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HEAVY METAL CONTAMINATION IN VEGETABLE PARTS AND SOIL OF CULTIVATED *CAPSICUM ANNUM* AND *ABELMOSCHUS ESCULENTUS*

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ABSTRACT

Vegetables are highly recommended in human diets due to the fiber and health benefits they present. Thus, contamination from any source particularly from tailing dams impounded with heavy metals raises public health concerns. The levels of heavy metals (As, Cd, Pb, Cu, and Fe) in *Abelmoschus esculentus* (okra) and *Capsicum annuum* (pepper) grown in the Asutifi District around a mining concession were investigated to determine their levels in soil samples, the fruits, stem, and roots cultivated in four farms using AAS. The mean differences in the level of metals in the fruits, roots, stems, and the sampled soils were separated using Tukey's B multiple comparison test (p<0.05). The levels of Cd, Pb, Cu, and Fe in the fruits of vegetables from the farms were within the recommended FAO/WHO standards (mg/kg) except for As. The order of increase in levels of the heavy metals in the fruits of vegetables from all farms was: F4Ca<F4Ae<F2Ca<F1Ca<F3Ae<F2Ae<F1Ae<F3Ca. The levels of the heavy metals were higher in farms 1 and 2 which were 1 km to a TSF than in farms 3 and 4 at 10 km to the storage facility. Therefore, continuous monitoring and assessment of As levels in the area are highly recommended.

KEY WORDS : Vegetables, Tailings facility, Heavy metals, Atomic Absorption Spectrometer (AAS), Health

INTRODUCTION

Food availability is a matter of concern globally in ensuring food security. However, major threats from mining activities over the world especially in Ghana are depriving people of safe, nutritious, and wholesome meals for a healthy and active life. Okra, pepper, cabbage, and tomato are among the popular vegetables which are cultivated and consumed daily by many people in Western Africa and Ghana is no exception. The vegetable is an herbaceous (Mensah *et al*., 2008) plant whose part or whole (fruits, seeds, roots, tubers, bulbs, stems, leaves, or flowers) is consumed as food (Zhuang *et al*., 2009). Agriculture and the food-producing industry have been the backbone of Ghana's economy for decades. The livelihoods of many rural and urban dwellers have solely depended on vegetable cultivation because vegetables can easily be grown in backyard gardens.

The benefit of mining activities in the Asutifi District has been keenly contested by locals over concerns about the recent dwindling in agricultural yield. A report by Ocansey (2013) pointed out that, the new mining operations in developing countries is as an act of "mining ourselves out of existence" because the largely uncovered tailings are depriving us of clean water, and clean air due to dust pollution, and food for our survival. Mine sites are part of the spheres from which heavy metals are emanated (Singh, 2012). Leachate from tailings dams and erosion of waste dumps in mine sites are major sources of heavy metals pollution. Heavy metals have the potential to bio-accumulate in plants (Singh, 2012) or animals, bind to, and render vital organs dysfunctional, and can also grow long-term persistence in the environment due to human interference in the earth's biogeochemical cycle. A study report by Chagomoka *et al*. (2015) showed that there is about 16 % low dietary diversity among rural households; a phenomenon that needs to be investigated.

Pollution of plant foods from heavy metals especially vegetables is an undesirable phenomenon that needs to be addressed by stakeholders. Adekunle *et al*. (2009) revealed the vulnerability of fruits and leafy vegetables to heavy metals from heavy metal contaminated soils, wastewater, and air pollution. Das *et al*. (1997) reported in a study that Cd interferes with the absorption, transport, and utilization of important plant nutrients (Ca, Mg, P, and K) and water by plants. Heavy metals impoundments in agricultural soils not only result in contamination but also affect food quality and safety. Antonious and Kochhar, (2009) advise frequent monitoring of food quality due to plants' potential to accumulate heavy metals from mine leachates. One of the means through which heavy metals enter the human system is the ingestion of vegetables containing heavy metals. Once entered, they are deposited in the bone and fat tissues, overlying essential minerals. Heavy metals can cause several diseases in the body of organisms either plants or animals. Arsenic, Mercury, and Lead have been reported to cause stagnant growth in plants and animals (Nagajyoti *et al*., 2010).

Ahafo Mines is located in the Asutifi North District, although contributes immensely to the gross domestic product of Ghana; this achievement is attained at the expense of great stress imposed on soil, water and farm produce (Afia, 2012; Asante and Ntow, 2009). The emerging trend of both legal and illegal mining activities in Ghana and their associated negative impacts on land and water has become significant to levels that need urgent attention. The impact of metal-contaminated fertile lands in the Asutifi area, and the set purpose of these lands for cultivating crops necessitate the need to examine the different levels of the heavy metal accumulation and distribution in the various plant parts (fruits, stem, and roots) of okra and pepper cultivated by farmers around Newmont mine concession in the Asutifi District of the Brong Ahafo region.

MATERIALS AND METHODS

Study and sampling site

Asutifi District is located between latitudes 6°40′ and 7°15′ North and Longitudes 2°15′ and 2°45′ West of Brong Ahafo region in Ghana. The total land area of this district is about 1500 sq. km, being the smallest district in the Brong Ahafo Region. Kenyasi I, Kenyasi II, Ntotroso, Acherensua, and Hwidiem are amongst the major towns within the district; with Kenyasi I as the district capital. The predominant soil type in the district is the Forest Ochrosols which are reddish-brown and well-drained. The total settlement in the district is recorded to be over 117 (Ghana Statistical Service, 2010). The district is situated in the Moist Semi-Deciduous Forest Belt and the nature of the land is characteristically water-logged. The district is endowed with forest reserves which include Asukese, Bia Tam, and Desiri Forest Reserves. River bodies in the district include Konkontre, Subin, Goa, and Subri rivers (Dauda *et al*., 2013). Two rainfall patterns are experienced annually in the Asutifi district which lies within the wet semi-equatorial zone. The first rainy season is from April to July (maximum) and the second rainy season is from September to October (minimum) when the district comes under the influence of the wet maritime air mass.

