Assessment Of Ecological And Human Health Risks Of Cu, Zn And Pb Accumulation In Agricultural Soils And Okra

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ABSTRACT

Emission from Vehicles manufacturing and processing industries have caused accumulation of heavy metals in soils and food crops, which could be harmful to public health and the environment. Heavy metals accumulate in foods as a result of their uptake by crops. This research was conducted to investigate Cu, Zn and Pb concentrations in soils and okra from two farmlands in Cape Coast; to assess the ecological and health risk and the relation between the metal transfer factor and soil properties, pH and organic matter. Twenty composite topsoil samples were collected in the dry season from each farm. The concentrations (mg/kg) of Cu, Zn and Pb in soils from UCC farm were respectively11.6, 18.24 and 4.88; the corresponding levels measured in the soils from Amamoma were 9.33, 14.83 and 4.65 respectively. The concentrations of the metals in the soils were significantly higher than corresponding levels found in the okra samples. The TF values ranged between 0.08 and 0.41. For all the metals TF < 1, suggesting that translocation of the metals from the soil solution to the okra were less effective. The uptake capabilities of heavy metals from soil to okra was in the order of Zn < Cu < Pb. Organic matter correlated negatively and insignificantly with TF of Cu and Pb. It, however, correlated significantly and positively with TF of Zn. pH correlated positively with TF values of all the three metals Cu, Zn and Pb; but only Zn showed significant correlation. the Enrichment Factor (EF), Contamination Factors (CF), Pollution Load Index (PLI), mean enrichment quotient (MEQ); and Geoaccumulation Index (*Igeo*) suggest the sites are not enriched and are practically unpolluted with the three metals. Consumption of okra from the farms was considered safe.

Keywords: Heavy metals, transfer factor, okra, farmland, Pollution Index

1. INTRODUCTION

Heavy metal Pollution of soils and crops is mostly from industrial emissions, vehicular emission, sewage sludge, wastewater irrigation, and fertilizer waste are the main sources of heavy metal pollution [1-4].

Metals present in a soil can be divided into a number of fractions including; the soluble metal in the soil solution, metal-precipitates, metal sorbed to clays, hydrous oxides and organic matter, and metals within the matrix of soil minerals. These different fractions are all in dynamic equilibrium with each other [5]. It has been observed that while the soluble metal in the soil solution is directly available for plant uptake other soil metal pools are less available. Of metal present in the growth substrate, only the bioavailable fraction of metal which is accessible to plants and can be absorbed [6, 7]. Soil factors, such as pH, organic matter, metal speciation, plant species, water regime, soil-plant interactions, clay and redox conditions, determine the proportion of total metal which is in the soil solution, and how much of this metals in the soil pool will be available to plants [8, 9].

The main sources of probable heavy pollution metals in agricultural are anthropogenic, from fertilization, industrial wastes, irrigation using sewage, traffic, *etc*. [10-12]. It has been observed that the primary root of human exposure to heavy metals is by intake via the soil-crop-human or soil-crop-animal-human. Heavy metal pollution in agricultural soils and crops is a matter of concern due to the potential health risks [13-16].

In this study, the objectives were: to compare the extent of Zn , Pb and Cu contamination of soil and okra from two different farms in the Cape Coast Metropolis; to investigate the metal transfer coefficient; to estimate the magnitude of human-induced change in each farm using mean enrichment quotient (MEQ); to estimate the spatial variation of these metals using two quantitative indices, the Index of Geo-accumulation (*Igeo*) and the Potential Ecological Risk Index (*RI*); to assess carcinogenic and non-carcinogenic health risks of soils and okra cultivated on the two different farms; and to assess the effects of pH and organic matter on the transfer factor.

