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Public health implications of heavy metal contamination of plants growing in the lead- zinc mining area of Ishiagu, Nigeria

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Abstract

The study assessed heavy metal content of plants growing in a lead-zinc mining pit in Ishiagu, Nigeria. Random sampling, involving a lucky dip without replacement was used to select twelve plants from thirty four identified in the mining pit, using a sampling ratio of 1 in 3. Metal content of plants followed the sequence; Zn > Co >Pb> Cr >Cd. Heavy metal content of plants was higher at the study area (138.85mg/kg) than at the control (16.92mg/kg). Heavy metals were accumulated mostly in plant roots. There was no significant difference (p-value <0.05) in heavy metal content of the various plants. However, heavy metal content varied significantly with respect to site (p-value =< 0.05). The high levels of these toxic metals at the study area pose a serious threat to human and animal health. Most of the plants studied have medicinal and food values; there is a high risk of heavy metals entering the food chain thereby posing health risks. It is important that inhabitants of the mining should be educated on the health risks associated with continuous consumption of plants exposed to heavy metals.

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Introduction

Heavy metal contamination of the environment from industrial activities is a growing problem on the global scale. A large number of mining sites worldwide are however contaminated by heavy metals (Lombi *et al.*, 2001). Hutton and Symon (1986) described mining operations as the most important source of heavy metals in the environment. This is why mining is considered an environmentally degrading enterprise (Adinna *et al.*, 2008).

Heavy metal pollution in the view of Nwaugo *et al.*(2007) is higher when mining is carried out in a crude manner, and associated wastes are untreated and improperly dumped or discharged. This is typical of Nigerian mining sites.

Plants can accumulate heavy metals and other contaminants due to their ability to adapt to changing chemical properties of the environment and have been described by Kabata–Pendias and Pendias (1984) as intermediate reservoirs through which contaminants from different environmental media move to man and animals. The main sources of trace elements or heavy metals to plants according to Vousta *et al*. (1996) are soil, atmosphere and nutrient solution, from which they are taken up by roots or foliage. Plant responses to high metal accumulation in soil involve two important mechanisms, namely: accumulation and exclusion (Baker, 1981).

It has been suggested by Kabata-Pendias and Pendias (1984) and Alloway (1990) that uptake, accumulation or translocation of heavy metals in plants, are influenced by plant species, organic matter content and binding capacity.

Heavy metals are involved in biochemical reactions in plants and for this; attention is drawn to their toxicity potential. Heavy metals, particularly, non-essential metals cause stress in plants that affect and change their physiochemical status (Garg and Singla, 2011;Ozdener and Kutbay, 2011; Van Assche and Clijsters, 1990). Metals induced visible stress symptoms in plants have been described by Abou El Sadaat *et al.* (2011) and (Andraino, 2001) among others. Duruibe *et al.* (2007) identified some channels through which humans are exposed to heavy metals and the associated biotoxic effects.

In the study area,Nwaugo *et al.*(2007) and Ogbonna *et al.* 2013 among others reported high levels of heavy metals in soils in the vicinity of metal mines. Onyedike and Nwosu (2008) also reported heavy metal presence in food crops in the study area. Other studies in the area, including Onwuemesi *et al.* (2011) and Akubugwo *et al.* (2012) indicated heavy metal contamination of water sources in the study area. There is therefore a high risk of heavy metal consumption by inhabitants of the study area through dietary intake.

It is therefore necessary that such data are regularly updated to generate a reliable database to aid environmental planning and management. The study aimed at assessing heavy metal accumulation in plants growing in the Ishiagu mining area and the associated environmental health implications.

Materials and method

Study area

Ishiagu, is located between latitudes 5^{o} 52’ to 5^{o} 60’ N and longitudes 7^{o} 30’ to 7^{o} 37” E, in Ebonyi State, South Eastern Nigeria. Due to the presence of solid minerals, mining is a key economic activity in the study area. Lead and zinc mines are located at Amaonye and Ihietutu. Associated minerals that are mined here include silver, barium, nickel and kaolin.

There are a few mining leases in operation in the study. The open cast mining method is common in the study area, and mining activity is largely artisanal (Ezeand Chukwu, 2011). Mean annual rainfall in the study area ranges from 1750mm to 2000mm, mean relative humidity is 70 percent and mean annual temperature is about 27^{o}C. The vegetation type is tropical rainforest. The soil of the study area is red ferrasols (Areola, 1982) or red- brown gravelly and pale clayey soils derived from shale. Other main economic activities in the study area are rock quarrying and farming.

Sampling Procedure and Treatment

Plant Sampling

Plant samples were collectedfrom an abandoned lead-zinc pit (05.55.695 N and 007.29.909 E), where vegetation has developed on excavated semi- mature soil. The thirty four plant species identified in the abandoned pit were numbered serially. Simple random sampling method, involving a lucky dip without replacement was used to select twelve from the bag, using a sampling ratio of 1 in 3.