The mean annual rainfall is between 125 cm and 200 cm. The highest point of the physiographic of the district is about 700 feet above sea level (Ghana Statistical Service, 2014). Most of the people in this area are peasant farmers who cultivate food crops such as cassava, plantain, pepper, okra, and other cash crops such as cocoa. These are made available in the district as almost all soil type supports the production of these crops. From a central Tailings Storage Facility within the mine concession, samples of vegetables (okra and pepper) were collected from two community farms of Dokyikrom and Manushed which were 1 km from the storage facility. Control samples were collected from 10 km away from the storage facility from two community farms of Atronie and Hwidiem (Fig. 1).

Vegetables and soil sampling

Soil sampling

Soil samples (5 g) were collected from the rhizosphere, from each harvested vegetable. In all, soils from the 2 sampled vegetables (pepper and

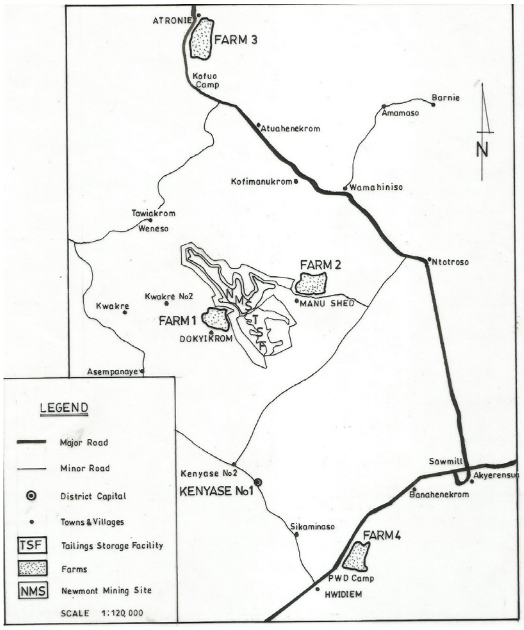

Fig. 1. Map showing sampling sites

okra) were collected in triplicates from all 4 farms. A total of 24 soil samples were taken for heavy metals analysis

Vegetable sampling

A farm within each community was selected randomly. From the farms, the same varieties of the two species of vegetables (okra and pepper) were sampled.

Three sampling plots of 10 m^2 were demarcated within an area of 1 ha in each farmland. Each plot served as they replicate. Within each plot whole plants of each vegetable (okra and pepper) were numbered. Sampled plants were randomly selected and harvested. Each sampled plant was then separated into fruits, stems, and roots and then placed into separate polythene bags and labeled according to the plant type, plant part, and farmland. All 96 samples were randomly collected for preparation and analysis.

Vegetables and soil preparation and digestion

The samples were air-dried for two weeks, ground, labeled, and stored in polyethylene bags for analysis. From each of the samples, 1 g was weighed separately into a beaker and 10 ml of concentrated nitric acid (HNO_3) was added to each sample. This was then placed on a hot plate (a catalyst) in a fume chamber to get rid of all the carbonates and oxidable materials. Each of the beakers containing the digested solution was top up with 50 ml of distilled water and filtered. The filtrates were analyzed for the presence of heavy metals.

Determination of heavy metals

The Atomic Absorption Spectrometer (AAS) was used to determine the analytical level of the heavy metals in the sample under study. To determine the level of the heavy metal, the solution (filtrate) is drawn into the system through a capillary tube to the nebulizer of the AAS where the sample becomes a fine spray of droplets. The droplets then moved into the flame chamber with a temperature of about (1000^{o}C), here the desolvation (burning off of the solvent used to dissolve the sample), atomization, and vaporization occurs. Free atoms and ions are produced in the flame chamber whose electrons are in an excitation state due to the high temperatures. A light was drawn into the flame chamber by a hollow cathode lamp using a monochromator to isolate the specific wavelength of light. The hollow cathode lamp used is specific for different metals. A detector sensitive to light detects and translates the amount of heavy metal available.

Data analysis

Levels of heavy metals were expressed as mean ± standard deviation using Microsoft Office Excel (2010) spreadsheet. Data obtained were subjected to Tukey-B Analysis of Variance (ANOVA) using SPSS version 20 to rank and compare the means at a significant level of $p < 0.05$. Results were presented in tables.

RESULTS

Levels of heavy metals in the fruits of Okra and Pepper from the four farms

The mean levels of As in the fruits of the two vegetables among the four farms are presented in (Table 1) at a significant level of $p<0.05$. The levels of Cd, Pb, Cu, and Fe in the fruits of vegetables from the farms were within the recommended WHO/FAO standards (mg/kg) except for As. The entire mean As levels between the fruits of okra and pepper and between the farms was significantly different. The highest level of As was recorded in okra fruits from farm 1 and the least level from farm 4 in pepper fruits. The increasing order of As levels in the fruits of vegetables from all farms was F4Ca<F4Ae<F2Ca<F1Ca<F3Ca<F2Ae<F1Ae<F3Ae.

The mean level of Cd in the fruits of the two vegetables among the four farms is presented in Table 1. Some of the recorded Cd levels were significantly different while others saw no significant difference. For instance, there was no significant difference between the level of Cd in pepper fruits from farms 2, 3, and 4. The mean levels of Cd in okra fruits in farm 4 and pepper fruits from farm 1 were not significantly different. Cadmium levels in okra fruits in farms 1 and 2 were not significantly different ($p<0.05$). The highest level of Cd was recorded in okra from farm 3 and the least was recorded in pepper at farm 4. The increasing order of Cd levels in both vegetable fruits in all the four farms was as: - F4Ca=F2Ca=F3Ca<F1Ca< F4Ae<F1Ae=F2Ae<F3Ae.