2. MATERIALS AND METHODS

2.1 SOIL AND OKRA SAMPLING

Two agriculture farm soil samples were used, and a total of twenty composited soil and twenty composited okra samples were collected. Five sets of composited surface soils (0 - 20 depth) were collected in March, 2011 from four pre-demarcated sites at the UCC farms (U_a, U_b, U_c, U_d) and a farm in Amamoma community (A_a, A_a, A_c, A_d). Each composited sample consisted of ten randomly collected topsoil samples, and then stored in polyethylene bags at 25˚C. From each farm, mature okra plants with a healthy appearance were selected from the pre-demarcated sites tagged for soil collection, the okra samples were collected together with soil samples. four okra were randomly collected from areas where soils were collected and pooled. Five pooled samples were obtained for each site.

2.2 TREATMENT OF SAMPLES

The samples were air-dried at room temperature, and passed through 2 mm ground and passed through a 2 mm stainless steel mesh to obtain a <2 mm size fraction. The okra were first thoroughly washed with tap water and finally with deionized water. The samples were dried in the sun and then in the oven at 60°C until constant weight was obtained. The dried samples were finally milled in a carbide mortar with a pestle and preserved in polyethylene bags in a desiccator until subsequent analysis [17].

2.3 PH AND ORGANIC MATTER DETERMINATION

Soil pH was determined in a 1:2.5 soil/deionised water suspension and in a soil/KCl suspension using a glass pH electrode, Model 701A. The organic matter (OM) was measured by dry combustion in a muffle furnace . The soils were heated at 450ºC in the furnace 4 hours after which the soils were cooled and their masses found. the loss in mass was express as percent organic matter. Detailed soil analysis procedures were described in [18, 19]

2.4 METAL ANALYSIS

The soil was digested using the method described by the Ministry of Agriculture, Fisheries and Food and Welch Office Agriculture Department [20], 1 g of each of the homogenized samples of soils was put into a 100 ml beaker and 10 ml of concentrated HNO_3 added. The mixture was heated until it almost dried. Further 10 ml of HNO_3 and 3 ml of $HClO_4$ were added and the solution heated and then allowed to evaporate to about 1-2 ml. 4 ml of hot concentrated HCl was added and then reflux for 10 minutes. Finally, the wall of the beaker was wash down with double distilled water, filtered in to a 50 ml volumetric flask, and diluted to the 50 ml mark. Two grams of the milled okra sample was placed into a 50 ml flask and the sample digested with 1ml of 5:1:1 60 % perchloric acid:98% sulphuric acid: 63% nitric acid mixture, and finally diluted to 50 ml. Blank and spiked samples were also prepared for soil and okra samples

All the digests, blank and spiked samples were analyzed in duplicate for Pb, Cu, Zn and Fe with an atomic absorption spectrometer (Spectr AA 220Fs, Varian). All analysis were carried out in duplicate and the mean calculated. Metal concentration in the extracts of soils and plants were calculated on the basis of dry weight.

2.5 QUALITY CONTROL

For the quality control, analytical and calibration blanks, and duplicate spiked samples were analysed. The recovery and precision of the analysis were assessed using three sets of Matrix spiked (MS) samples. The precision was evaluated as the relative percent difference (%RPD) of duplicates. Matrix spike duplicate (MSD) accuracy was expressed as percent recovery; it was calculated by using the same equation as for Matrix Spike:

$$\%R = \frac{(\text{matrix spike duplicate result} - \text{unspiked sample result}) \times 100}{\text{Known spike added concentration}}$$

MSD precision was expressed as relative percent difference between MS and MSD; it was calculated as %RPD between a sample and sample duplicate:

$$\%RPD = \frac{(\text{MS result} - \text{MSD result}) \times 100}{(\text{MS result} + \text{MSD result})/2}$$

2.6 DATA ANALYSIS

Statistical analysis of data was carried out using the Statistical Package for Social Sciences (SPSS) SPS 16.0 statistical package program and Microsoft Office Excel 2008. The Pearson correlation test was used to check for correlations between transfer factor (TF) values of heavy metals and soil properties, pH and organic matter. Calculations of the ecological risk, pollution indices, and health risk through exposure to heavy metals via consumption of okra for the local population were performed using Microsoft Office Excel 2008 and the appropriate formula.

