | 19-56 | 0.5-18 |
| | | | | | | |
| | Mean±Se | 11.4±0.77 | 0.53±0.03 | 24.72±7.95 | 12.80±1.69 | 0.83±0.15 |
| | Skewness | 0.581 | 0.889 | 0.187 | -0.149 | 1.414 |
| | Kurtosis | 1.672 | -0.582 | -0.323 | -0.252 | 1.500 |
| | CV (%) | 39.6 | 118.2 | 41.3 | 34.2 | 80.0 |
| | Range | 2-15 | 0.5-1 | 5.35-33.5 | 4-29.5 | 0.5-2.5 |
| | | | | | | |
| Shapiro wilk test | p-value | 0.4345[a] | 0.9982[a] | 0.4345[a] | 0.447[a] | 0.5288[a] |
| Independent t-test | p-value | 0.011* | 0.0063* | 0.037* | 0.207[a] | 0.011* |

'Two. Sided'. conf. level=.95. * = significant at $p < 0.05$; a= non-significant

**Tomato:** The result showed that tomato grown near the mining areas had higher concentrations of Cd, Ni and Pb compared to the concentrations in the samples from the control sites. Independent t-test showed that the means of all metals in tomato collected from both the mining areas and the control sites were significantly different at 95% confidence level except for Zn (Table 6).

**Table 6: Heavy metals concentration (mg/Kg) in Tomato *(Lycopersicum esculentum M.)***

| Sampling sites | Statistical indices | Cu | Cd | Zn | Ni | Pb |
|---|---|---|---|---|---|---|
| Mining/ smelting areas N= 15 | Mean±Se | 25.0±1.34 | 4.7±0.56 | 39.2±4.39 | 74.2±5.34 | 18.8±1.06 |
| | Std. Deviation | 5.218 | 2.175 | 17.0 | 20.68 | 15.08 |
| | Skewness | -1.375 | -0.338 | -1.415 | -0.992 | -0.897 |
| | Kurtosis | 0.213 | -0.673 | 0.234 | 0.277 | -0301 |
| | CV (%) | 70.2 | 148.4 | 64.9 | 124.1 | 1.215 |
| | Range | 9-26 | 1-10 | 15-72 | 3-145 | 1-50 |
| | | | | | | |
| Control sites N = 15 | Mean±Se | 8.093±1.518 | 0.15±0.05 | 13.17±4.77 | 4.45± 1.05 | 2.49±0.75 |
| | Std. Deviation | 5.87 | 0.194 | 18.48 | 4.079 | 2.905 |
| | Skewness | 0.581 | 0.889 | 0.187 | -0.149 | 1.414 |
| | Kurtosis | 1.672 | -0.582 | -0.323 | -0.252 | 1.500 |
| | CV (%) | 78.8 | 164.3 | 1.404144 | 1.186 | 102.4 |
| | Range | 0.08 -23.50 | 0.01- 5.0 | 0.28 -52.0 | 0.06 56.50 | 0.02 20.0 |
| | | | | | | |
| Shapiro wilk normality test | p-value | 0.4345[a] | 0.9982[a] | 0.4345[a] | 0.447[a] | 0.5288[a] |
| Independent t-test | p-value | 0.001* | 0.013* | 0.276[a] | 0.028* | 0.004* |

'Two. Sided'. Conf. level=.95. * = significant at $p < 0.05$; a= non-significant

## 3.2 Agricultural soils degree of contamination using Pollution index (Pi)

Table 7 shows significant variation in metal concentration between control sites and the sites near polluting facilities. For example, the concentration of Cu (1172.80mg/kg) compared to the concentration (109.47 mg/kg) from the control sites. The results showed a significant difference in metal concentrations for all the heavy metals for both the mining and the control sites.

