Health Risk Assessment of Heavy Metals In Ameri Lead-Zinc Mining Community Via Consumption of Cassava (\textit{Manihot esculenta} Cruz) In Ikwo L.G.A., Ebonyi State, Nigeria

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Received 12 September 2017; Accepted 25 December 2017; Published Online 30 December 2017

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ABSTRACT

Background and Objective: In countries with rich mine deposits like Nigeria, solid mineral mining have the potential of contributing to economic development via enhancing employment opportunities and supporting national income among others. In Ebonyi State, Southeast Nigeria, solid mineral mining is next to agricultural sector in her economies. While the contributions of mining activities to the economic development of Ebonyi State vis-à-vis Nigeria is well acknowledged, the environmental and health impacts of mining on surrounding communities have been a major concern to the general public and stakeholders. The use of lands within the vicinity of mining sites as arable farmlands for the cultivation of edible food crops is increasingly worrisome. This study investigated the uptake of heavy metals by cassava food crop cultivated in farmlands within the vicinity of Ameri Pb-Zn mining site in Ikwo, Ebonyi State, Nigeria to extrapolate the associated ecological and health risks. Materials and Methods: The soil and cassava samples were obtained from farmlands in the vicinity of Ameri Pb-Zn mine site in Ikwo and a nearby farm land at Ndufu-Alike where there was no solid mineral mining in the vicinity (control site). The samples were processed and analyzed using standard protocols. Data obtained were analyzed using one way analysis of variance (ANOVA) by SPSS version 15.0 (Inc. Chicago, USA) and significant differences were established at \( P < 0.05 \) using Duncan Multiple Range Test. Results: The results showed order of metal levels in soil as \( \text{Zn} > \text{Fe} > \text{Pb} > \text{Cd} > \text{Ni} > \text{Cu} > \text{Cr} \) and in cassava as: \( \text{Zn} > \text{Fe} > \text{Pb} > \text{Cu} > \text{Cd} > \text{Ni} > \text{Cr} \). The results also indicated significantly higher (\( P < 0.05 \)) metals at mining sites compared to non-mining sites. The results showed order of metal pollution load indices (PLI): \( \text{Zn} > \text{Cd} > \text{Pb} > \text{Fe} > \text{Ni} > \text{Cr} \), soil-plant transfer factors: \( \text{Zn} > \text{Cu} > \text{Fe} > \text{Pb} > \text{Cd} > \text{Ni} > \text{Cr} \) and estimated Health Risk Indices (HRIs) for adult: \( \text{Pb} > \text{Cd} > \text{Fe} > \text{Zn} > \text{Cu} > \text{Cr} > \text{Ni} \). Although the results showed that the dietary intake of metals were within permissible limit of Food and Agricultural Organization/World Health Organization, the estimated HRIs were > 1 for Pb, Cd and Fe in adults for the cassava. Conclusions: The high values of pollution load indices for the different metals in the samples indicated anthropogenic inputs and the soil-plants transfer coefficients and the estimated HRIs > 1 for Pb, Cd, and Fe in adults for the cassava indicated increased ecological and health risks implications. Hence, the need for enacting and enforcing policies on environmental regulatory standards is urgent for optimal public health.

KEY WORDS
Health Risk, Mining, Food Crop, Pollution Load Index, Heavy Metals
INTRODUCTION

Nigeria is richly endowed with vast natural resources such as solid minerals, petroleum and natural gas that are widely distributed across the country [1]. Reports have shown that about fifty solid minerals have been discovered in about five hundred different locations spanning across all the states in the country [2]. World all over, solid mineral mining have the potential of contributing to social and economic development via enhancing employment opportunities and in many countries like Nigeria, support local consumption and national income among others [3,4]. In Ebonyi State, Southeast Nigeria, solid mineral mining is next to agricultural sector in her economies [5]. The mining of these solid minerals is without its associated wide spread problem especially in the areas of pollution [3, 5].

The pollution of the environment by heavy metals is a widespread problem all over the world. The contamination of the ecosystem by these potentially harmful elements whenever the exceeded their required threshold limits have negative effects on human health and all biota [6]. Their wide spread distribution in the environment are as a results of multiple anthropogenic activities arising from technological and industrial advancement and these have led to their rising concerns over their potential effects on human health and the environment [7]. Thus, concerted attention has been drawn on heavy metal contamination in soil, especially farmland soils around mine areas and the cultivated crops [8]. Reports have shown that in heavy metals polluted soils, the uptake of these metals from the soil by food crops is the predominant route through which such elements enter the food chain and finally become ingested by humans [6,9], leading to negative health consequences [10]. When farmland soils are contaminated, the constitutive heavy metals are taken up by plants and accumulate in their tissue [11]. The absorption of these potentially toxic elements by plants generally disrupts the physiological and biochemical processes in plant metabolism [12]. The ability of plants to accumulate high levels of metals may result from their ability to possess mechanisms that could improve their phyto-accumulation potentials and metal detoxification [13]. Such bio-accumulated metals by edible food plants may pose health risks on biota of the ecosystem [14-16].