The twelve plants selected were, *Adiantumcaudatum, Alchorneacordifolia, Andropogontectorum, Centrosemapubescens, Chromolaenaodarata, Clotalariaretusa, Imperatacylindrica, Ipomoea asarifolia, Milletiaaboensis, Urenalobata, Vernoniaambigua* and *Vitexdoniana*.

For each of the selected plant species above, three each were again randomly uprooted from the abandoned pit to form a composite sample for analysis. Plant samples were collected in labeled, polythene bags and stored in ice packs. Before analysis, plant roots, stems and leaves were carefully removed and washed with de-ionised water to remove soil and surface dust.

Laboratory Analysis

Plant samples were dried in an oven for 48hours after washing with distilled water. The dried samples were pulverized to 4 microns and stored in black plastic containers with lids. The samples were appropriately labeled and kept away from sunlight.

Analysis was done following AOAC (2005). 1g of each plant sample was wet digested using aqua regia (1: 2vol of NHO_3, Hcl) and extracted with deionised water. The extract was aspirated into the Spectra AA 220 FS spectrophotometer after inserting lead hollow cathode lamp.Statistical analysiswas done using Minitab version 14.

Results

Heavy metal content of plants is shown in figures 1-12 At the study area, cobalt content of root ranged from 13.40mg/kg in *C.retusa* to 89.75mg/kg in *A. tectorum*. In the stem, cobalt content ranged from 2.20mg/kg in *I. cylindrica* to 78.20mg/kg in *A. cordifolia*. The lowest concentration of cobalt in leaf was in *I.cylindrica* with a value of 8.85mg/kg while the highest leaf content of cobalt was *I. asarifolia* with a value of 55.40mg/kg.

At the control, cobalt concentration in the root ranged from 0.01mg/kg to 34.65mg/kg in *A. caudatum*. In stem, it ranged from 0.01mg/kg in *C. odorata* to 36.55mg/kg in *vitex doniana*. Leaf content of cobalt ranged from 0.00 mg/kg in *C.odorata* to 39.30mg/kg in *A. caudatum*.

Lead concentration in plant roots at the study area ranged from 7.00mg/kg in *M. aboensis* to 190.85mg/kg in *A. tectorum*. In stem, lead content was lowest in *I.cylindrica* with a value of 3.50mg/kg and highest in *V. ambigua* with a value of 117.50mg/kg. *A. candatum* had the lowest leaf lead content of 3.00mg/kg while *V. ambigua* accumulated the highest amount of lead in the leaf with a concentration of 100.50mg/kg. At the control, lead concentration in roots ranged from 0.01mg/kg for all other plants to 4.50mg/kg for *M. aboensis*. *V.ambigua* had the highest concentration of lead in stem with a value of 3.00mg/kg while other plants had a value of 0.01mg/kg each. Leaf accumulation of lead was also highest in *V. ambigua* with a value of 4.50mg/kg. Leaf lead content in other plants was 0.01mg/kg.

Zinc concentration in roots ranged from 5.70mg/kg in *I.cylindrica* to 181.59mg/kg in *A. caudatum*at the study area. In stem, zinc content ranged from 43.68mg/kg in *A. caudatum* to 241.74mg/kg in *V.doniana*.The lowest zinc content in leaf was in *A. tectorum*, with a value of 26.63mg/mg while *U. lobata* had the highest zinc content for leaf with a value of 174.35mg/kg. At the control, zinc accumulation in roots ranged from 15.58mg/kg in *I. cylindrica* to 192.80mg/kg in *V. ambigua*. The lowest concentration of zinc in stem was in *V. ambigua* (21.74mg/kg) while *I. cylindrica* had the highest stem concentration of zinc (137.22mg/kg). Zinc content of leaf, ranged from 16.49mg/kg in *V. ambigua* to 186.16mg/kg in *U. lobata*.

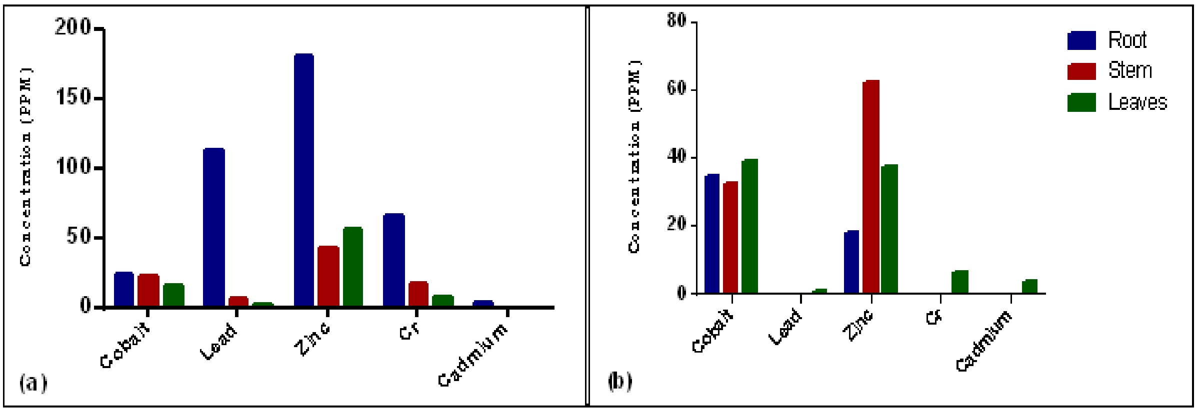

Fig. 1. Heavy metal content of *Adiantum candatum* at study area (a) and control (b).

