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Health Risks of Heavy Metals in selected Food Crops cultivated in Small-scale Gold-mining Areas in Wassa-Amenfi-West District of Ghana

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Abstract

An assessment of heavy metals (Pb, Cu, Zn, Ni, and Cd) in soils, Cassava (Manihot esculenta crantz) and plantain (Musa paradisiacal) was conducted in Wassa-Amenfi-West District, a small-scale gold-mining area in Ghana. Metal levels in soil samples were within the permissible limits of Indian and EU standards even though, the Pollution Load Index (PLI) revealed significant metal loading. PLI values were 26.35, 4.81, 54.18, 2.01 and 1.55 for Cd, Ni, Pb, Zn and Cu, respectively. Metals in food crops were higher than in soils, with ranges of 19.63-53.93, 19.45-142.39, 99.42-357.15, 27.01-76.21, and 1.42-5.84mg/kg for Ni, Cu, Zn, Pb and Cd, respectively. Pb, Cd, Zn and Cu in plantain exceeded FAO/WHO recommended values while in cassava, Pb, Cd and Zn exceeded recommended levels. Analysis of daily intake of metals (DIM) and health index (HRI) for cassava and plantain showed that local inhabitants were not safe and were at risk of potentially long term health effects from dietary Pb, Cd, Ni, Cu and Zn.

Keywords: Cassava, Ghana, Heavy metals, health risk, Plantain, Wassa-Amenfi-West

1. Introduction

The subject of environmental contamination with respect to toxic substances (including heavy metals) has taken the centre stage globally, in recent and current environmental research activities (Yeast and Brewers, 1983; Jarup, 2003; and Anim-Gyampo et. al., 2012). Heavy metals are found in extremely small quantities in animals and plant tissues by the consumption of food and water. Naturally, heavy metals are accumulated in the environment through the processes of weathering and dissolution while artificially; they may be introduced to the environment (soil and water) and humans during mining, agricultural and industrial activities. Once present in the soil and water, many of these metals may contaminate water, soil and entered the food chain (Wolink and Fricke, 1985) as a result of their uptake by plants as comestibles. Heavy metals are an important source of food contamination and health hazard. The main threat to human health is associated with exposure to arsenic, cadmium, lead and mercury and copper. Sources of food contamination include mining and smelting (Dudka and Adriano, 1997 and Navarro et al., 2008), environmental and industrial pollution, agricultural practices (Wcisło et al., 2002; Liu et al., 2005 and Kachenko and Singh, 2006), food processing and packaging. Absorption of heavy metals in low doses by humans over a long period of time through food has been shown to have resulted in serious health consequences, declining economic development in terms of low productivity as well as direct costs of treating illnesses. Some common health implications of heavy metals in humans include kidney disease, damage to the nervous system, diminished intellectual capacity, heart disease, gastrointestinal diseases, bone fracture, cancer and death (Jarup, 2003).Uncontrolled mining activities and illegal mining in developing countries have exposed the environment to serious hazards through the generation of enormous amount of wastes, which tend to be very toxic and impart adversely on the human health and the ecosystem (Tomov and Kouzmova, 2005). There exist concerns and question on the state of the soil and quality of food crops, fruits and vegetables cultivated and grown in areas where heavy mining and exploration are carried out. Some heavy metals such as lead, zinc and cadmium in crops are studied because they are related to environmental problems and also have accumulative properties. Traces of these metals can be found naturally in the environment where levels of concentrations had been increased through industrial activities leading to pollution (Adediran et al., 1990). In mineralized areas such as Ishiagu in Nigeria and in the western regions of Ghana, one of the major sources of lead and cadmium to the environment is from mining activities by industrial and local miners. The interactions between metals and solid phases of soil, soil water, and air within and above soil depend on a variety of chemical factors and determine the heavy metal transport and fate. Absorption of metals from soil water to soil particles is the most important chemical determinant that limits mobility in soils (Curtis et al., 2002). As a result of increasing anthropogenic activities, heavy metal pollution of soil, water, and atmosphere represents a growing environmental problem affecting food quality and human health. Heavy metals may enter the food chain as a result of their uptake by edible plants, thus, the determination of heavy metals in environmental samples is very important. Heavy metals from soil enter plants primarily through the root system. In general, plant roots are the most important site for uptake of chemicals from soil (Bell, 1992). Constant exposure to very low levels of elements such as lead (Pb), cadmium (Cd) and mercury (Hg) have been shown to have cumulative effects since there is no homeostatic mechanism which can operate to regulate their toxicity (Yeast and Brewers, 1983). The high level of heavy metals in the soil could indicate similar concentration in plant by accumulation at concentration causing serious risk to human health when consumed (Singh et al., 2010). This study assesses the concentration of some heavy metals; Lead, Cadmium, Cobalt, Copper, Antimony, Nickel and Zinc in some selected common consumed food crops: cassava (Manihot esculenta crantz) and plantain (Musa paradisiacal) Cultivated in mining communities in the Wassa-Amenfi West district of the Western Region of Ghana.