Similarly, Pi for all the elements was significantly high between sites with the one for Copper being the highest. The Pollution Index (PI)ranged from 2.28 to 46.92for the samples collected near the polluting facilities compared to the range of 0.42 to 4.37 in the control site(Table 7). The NIPI values showed the same trend as PI for both sites.

**Table 7: Heavy metals concentration (mg/Kg) soil Pollution index (Pi)**

| Heavy metals | Sampling points | Background values (mg/kg) a | Concentration (mg/kg) | | | Pollution index (Pi) | | | NIPI |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Mean | Max | Min | Mean | Max | |
| **Cu** | Mi ni | 25.0 | 418 | 1172.8 | 5160 | 16.72 | 46.92 | 206.4 | **211.66** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Cd** | | 3.0 | 2.0 | 7.73 | 22 | 6.66 | 25.76 | 73.3 | **77.72** |
| **Zn** | | 70.0 | 134 | 195.20 | 304 | 1.91 | 2.78 | 4.34 | **5.15** |
| **Pb** | | 29.2 | 68 | 153.73 | 258 | 2.32 | 6.68 | 8.83 | **11.07** |
| **Ni** | | 75.0 | 100 | 171.33 | 238 | 1.33 | 2.28 | 3.17 | **3.90** |
| | | | | | | | | | |
| **Cu** | Control sites | 25.0 | 46 | 109.47 | 162 | 1.84 | 4.37 | 6.48 | **7.81** |
| **Cd** | | 3.0 | 2.0 | 2.0 | 2.0 | 6.66 | 6.66 | 6.66 | **9.41** |
| **Zn** | | 70.0 | 22 | 38.93 | 70 | 0.31 | 0.55 | 1 | **1.14** |
| **Pb** | | 29.2 | 6 | 28.80 | 44 | 0.20 | 0.98 | 1.50 | **1.77** |
| **Ni** | | 75.0 | 4 | 31.53 | 58 | 0.05 | 0.42 | 0.77 | **0.87** |

**a**=World soil background value according to (Hooda, 2010);

### 3.3 Bioaccumulation factor (BAF) and contamination indices of tomato and cabbage

The result showed that the BAFs of heavy metals varied significantly among the selected vegetables grown at 0.5 Km downstream of the mine polluting facilities in all the study sites. The elemental Cd was observed to have highest bioaccumulation factor in cabbage (Table 8).Generally, the values obtained for all the metals except Cu and Pb in all sites in cabbage leaves and fruits were above 0.2, thus indicating anthropogenic contamination and also high metal uptake from soil by cabbage and tomato.

**Table 8: Bioaccumulation factor (BAF) of *Brassica oleracea* and *Lycopersicum esculentum***

| **Sampling points** | **Brassica oleracea L** | | | **Lycopersicum esculentum** | | |
|---|---|---|---|---|---|---|
| | **Elements** | Mean±Se | BAF-cab | Mean_Soil | Mean±Se | BAF-tom |
| Mining smelting areas (0.5 Km) | **Cu** | 51.4±7.63 | 0.04 | 1172.80±298.9 | 25.0±1.34 | 0.02 |
| | **Cd** | 7.7±0.79 | 1 | 7.7±1.37 | 4.7±0.56 | 0.61 |
| | **Zn** | 72.2±7.95 | 0.37 | 195.2±16.22 | 39.2±4.39 | 0.2 |
| | **Ni** | 42.2±2.91 | 0.24 | 171.33±11.5 | 74.2±5.34 | 0.43 |
| | **Pb** | 10.9±1.06 | 0.07 | 153.7±14.70 | 18.8±1.06 | 0.122 |
| | | | | | | |
| Control sites (25 Km) | **Cu** | 15.47±1.58 | 0.141 | 109.47±7.36 | 10.36±8.16 | 0.094 |
| | **Cd** | 1.63±0.35 | 0.815 | 2.00±0.00 | 0.56±0.16 | 0.28 |
| | **Zn** | 37.47±4.0 | 0.962 | 38.93±3.48 | 13.16±4.77 | 0.338 |
| | **Ni** | 23.27±2.06 | 0.807 | 28.80±2.95 | 14.25±4.36 | 0.494 |
| | **Pb** | 2.30±0.47 | 0.072 | 31.53±4.232 | 5.56±1.47 | 0.176 |