3. RESULTS AND DISCUSSION

The recovery rates ranged from 87% to 103% and the precision,

Accumulation of Cu, Zn and Pb in soils and okra

All the analyzed soils and okra samples contained detectable concentrations of Cu, Zn, and Pb and Pb The mean concentrations (and range) of the metals in the soils (Table 1) were 9.33 (5.48- 13.3), 14.83 (5.10-29/60), and 4.64 (1.78-7.18) mg kg^{-1}, respectively for farmland soil samples from Amamoma. The metal levels in soils from UCC form were 11.26 (6.5- 9.58), 18.24 (12.23-30.78), and 4.88 (2.60-8.90) mg kg^{-1} respectively. There were variations in the levels of metals in soils from both farms as revealed by the coefficient of variation (CV). The variation follow the order Pb > Cu >Zn and Zn > Pb > Cu for samples from Amamoma and UCC farms respectively.

Table 1: Concentrations of Pb, Zn and Cu in soils from the study sites

Metal (mg/kg) in soils from Amamoma farm					Metal (mg/kg) in soils from UCC Agric farm				
	Cu	Zn	Pb	Fe	Cu	Zn	Pb	Fe	
mean	9.33	14.83	4.65	925.37	11.26	18.24	4.88	1475.36	
SD	2.38	7.27	1.23	424.53	5.19	4.51	1.91	275.84	
CV %	3.77	2.04	3.9	2.18	2.17	4.05	2.55	5.35	
max	13.3	29.60	7.18	1632.23	24.78	30.78	8.90	1837.48	
min	5.48	5.10	1.78	284.50	6.50	12.23	2.60	962.35	
median	9.56	11.86	4.63	975.38	8.68	16.68	4.13	1517.81	

Generally, the overall average concentrations of Cu, Zn and Pb metals (Fig 1), as well as the average concentrations of metals measured in soils from each sampling site at the two study areas (Fig 2) showed the concentrations is in the order Zn > Cu > Pb, similar to other report . The concentrations of the metals were lower than the World Average value [21], Cu and Zn have been found to be higher than the world average the in some agricultural soils [22].

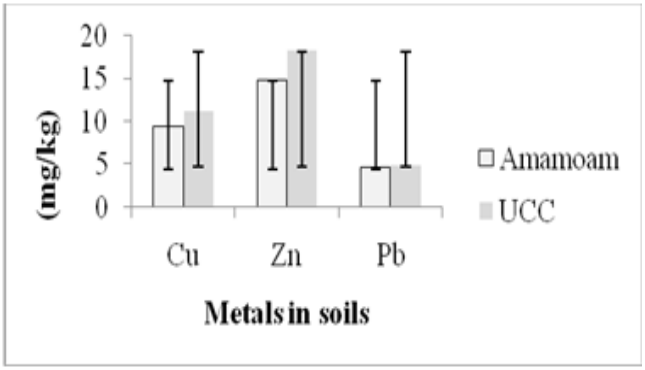

Figure 1: Distribution of metals in soils from UCC and Amamoma farms

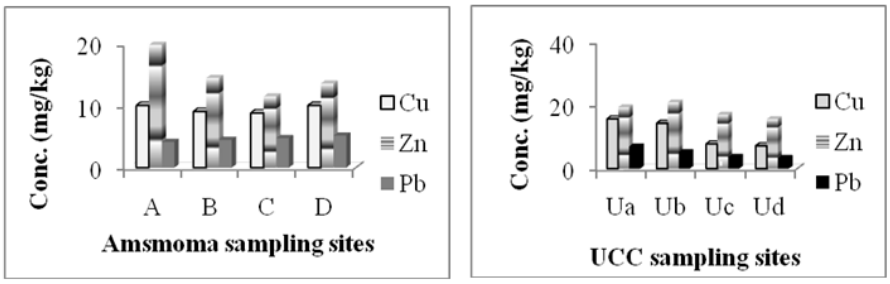

Figure 2: Distribution of Cu Zn and Pb in soils from selected sited at UCC and Amamoma farms