2. Materials and Methods

2.1 The Study Area

Wassa-Amenfi-West District located in the middle part of the Western Region of Ghana. It lies between latitude 5^o 30' and 6^o 15'N and longitude 1^o 45 W and 2^o 11'W with a total land area of 3,464.61 km^2. It is bounded to the west by Sefwi-Wiaso and Awowin-Suaman districts, to the south by Jomoro and Ellembele, to the south east by Prestea-Huni Valley and to the north by Bibiani-Anwiasi-Bekwai and to north-east by Wassa-Amenfi-East (Sourced on 12th March, 2013 from www.ghanadistrict.gov.gh) .The topography is generally undulating with summit averaging 153m above mean sea level. There is a good network of rivers and streams and notable among them are Tano and Anokobra rivers. The former serves as the boundary between Amenfi-West and Awowin-Suaman district, while the latter also serves as the boundary between Amenfi West and Amenfi East. The rivers serve as sources of water for irrigation purposes especially for vegetable farmers in the dry season. The area falls within two climatic regions in Ghana (Dickson and Benneh, 1980). The Semi Deciduous Forest is found in the northern part while the Tropical Rain forest, which is the wettest region of the country, is found in the southern part. The mean annual rainfall tapers off from 173mm at the south to 140mm at the north. There are two main rainfall regimes, occurring between March-July and September to early December with a short period of dry season occurring between December-February. Temperatures are generally high, ranging from 24-29^{o}C. Maximum temperatures occur in March and coolest month is August.

Geologically, the study area lies within the shield area of the West African Craton. It consists of the lower Proterozoic volcanic and the flyschoid metasediments of the Birimain Supergroup (Griffis et al., 2002). The area is associated with major gold belts in Ghana, namely, , the Sefwi and the Axim-Konongo belts (Kesse, 1985). However major part of the district is positioned on the Asankrangwa-Manso-Nkwanta belt, which is mineralized with gold, bauxite, manganese, and iron and in the transitional zone of Sefwi and the Axim-Konongo gold belts. The area has large gold reserves which require extensive exploration to prove the mineral characteristics for economic exploitation. Illegal gold mining is intensive within all the tributaries of Rivers Tano and Ankrobra. The soil types of the study area mainly Forest Ochrosols and Forest Ochrosol-Rubrisol Intergrades. The Forest Ochrosols are by far the most extensive and the most important soils within the Forest belts for both food and tree cash crop cultivation. Such soils, under natural conditions contain adequate nutrients that are tied-up with the organic layers in their topsoil and therefore, sustain good crop growth (Obeng, 2000). Major food crops cultivated are plantain, cassava, Yam, Coco-yam and maize, while major cash crops include cocoa, rubber, oil palm and citrus (MOFA, 1997).

2.2 Sample Collection

Plantain, Cassava and soil samples were taken from four small-scale mining communities (Sang, Kwabeng, Breman and Amoamang) and one non-mining community (Asankrangwa), respectively within the study area. Samples from the non-mining community were collected and analysed to provide background data as a basis of comparison to the mining areas. Four samples of plantain and cassava with their corresponding soil samples were collected in each community. The cassava and plantain samples were harvested from two farms within each community, depending on the availability of the crops. Samples of each crop collected were wrapped in calico bags and properly labelled. All the samples were stored in dried polythene bags and transported for further analysis. The samples were well labelled according to the location and also GPS coordinates were taken as well. The cassava and plantain samples were peeled and the edible parts were washed with deionised distilled water, cut into smaller pieces and air dried for a week. Soil samples were collected at 0-20 cm depth and stored in polyethylene bags for transport to laboratory.