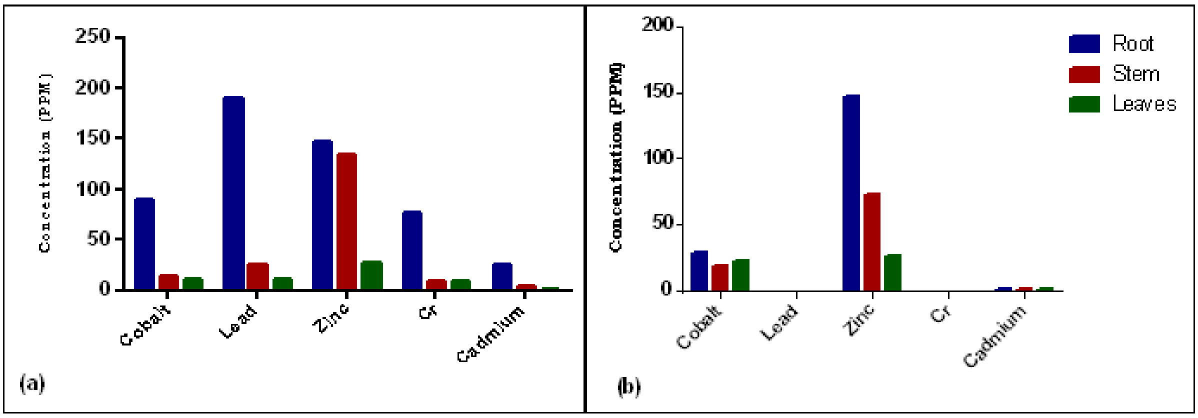

Fig. 2. Heavy metal content of *Andropogon tectorum* at study area (a) and control (b).

At the study area, chromium concentration in the root of *C. retusa* was 6.50mg/kg, while in *A. tectorum* it was 76.15mg/kg. In the stem, chromium concentration ranged from 6.25mg/kg in *I. cylindrica* to 21.85mg/kg in *C. pubescens*. *Milletia aboensis* had the lowest concentration of chromium in root with a value of 7.40mg/kg while *C. adorata* had the highest concentration of chromium in roots with a value of 19.40mg/kg. At the control, chromium concentration in root ranged from 0.00mg/kg in *A.caudatum* to 5.55mg/kg in *M.aboensis*. In the stem, it ranged from 0.01mg/kg in *A. caudatum, A.cordifolia, A.tectorum, C.pubecsens, C.retusa, I.cylindrica, I.asarifolia, U.lobata*, and *V.doniana* to 4.35mg/kg in *V.ambigua*. The range for chromium accumulation in the leaf was from 0.00 mg/kg in *A.caudatum* to 8.25mg/kg in *V.ambigua*.

Cadmium concentration in the roots at the study area ranged from 0.01mg/kg in all other plants to 170.90mg/kg in *C. pubescens*. In the stem, *V.ambigua* had the highest root concentration of cadmium with a value of 8.30mg/kg while the concentration of cadmium in stem for other plants was 0.01mg/kg. In the root, cadmium level ranged from 0.01mg/kg in other plants to 45.05mg/kg in *C.pubecens*. Cadmium concentration in the roots of plants at the control ranged from 0.01mg/kg in *A. caudatum* to 6.45mg/kg in *M.aboensis.*

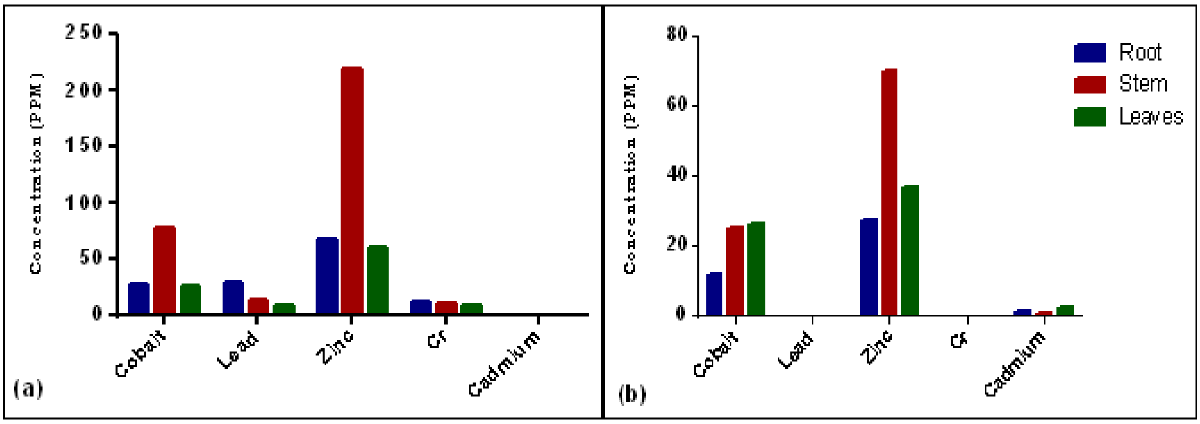

Fig. 3. Heavy metal content of *Alchornea cordifolia* at study area (a) and control (b).