The mean level of Cu in the fruits of the two vegetable plants is presented in Table 1. There was no significant difference between the levels of Cu recorded in okra fruits from farms 3 and 4 ($p<0.05$). The highest level of Cu was recorded in pepper fruit from farm 3 and the least in pepper fruit from farm 4. The increasing order of Cu levels in both vegetable fruits in all the four farms was as:- F4Ca<F2Ca<F2Ae<F4Ae<F3Ae<F1Ae<F1Ca<F3Ca.

The mean level of Fe in the fruits of the two vegetables among the four farms is presented in Table 1. No significant difference in the mean levels of Fe was recorded between farms 1 and 4 in the fruit of okra and pepper fruits in farms 4 and 2. The mean levels of Fe in okra fruits in farms 2 and 3 were not significantly different. This was the same in the fruits of pepper from farms 1 and 2 which were not significantly different ($p<0.05$). The highest level of Fe was recorded in pepper fruits from farm 3 and the least in okra fruits on farm 3. The increasing order of Fe levels in both vegetable fruits in all the four farms was F3Ae<F2Ae<F4Ca<F1Ae< F4Ae<F2Ca<F1Ca<F3Ca.

The mean level of Pb in the fruits of the two vegetables among the four farms is presented in (Table 1). The mean levels were significantly different. But there was no significant difference between okra fruits in farms 3 and 4. Lead levels in pepper fruits from farms 3 and 4 were not significantly different ($p<0.05$). The highest level of Pb was recorded in okra from farms 3 and 4, and the least was recorded in farm 2. The increasing order of Fe levels in both vegetable fruits in all the four farms was F3Ae<F2Ae<F4Ca<F1Ae<F4Ae<F2Ca<F1Ca< F3Cas. Considering the levels of heavy metals in the fruits of okra and pepper in all the four farms, the increasing order of level was: F4Ca<F4Ae<F2Ca<F1Ca<F3Ae<F2Ae<F1Ae<F3Ca. The increasing order of levels of heavy metals in the fruits of our and pepper within each farm was F4<F2<F1<F3.

Heavy metal levels in the stem of Okra and Pepper

The mean levels of the heavy metals in the stem of okra and pepper vegetables from the four farms sampled in the Asutifi district are represented in (Table 2). According to the NPV recommended standard in mg/kg the level of Cd, Pb, Cu, and Fe were within the set standards among the farms in the stems of the two vegetables. The CPC set standard to guide the study was evaluated, with Cu, Cd, and Pb being within the recommended threshold except As which was above in all the farms and the vegetables. The increased levels of heavy metals in the stem of each vegetable were in the order Cd<Pb<Fe<As<Cu.

Table 1. Mean levels of As, Cd, Cu, Fe, and Pb in okra and pepper fruits

Farm	Sample	As	Cd	Cu	Fe	Pb
Farm 1	Okra (fruits)	3.019±0.002^{g}	0.030±0.003^{c}	0.362±0.003^{e}	1.515±0.002^{d}	0.282±0.004^{e}
	Pepper (Fruits)	2.113±0.002^{d}	0.023± 0.003^{b}	0.465±0.003^{f}	1.408± 0.003^{c}	0.057± 0.003^{b}
Farm 2	Okra (fruits)	2.985±0.003^{f}	0.031±0.002^{c}	0.302±0.055^{c}	0.787± 0.004^{b}	0.193± 0.002^{d}
	Pepper (Fruits)	1.995±0.003^{c}	0.016± 0.002^{a}	0.259±0.004^{b}	0.677±0.006^{a}	0.049± 0.002^{a}
Farm 3	Okra (fruits)	3.223±0.002^{h}	0.036± 0.002^{d}	0.311±0.003^{d}	1.404± 0.003^{c}	0.330± 0.002^{f}
	Pepper (Fruits)	2.303±0.002^{e}	0.017± 0.002^{a}	0.755±0.004^{g}	0.784± 0.003^{b}	0.169± 0.013^{c}
Farm 4	Okra (fruits)	1.896±0.002^{b}	0.024± 0.002^{b}	0.309±0.003^{d}	1.573± 0.005^{e}	0.333± 0.003^{f}
	Pepper (Fruits)	1.626±0.003^{a}	0.014±0.002^{a}	0.207±0.003^{a}	0.680± 0.009^{a}	0.170± 0.002^{c}
Standards	FAO/WHO (mg/kg)	0.2	0.1	40	150	0.3
	CODEX (mg/kg)	0.1	0.05	0.5	0.8	0.1
	*CMH (mg/kg)	0.05-0.2	0.1-0.3	-	-	

Means and standard deviations in the same column with different letters in superscripts differ significantly ($p<0.05$)
CMH Chinese Ministry of Health

Generally, the mean level As in the stem of the two vegetables from the four farms presented in (Table 2) was significantly different (p<0.05). The highest level of As was recorded in pepper stem (3.422 mg/kg) from farm 3 and the least also in pepper stem (1.831 mg/kg) from farm 4. The increasing order of As levels in both vegetables stem in all the four farms was: - F4Ca<F4Ae<F2Ca< F1Ae<F1Ca<F2Ae< F3Ae<F3Ca.