2.3 Digestion of Soil Samples for Analysis

The soils were air-dried for 24 hours, grounded, homogenized and sieved through a 0.4µm-mesh to remove debris and sediment, and were digested after sieving according to Kouadia and Trefry (1987) method. About 2.0g of sieved soil was weighed into an acidic washed centrifuge bottle, and about 35ml of the HNO3 solution was added and the lid tightly closed and put in an end-over-end shaker and shaken vigorously for 16hrs. The sample was then centrifuged at high speed (3000 revolution for 10min). The supernatant was removed with a pipette and the filtered solution stored in a scintillation bottle for analysis.

2.4 Digestion of Plantain and Cassava Samples for Analysis

Samples of cassava and plantain were put in a crucible and then placed in a pre-heated muffle furnace at 200–250 0C for 30 min, and then ached for 4 h at 480 0C. The sample was removed from the furnace and cooled down; 2 ml of 5 M HNO3 was added and evaporated to dryness on a sand bath. The samples were then placed in a cool furnace and heated to 400 0C for 15 min, before being removed from the furnace, cooled and moistened with four drops of distilled water. The soil samples were air-dried, mechanically ground and sieved. 1g of sample was taken from the ached samples and 2 ml of concentrated HCl was added and the sample was evaporated to dryness, removed, and then 15 ml of 2 M HCl was added and the tube was again swirled. The solution was filtered through Whatman No. 42 filter paper and <0.45 ml Millipore filter paper, and then transferred quantitatively to a 100 ml volumetric flask by adding distilled water (Issac and Kerber, 1971). 2 grams of soil sample transfer into 100 ml volumetric flask. Add 10 ml of acid mixture of nitric (HNO3) and hydrochloric (HCL) acids in the ratio 3:1. Mix and swirl the content. Place the flask on a hot plate in fume-hood and heat, starting at 900C to 1800C. The mixture is heated until production of red nitrogen (IV) oxide fume cease. The content is cooled and the volume is made up with distilled water to the 100 ml mark, and filtered using NO.42 Whatman filter paper. The resulting filtrates were subsequently analysed for lead, zinc, copper, antimonite, nickel, and cadmium concentration by an air-acetylene flame atomic absorption spectrophotometer (iCE 3000 series) by the standard calibration techniques. All reagents used in the analysis were of analytical grade. Analyses were done in duplicates. In all determinations, blanks were included.

2.5 Data analysis

2.5.1 Pollution Load Index (PLI)

The degree of soil pollution for each metal was measured using the pollution load index (PLI) technique depending on soil metal concentrations. The following modified equation was used to assess the PLI level in soils;

$PLI = \frac{C_{soil\,(sample)}}{C_{reference}}$ (Liu et al., 2005),

where Csoil (sample) = the heavy metal concentration in soils from small-scale mining areas and C (reference) = heavy metal concentration in soils from non-mining (control) areas.

2.5.2 Transfer Factor

Metal concentration accumulated in food crops from soils were estimated using the Plant Concentration Factor (PCF). This factor is defined as the ratio of the concentration of heavy metal in food crop (Cplant) to that of contaminated soil (Csoil) from small-scale mining area.

$PCF = Cplant/Csoil$ (Cui et al., 2005)

2.5.3 Health Risk Assessment

The health risks associated with the consumption of heavy metals-contaminated food crops by locals were assessed using the Health Risk Index (HRI). The HRI is defined as the ratio of daily intake of metals (DIM) to the reference oral dose (RfD).