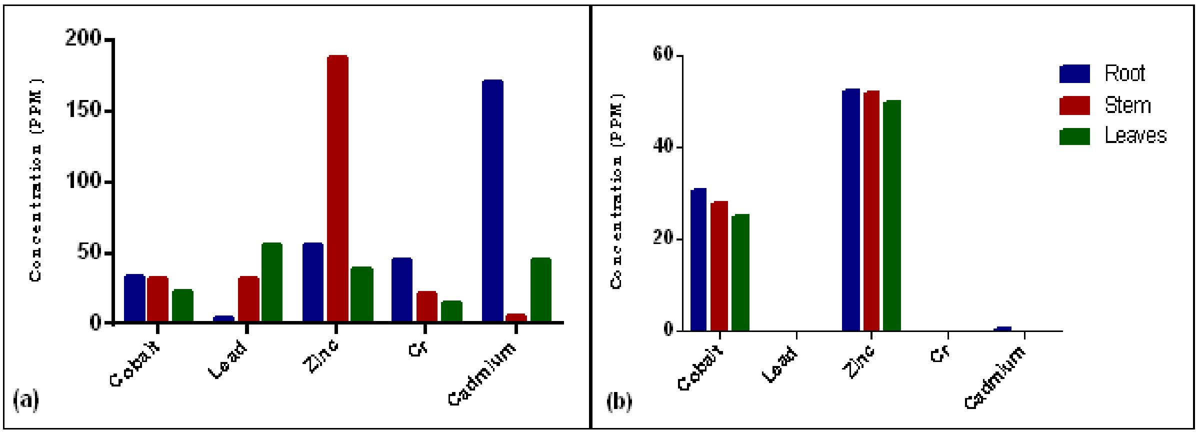

Fig. 4. Heavy metal content of *Centrocema pubescens* at study area (a) and control (b).

Cadmium accumulation in the stem ranged from 0.01mg/g in *A.caudatum* and *C.pubesens* to 6.30mg/kg in *M.aboensis*. Cadmium content in the leaf ranged from 0.00mg/kg in *V.doniana* to 8.25mg/kg in *V.ambigua*.

Total heavy metal content of plants also varied. At the study area, total cobalt content ranged from 49.15mg/kg in *I.cylindrica* to 130.4mg/kgin *A. cordifolia*. Total lead content varied from 38.00mg/kg in *U. lobata* to 36.10mg/kg in *V.ambigua* while zinc had the least total accumulation in *A. caudatum* and the highest in *C. retusa*. Zinc content ranged from 117mg/kg in *A. caudatum* to 530mg/kg in *C.retusa*. Chromium content ranged from 26.85 mg /kg in *M. aboensis* to 94.30mg/kg in *A. tectorum*. Cadmium content of plants varied from 0.03mg/kg in *M. aboensis* to 221.45 mg/kg in *C. pubescens*.

At the control, total heavy metal content of plant species also varied. Total cobalt`content ranged from 7.91 mg/kg in *I. asarifolia* to 96.15 mg/kg in *A.caudatum* while lead content varied from 0.03mg/kg in *I. cylindrica, I.asarifolia, A.tectorum A. cordifolia, C.pubescens, C. odorata C. retusa U. Iobata* and *V.doniana* to 9.50mg/kg in *V. ambigua*. Total zinc content of plants ranged from 96.12mg/kg in *V. doniana* to 394.46 mg/kg in *U.Iobata,* while total chromium content ranged from 0.03mg/kg in *A.tectorum, A. Cordifolia, C. pubescens, C. retusa, I. cylindrica, I. asarifolia, U. Iobata* and *V. doniana* to 15.80mg/kg in *V.ambigua*. Cadmium content of plants ranged from 0.52 mg/kg in *C. pubescens* to 18.30mg/kg in *M. aboensis*. There was no significant difference (p-value <0.05) in heavy metal content of the various plant species. However, heavy metal content varied significantly with respect to site (p-value< 0.05).