The mean level of Cd in the stems of the two vegetables from the four farms is presented in (Table 2). To begin with, there was no significant difference between Cd levels in pepper stems from farms 3 and 4 and okra stems from farms 4. The mean level of Cd in okra stems from farms 2 and 4, and as well pepper stems in farms 1 and 3 were not significantly different. Similarly, the level of Cd in okra stems from farms 2 and 3, and pepper stems from farms 1 were not significantly different, and also Cd level in the okra stems in farms 2 and 3, and pepper stems in farms 2 also did not differ significantly. No significant difference was noted between Cd level in okra stems from farm 1 and pepper stems in farm 2 (p<0.05). The highest level of Cd in the stems of the two vegetables was recorded in okra (0.038 mg/kg) from farm 1 and the least was in pepper stem (0.023 mg/kg) from farm 4. The increasing order of Cd levels in both vegetables stems in all the four farms was: - F4Ca<F3Ca<F4Ae<F1Ca<F2Ae<F3Ae< F2Ca<F1Ae.

The mean levels Cu in the stems of the two vegetables among the four farms is presented in (Table 2). Nevertheless, no significant difference was observed between the levels of Cu in okra stems from farm 4 and pepper stems at farm 4. Also, the mean levels of Cu in pepper stems from farms 2 and 4 were not significantly different. That of pepper stems from farm 2 and okra stems from farm 3 saw no significant difference in Cu levels. Similarly, the levels of Cu in okra stems from farms 1 and 3 were not significantly different (p<0.05). The increasing order of Cu levels in vegetable stems in all the four farms was as: - F2Ae<F4Ae<F4Ca<F2Ca<F3Ae< F1Ae<F3Ca<F1Ca (Table 2).

The mean level of Fe in the stems of the two vegetables from the four farms was significantly different as presented in (Table 2). However, there was no significant difference between the level of Fe in okra stems in farms 1, 2, 3, and 4, and pepper stems from farms 4. There was no significant difference between was noted in okra stems from farms 1 and 4, and pepper stems from farms 2 and 4. Also, the mean levels of Fe in pepper stems from farms 1 and 2 were not significantly different (p<0.05). The highest level of Fe was recorded in pepper at farm 3 (3.201 mg/kg) and the least was recorded in okra stems from farm 3 (0.732 mg/kg). The increasing order of Fe levels in vegetable stems in all the four farms was F3Ae<F2Ae<F4Ca<F1Ae< F4Ae<F2Ca<F1Ca<F3Ca.

The mean level of Pb in the stems of the two vegetables from the four farms is presented in (Table 2). No significant difference was recorded between Pb levels in okra stems from farms 1 and 3. Also, the mean levels of Pb in okra stems from farm 2 and pepper stems from farm 2 were not significantly different (p<0.05). The highest level of Pb in the stems of the vegetables was recorded in okra (0.318 mg/kg) from farm 4 and the least in pepper (0.113 mg/kg) from farm 1. The increasing order of Pb levels in both vegetable stems in all the four farms was as: - F1Ca<F1Ae<F3Ae<F2Ca<F2Ae<F4Ca<

Table 2. Mean level of As, Cd, Cu, Fe, and Pb in stems of okra and pepper in the four farms

Farm	Sample	Cu	Fe	As	Cd	Pb
Farm 1	Okra	0.432 ± 0.003^{e}	1.069 ± 0.002^{ab}	2.074 ± 0.007^{d}	0.038 ± 0.003^{e}	0.142 ± 0.004^{b}
	Pepper	8.088 ± 0.003^{g}	2.294 ± 0.004^{c}	2.413 ± 0.001^{e}	0.028 ± 0.003^{bc}	0.113 ± 0.003^{a}
Farm 2	Okra	0.265 ± 0.055^{a}	0.894 ± 0.004^{a}	2.607 ± 0.005^{f}	0.031 ± 0.002^{bcd}	0.195 ± 0.002^{c}
	Pepper	0.382 ± 0.004^{cd}	1.686 ± 0.006^{bc}	2.004 ± 0.003^{c}	0.034 ± 0.002^{de}	0.192 ± 0.002^{c}
Farm 3	Okra	0.412 ± 0.003^{de}	0.732 ± 0.003^{a}	2.884 ± 0.003^{g}	0.033 ± 0.002^{cd}	0.145 ± 0.002^{b}
	Pepper	6.889 ± 0.004^{f}	3.201 ± 0.003^{d}	3.422 ± 0.003^{h}	0.026 ± 0.002^{ab}	0.294 ± 0.013^{e}
Farm 4	Okra	0.321 ± 0.003^{b}	1.228 ± 0.005^{ab}	1.925 ± 0.003^{b}	0.027 ± 0.002^{ab}	0.318 ± 0.003^{f}
	Pepper	0.351 ± 0.003^{bc}	1.001 ± 0.009^{ab}	1.831 ± 0.002^{a}	0.023 ± 0.002^{a}	0.226 ± 0.002^{d}
Standards	NPV(mg/kg)	5.00-15.00	140.00		1.00-2.40	0.10-10.00
	CPC (mg/kg)	20.00-100.00		0.2	5.00-30.00	20.00-300.00

Means and standard deviations in the same column with different letters in superscripts differ significantly (p<0.05)
NPV= Normal Plant Value (Sharma and Chettri, 2005), CPC= Range of Critical Plant Concentration (Sharma and Chettri, 2005).

F3Ca<F4Ae. Considering the levels of heavy metals in the stems of okra and pepper in all the four farms, the decreasing order of level is F3Ca<F1Ca< F2Ca<F2Ae<F3Ae<F1Ae< F4Ae<F4Ca. The decreasing order of levels of heavy metals in the stems of okra and pepper within each farm was: F3<F1<F2<F4.

Heavy metals levels in the roots of Okra and Pepper

The mean level of the heavy metals in the roots of okra and pepper vegetables from the four farms sampled in the Asutifi district is represented in Table 3. According to the NPV recommended standard in mg/kg, Cd and Fe were within the set standards among the farms in the roots of the two vegetables. The Cu, Cd, and Pb levels in the roots of okra and pepper were evaluated against the CPC set standard which came out within the recommended threshold except As which exceeded this limit in all the farms. The increasing order of heavy metals in the roots of the two vegetables was: Cd<Pb<Cu<As<Fe.