$HRI = \frac{DIM}{RfD}$ (USEPA, 2002), where Daily Intake of Metal (DIM) was estimated using the relation;

$DIM = (\mathbf{C}\text{metal } \times \mathbf{C}\text{ factor } \times \mathbf{D}\text{food intake}) \,/\, (\mathbf{B}\text{ average weight})$

Where C metal = heavy metal concentrations in plants (mg/kg); C factor = conversion factor; D food intake = daily intake of food, and B average weight = average body weight. The conversion factor of 0.085 (Singh, 2009) was used to convert fresh food crop weight to dry weight while the average body weight of adult used was 50Kg for this study. The daily maximum intake of 800g for cassava and plantain (Hayford et al., 2008) was assumed for this study.

3. Results

Table 1 shows the levels of Cd, Ni, Pb, Zn and Cu (mg/kg) in soils obtained from mining and non-mining (control) areas in the study area. The mean concentrations of all heavy metals ranged from1.025-17.46mg/kg. Lead ranged from 1.03-5.5mg/kg and cadmium ranged from 1.87-2.48mg/kg in mined soils while their values were 0.055mg/kg and 0.085mg/kg in non-mined soils, respectively. The range of various heavy metals were 7.93-17.46, 4.42-12.87 and 1.87-7.7.6mg/kg for zinc, copper and Nickel, respectively while the values were 6.765, 5.635 and 0.875mg/kg for zinc, copper and nickel, respectively. Table 2 shows the heavy metal concentrations in the selected food crops (plantain and cassava) in the study area. The concentrations in plantain ranged from 5.546-5.84, 34.85-40.45, 32.29-67.07, 169.68-357.15 and 42.91-142.39mg/kg with mean values of 5.58±0.18, 37.28±2.71, 53.95±5.89, 297.55±6.25 and 88.55±5.14 respectively for Cd, Ni, Pb, Zn and Cu while the concentrations in cassava ranged from 4.43-5.32, 26.71-53.39, 58.85-76.21, 145.71-188.86 and 24.37-63.19mg/kg with means of 4.81±0.43, 42.05±1.19, 65.01±2.75, 163.5±2.88 and 41.23±1.12 respectively. Table 3 shows the levels of heavy metals in food crops cultivated in non-mining soils while Table 4 shows the difference levels of the concentrations of heavy metals in the food crops cultivated in both mining and non-mining soils in the study area.

4. Discussions

4.1 Soils Contamination

Generally, the mean concentrations of heavy metals in soils from mining areas were higher than observed in soils from non-mining area (Fig. 1). Zinc was found to have the highest levels in soils from both mining and non-mining areas with cadmium being the lowest in soils from mining areas while lead was the lowest in soils from non-mining areas. There was a general similarity in trend of dominance metal levels in soils from both mined and non-mining areas decreasing in order of Zn>Cu>Ni>Pb>Cd while the dominance in non-mining soils were Zn>Cu>Ni>Cd>Pb (Table 1). Results from this study showed that levels of all heavy metal were generally low and within permissible limits of Indian (2000) and EU (2002) standards. However, it was observed from the analysis of the results that despite the low metal concentrations, there were significant loading or accumulation of heavy metals in soils from mining areas as indicated by the estimated pollution load index (PLI) in Table 4 above. According to Liu et al., (2005), PLI is the degree of pollution of each metal in mined soil compared to a reference value (non-mined soils). If it is greater than 1 then there is significant metal loading in the soil of interest. The indices of PLI for metals measured in this study were 26.35, 4.81, 54.18, 2.01 and 1.55 for cadmium, nickel, lead, zinc and copper respectively, with the rate of accumulation being in order of Pb > Cd > Ni > Zn > Cu. Lead has the highest PLI (54.18) while copper had the least PLI (1.55) in the soil from the mined area. The high PLI indices of metals in the soils in this study showed significant loading and an indication of heavy metals accumulation (contamination) in the soils within the areas from small-scale mining activities, which is consistent with the findings of several previous studies (Liu et al., 2005; Pruvot et al., 2006; Pastor et al., 2007; Lim et al., 2008 and Zhuang et al., 2009). Thus, small-scale mining operations in the study area had resulted in the elevation of the concentrations of heavy metals in the soil.