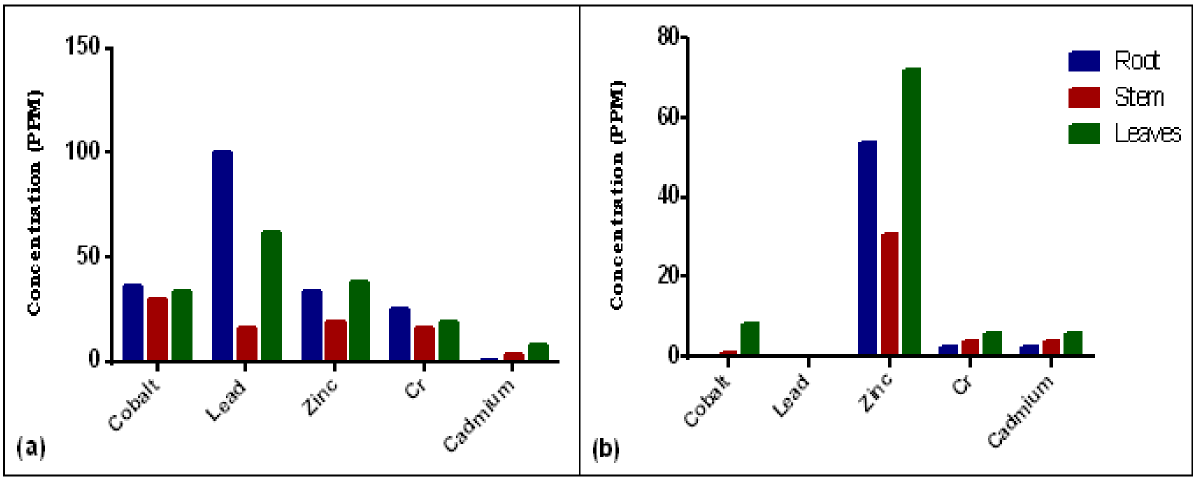

Fig. 5. Heavy metal content of *Chromolenae odorata* at study area (a) and control (b).

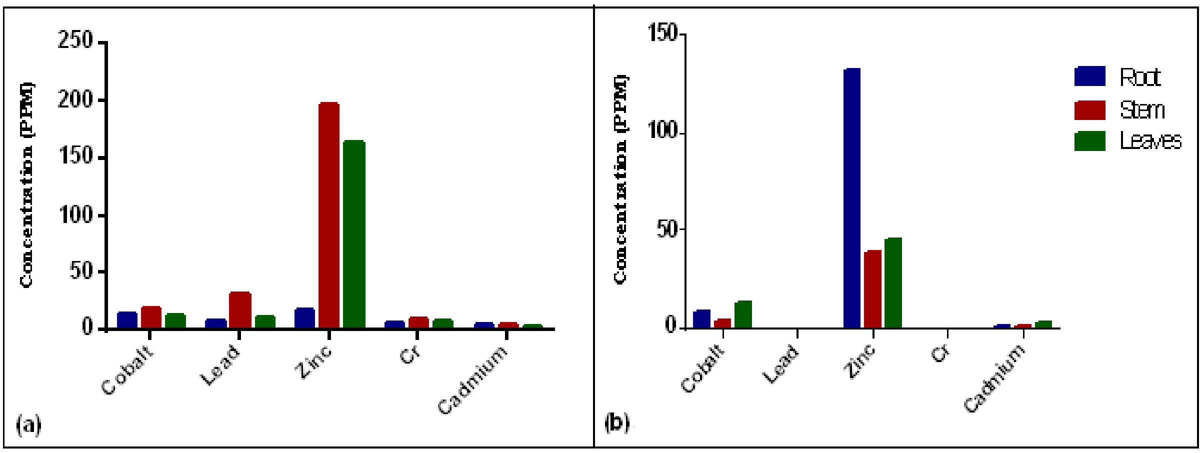

Fig. 6. Heavy metal content of *Clotalaria retusa* at study area (a) and control (b).

Discussion

Mean heavy metal content of plants was higher at the study area (138.85mg/kg) than at the control (16.92mg/kg). This agrees with the findings of other researchers including Ashraf *et al.* (2011) and Deo *et al.*(2011). Heavy metals were accumulated mostly in plant roots. Similar trend was observed by Anh *et al.* (2011), Ashraf *et al.*(2011) and Solhi *et al.*(2012).