Soils in mining areas are prone to contamination by potential harmful metals such as lead (Pb), Copper (Cu), chromium (Cr), cadmium (Cd), zinc (Zn), iron (Fe) and nickel (Ni) etc. The increasing demand for resources and viable socioeconomic enterprise required by humans for survival has led to mining and other similar activities [12,17,18]. Indiscriminate release of heavy metals into the soil and water is a worldwide major health and ecological concern since heavy metals are not biodegradable and as such tend to persist in the ecosystem [19,20]. The persistence of these metals and their accumulation in quantities quite above the threshold limits lead to toxic outcomes on flora and fauna of the affected environment [15,16,21,22]. Reports have shown that metal contamination caused by mining persists several years after the cessation of mining activities [23]. Apart from being toxic to plants and deteriorating soil optimal bio-productivity, heavy metal pollution is a severe threat to human health especially at elevated levels [5]. The three routes of human exposure to heavy metals include ingestion, inhalation and skin absorption [24]. The toxic effects of heavy metals on human health include DNA damage, skin and lung cancer caused by their mutagenic ability, neuro-toxic effects, as well as alteration of body metabolism among others [25].

Cassava (Manihot esculenta Crantz) is a leading staple food crop cultivated mainly in the tropic and sub-tropic regions of the world, over a wide range of environmental and soil conditions. It is tolerant and none labour intensive crop that produces well on marginal soils. The total estimate of the Food and Agriculture Organization of the United Nations for the world production of cassava is over 230 million metric tonnes annually [26]. Major producers of cassava include Nigeria (37.5 million tonnes), Brazil (24.5 million tonnes) and Thailand (22.0 million tonnes) per annum [26]. Reports have shown that cassava is an important component in the diets of more than 800 million people around the world [27] and is the third largest carbohydrate food source within the tropical regions, after rice and corn [28]. Barratt et al. [29] described cassava as a food security crop because it can be left in the ground for extended periods of up to two years, until required. It is used mainly as a fresh food item and various processed food and non-food products, such as starch, flour, beverages, animal feeds, biofuels and textiles. Cassava is a major staple food consumed in various processed forms in Ebonyi State, South-East, Nigeria. It is cultivated both at subsistence and commercial level.

The study area, Ameri is a community located in the southern part of Enyigba in Ikwo L.G.A., Ebonyi state, Nigeria. The community has long exploration history that can be traced back to 1940. Presently, it is one of the major mining communities in Abakaliki Pb-Zn areas of Ebonyi state. It is dominated by many illegal artisan mining activities with Royal salt mining company being the only legal registered company exploring the Pb-Zn mineral deposit in commercial quantity. Effluents from the mining pits and metal processing are channeled underground into a constructed pond and some into the tributaries of Ebonyi River which the farmers use for irrigation.

Recently, research activities have focused on the level of heavy metal contaminants of the soil and water bodies without attention to the health risk to populations imposed by the burden of these metals at the level beyond threshold limit in food crops and vegetables. This work is therefore designed to fill in this scientific gap
since it will generate baseline data on the level of heavy metals in the soil and food crop, cassava (M. esculenta Cruz) and use this to extrapolate the health risk index for populations depending on this food crop. Thus, the major aim of this work is to evaluate the potential human health risk of selected toxic metal exposure to residence in Ameri lead-zinc mining community through consumption of cassava (Manihot esculenta Cruz) food crop. The data generated will be invaluable for environmental and public health policies.