Table 2: Mean concentrations of Pb, Zn and Cu in okra from the study sites

Metal (mg/kg) in okra from Amamoma farm						Metal (mg/kg) in okra from UCC farm			
	Cu	Zn	Pb	Fe		Cu	Zn	Pb	Fe
mean	2.47	2.45	1.91	20.51		1.94	1.54	1.45	8.51
SD	0.73	0.34	0.31	6.54		0.98	0.45	0.36	2.10
CV %	29.64	13.81	16.40	31.87		50.14	29.07	24.50	24.72
max	3.80	2.91	2.50	36.41		3.86	2.47	2.16	11.99
min	0.91	1.88	1.44	11.79		0.86	0.91	0.55	4.29
median	2.31	2.54	1.95	18.95		1.54	1.50	1.48	9.01

The mean concentrations (and range) of detectable concentrations of Cu, Zn, and Pb in the okra samples are shown in Table 2. The metal levels in okra samples from UCC farm were Cu,1.94; Zn, 1.54 and Pb, 1.45 mg kg^{-1} for samples from Amamoma farms, the concentrations of Cu, Zn, and Pb in mg kg^{-1}were 2.47, 2.45 and 1.19 respectively. These levels are lower than the maximum limits of 2 mg/kg for Pb, 30 mg/kg for Cu, 40 mg/kg for Zn recommended for metal contamination in vegetable [23].

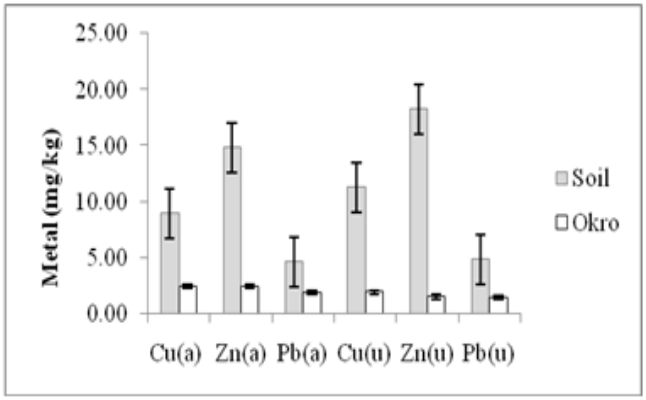

Figure 3: Cu, zn and Pb in soils and okra from UCC (u) and Amamoma (a) farms

The mean concentrations of metals in okra samples from the farms follow the sane order Cu >Zn > Pb. The variations in the distribution of the metals in the okra samples, 13.81- 50.14%, were higher than those of the soils 2.04-2.55%. The distribution of Cu in the okra samples varied greatly, with samples from UCC farm showing greater variation 50.24%, than those from Amamoma, 29.64%. The mean concentrations of the metals in the soils were higher than corresponding concentrations measured in the okra samples (Fig 3).

Effects of pH and organic matter on concentration of metals

Even though the metals levels in soils from the UCC farm were high than corresponding levels found in soils from Amamoma, the concentrations of metals in the okra samples from the farm at Amamoma were higher. This variation in the levels of the metals in okra from the different farms could be due to the pH and organic matter content of the soil among others.

Generally, the soil pH correlated negatively with the metals, Cu (r= -0.44, n= 40); Zn (r= -0.28, n=40) and Pb (r=-0.37, n=40). Except for Cu, the correlations were weak and insignificant ($p < 0.05$). No significant correlation were observed for metals and soil pH of samples from Amamoma. The significant relation between the metals and pH of soils from UCC farm at the 0.05 level were: Cu (r=-0.68 n= 20); Zn(r=-0.50, n=20) and Pb (r=-0.69, n=20). Negative but insignificant correlation were observed at the 0.05 level between concentrations of metals in the soils and their corresponding concentrations in the okro. For Cu (r= -0.28, n= 40), Zn (r= -0.44, n=40) and Pb (r= - 0.002, n=40).