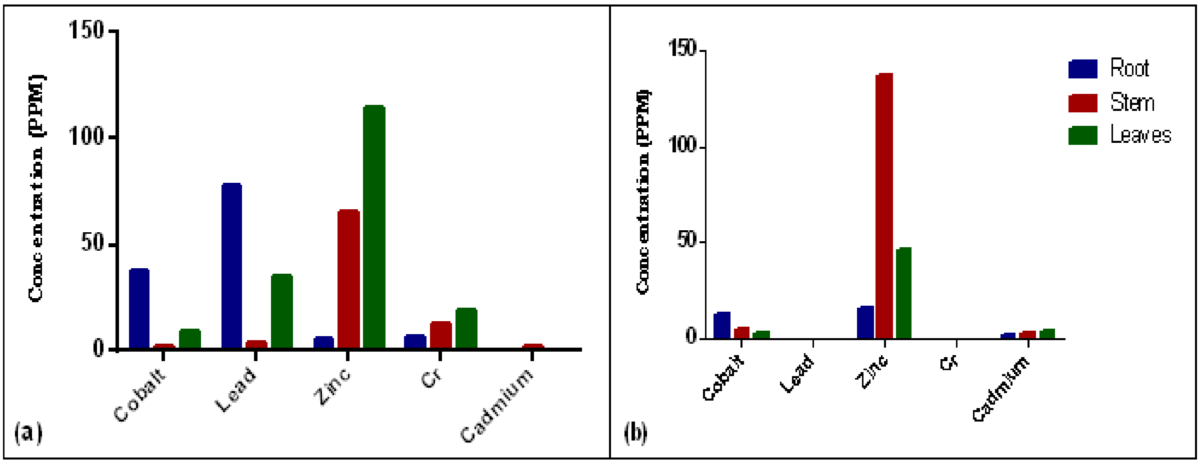

Fig. 7. Heavy metal content of *Imperata cylindrica* at study area (a) and control (b).

Metal immobilization in roots and subsequent inhibition of ion translocation may result from their complexation and sequestration in cellular such as vacuoles (Lasat, Baker and Kochian, 1998). When this occurs, translocation to shoots is hindered.Individual heavy metal concentrations were also higher than the normal value in plants as given by Kabata – Pendias and Pendias (1984). On leaving the rhizosphere, most metals are unable to move into the vascular surfaces (Raskin, 1999). Zinc, an essential plant element was the metal with the highest accumulation by all plants studied.

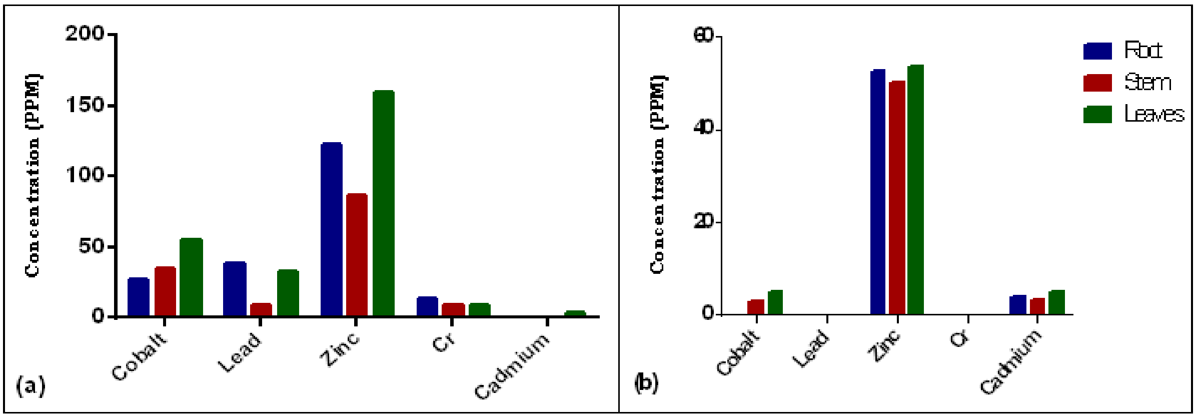

Fig. 8. Heavy metal content of *Ipomoea asarifolia* at study area (a) and control (b).

Metal content of plants followed the sequence; Zn > Co > Pb > Cr >Cd. Similar findings have been reported by Anh *et al.* (2011). In addition, it is known that plants are capable of excluding toxic metals or even detoxifying them (Salt, 1998;Ghosh and Singh, 2005).

At both study area and control, cobalt content for various plants exceeded the required range in plants 0.02-1.0mg/kg (Kabata- Pendias and Pendias, 2000) and 0.05- 5mg/kg as given by Alloway (1986).

Lead concentration in plants at the study area, exceeded those obtained by Onyedike and Nwosu (2005) in the study area, but were lower than those obtained by Kim *et al.* (2002) at Korea. They are however comparable to what was reported by Solhi *et al.* (2012) for different plants in Iran.

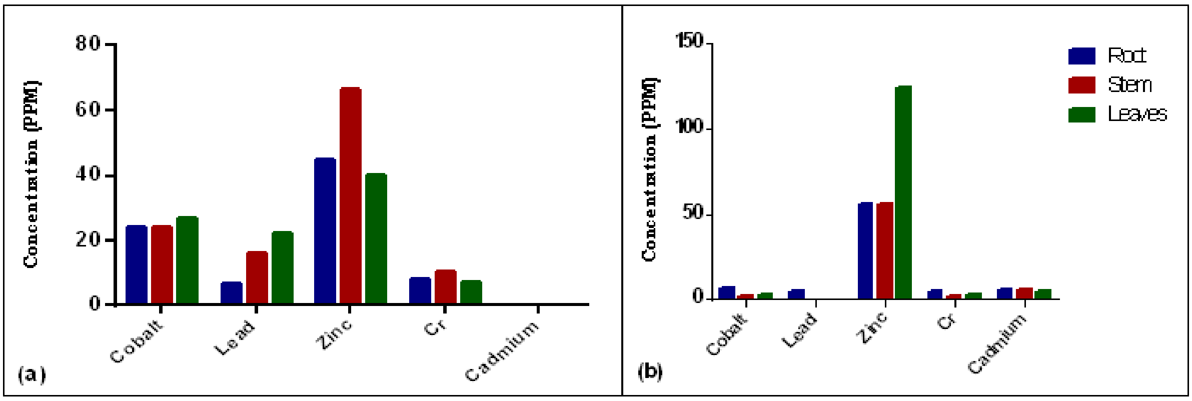

Fig. 9. Heavy metal content of *Millettiaaboensis* at study area (a) and control (b).