MATERIALS AND METHODS

Description of the Study Area:
The study area, Ameri Pb-Zn mine is located in Ikwo Local Government Area of Ebonyi state. This site is located at the southern part of Eyigba in Ebonyi State, South-East, Nigeria. The site lies between latitude 6˚ 27’ 5.1” N and longitude 8˚ 26’ 11”E with 21.8km² land area coverage. The topography of the area is gentle slope to plane with 59m above the sea level. The flow direction of Ebonyi river tributaries is perpendicular to the mineralization areas. Geographically the area lies within the Benue trough (lower trough, southern part). It consists of creaticoius sediments of the ASU river group [5]. Lead and zinc is the major mineral of economic quantity. The host rock is shale that is greatly fractured with a colour range between brown to dark. The gang minerals include siderite, quartz, chalcopyrite, etc. The inhabitants of Ameri are mostly farmers. They produce large amounts of edible crops and vegetables. Their farm products are not only for local consumption but also for commercial supply to other parts of the state and the country, Nigeria at large. The major food crops are cassava (M. esculenta Cruz), potatoes (Ipomea spp.), yam (Dioscorea spp.), rice (Oryza sativa) and vegetables.

Collection and Processing of Soil and Cassava Samples:
Cassava samples were collected from farmlands in mapped transect (0-2km) within the mining site and mixed to form a composite sample. The corresponding soil samples were collected from the rhizosphere of the cassava and mixed to form a composite sample. The control soil and cassava sample were collected in farmland at Federal University Ndufu-Alike Ikwo, Ebonyi State which is about 10.21km north of the mining site (where there is no record of mining activities). At each collection point, the cassava plants were uprooted to get its tubers into a clean polythene bag. Then, the soils were collected from the rhizosphere of the cassava plant up to 25cm down using small plastic shovel into a clean polythene bag. The cassava samples were properly washed with clean water to remove soil and other particles. Then they were peeled to get the edible parts that were oven-dried to constant weight. The soil samples were air-dried to remove any moisture present.

During processing of soil samples, large stones, organic particles and plant roots were removed from the soil samples and the soil was mechanically ground using clean mortar and pestle to obtain fine particles. Thereafter, the soil was sieved with < 2mm plastic mesh into a plastic container. The fine particles were mixed to homogenize and used for analysis. During processing of cassava samples, each of the samples were crushed and then ground using a clean agate mortar and pestle to obtain smaller particles and then sieved with < 2mm mesh to get powdered particles into a clean plastic container and used for analysis.

Chemical Analysis:
Determination of Heavy Metals in Soil Samples:
Exactly 1.0g of the homogenized soil sample was weighed and transferred into a beaker and 12ml of freshly prepared aqua regia (3ml HNO3 + 9ml HCl i.e. ratio of 1:3) was added. The beaker was covered and the content heated for about two hours on the medium heat of hot plate. The mixture was allowed to cool and then filtered through a Whatman no. 42 filter paper into 50ml standard volumetric flask. The filtrate was diluted to 50ml with distilled water and then used for elemental analysis with Atomic Absorption Spectrophotometer (Varian spectra AA SSB Air acetylene flame) for determination of Cd, Cu, Cr, Pb, Fe, Ni and Zn. The working standard for Atomic Absorption Spectrophotometer was prepared by dilution from the 1000ppm stock solutions according to the manufacturer’s instructions.

Determination of Heavy Metals in Cassava Samples:
Exactly 1.0g of the powdered cassava sample was weighed and transferred into a glass beaker and then, 5ml of 65% HNO3 was added. The mixture was stirred and then boiled gently over a water bath until a clear solution was obtained. Thereafter, 2.5ml of 65% HNO3 was added followed by further heating until the total digestion has been obtained. On cooling, the mixture was filtered through Whatman no. 42 filter paper. The volume was adjusted to 100ml with de-ionized water and stored in a reagent bottle for the determination of Cd, Cu, Cr, Pb, Fe, Ni and Zn using Atomic Absorption Spectrophotometer (Varian spectra AAS 5BB Air Acetylene flame). The working standard solution for each metal was prepared by dilution from the 1000ppm stock standard according to the manufacturer’s instructions.
Data analysis:

**Determination of Pollution Load Index (PLI):**

The level of soil pollution for each metal was measured using pollution load index (PLI) technique. The following equation was used to assess the PLI levels in soils.

\[ \text{PLI} = \frac{C_{\text{soil}}}{C_{\text{reference}}} \]

Where \( C_{\text{soil}} \) = the mean value of heavy metal concentration in soils from the mining areas and \( C_{\text{reference}} \) = heavy metal concentration in soil from (control) areas.