Table 9 shows Contamination Load Index (CLI) of vegetable samples collected from the sites located at 0.5 Km from the mining areas and from the control sites. The Contamination Load Index of vegetable samples near the polluting facility was higher than that of vegetable samples of the control sites. The samples of cabbage collected at 0.5 km from the polluting facility were observed to be contaminated by all the studied heavy metals compared to the samples from the control site where only Cd

(1.76 >1) was observed to have elevated concentration. Similarly, high CLI of Cd. Ni and Pb were observed from samples collected at 0.5 km from the polluting facility. In the control sites (25 km away from the polluting facility), the CLIof Cd and Pb in tomato were higher than the threshold limit value of 1 showing extreme contamination.

**Table 9. Contamination Load Index (CLI) of *Brassica oleracea* and *Lycopersicum esculentum***

| Sampling points | Elements | Brassica oleracea L | | | Lycopersicum esculentum | | |
|---|---|---|---|---|---|---|---|
| | | **MPC** | **CLI** | Mean±Se | **MPC** | **CLI** | Mean±Se |
| Mining areas (0.5 km) | **Cu** | 40 | 1.21 | 51.4±7.63 | 40 | 0.62 | 25.0±1.34 |
| | **Cd** | 0.3 | 25.66 | 7.7±0.79 | 0.3 | 15.6 | 4.7±0.56 |
| | **Zn** | 60 | 1.20 | 72.2±7.95 | 60 | 0.65 | 39.2±4.39 |
| | **Ni** | 20 | 2.11 | 42.2±2.91 | 20 | 3.71 | 74.2±5.34 |
| | **Pb** | 5 | 2.18 | 10.9±1.06 | 5 | 3.76 | 18.8±1.06 |
| | | | | | | | |
| Control sites (25 km) | **Cu** | 40 | 0.386 | 15.47±1.58 | 40 | 0.202 | 10.36±8.16 |
| | **Cd** | 0.3 | 5.43 | 1.63±0.35 | 0.3 | 1.86 | 0.56±0.16 |
| | **Zn** | 60 | 0.624 | 37.47±4.0 | 60 | 0.219 | 13.16±4.77 |
| | **Ni** | 20 | 1.18 | 23.27±2.06 | 20 | 0.222 | 14.25±4.36 |
| | **Pb** | 5 | 0.46 | 2.30±0.47 | 5 | 1.12 | 5.56±1.47 |

## 4. DISCUSSION

### 4.1 Comparison of heavy metal content in soils

The observation from this study about the mean concentration of heavy metals in the soil samplesindicate that the soils within the vicinity near mining areas have higher concentration of heavy metals compared to the soils in the control sites. Similar observation was also made by Cao *et al.,* (2010), in Jiangsu, China where a rice-cultivated lands within industrial zone were found contaminated by Cd and Pb.

Within the Copperbelt Province, Zambia, other studies have observed high concentration of heavy metals in soils (Kapungwe et al., 2013; Lindahl, 2014; Ncube, 2012;Kříbek *et al*.,2010).

The decrease ofthe soil contamination degree with depth has been observed. Lindahl, (2014), observed that in Copperbelt province, surface soil samples are 10 to 50 times highly contaminated with copper than the subsurface samples. Although, pollution from mining activities such as smelting activities is the major contributor to soil pollution, other sources such as, the natural pedogeochemical background of the study area and the extensive application of inorganic compounds such herbicides, insecticides, fungicides, and other agrochemicals (Murphy and Aucott, 1998; Anawar*et al.,*2003) also do contribute towards soil pollution on the Copperbelt Province. Soil contamination is often a direct or indirect of industrial activities

(McLaughlin et al., 1999). On the average, the value observed in this study is higher than the world soil background values (Hooda *et al.*,2010).