The mean As levels in the roots of okra and pepper is presented in Table 3. Overall mean levels of As in the roots of the two vegetables among the four farms were significantly different at (p<0.05). The highest level of As in both vegetables was recorded in pepper (9.305 mg/kg) at farm 3 while the least was also in pepper (6.244 mg/kg) at farm 2. The increasing order of As levels in vegetable roots in all the four farms was as: - F2Ca<F1Ae<F4Ca< F4Ae<F1Ca<F3Ae<F2Ae<F3Ca.

The mean levels Cd in the roots of the two vegetables between the four farms presented in (Table 3) were significantly different. There was no significant difference between Cd levels in okra roots in farm 3 and pepper roots in farms 1, 2, 3, and 4. Also, there was no significant difference between Cd levels in okra roots in farms 3 and 4 and pepper roots in farms 1, 2, and 3. Likewise, the levels of Cd in the roots of okra in farms 2 and 4 were not significantly different which was the same as Cd levels in okra roots in farms 1 and 2 at p<0.05. The highest level of Cd in the roots of both vegetables was recorded in okra (0.035 mg/kg) at farm 1 but the least was in pepper (0.022 mg/kg) at farm 4. The increasing order of Cu levels in vegetable roots in all the four farms was as: - F4Ae<F2Ae<F1Ae<F3Ae< F4Ca<F2Ca<F3Ca<F1Ca.

The mean level of Fe in the roots of the two vegetables among the four farms is presented in Table 3. There was no significant difference between Fe levels in pepper roots in farms 1, 2, and 4. The mean levels of Fe in okra roots in farm 3 and pepper roots in farm 3 were not significantly different (p<0.05). The highest level of Fe in the roots of the two vegetables was recorded in okra (32.189 mg/kg) at farm 2 and the least also in okra (5.153 mg/kg) at farm 4 (Table 3). The increasing order of Fe levels in vegetable roots in all the four farms was as: - F4Ae<F1Ae<F2Ca<F1Ca<F4Ca<F3Ca<F3Ae<F2Ae.

The mean level of Pb in the roots of the two vegetables is presented in Table 3. There was no significant difference between Pb level in okra roots in farm 3 and pepper roots in farm 1. Also, the mean levels of Pb in pepper roots in farms 2 and 3 were not significantly different (p<0.05). The highest levels of Pb in the roots of the two vegetables were recorded in pepper (0.311 mg/kg) at farm 3 and the least in okra (0.511 mg/kg) at farm 2. The increasing order of Pb levels in vegetable roots in all the four farms was F2Ae<F1Ca=F3Ae<F4Ca< F1Ae<F4Ae< F2Ca=F3Ca. Considering the levels of cyanide and heavy metals in the roots of okra and pepper in all

Table 3. Mean level of As, Cd, Cu, Fe, and Pb in the roots of okra and pepper from the four farms

Farm	Sample	As	Cd	Cu	Fe	Pb
Farm 1	Okra	6.820 ± 0.124^{b}	0.035 ± 0.003^{d}	0.281 ± 0.004^{b}	11.459 ± 0.002^{b}	0.281 ± 0.003^{d}
	Pepper	7.342 ± 0.001^{e}	0.027 ± 0.002^{ab}	0.724 ± 0.004^{g}	17.132 ± 0.005^{c}	0.140 ± 0.003^{a}
Farm 2	Okra	9.011 ± 0.001^{g}	0.033 ± 0.002^{cd}	0.274 ± 0.005^{b}	32.189 ± 0.002^{e}	0.115 ± 0.002^{a}
	Pepper	6.244 ± 0.004^{a}	0.027 ± 0.002^{ab}	0.390 ± 0.003^{e}	17.066 ± 0.011^{c}	0.309 ± 0.002^{f}
Farm 3	Okra	8.775 ± 0.004^{f}	0.025 ± 0.001^{ab}	0.314 ± 0.003^{c}	27.301 ± 0.002^{d}	0.142 ± 0.001^{a}
	Pepper	9.305 ± 0.002^{h}	0.025 ± 0.002^{ab}	0.438 ± 0.004^{f}	24.040 ± 0.008^{d}	0.311 ± 0.003^{f}
Farm 4	Okra	7.104 ± 0.002^{d}	0.028 ± 0.003^{bc}	0.176 ± 0.003^{a}	5.153 ± 0.004^{a}	0.298 ± 0.003^{e}
	Pepper	6.995 ± 0.006^{c}	0.022 ± 0.003^{a}	0.337 ± 0.001^{d}	17.802 ± 0.007^{c}	0.253 ± 0.003^{c}
Standards	NPV (mg/kg)	0.2	1.00-10.00	5.00-15.00	140.00	0.10-10.00
	CPC (mg/kg)		5.00-30.00	20.00-100.00		20.00-300.0

Means and standard deviations in the same column with different letters in superscripts differ significantly (p<0.05)
NPV= Normal Plant Value (Sharma and Chettri, 2005), CPC= Range of Critical Plant Level (Sharma and Chettri, 2005).

the four farms, the increasing order was F4Ae<F2Ae<F1Ae<F2Ca<F1Ca<F4Ca<F3Ca< F3Ae. The increasing order of levels of heavy metals in the roots of okra and pepper within each farm was: F2<F4<F1<F3.

Heavy metal levels in the soil samples of cultivated Okra and Pepper

The mean levels of heavy metals level in the soil samples around okra and pepper plants from four farms in the Asutifi Districts is presented in Table 4. By the USEPA recommended standard for heavy metals in soils, the levels of As, Cd, Cu, and Pb were all within their safe threshold. The WHO set the standard for heavy metals in soils used as a guideline to this study showed that Cu, Fe, Cd, and Pb levels do not exceed the set limits while As was way above the recommended standard guide. The increasing order of the heavy metals in the soil samples around the two vegetables was Cd<Pb<Cu<As<Fe.