**Determination of Transfer Factor (TF):**

The concentrations of selected metal in cassava samples from soils were estimated using the plant concentration factor (PCF) also known as transfer factor (TF). This factor is the ratio of the concentration of heavy metal in plant \( (C_{\text{plant}}) \) to that of contaminated soil \( (C_{\text{soil}}) \) from the mining area.

\[ \text{PCF} = \frac{C_{\text{plant}}}{C_{\text{soil}}} \]

**Determination of Daily Intake of Metals (DIMs):**

Daily intake of metal (DIM) was estimated as:

\[ \text{DIM} = (C_{\text{metal}} \times C_{\text{factor}} \times D_{\text{food intake}} \times B_{\text{average weight}}) \]

Where \( C_{\text{metal}} \) = heavy metal concentration in plant (mg/kg); \( C_{\text{factor}} \) = conversion factor; \( D_{\text{food intake}} \) = daily intake of food (cassava) = 800g=0.8kg (33), and \( B_{\text{average weight}} \) = average body weight. The conversion factor of 0.085 (34) was used to convert fresh food crop weight while the average body weight of adult used for this study was 70kg.

**Determination of Health Risk Index (HRI):**

The health risks associated with the consumption of heavy metal contaminated edible crop by local inhabitants were assessed using the Health Risk Index (HRI). HRI is the ratio of daily intake rate of metals (DIM) to the reference oral dose of the same metal (RfD).

\[ \text{HRI} = \frac{\text{DIM}}{\text{RfD}} \]

RfD for metals include: Cd = 1.0×10^{-3}, Cu = 4.0×10^{-2}, Cr = 3.2×10^{-3}, Pb = 3.6×10^{-3}, Fe = 3.0×10^{-2}, Ni = 2.0×10^{-2}, and Zn = 3.0×10^{-1}.

**Statistical Analysis:**

Results were expressed as mean ± standard deviation of three replicates. Data obtained were analyzed using one way analysis of variance (ANOVA) with SPSS (version 15.0 Inc., USA). Figures followed by the same superscript alphabets along the same column are not statistically significant at \( P < 0.05 \) using Duncan Multiple Range Test (DMRT).

**Result:**

Table 1 showed the concentrations (mg/kg) of the selected metals in soil samples from mining and control areas. The order of the mean concentrations of the metal is Zn > Fe > Pb > Cd > Ni > Cu > Cr for mining area and Zn > Fe > Pb > Cu > Ni > Cd > Cr for control site. From the results, the mean concentrations of the metals were significantly (\( P < 0.05 \)) higher in the mining site compared to the control site. The result of the mean concentrations of the selected heavy metals (mg/100g) in the cassava samples from both the mining area and the control site are shown in Table 2. The results showed that the mean concentrations of metals in cassava samples from farmlands within the vicinity of Ameri Pb-Zn mining area were in the order: Zn > Fe > Pb > Cu > Cd > Ni > Cr and Zn > Fe > Pb > Cd > Cu > Ni > Cr in control site. The mean concentrations of the metals were significantly higher (\( P < 0.05 \)) in cassava samples from the mining area compared to those in the control site. The results for the pollution load index (PLI) of the farmland soils from the mining area were shown in Figure 1. The results showed that the soil had very high PLI value for the metals studied with values greater than unity (\( > 1 \)) except for Cu that had PLI value less than unity (\( < 1 \)). The order of PLI values were: Zn > Cd > Pb > Fe > Ni > Cr > Cu. Figure 2 shows the plant concentration factors/transfer factors (PCF) of cassava samples from the mining area for the selected heavy metals. The results showed that the soil had high PCF values for the metals studied with values greater than unity (\( > 1 \)) except for Ni and Cr that had PCF values less than unity (\( < 1 \)). The order of PCF values were: Zn > Cu > Fe > Pb > Cd > Ni > Cr. The daily intake of metals (DIMs) through the consumption of cassava from the study area and the control site are shown in Table 3. The results showed that Zn and Cr had the highest and lowest value of DIMs in both the mining area and the control site respectively. The order of DIMs in mining and control sites were: Zn > Fe > Pb > Cu > Cd > Ni > Cr. and Zn > Fe > Pb > Cd > Cu > Ni > Cr respectively. The results showed that DIMs were all below the maximum permissible limit set by WHO/FAO [36]. The Health Risk indices (HRIs) of the metals in the study area via consumption of Cassava are shown in Figure 3. The results showed that the HRI of Pb was very high compared to other metals studied in the farmlands within the vicinity of the mining sites. The HRIs in the mining and control sites were in the order:
Pb > Cd > Fe > Zn > Cu > Cr > Ni and Cd > Fe > Pb > Zn > Cr > Ni > Cu respectively. The results also showed that only Pb, Cd and Fe in the farmlands within the vicinity of Ameri Pb-Zn mining area had HRI greater than unity (> 1) while all the metals in the control site had HRI less than unity (< 1).