The coefficients of determination for heavy metals transferred from soil into the plants is the expressed variation of the metal levels in plant due to variation in the soil pH, organic matter and other soil characteristics. In this study the coefficient of determinations for distribution of the metals in the okra due to the soils pH were 46.3%, 25 % and 47.6 % for Cu, Zn and Pb respectively.

Table 3: pH and organic matter of soils from the study sites

	Soil from Amamoma		Soil from UCC farm	
	pH	OM %	pH	OM%
mean	7.32	1.06	6.61	1.87
CV (%)	4.97	55	3.82	34
median	7.18	0.94	6.60	1.77
max	8.1	2.23	7.04	2.92
min	6.89	0.34	6.19	0.94

Even though the soils from UCC farm were slightly acidic, pH 6.61, with a higher organic matter 1.87 (Table 3), the levels of metals in the okra samples from Amamoma were higher than those found in samples from the UCC farm. Metal dissolution in solution increase with decreasing pH. With soils from UCC containing relatively higher concentrations of metals, it would be expected that the levels of metals in okra from UCC would be higher than corresponding levels in okra samples from the Amamoma farm.

However, okra samples from the Amamoma farm contained higher concentrations of the metals. This observation could be due to the relatively higher organic matter contents of the soils from UCC farm coupled with his slightly acidic nature which limits the dissolution and mobility of metals. The soil pH has been found to impact greatly on the desorption and bioavailability of heavy metals, because of its strong effects on solubility and speciation of heavy metals both in the soil as a whole and particularly in the soil solution [24-26].

Although plant uptake of heavy metals depends mainly on the mobility and availability of heavy metals in soils, metals in soils with high organic matter are strongly bound to soils, and are not easily desorbed into the

soil solution and made available for translocation into plants as have been observed [27-28]. Also the transfer of heavy metals from soils to vegetables have been found to be dependent on the vegetable species, soil texture, cation exchange capacity, pH, organic matter, clay content and hydrous oxides, i.e. oxides of Al, Fe and Mn, concentration of metal in soil solution and organic and inorganic complexation agents [29-31]. Several environmental and human factors and nature of the plant may also alter metal uptake [32].

Transfer factor

The soil-plant transfer factor (TF) which is the ratio of contaminant concentration in plant parts to concentration in dry soil [33-34], was calculated as follows.

$$TF = C_{plant}/C_{soil} \quad (1)$$

Where C_{plant} and C_{soil} represents the toxic metal concentration in extracts of plants and soils on dry weight basis, respectively. the metal transfer factors calculated for metals in this study is shown in Table 4. The plant transfer factors for the metals Cu,0.17; Zn, 0.08 and Pb, 0.30 for samples from the UCC farm were lower than those found for Cu, 0.27; Zn, 0.17 and Pb,0.41 for samples from the Amamoma farm (Table 4). The lower TF values observer for samples from UCC were probably as a result of higher metal levels in the soils with corresponding lower levels of metals in the okra could be partly due to the relatively higher organic matter contents of the soil in the UCC farmland, which binds the metals strongly and limits their translocation into the crop as reported [35].

Table 4: Soil-okra metal transrer factor (TF) for the two farms

		Amamoma			UCC	
	Cu	**Zn**	**Pb**	**Cu**	**Zn**	**Pb**
Metals in soil (mg/kg)	9.00	14.83	4.65	11.26	18.24	4.88
Metals in okro (mg/kg)	2.47	2.45	1.91	1.94	1.54	1.45
TF	0.27	0.17	0.41	0.17	0.08	0.30