The mean levels of As in the soil samples around vegetables from the four farms are presented in Table 4. The recorded As levels in soils around both vegetables were significantly different at $p<0.05$ between the farms. The highest level of As around soil samples of vegetables was recorded in pepper (23.215 mg/kg) at farm 3 but the least was at farm 2; also in pepper (18.061 mg/kg) (Table 4). The increasing order of As levels in vegetable soil samples in all the four farms was as:- F2Ca<F4Ca<F4Ae<F1Ae<F1Ca<F2Ae<F3Ae<F3Ca (Table 4).

The mean level of Cd in the soil samples around the two vegetables among the four farms is presented in Table 4. All recorded Cd levels in the vegetables within and between farms were significantly different. However, there was no significant difference between soil samples around okra in farms 4 and soil samples around pepper in farms 4. Similarly, there was no significant difference in Cd levels in soil samples around okra between farm 2 and soil samples around pepper in farms 1, 2, and 3. There was no significant difference in Cd levels in soil samples around okra in farms 1, 2, and 3 and pepper in farms 1, 3. The came can also be seen in the soil samples around okra in farms 1 and 3 ($p<0.05$). The highest level of Cd in soil samples around both vegetables was recorded in okra (0.031 mg/kg) at farms 1 and 3 but the least was in pepper (0.014 mg/kg) at farm 4. The increasing order of Cd levels in soil samples around both vegetables in all the four farms was as: -F4Ca<F4Ae<F2Ca<F3Ca< F2Ae<F1Ca<F3AeF1Ae.

The mean levels of Cu in the soil samples around the two vegetables from the four farms are presented in Table 4. All recorded levels of Cu were between farms were not significantly different at ($p<0.05$). The highest level of Cu in the soil samples around the two vegetables was recorded in the value of 1.313 mg/kg at farm 1 around okra while the least Cu level, 0.199 mg/kg was recorded around okra at farm 4. The increasing order of Cu levels in both vegetable soil samples in all the four farms was as: - F4Ae<F4Ca<F2Ca<F2Ae< F3Ca<F3Ae<F1Ca<F1Ae (Table 4).

The mean levels of Fe in the soil samples of the two vegetables among the four farms are presented in Table 4. The levels of Fe in soil samples around the vegetables, okra, and pepper were significantly different ($p<0.05$). The highest level of Fe in the soil samples around the two vegetables was recorded at

Table 4. Mean level heavy metals in the soil samples of cultivated okra and pepper plants

Farm	Sample	As	Cd	Cu	Fe	Pb
Farm 1	Soil around okra	20.265 ± 0.133^{d}	0.031 ± 0.003^{c}	1.313 ± 0.004^{a}	57.862 ± 0.003^{e}	0.312 ± 0.003^{b}
	Soil around pepper	21.331 ± 0.002^{e}	0.029 ± 0.003^{bc}	1.234 ± 0.003^{a}	58.141 ± 0.005^{f}	0.365 ± 0.003^{d}
Farm 2	Soil around okra	21.928 ± 0.007^{f}	0.028 ± 0.003^{bc}	0.441 ± 0.002^{a}	58.480 ± 0.004^{g}	0.394 ± 0.003^{f}
	Soil around pepper	18.061 ± 0.003^{a}	0.024 ± 0.003^{b}	0.263 ± 0.061^{a}	54.768 ± 0.007^{c}	0.386 ± 0.003^{e}
Farm 3	Soil around okra	22.579 ± 0.004^{g}	0.031 ± 0.002^{c}	0.511 ± 0.002^{a}	57.545 ± 0.004^{d}	0.405 ± 0.003^{g}
	Soil around pepper	23.215 ± 0.013^{h}	0.027 ± 0.002^{bc}	0.458 ± 0.001^{a}	59.224 ± 0.039^{h}	0.410 ± 0.002^{g}
Farm 4	Soil around okra	19.352 ± 0.002^{c}	0.015 ± 0.002^{a}	0.199 ± 0.003^{a}	48.138 ± 0.006^{a}	0.322 ± 0.003^{c}
	Soil around pepper	19.129 ± 0.003^{b}	0.014 ± 0.001^{a}	0.207 ± 0.003^{a}	49.831 ± 0.048^{b}	0.200 ± 0.003^{a}
Standards	USEPA (mg/kg)	41	39	1500		300
	WHO (mg/kg)	12	1.4	63	5000-10000	70

Means and standard deviations in the same column with different letters in superscripts differ significantly ($p<0.05$)
The USEPA United States Environmental Protection Agency
WHO World Health Organization

farm 3 around pepper (59.224 mg/kg) whilst the least was in the soil around okra (48.138 mg/kg) at farm 4. The increasing order of Fe levels in vegetable soil samples in all the four farms was F4Ae<F4Ca<F2Ca<F3Ae<F1Ae<F1Ca<F2Ae<F3Ca.

The mean level of Pb in the soil samples around the two vegetables among the four farms is presented in Table 4. There was no significant difference between soil samples around okra in farm 3 and soil samples around pepper in farm 3 ($p<0.05$). The highest level of Pb in soil samples around vegetables was recorded in pepper (0.410 mg/kg) at farm 3 and the least was at farm 4 in soil samples around pepper (0.200 mg/kg). The increasing order of Pb levels in soil samples around vegetables in all four farms was F4Ca<F1Ae<F4Ae< F1Ca<F2Ca<F2Ae<F3Ae<F3Ca (Table 4). Considering the levels of heavy metals in the soil samples around okra and pepper in all the four farms, the increasing order of level was F4Ca<F2Ca<F4Ae<F3Ae<F1Ca<F3Ca<F1Ae< F2Ae. The increasing order of levels of cyanide and heavy metals in the soil samples around okra and pepper within each farm was: F4<F2<F3<F1. Generally, heavy metals in soil samples of cultivated okra and pepper from Farm 1 was 4 points less and 23 points more than samples from farms 3 and 4 respectively.