4.2 Heavy Metal Contamination in Food Crops

The mean concentrations (in mg/kg dry wt.) of heavy metals (Cd, Ni, Pb, Zn and Cu) in the selected food crops (plantain and cassava) in the study area were all higher than values obtained in their respective soils (both mining and non-mining soils) as shown in Table 1, 2 & 3, giving an indication of heavy metal accumulation in food crops. The elevated metal concentrations in the food crops may have been enhanced by the observed increase in heavy metal levels due to mining activities as can be deduced from the analysis of the pollution load index (PLI) of soils from mining areas with respect to those sampled from non-mining areas (control) in Table 4. The PLIs of all the metals were greater than 1 indicating a significant accumulation of metals in soils in the mining areas. With the exception of Nickel, the mean concentrations of all the heavy metals measured in plantain (Fig.2) cultivated in the mining areas exceeded the recommended levels of FAO/WHO (2007) while in the case of cassava, cadmium, lead and zinc far exceeded the recommended levels. Studies shown that food crops cultivated on soils found in mining areas could be contaminated with heavy metals and therefore could expose consumers of such food to serious health hazards (Liu et al., 2005; Pruvot et al., 2006 and Zhuang et al., 2009). The results obtained from this study showed that cadmium, lead, zinc and copper in plantain exceeded the standard permitted by the Joint FAO/WHO Expert Committee on Food Additives and Food and Nutrition Board (2007) by 96.4, 99.4, 64.4 and 17.1% respectively, while in cassava cadmium, lead and zinc exceeded FAO/WHO (2007) standard by 95.8, 99.3 and 39.2% respectively. Thus, Cd and Pb represent the major sources of heavy metal contamination in the selected food crops in the communities in the study area with Zn and Cu representing minor contaminants, and this correlates with the findings of Xu et al., (2012).

4.3 Heavy Metal Transfer from Soils to Food Crops

Generally, as a result of acid mine drainage, chemicals entering the water system, subsequently, enter the soil. The soil absorbs part of the chemicals which, subsequently, become part of the photosynthetic processes. It was therefore expected that the concentrations of metals in the cassava and plantain would reflect the concentrations in the soil samples. According to Liu et al. (2005), there is significant correlation between metal concentrations in rhizosphere soils and grown crops. However, the results of this study showed otherwise. The correlation between metal contents measured in soils vis-à-vis grown food crops was found to be quite varied and insignificant. The concentrations of metals in soils were in the order of Zn>Cu>Ni>Cd>Pb while the order in plantain and cassava crops was Zn>Cu>Pb>Ni>Cd and Zn>Pb>Ni>Cu>Cd respectively. However, the analysis of the Pollution Load Index (PLI) on soils in this study showed a substantial variation in the order of the PLI and accumulated metal concentrations in food crops. The order of metals with respect to PLI was Pb>Cd>Ni>Zn>Cu while the order of metals accumulation in plantain and cassava were Zn>Pb>Cu>Ni>Cd and Pb>Zn>Ni>Cu>Cd respectively. This is consistent with conclusions of Sipter et al. (2008) that concentrations coefficients of Cd, Pb, Zn and As in soils varied substantially with the concentrations found in vegetables cultivated on the soils in mining areas. Zinc and lead were found to be the most accumulated in both plantain and cassava with cadmium being the least. This implies that the local inhabitants were at high risk of being exposed to lead and cadmium-related health diseases. It was further observed that cadmium which was the second most accumulated heavy metal in the soils was the least absorbed in the food crops while zinc which was the second least accumulated in the soil is amongst the most absorbed metal by the two food crops. Lead which is the highest accumulated metal in the soils is also easily absorbed by the two food crops (Tables 1 and 4).