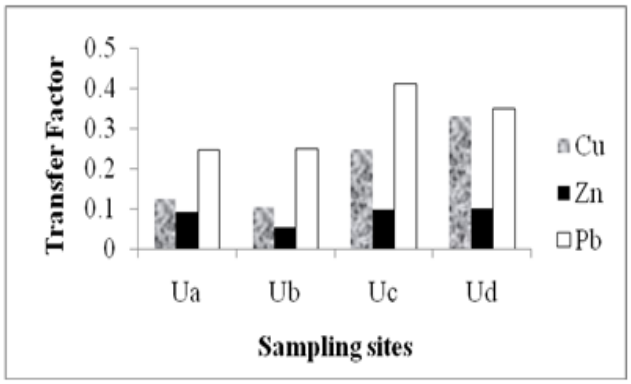

Figure 4:Soil-okro metal Transfer Factor for different sites in UCC farm

The mean (and ranges) of the TF values calculated for the samples from the UCC farm were Cu, 0.20 (0.10-0.33); Zn, 0.09 (0.05 -0.11) and Pb, 0.32 (0.25-0.41). The mean and range of TF for Cu, Zn and Pb for the Amamoma farm were 0.23 (0.11-0.37), 0.15 (0.10 -0.24) and 0.34 (0.08- 0.45) respectively. For all samples analyzed, a TF<1were recorded for the metals suggesting that Cu, Zn and Pb translocation from the roots to the okra were less effective. Probably, the low TF values is as a result of the retention of the metals by soil solids, organic matter, thus decreasing their mobility and bioavailability.

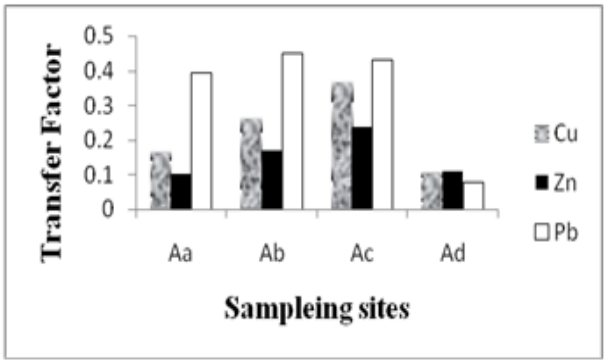

Figure 4:Soil-okro metal Transfer Factor for different sites in Amamoma farm

Table 5: Correlation between TF values of metals, pH and OM

	TF_{Cu}	TF_{Zn}	TF_{Pb}	pH	OM
TF_{Cu}	1				
TF_{Zn}	0.718	1			
TF_{Pb}	0.721	0.497	1		
pH	0.185	0.666	0.071	1	
OM	-0.03	0.301	-0.03	0.475	1

Generally, a negative correlation has been observed between heavy metal bioavailability (TF) and soil pH, and a positively correlation with soil organic matter [36-39], because as soil pH decreases, solubility of metal increases in the soil solution and a greater proportion is present as highly available free metal ions in the soil solution for translocation. However, in this study pH correlated positively with TF values of all the three metals Cu, Zn and Pb; but only Zn showed significant correlation ($r=0.066$, $p<0.05$). This means as pH decreases the concentration of Zn transferred into the okra plant also decreases. This observation is opposite to those found by others, that plant uptake of Zn increases as soil pH decreases [40, 41]. The decreased in Zn uptake by the okra with decreasing pH may be attributed partly to the metal binding to organic matter in the soil solution even as the pH decreased. There seem to be little relationship between soil pH and the metal, Cu and Pb, concentrations in the soil solution; and their translocation in to the okra as have been reported for other plants [35, 42-44].

The very low TF values observed for the metals could be as a result of the nature of the soil solutions, slightly acidic to slightly basic with pH, 6.6-8.1, which decreased the mobility of the metals. Metals maintained at

neutral to slightly alkaline condition show low mobility of heavy metals in the soil solution, but the mobility is increased as he pH is lowered [44, 45].

Even though it has also been reported that heavy metal adsorption declined with decreasing OM in soils [46-47], in this study organic matter correlated negatively and insignificantly with TF of Cu and Pb. However, Zn showed significantly very weak and positive correlation ($r=0.3$, $p<05$). This was similar to what has been reported, that metals accumulation in vegetables correlate positively with organic matter [48]. The significant correlation between Zn transfer into the okra and the soil properties, pH and OM, suggest that zinc was more available as free metal ions in the soil solution for translocation into the okra plant than were lead and copper, though other factors may be partly responsible. Bjerre and Hans-Henrik, found Zn to be more mobile than Cu and Pb in oat plant [49]. Correlation of TF values of Cu, Zn and Pb showed significantly positive relations amongst the metals.