All plants at the study site accumulated lead above their normal range of 5-10mg/kg (Kabata – Pendias and Pendias, 2000) and 0.1-10mg/kg,Alloway (1986). On the other hand, at the control, lead content of plants was within these limits. Cadmium content of plants was above normal levels (0.05-0.2mg/kg) as given by Kabata- Pendias and Pendias (2000).

Of all the metals studied, zinc had the highest plant accumulation at both study area and at the control. This may be attributed to the fact that zinc is an essential and more bioavailable micronutrient for plants. Zinc concentration was however higher than normal value in plants (27-150mg/kg) as given by Kabata – Pendias and Pendias (1984).The values were however lower than those obtained for other plants by Solhi *et al.* (2012). Zinc is toxic to plants at concentrations above 120mg/kg (Alloway, 1986; Kabata- Pendias and Pendias, 2000). This suggests that with the exception of *A.caudatum* at the study site and *V.doniana* at the control, all other plants were prone to zinc toxicity.

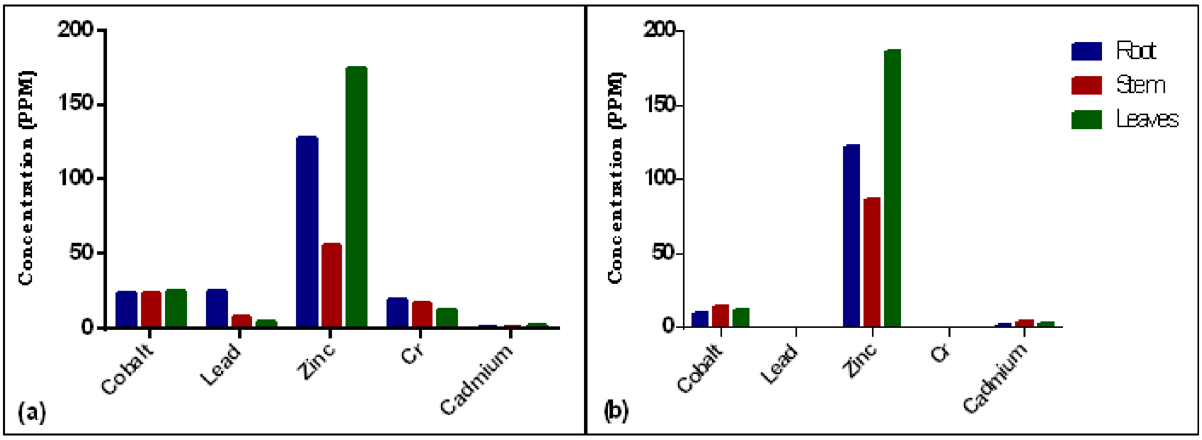

Fig. 10. Heavy metal content of *Urena lobata* at study area (a) and control (b).

Chromium concentration was also higher at the study area. However at the study site, chromium content was above the normal limits of 0.2-1.0 mg/kg Alloway (1986) and 01- 0.5mg/kg (Kabata – Pendias and Pendias, 2000). Similar trend was observed for cadmium where the values at the study area exceeded the normal range in plants of 0.2-0.85 mg/kg as given by Alloway (1986) and 0.05 – 0.2 (Kabata – Pendias and Pendias, 2000).