Table 1: Levels of heavy metals (mg/kg) in Farmlands soils within the vicinity of Ameri Pb-Zn mining area

<table>
<thead>
<tr>
<th>Metals</th>
<th>Ameri Soil (mg/kg)</th>
<th>Control Soil (mg/kg)</th>
<th>Standard (37) (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cd</td>
<td>2.83 ± 0.93</td>
<td>1.44 ± 1.10</td>
<td>3.0</td>
</tr>
<tr>
<td>Cu</td>
<td>3.39 ± 1.12</td>
<td>3.55 ± 1.43</td>
<td>40</td>
</tr>
<tr>
<td>Cr</td>
<td>1.15 ± 1.05</td>
<td>0.92 ± 0.71</td>
<td>NS</td>
</tr>
<tr>
<td>Pb</td>
<td>14.27 ± 1.94</td>
<td>5.80 ± 1.86</td>
<td>300</td>
</tr>
<tr>
<td>Fe</td>
<td>23.25 ± 2.02</td>
<td>12.91 ± 1.31</td>
<td>280</td>
</tr>
<tr>
<td>Ni</td>
<td>2.78 ± 1.21</td>
<td>1.69 ± 1.45</td>
<td>75</td>
</tr>
<tr>
<td>Zn</td>
<td>31.88 ± 1.56</td>
<td>12.76 ± 2.33</td>
<td>300</td>
</tr>
</tbody>
</table>

NS = Not Specified. Data is mean ± standard deviation (SD) of three replicates. Superscript followed by the different alphabets along the same row is statistically significant at P < 0.05 using Duncan Multiple Range test (DMRT).

Table 2: Levels of heavy metals (mg/100g DW) in cassava (M. esculenta Cruz) in Farmlands within the vicinity of Ameri Pb-Zn mining area

<table>
<thead>
<tr>
<th>Metals</th>
<th>Ameri Cassava (mg/100g DW)</th>
<th>Control Cassava (mg/100g DW)</th>
<th>Standard (36) (mg/100g DW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cd</td>
<td>0.37 ± 1.01</td>
<td>0.09 ± 0.41</td>
<td>0.20</td>
</tr>
<tr>
<td>Cu</td>
<td>0.84 ± 0.72</td>
<td>0.07 ± 0.10</td>
<td>73.30</td>
</tr>
<tr>
<td>Cr</td>
<td>0.08 ± 1.11</td>
<td>0.02 ± 0.33</td>
<td>1.0</td>
</tr>
<tr>
<td>Pb</td>
<td>2.96 ± 1.82</td>
<td>0.17 ± 1.10</td>
<td>0.3</td>
</tr>
<tr>
<td>Fe</td>
<td>7.75 ± 0.94</td>
<td>2.13 ± 0.52</td>
<td>69.3</td>
</tr>
<tr>
<td>Ni</td>
<td>0.26 ± 0.28</td>
<td>0.06 ± 0.10</td>
<td>67.9</td>
</tr>
<tr>
<td>Zn</td>
<td>15.92 ± 1.21</td>
<td>3.14 ± 1.27</td>
<td>99.40</td>
</tr>
</tbody>
</table>

Data is mean ± standard deviation (SD) of three replicates. Superscript followed by different alphabets along the same row is statistically significant at P < 0.05 using Duncan Multiple Range test (DMRT).

Table 3: Daily Intake of Metals (DIM) (mg/kg/day) via consumption of cassava (M. esculenta Cruz) in Farmlands within the vicinity of Ameri Pb-Zn mining area

<table>
<thead>
<tr>
<th>Metals</th>
<th>RfD (mg/kg/day) (USEPA, 1995; 2002)</th>
<th>Daily Intake of Metals (DIM) (mg/kg/day)</th>
<th>WHO/FAO (36)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cd</td>
<td>1 x 10^{-3}</td>
<td>0.003594</td>
<td>0.06</td>
</tr>
<tr>
<td>Cu</td>
<td>4 x 10^{-2}</td>
<td>0.00816</td>
<td>3.00</td>
</tr>
<tr>
<td>Cr</td>
<td>5 x 10^{-3}</td>
<td>0.0007771</td>
<td>0.10</td>
</tr>
<tr>
<td>Pb</td>
<td>3.5 x 10^{-3}</td>
<td>0.02875</td>
<td>0.21</td>
</tr>
<tr>
<td>Fe</td>
<td>3 x 10^{-2}</td>
<td>0.075285</td>
<td>NA</td>
</tr>
<tr>
<td>Ni</td>
<td>2 x 10^{-3}</td>
<td>0.002526</td>
<td>1.40</td>
</tr>
<tr>
<td>Zn</td>
<td>3 x 10^{-3}</td>
<td>0.154651</td>
<td>60.00</td>
</tr>
</tbody>
</table>