4.4 Health Risk Assessment for Local Inhabitants

To assess the health risk of inhabitants of these crops in the study area, the daily intake rates of metal (DIM) and the health risk index were estimated. It was observed in this study (Table 5) that the daily intake rates of all the heavy metals (lead, copper, zinc, nickel and cadmium) in the food crops (plantain and cassava) are at levels which were higher than permitted by FAO/WHO (2007). Thus, the inhabitants in the study area were likely to be exposed to sicknesses from excess intake of Cd, Cu, Ni, Pb and Zn in cassava and plantain. The HRI has been recognized as a very useful index to evaluate the health risk associated with the consumption of heavy metal-contaminated food crops (USEPA, 2002; Cui et al., 2004 and Wang et al., 2005). If the index of a particular crop is less than 1, it is considered to be safe for human health to consume such food. But if the index is greater than 1, it is considered as not safe for human health (USEPA, 2002). The estimated HRI in this study for plantain and cassava far exceeded 1. Their values ranged from 8.58-149.06 and 3.89-169.36 respectively. Cassava, being a tuber food crop had higher index compared to plantain, which is a rhizome food crop. Pb had the highest HRI index, ranging from 71.8-149.1 and 130.8-169.4 in plantain and cassava respectively, followed by Cd with a range of 43.7-46.7 and 35.4-42.6 in cassava and plantain respectively. The order of dominance of HRI index for the metal is Pb>Cd>Ni>Cu>Zn. This clearly shows that the local inhabitants are most likely to be exposed to potential health risk from dietary Pb, Cd, Ni, Cu and Zn.

5. Conclusion

The selected Food crop (plantain and cassava) are the staple food for the inhabitants of the study area (Wassa-Amenfi District) and greater part of especially middle and southern parts of Ghana. It is in these areas that both large-scale and small-scale mining activities are carried out in Ghana. Even though, the concentration of heavy metals in soils from the small-scale mining area where the study was conducted was quite low and within permissible limits proposed by Indian and EU standards. The activities of small-scale miners had resulted in heavy metal loading or contamination as observed from the estimated PLIs. Analysis of metal transfers (transfer factors) had shown that there had been high accumulation of heavy metals in the selected food crops, the concentrations of some of which (Pb, Cd and Zn) far exceeded the recommended tolerable levels proposed by

FAO/WHO. Variation in the heavy metal concentrations in the two food crops is a reflection of the differences between the uptake capabilities and their translocation to the edible portions of the plants. The assessment of HRI and DIM has shown that cassava is more contaminated with heavy metals than plantain. The study further shows that the inhabitants were not safe and at risk of being exposed to long term health effects from dietary Pb, Cd, Ni, Cu and Zn and this is of public health importance. It is recommended that people is living in this area and other areas of similar mining activities in southern Ghana be encouraged not to consume large quantities of these food crops, so as to minimise or avoid excessive accumulation of heavy metals in their bodies. Heavy metal accumulation through dietary intake of food generally occurs slowly and over a long period of time (years) and could have a detrimental impact on human health. It is therefore also recommended that urgent attention is needed to devise and implement appropriate means of monitoring heavy metal concentrations in food crops grown in mining areas to prevent their excessive build-up in the food chain.

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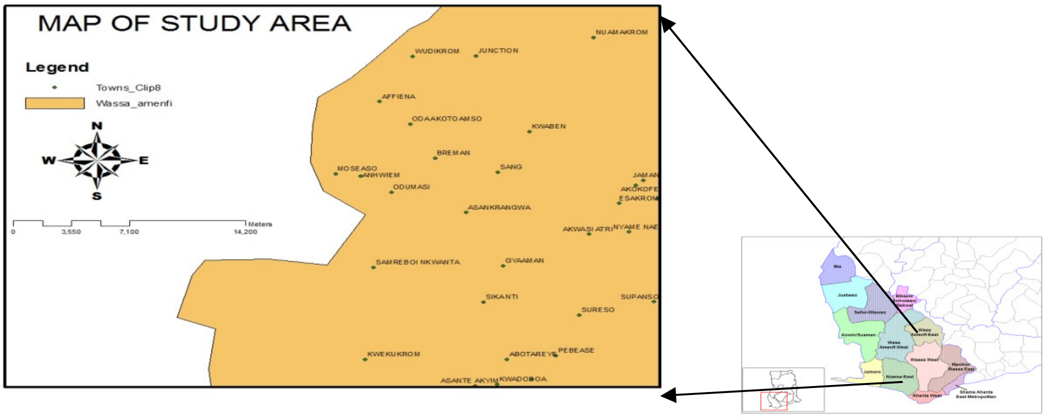