DISCUSSION

Heavy metal distribution in vegetable parts and cultivated soil

An important component of humans' survival and existence is the intake of food particularly vegetables. Vegetables are essential for human survival and sustenance owing to their inherent nutritional and health benefits. It is therefore prudent to present them as wholesome, devoid of harmful and toxic substances such as heavy metals emerging from biological as well as anthropogenic activities. Organized bodies like WHO (World Health Organization), FAO (Food and Agricultural Organization), and USEPA (the United States Environmental Protection Agency) among others have instituted standards and guidelines indicating permissible heavy metals tolerable in plant foods and soils to protect humans and livestock from contamination. Probably, as cited by (Arora *et al*., 2008) vegetables risk accumulating heavy metals from wastewater used for irrigation or grown near dumpsites (Arora *et al*., 2008). Heavy metals in plants and soils are on the rise due to alterations in anthropogenic activities and changes in natural mechanisms. The excessive application of fertilizers, pesticides, and herbicides on either farmlands or crops by farmers as well as the natural eruption of volcanoes and mining all amount to the introduction of heavy metals into the environment. When the level of heavy metals present in crops is exceeded, they become polluted and hence unhealthy for consumption.

There are several instances where these standards were exceeded as confirmed by (Radwan and Salama, 2006) and in this study, Arsenic (As) demonstrated such. Okra and pepper are globally consumed vegetables by humans daily, therefore the level of heavy metals present in them should be very minimal if not absent. According to the FAO, more than 2 million tonnes of okra are consumed annually worldwide and in Ghana 7000 and 15000 tonnes of okra and pepper respectively are consumed daily as studies carried out by the FAO suggest (Ngbede *et al*., (2014). This indicates that these vegetables are of global and national importance and hence their heavy metals levels should conform to the acceptable limit. It is noteworthy that the findings from this study indicate that the levels of Cadmium, Lead, Copper, and Iron in the fruits of okra and pepper were within the safety limit set by (FAO, 1999). Cadmium and Pb levels in this study were within WHO/FAO (2011) standards but that of Cu, As and Fe were above. According to the CMH standard, Arsenic and Cadmium levels reported in this study were above and within respectively.

Naturally, plants can remove elements from the soil and dispense them to the roots and stems (Ximénez-Embún, 2002). It has been found that heavy metals with reference given to As, Cu, Fe, Cd, and Pb can accumulate more in leafy vegetables than those of other plant parts because these leaves are considered as entry points of heavy metals from the air as opposed to the stem (Vousta *et al*., 1996). It is therefore essential to determine the heavy metals even if the stems are not consumed. The results from this study showed that the level of heavy metals in the stems of okra and pepper was below and in some instances within the Normal Plant Values (Alloway, 1968). However, the levels of the heavy metals in the stems of the two vegetables were below the Range of Critical Plant Concentration (Kabata-Pendias and Pendias, 1992). Lower levels of

Pb in the okra stem were recorded in this study as compared to the findings of (Hung *et al*., 2014) in okra leaves while working on the Lead accumulation in different parts of the okra plant. These variations in Pb levels from a similar plant may be due to the differences in the plant part assessed in each study and the sources of pollutants.

The levels of Cd and Pb are the lowest among the heavy metals because of their unknown biological functions in the growth of plants, although occur naturally in the soil (Cho-Ruk *et al*., 2006; Sharma and Dubey, 2005). More so, plants are known to have different affinities for different metals (Mourato *et al*., 2015). The stems of pepper may have high affinity for heavy metals than that of okra stems leading to higher levels of the heavy metals in pepper stems than in okra stems (Burken, 1996). Iron (Fe), As and Cu also occur naturally in the soil as a result of processes like weathering of rocks, and volcanic eruptions and hence can simply be released into the soil and subsequently be made bioavailability to plant stems after extraction (Chopra e*t al*., 2009).

The root is a major source through which nutrients and unwanted materials in the soil become available to plants. Most literature refers to it as the interface between the plants and the soil. Plants are autonomic to absorption of soil nutrients that may include heavy metals, for a variety of purposes through the root. In the roots of vegetables and other plants, rhizofiltration occurs to filter water through a mass of roots. The leafy parts of plants are therefore exposed to contaminants in the water (Haiyan and Stuanes, 2003). Plants in such medium continue to absorb contaminants until they are harvested and therefore it is important to determine the level of these contaminants in the roots (Singh *et al*., 2012).

Determination from this study on the level of As, Cd, Cu, Fe, and Pb in fruits of okra compared to findings from (Opulawa *et al*., 2012) around dumpsites in Lafia Metropolis, Nasarawa showed varying levels. This could be due to the different environments and the origin of pollution. This study was conducted in a mining area while their study was carried out on a dumpsite. The ranking Cd<Pb<Cu<As<Fe indicates that the area of study is least contaminated with Cd and hence acceptable limit in the fruits of the vegetables. Lead (Pb) was also low in the two vegetables from the four farms. Lead has been noted to be released through mining and smelting activities (Sharma and Dubey, 2005). Copper (Cu) exists in higher levels naturally in plants and is also required by plants for growth (Cho-Ruk *et al*., 2006; Sharma and Dubey, 2005) but low levels of Cd were recorded in the fruits of the two vegetables and were within the WHO safe limit. Though As is toxic, its level was the highest in the fruits of the two vegetables. This may be a result of high levels of As which is usually associated with gold ore in the form of Arsenopyrites, FeAs occurring naturally in the soil, especially in mining areas (Dauda *et al*., 2013; Morin and Calas, 2006; Opaluwa *et al*., 2012) and (Vousta *et al*., 1996). Iron (Fe) exists at high levels naturally in the environment and is necessary for plant growth and chemical reactions (Morrissey and Guerinot, 2009). Therefore, it is essential to have it at higher levels but not exceed the safe limit in edible plants such as vegetables. Contrary to this recommendation, low levels of Fe were noted in the fruits of the vegetables; though in some instances exceeded the CODEX standard but generally did not exceed the WHO standard.