NA = Not Available

Fig. 1: Pollution load index (PLI) of metals in Farmlands soils within the vicinity of Ameri Pb-Zn mining area
Fig. 2: Transfer factor of cassava (M. esculenta Cruz) in Farmlands within the vicinity of Ameri Pb-Zn mining area

Fig. 3: Health Risk Index (HRI) of metals via consumption of cassava (M. esculenta Cruz) in Farmlands within the vicinity of Ameri Pb-Zn mining area

Discussion:
The results (Table 1 and 2) showed high levels of metals in soils and cassava samples from mining site compared to those of the control site. This could be attributed to higher anthropogenic input of these metals from mining activities in the study area. Also, the mean concentrations of Cd and Pb in cassava from mining area were much higher compared to the set standard of FAO/WHO [36] standard. Obasi et al. [9] have reported elevated values far above threshold limits for metals in edible food crops grown on heavy metal polluted sites. Similar results have been reported for heavy metals pollution from mining and dump sites [32,34,38,39].

Pollution load index (PLI) greater than 1 for a given heavy metal shows a significant contamination of the soil of interest with the particular metal [32]. The results in Figure 1 showed that all the metals studied except Cu had PLI values greater than 1. This indicated that the soil within the vicinity of the mining area is significantly contaminated by the metals. The high PLI for Zn and Pb is an indication of their accumulation in soil due to Pb-Zn mining activities in the study area. Similar results have been reported by Zango et al. [32], Oti et al. [5] and Zuan et al. [40]. High levels of Cd, Fe, Ni and Cr in the mining area might be attributed the pollution from blasting instruments such as car batteries and explosives used for the illegal artisan mining in the study area.
The finding by Liu et al. [30] showed that there is significant correlation between metal concentration in rhizosphere soil and the transfer factor of plants. The results of this study varied (Figure 2) because plants concentration factors/transfer factors were observed not to be dependent on the concentration of the metals in the soils. The accumulation of some of the metals in quantities higher than others suggests that they are more bio-available than other metals for the cassava uptake in the mining area within the prevailing physicochemical features of the studied sites. This is because plant uptake of heavy metals depends mainly on mobility and bio-availability as previously reported by Obasi et al. [9, 41].

Daily intake rate of metals (DIMs) can be used to assess the health risk on inhabitants through consumption of heavy metal contaminated food crops [32, 38]. The results (Table 3) showed that the DIM for all the selected metals were lower than the standard (maximum permissible value) of WHO/FAO [36] implicating that the risk may be chronic and not acute. HRI is a very useful index to evaluate the health risk index of heavy metal contaminated crops [34, 35]. If the HRI for a given metal in a food crop is greater than unity (>1), the food is considered not safe for human consumption. The estimated HRI for the cassava sample from the mining area for Pb, Cd and Fe is greater than unity (> 1). Thus, dietary consumption of cassava harvested from farmlands within the vicinity of Ameri Pb-Zn mining by the inhabitants may cause toxicological health risks for these metals. Although the DIM for these metals were below maximum threshold limit of the WHO/FAO [36], the estimated HRI for these metals implicate health risks for the cultivated cassava. Similar results have been reported for selected food crops in Ghana and China and other countries with record of mining activities [32,40,42,43].

Conclusion:
This study revealed anthropogenic input of heavy metals through mining activities to the soils within the vicinity of the active mining site in the community, Ameri. Cassava food crop obtained from the farmland in the mining vicinity contain higher levels of toxic metals which could pose serious health risks for the inhabitants or populations consuming them. Although, this study showed that the concentrations of the selected metals in soil and cassava samples from the study area were lower than the set standard of EU and WHO/FAO respectively, the mining activities in this area had resulted in pollution of the soil and contamination of the food crop. Accumulation of these metals via dietary intake occurs slowly over a long period and could pose a detrimental impact on human health as multiple toxicities of heavy metals. Further research is needed in this area to completely assess the health risks of heavy metals in this area via different farm products since the inhabitants are predominantly farmers and depend on their farm produce. Also, the need to avoid the cultivation of food crops in lands within the mining vicinity should be encouraged or properly remediation strategies adopted if mining could be prevented.

REFERENCES