Figure 1: Map of Ghana showing the Study Area

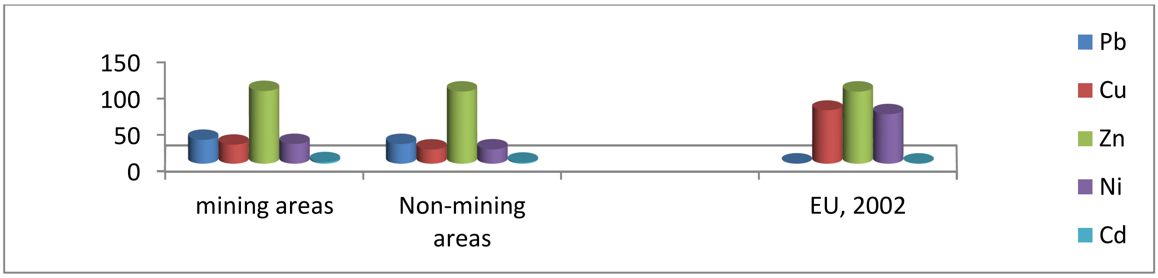

Figure 2: Comparison of heavy metal concentrations is soils in the study area.

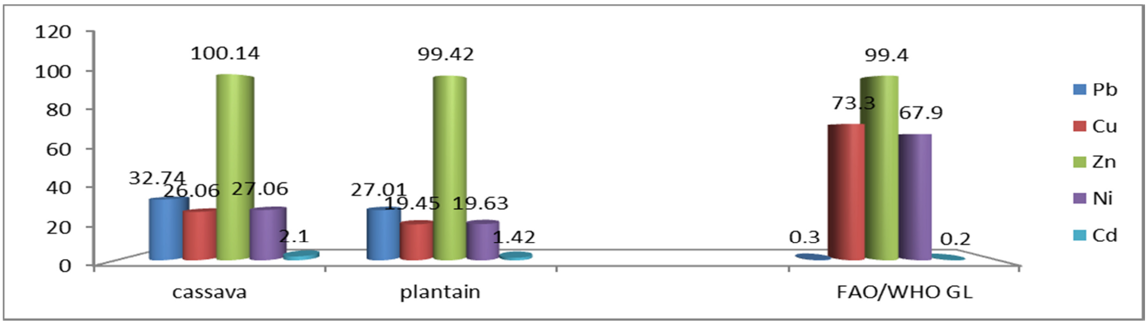

Figure 3: Mean concentrations of heavy metal in the selected food crops in mining areas.

Table 1: Heavy metals concentrations in soil from mining and non-mining area

Community	**Heavy metal concentration in soil samples (mg/kg Dry wt.)**					**Remarks**
	Cd	**Ni**	**Pb**	**Zn**	**Cu**	
Amoamang	1.865	1.865	5.500	7.925	12.470	Mining areas
Breman	2.375	7.600	1.025	12.135	4.420	
Kwabeng	2.245	4.885	1.485	17.460	5.310	
Sang	2.480	3.900	3.900	16.795	12.870	
Range	1.87-2.48	1.87-7.60	1.03-5.50	7.93-17.46	4.42-12.87	
Mean	2.240±0.270	4.210±2.610	2.980±2.100	13.580±4.450	8.770±4.520	
Asankrangwa (control)	0.085	0.875	0.055	6.765	5.635	Non-mining area
Guidelines	**3-6**	**75-150**	**250-500**	**300-600**	**135-270**	**(Awashthi) Indian, (2000)**
	3.0	**75**	**300**	**300**	**140**	**EU, (2002)**

Table 2: Heavy metals concentrations in selected foodstuffs in mining areas in the study area

Community	**Foodstuff**	**Metal concentration in Plantain (mg/kg Dry wt.)**				
		Cd	**Ni**	**Pb**	**Zn**	**Cu**
Amoamang	**Plantain**	5.46	40.45	32.29	338.11	142.39
Breman		5.46	38.61	67.07	169.68	46.83
Kwabeng		5.56	35.22	64.54	325.27	122.05
Sang		5.84	34.85	51.91	357.15	42.91
Range		5.46-5.84	34.85-40.45	32.29-67.07	169.68-357.15	42.91-142.39
Mean		5.58±0.18	37.28±2.71	53.95±5.89	297.55±6.25	88.55±5.14
FAO/WHO, (2007)	**Guideline**	**0.20**	**67.90**	**0.30**	**99.40**	**73.30**
Amoamang	**Cassava**	5.32	26.71	58.85	166.07	24.37
Breman		5.02	53.39	63.95	188.86	38.46
Kwabeng		4.43	42.62	76.21	153.36	38.88
Sang		4.48	45.46	61.03	145.71	63.19
Range		4.43-5.32	26.71-53.39	58.85-76.21	145.71-188.86	24.37-63.19
Mean		4.81±0.43	42.05±1.19	65.01±2.75	163.50±2.88	41.23±1.12
FAO/WHO, (2007)	**Guideline**	**0.20**	**67.90**	**0.30**	**99.40**	**73.30**