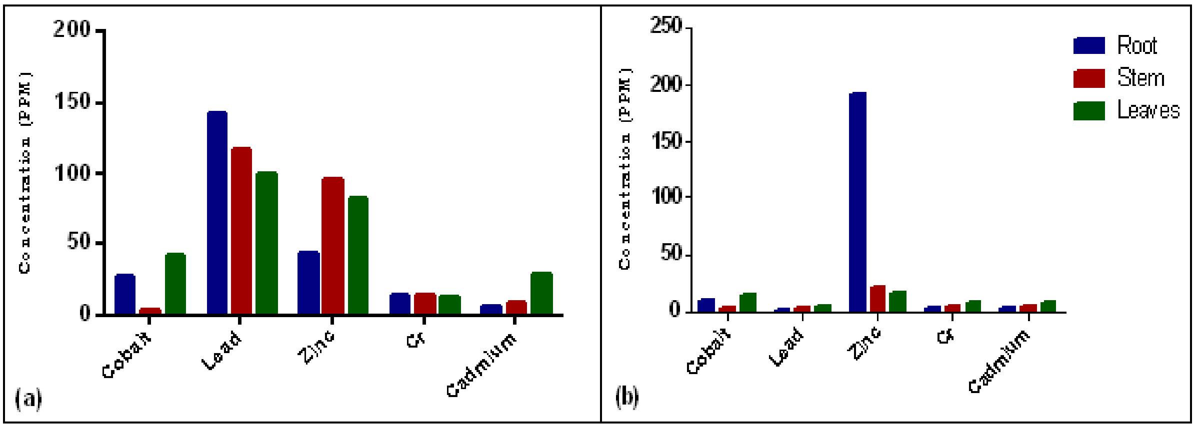

Fig. 11. Heavy metal content of *Vernonia ambigua* at study area (a) and control (b).

Generally the concentration of heavy metals in plants at the study area was higher than that of the control. This trend has also been reported by other researchers including Jung (2008) and Solhi*et al.* (2012). Heavy metals are toxic to plants and by extension other organic components the environment (Jung and Thurton, 1997; Wu and Bradford, 2003; Jung 2008). Specifically, Andriano (2001) listed symptoms of metal toxicity in plants to include necrosis, chlorosis, leaf discolouration and reduction in growth. These symptoms were observed in some plants at the study area. In addition, enzymes involved in biosynthetic activities are metal labile, and are therefore easily depotentiated in metal contaminated cellular environments (Van and Clijsters, 1990). Besides plants growing on metal contaminated soil, suffer from foliar occlusion, thereby having reduced evo-transpiration which leads to epidermal turgidity and low nutrient yields (Ogbonna *et al.*, 2013; Otuu *et al.*, 2014). Phytopotency of medicinal plants is compromised when cellular biochemistry and physiology are altered, as is the case with the formation of stable complexes of metal enzyme and metal ligand complexiometric reactions. In such situations, active excipients inherent in phytoconstituents will be deformed, destroyed or transformed into less useful and often toxic forms, thereby exposing users to a variety of ill health (Inya-Agha, 2008).

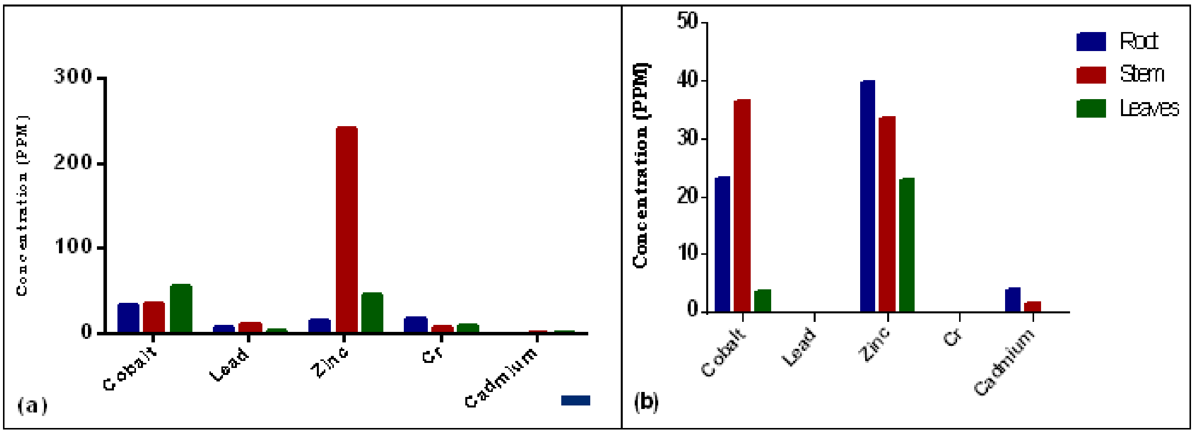

Fig. 12. Heavy metal content *Vitex doniana* at study area (a) and control (b).

The high levels of these toxic metals at the study area pose a serious threat to human and animal healthin the study area. Since most of the plants have medicinal and food (both man and wildlife) values, there is a high risk of their entering the food chain thereby posing health risks to man and animals through direct consumption. Some of the secondary plant metabolites have antimicrobial properties which have been exploited in ethnomedical practices. The attenuation of these properties will have negative consequences if such plants are continuously used in phytotheraphy. Inhabitants of the study area are therefore at a higher risk of having heavy metal related health problems as outlined by Ogwuegbu and Muhanga (2005) and Duruibe*et al.* 2007 and among others.

Conclusion

The study assessed heavy metal content of some plants growing in an abandoned mining pit in Ishiagu. Heavy metal accumulation was highest in plant roots, and was higher at the study site plants than in those of the control. This implies that plant uptake of metals was of influenced by location. The high concentration of heavy metals in study site plants has serious environmental health implications including possible transfer to humans through consumption of some of these plants. A number of these plants have food and medicinal values any may be used by inhabitants. To prevent this from happening, inhabitants should be educated on the health risks of heavy metal consumption.

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