### 4.2 Comparison of Bioaccumulation Factors (BAF) and contamination load index (CLI) of vegetables grown in mining areas and non-industrialized areas

The result of this study, showed that contamination levels in cabbage and tomato are higher near industrial compared to the control sites. Similar studies on vegetables grown in area close to industrial areas have reported high levels of heavy metals through bioaccumulation from soil to roots as well as aerial uptake through leaves (Kachenko & Singh, 2006).

The analysis of cabbage collected in this study at 25 km from the mine areas was also contaminated by Cd and Ni while tomatoes collected from the same sites were contaminated by Cd and Pb.It appears that Cd transfer from soil to the edible parts of the studied crops is more rapid than the other metals. Dixit, *et al.*, (2010)observed that Cd can gradually accumulate from soil to the roots, the stems and then the leaves or fruits of plants.High concentration of Cd in vegetables have been observed in Enyigba mines, Nigeria by (Orisakwe *et al.*, 2012).

The high concentration of Ni in cabbage found in this study, may be explained by the acidity of the soils of the study area (slightly acidic). However, even though Ni has been observed to be more mobile in acidic soils, it is not known to accumulate in plants or animals nor to biomagnify up to the food chain(Raymond, *et al.*, 2011).

BAF of 0.1 indicates that plant is excluding the element from its tissues while the transfer coefficient of 0.2 for vegetables indicate the chances of metal contamination by anthropogenic activities (Khan, *et al.*, 2009), and so the need for environmental monitoring of the area will be required (Sponza & Karaoglu, 2002). Since vegetables are known to take up and accumulate trace metals from contaminated soil (Khan, *et al.*, 2009), detection in tomato fruit samples were not surprising. Higher transfer coefficients reflect relatively poor retention in soils or greater efficiency of plants to absorb metals. Low coefficients reflect the strong sorption of metals to the soil colloids.

The result of this study showed that the contamintion load index showed that cabbage grown near the polluting facility were contaminated by Cu, Cd, Zn, Ni and Pb while those from the control sites were safe from contamination. Tomatoes grown both from the mining areas and the control sites were contaminated by Cd, Pb and Ni. Similar observation was made in Zarrinshahr and Mobarakeh regions, Isfahan province in central Iran by Moradi *et al.*, (2015), who observed the CLI value of heavy metals in selected crops higher than 1.In the control sites, only Cd and Ni in cabbage, and Cd and Pb in tomato were above the threshold value (CLI>1). According to Saha & Zaman, (2013), high value of CLI (CLI>1) through consumption of vegetables is detrimental to human health.

## 5. CONCLUSION AND RECOMMENDATIONS

The result of the study showed that vegetables grown in the vicinity of an industrial area were most contaminated. This is due to high content of metals in the soil but most importantly to the use of contaminated water released from industries for irrigation. Vegetables grown from the industrial areas were also contaminated by Cadmium. Very high metal transference from soil to cabbage and tomatoes was observed which is a concern for public health particularly for urban vegetables in which the roots, stems, stalks, leaves or fruits are consumed.

By controlling industrial and vehicular pollution of water, soil and air can prevent cadmium and lead, copper, nickel and zinc contamination. Limiting the use of wastewater for irrigation and minimizing the use of sewage sludge, fertilizers and certain pesticides can help in controlling heavy metals pollution. Farmers need to be made aware of side effects associated with certain pesticides, fertilizers and irrigation water sources during cultivation. Washing of vegetables at farm should be done with clean water. Care should be taken during the transport and sale of vegetables. The results of the present study showed that consumers are at greater risk of purchasing fresh vegetables with high levels of heavy metals beyond permissible limits as defined by the FAO/WHO (2013).

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