Table 3: Heavy metals concentrations in selected foodstuffs in non-mining areas

Community	Foodstuff	Heavy metal concentrations (mg/kg Dry wt.)				
		Cd	Ni	Pb	Zn	Cu
Asankrangwa	Plantain	2.10	27.06	32.74	100.14	26.06
	Cassava	1.42	19.63	27.01	99.42	19.45
FAO/WHO, (2007)	**Guideline**	**0.20**	**67.90**	**0.30**	**99.40**	**73.30**

Table 4: Transfer Factors and Pollution Load Index of heavy metals in food crops and soils in mining areas

Food crop	Transfer factors				
	Cd	Ni	Pb	Zn	Cu
$Plantain/soil_{(mined)}$	2.49	8.85	18.10	21.91	10.09
$Cassava/soil_{(mined)}$	2.14	9.98	21.81	12.03	4.70
Soil	**PLI**				
	Cd	**Ni**	**Pb**	**Zn**	**Cu**
$Soil_{\ (mined)}$	26.35	4.81	54.18	2.01	1.55

Table 5: Daily intake of metals (mg/kg) for individual heavy metals in foodstuff cultivated in mining areas

Community	Heavy Metal	Mean Conc. (mg/kg)		DIM (mg/kg/day)		TDI (mg/kg/day)	HRI		Remarks
		CAS.	PLA.	CAS.	PLA.		CAS.	PLA.	
Amoamang	Pb	58.85	32.29	0.4708	0.2383	**0.0036**	130.8	71.8	Not Safe
	Cu	24.37	142.39	0.1950	1.1391	**0.04**	4.9	28.5	
	Zn	166.07	338.11	1.3286	2.7049	**0.3**	4.4	9.0	
	Ni	26.71	40.45	0.2137	0.3236	**0.02**	10.7	16.2	
	Cd	5.32	5.46	0.0426	0.437	**0.001**	42.6	43.7	
Breman	Pb	63.95	67.07	38.46	46.83	**0.0036**	142.1	149.1	Not Safe
	Cu	38.46	46.83	0.3077	0.3746	**0.04**	7.7	9.4	
	Zn	188.86	169.68	1.5109	1.3574	**0.3**	5.04	4.5	
	Ni	53.39	38.61	0.4271	0.3089	**0.02**	21.4	15.5	
	Cd	5.02	5.46	0.0402	0.0437	**0.001**	40.2	43.7	
Kwabeng	Pb	76.21	64.54	0.6097	0.5163	**0.0036**	169.4	143.4	Not Safe
	Cu	38.88	122.05	0.3110	0.9764	**0.04**	7.8	24.4	
	Zn	153.36	325.27	1.2269	2.6022	**0.3**	4.1	8.7	
	Ni	42.62	35.22	0.341	0.2818	**0.02**	17.1	14.1	
	Cd	4.43	5.56	0.0354	0.0445	**0.001**	35.4	44.5	
Sang	Pb	61.03	51.91	0.4882	0.4153	**0.0036**	135.6	115.4	Not Safe
	Cu	63.19	42.91	0.3055	0.3432	**0.04**	12.6	8.6	
	Zn	145.71	1.1657	1.1657	2.8572	**0.3**	3.9	9.5	
	Ni	45.46	34.85	0.3657	0.2788	**0.02**	18.2	13.9	
	Cd	4.48	5.84	0.0358	0.0467	**0.001**	35.8	46.7	

*CAS = cassava, +PLA= plantain