Assessment of Heavy metal pollution

The magnitude of CU, Zn and Pb contaminants in the farm lands were determined using the enrichment factor values. The background concentrations of Cu 45µg/g), Zn (9545µg/g), Pb (20 µg/g) and Fe (47,000 µg/g) in the average shale obtained from Turekian and Wedepohl [50], were used for the calculation of pollution indices. Iron has been found to be the most important sorbent phase for trace metals, and is a quasi conservative tracer of the natural metal-bearing phases in fluvial and coastal sediments [51, 52], therefore for the calculation of enrichment factor Fe was used to normalize metal concentrations.. and the EF defined as follows [53]:

$$EF = \frac{(\frac{M}{Fe})_{Sample}}{(\frac{M}{Fe})_{Background}} \quad (2)$$

where $(M/Fe)_{Sample}$ is the ratio of metal and Fe concentrations in the sample, and $(M/Fe)_{Background}$ is the ratio of metal and Fe concentrations of the background. A mean enrichment quotient (MEQ) for the three metals was used to estimate the magnitude of human-induced change in the farms, by summing EFs for Cu, Pb, and Zn and dividing by three. MEQ >1.5 was considered indicative of human influence.

Table 6: Enrichment Factors for metals in soils from farms

Site	EF_{Cu}	EF_{Zn}	EF_{Pb}	MEQ
Aa	0.41	0.12	2.20	0.91
Ab	0.16	0.10	0.58	0.28
Ac	0.40	0.12	0.22	0.25
Ad	0.04	0.04	0.12	0.07
mean	**0.25**	**0.08**	**0.78**	**0.38**
Ua	0.09	0.03	0.17	0.10
Ub	0.03	0.02	0.07	0.04
Uc	0.24	0.04	0.90	0.39

Ud	0.10	0.03	0.23	0.12
mean	**0.12**	**0.03**	**0.34**	**0.16**

EF<2 means minimal enrichment [54]. Since the E*F* values (Table 6) are all less than 1, it indicate that the soils from the farms are not significantly enriched in Pb, Cu and Zn. However, the E*F* values follow the order Pb > Cu > Zn. The MEQ >1.5 for all sites, meaning there is no significant human influence on the levels of metal enrichment.

The pollution load index (PLI) has been used in this study to measure pollution load of metals from agricultural soils [55]. The contamination factors ,CF is the metal concentration in the sediment (C_M) divided by the background value of the metal (C_{Mb}). The PLI for a single site is the *n*th root of *n* number multiplying the (CF values) together. The CF and PLI were calculates as follows:

$$CF = C_M / C_{Mb} \qquad (3)$$

$$PLI \text{ for a site} = (CF \times CF \ldots \times CF_n)^{1/n} \qquad (4)$$

Table 7: Contamination Factor and PLI values for Pb, Cu and Zn

Site	CFCu	CFZn	CFPb	PLI
Amamoma farm				
Aa	0.0037	0.0011	0.0198	4.29×10^{-3}
Ab	0.0058	0.0018	0.0226	6.10×10^{-3}
Ac	0.0082	0.0025	0.0216	7.60×10^{-3}
Ad	0.0024	0.0011	0.0040	2.21×10^{-3}
Mean	0.0050	0.0016	0.0170	2.40×10^{-3}
UCC farm				
Ua	0.0028	0.0010	0.0124	3.23×10^{-3}
Ub	0.0023	0.0006	0.0125	2.53×10^{-3}
Uc	0.0055	0.0010	0.0206	6.00×10^{-3}
Ud	0.0074	0.0011	0.0176	6.15×10^{-3}
Mean	0.0045	0.0009	0.0158	4.02×10^{-3}