Heavy metals in soil samples of cultivated okra and pepper from Farm 1 showed significant levels than farm 3. This can be attributed to its nearness to the TSF. Shilev and Babrikov (2005) and (Walker and Jamieson, 2005) suggest the tendency of heavy metal absorption by plants to increase when plants are proximal to a mining or tailings site. This assertion corroborates the findings of this study. Comparing each of the vegetables from the various farms, okra in Farm 1 had increased levels of heavy metals which according to Lima *et al*. (2009) and (Ximénez-Embún *et al*., 2002) indicate their inclusion as vegetables that can absorb and accumulate heavy metals; with okra, tomato, and pepper ranking accordingly.

Generally, heavy metals levels from the area of study can be said to be at levels not deemed pollutants. This assertion can be linked to the ability of roots to transport the quantum of their contaminants to the stem, leaves, and fruits of plants (Haiyan and Stuanes, 2003). Interestingly, Farm 3 which is a control farm in this study had the highest levels of heavy metals which may be linked to active anthropogenic activities within the Atronie community. This is further confirmed by (Atafar *et al*., 2010; Gondek and Filipek-Mazur, 2003; Lavison, 2013) who emphasize the effects of the usage of unapproved inorganic fertilizers on farms by farmers.

CONCLUSION

The levels of heavy metals in the soils from the four farmlands in the study area showed contamination levels of Cd<Pb<Cu<As<Fe. Guided by the USEPA and WHO set the standard of heavy metals in soil, the level of Cu, As, Cd, and Pb was within the acceptable limit but As level fell short of these standards. Iron (Fe) being an essential mineral for plants growth was highest in the soils of the farmlands. Generally, pepper stems recorded the highest level of heavy metals than okra stems. Yet, the levels of Cd in farms 1, 3, and 4 were higher in okra stems than in pepper stems.

From the study, the levels of heavy metals in fruits of vegetables were higher on the farms and as such may render them unfit for human consumption due to phytotoxicity. However, among the two vegetables, the fruits pepper is deemed better and good for consumption than okra. Farm 1 which is about 1 km away from the tailings storage facility recorded the highest level of heavy metals. Farm 4 which was 10 km away from this facility recorded the least concentration of heavy metals. The present study has demonstrated that mining operation in the Asutifi districts has contributed to the increased levels of heavy metals in the farmlands and consequently may enter the food chain. Other sources of contamination either point or diffuse in the area may be emissions from either natural or anthropogenic activities like fertilizer application. It was obvious from this study that heavy metals can be transported from one point to another in an immeasurable magnitude. Continuous monitoring and auditing of As concentration is highly recommended. Notwithstanding, farmers are entreated to cultivate vegetables and other farm produce at least 10 km away from mining concessions.

Statement of Competing Interests

The authors have no competing interests.

List of Abbreviations

AAS	Atomic Absorption Spectrophotometer
TSF	Tailings Storage Facility
Ae	*Abelmoschus esculentus* (okra)
Ca	*Capsicum annuum* (pepper)
F1AeFt	Farm 1 *Abelmoschus esculentus* Fruit
F1CaFt	Farm 1 *Capsicum annuum* Fruit
F1AeSt	Farm 1 *Abelmoschus esculentus* Stem
F1CaSt	Farm 1 *Capsicum annuum* Stem
F1AeRt	Farm 1 *Abelmoschus esculentus* Root
F1CaRt	Farm 1 *Capsicum annuum* Root
F1AeSl	Farm 1 *Abelmoschus esculentus* Soil
F1CaSl	Farm 1 *Capsicum annuum* Soil
F2AeFt	Farm 2 *Abelmoschus esculentus* Fruit
F2CaFt	Farm 2 *Capsicum annuum* Fruit
F2AeSt	Farm 2 *Abelmoschus esculentus* Shoot
F2CaSt	Farm 2 *Capsicum annuum* Shoot
F2AeRt	Farm 2 *Abelmoschus esculentus* Root
F2CaRt	Farm 2 *Capsicum annuum* Root
F2AeSl	Farm 2 *Abelmoschus esculentus* Soil
F2CaSl	Farm 2 *Capsicum annuum* Soil
F3AeFt	Farm 3 *Abelmoschus esculentus* Fruit
F3CaFt	Farm 3 *Capsicum annuum* Fruit
F3AeSt	Farm 3 *Abelmoschus esculentus* Stem
F3CaSt	Farm 3 *Capsicum annuum* Stem
F3AeRt	Farm 3 *Abelmoschus esculentus* Root
F3CaRt	Farm 3 *Capsicum annuum* Root
F3AeSl	Farm 3 *Abelmoschus esculentus* Soil
F3CaSl	Farm 3 *Capsicum annuum* Soil
F4AeFt	Farm 4 *Abelmoschus esculentus* Fruit
F4CaFt	Farm 4 *Capsicum annuum* Fruit
F4AeSt	Farm 4 *Abelmoschus esculentus* Stem
F4CaSt	Farm 4 *Capsicum annuum* Stem
F4AeRt	Farm 4 *Abelmoschus esculentus* Root
F4CaRt	Farm 4 *Capsicum annuum* Root
F4AeSl	Farm 4 *Abelmoschus esculentus* Soil
F4CaSl	Farm 4 *Capsicum annuum* Soil
G.S.S.	Ghana Statistical Service
SPSS	Statistical Package for the Social Sciences

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