Index of Geo-accumulation (*Igeo*) was introduced to assess metal pollution in sediments and has been applied in recent pollution studies to enable the qualitative assessment of soil contamination by heavy metals [56-58], *Igeo* is computed by:

$$Igeo = \log_2 (Cn/1.5Bn) \qquad (5)$$

where *Cn* is the concentration of the element in the tested soil, *Bn* is the geochemical background value in the average shale of element [59], and the constant 1.5 compensates for natural fluctuations of given metal and for minor anthropogenic impacts [60]. The seven classes of *Igeo* as proposed by Müller are as follows: $Igeo \leq 0$, uncontaminated (Class 0); $0 < Igeo \leq 1$, uncontaminated to moderately contaminated (Class 1); $1 < Igeo \leq 2$, moderately contaminated (Class 2); $2 < Igeo \leq 3$, moderately to heavily contaminated (Class 3); $3 < Igeo \leq 4$,

heavily contaminated (Class 4); 4 < *Igeo* ≤ 5, heavily to extremely contaminated (Class 5); *Igeo* > 5, extremely contaminated (Class 6) [61].

The Index of Geo-accumulation values (Table 8) indicate that the soils are not contaminated with the three metals.

Table 8: Igeo value for metals in Agricultural soils

	Amamoma	UCC	**Soil Quality**
Cu	-8.2202	-8.3854	Uncontaminated
Zn	-9.8519	-10.694	Uncontaminated
Pb	-6.4632	-6.5714	Uncontaminated

Potential Ecological Risk Index (RI) and Health risk index

The Potential Ecological Risk Index, RI, advanced by Hakanson [62], which represents the toxicity of heavy metals and the extent of pollution of the environment, is defined as:

$$RI = Er^i = \sum(T_i \times C_i / B_i) \quad (6)$$

where RI is calculated as the sum of all six risk factors for heavy metals (Cu, Pb and Zn) in soils, Er^i is the single potential ecological risk factor, T_i is the developed metal toxicity factor. The toxic factors for Cu and Pb are 5, and 1 for Zn. C_i / B_i is the metal pollution factor, C_i is the practical concentration of metals in soil, and B_i is the background value for metals. The meaning of potential ecological risk index values are as follows: RI<150, low ecological risk; 150≤RI<300, moderate ecological risk; 300≤RI<600, considerable ecological risk; and RI>600, very high ecological risk.

In the present study it was found that the risk index values (Table 9) for the individual metals as well as the RI were all lower than 1. Thus indicating very low ecological risk.

Table 9: Results of Ecological Risk and Health hazard Assessment

	Single Index Risk (Er^i)			RI	Hazard Index (HI) QH		
	Cu	Zn	Pb		Cu	Zn	Pb
Amamoma	0.025	0.002	0.085	0.112	0.009	0.009	0.0001
UCC	0.022	0.001	0.079	0.102	0.011	0.009	0.0002

Hazard Index, Hazaed Quotient-based risk assessment provides an indication of health risk level due to exposure to pollutants [63]. The risk to human health by the intake of metal-contaminated okra (Table 9) was evaluated using the ratio between exposure and the reference oral dose (R_fD) [64]. The potential hazard of metal to human health (HQ) through consumption of the okra was estimated using the following equation:

$$HQ = (Div) \times (C_{metal})/R_fD \times Bo$$

Where (Div) is the daily intake of vegetables (kg/day), which was found to be 0.08; (C_{metal}) is the concentration of metal in the okra (mg/kg); Bo is the human body weight (70 kg); the oral reference dose R_fD (mg/kg of body weight/day) for Pb, Cu and Zn were 0.245, 0.25 and 15.00 respectively [65, 66]. The HQ for each of the metals Cu, Zn and Pb were lower than one (1), implying no obvious risk. Thus, the potential health risks posed by these metals were considered insignificant. This means at those levels, it was safe, and consumption of okra from the farms do not posed Cu, Zn and Pb health hazard.

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