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Assessment of the Levels of Some Trace Metals in Soils and Roots of Cassava Grown Under Usage of Agrochemicals in Some Parts of Benue State, Nigeria

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Abstract

The indiscriminate usages of agrochemicals by rural farmers in crops cultivations as efforts are intensified to enhance food security present great environmental challenges. This study used some analytical methods to determine the levels of some trace metals in soils and roots of cassava (Manihot esculenta Crantz) grown in selected farms in Otukpo, Ohimini and Katsina-Ala Local Government Areas (L.G.A) of Benue State, Nigeria. The cassava roots were harvested twelve months after planting (12 MAP) from six farmers' fields and control farms cultivated in each of the L.G.A between June, 2008 and May, 2009. In the farmers' fields, cassava roots content of the trace metals varied between 0.031±0.003µg/g Cr to 0.870±0.250µg/g Pb while the control cassava roots content ranged from 0.022±0.001µg/g Ni to 0.548±0.130µg/g Pb. The soil levels of the trace metals varied between 0.058±0.002µg/g Ni to 3.780±0.033µg/g Pb in the farmers' fields and 0.040±0.005µg/g Ni to 2.520±0.330µg/g Pb in the control farms. These results were significantly ($P < 0.05$) higher in the farmers' fields and this suggests an anthropogenically induced source. However, the present levels of the soil and cassava roots content of the trace metals were below WHO/FAO's reported human toxicity levels. However, it is important to carryout periodic review of the levels of the trace metals to monitor future accumulation in soil and cassava roots as a result of the continued usage of the agrochemicals.

Keywords: Agrochemicals, Benue state, cassava roots, farmers' fields.

Introduction

Nigeria, like any other typical African country, is an agrarian economy in which agriculture and agro-allied enterprises are the most popular income-generating activities providing employment for up to 90% of the rural dwellers[1]. Nigeria is the largest producer of cassava in the world with about 45 million metric tonnes[2] and her cassava transformation has been reported as the most advanced in Africa[3]. Cassava is grown throughout the tropic and could be regarded as the most important root crop, in terms of area cultivated and total production[4]. It is a major food crop in Nigeria[5] strategically valued for its role in food security, poverty alleviation and as a source of raw materials for agro-allied industries with huge potential for the export market[6]. Cassava has in recent years transformed from famine reserve commodity and rural staple to a cash crop in Africa[3]. Currently in Nigeria, cassava is one of the cardinal crops being focused upon for enhanced productivity in the current effort to ensure food security for the populace. In the urban areas, cassava consumption of poor households is double that of non-poor households while in rural areas, poor households consumption of cassava is triple that of non-poor households[7].

In the efforts by farmers to improve the productivity of low nutrient status soils in Nigeria, there have been cases of wrong applications of agrochemicals (chemical fertilizers, pesticides and herbicides) to crop. Even though, the practice of agriculture is essential for human existence, careless and inappropriate agricultural practices can degrade and contaminate natural resources and in so doing, harm human health. It was also reported that the anthropogenic activities aimed at enhancing food production could facilitate the accumulation of undesirable substances in plants and affect the qualities of both soil and water resources adversely[8,9]. The health impacts of agricultural chemicals (pre and post emergence herbicides, insecticides and pesticides) used in cassava production are a function of their degree of accumulation in environmental sinks: soil, air, water, plants and the degree to which humans are exposed to them[7]. The wrong use of certain agro-chemicals in crop cultivations have been reported to account for about 50% of the free radical molecules available in our food[10], with potential adverse health effects following excessive ingestion.

While increased agriculture and agrochemical uses are generally considered as panacea for farmers to increase production; the farming practices and uses of agrochemicals including possible environmental pollution from agriculture in many parts of Benue State, Nigeria (The Food Basket of the Nation) have not been investigated[11]. Some potentially toxic metals and trace elements present in agricultural soils enter the human body through the food chain. Low levels of these elements occurred naturally in soils and some are essential for plants and animals.

However, even the essential elements create toxicity problem if high levels are present in the environment[12]. Risks due to chemical contaminants in the terrestrial environment are often assessed by comparing current concentrations against reference concentrations above which adverse effects are considered likely to occur. Thus, The current study was conducted to investigate the effects of chemical fertilizers (single superphosphate fertilizers) and herbicides (mostly diuron and paraquat) on the levels of some heavy metals in soils and cassava roots cultivated in some farms in Otukpo, Ohimini and Kastina-Ala Local Government Areas of Benue State, Nigeria and the outcome recommended to Government Agricultural and Rural Development Authority for education to rural farmers. It is envisaged that the baseline information presented in this study will contribute to the understanding of agricultural situation in developing countries and the effort towards sustainable agriculture.

Materials and Methods

Study Area: This study was conducted in Otukpo (latitude $6^0$49′N and longitude $8^0$40′E), Ohimini (latitude $6^0$25′N and longitude 7o47′E) and Kastina-Ala (latitude 9o20′N and longitude $7^0$11′E). In this L.G. As of Benue State Nigeria, cassava cultivations have been carried out by over 90% of rural dwellers with little or no knowledge of the negative impact of the wrong usage of chemical fertilizers, pesticides and herbicides in crops cultivations. There are also problems of wrong choice of certain agro-chemicals in relation to the local environment. Thus, the residual effects of these agrochemicals is highly anticipated in the farming communities and it becomes pertinent for close environmental monitoring with a view to determining and documenting the impact of this agricultural activity on the environment.

Sample Collection: Samples of the soils and roots of cassava (*Manihot esculenta*) were randomly collected using standard procedure described by Radojevic and Bashkin[13]. Bulk soil samples were collected at a depth of 0-30cm using soil auger. Samples were collected from both farmers' fields where chemical fertilizers (single superphosphate fertilizers) and herbicides (mostly diuron and paraquat) were applied to enhance soil fertility and control weeds respectively and the experimental (control) farms where no fertilizer and herbicide was applied. The cassava roots were harvested twelve months after planting (12MAP) (June, 2008 and May, 2009) from six farms each in Otukpo, Ohimini and Kastina-Ala Local Government Areas of Benue State.

Sample preparations: Cassava roots: The cassava roots harvested from the farmers' fields and control farms were separately peeled, washed with distilled water and sliced using stainless steel knife. Then, they were air-dried in the laboratory, ground with porcelain mortar and pestle and then sieved (<1mm). 2.0g each of the powder were weighed into labelled acid-washed porcelain crucibles and placed in muffle furnace and the temperature was raised slowly over 2hrs to reach 500^{o}C. The samples were ashed at this temperature for 4hrs after which they were removed and cooled in desiccators at room temperature. Then, 10.0cm^3 of 6M HCl was added to each sample, covered and heated on a steam bath for 15mins followed by the addition of 1.0cm^3 of concentrated HNO_3 and evaporated to dryness. The heating was continued further for 1hr to dehydrate silica[13, 14]. Another 1.0cm^3 of 6M HCl was added and swirled to mix followed by the addition of 10.0cm^3 distilled water. Again, it was heated on a steam bath to complete dissolution, cooled and filtered through Whatman No. 541 filter paper into separate 50cm^3 volumetric flasks and the volume made up to the mark with water.

Soil: Bulk soil sample from each farm was air-dried, ground and sieved (< 2mm) and 1.0g each was weighed into 100cm^3 tall beaker followed by the addition of 30.0cm^3 of 1:1 HNO_3. This was boiled gently on a hotplate with stirring until the volume reduced to about 5cm^3 [13-15]. Then, another 10.0cm^3 of 1:1 HNO_3 was added and the heating was similarly repeated after which the extract was cooled to room temperature and filtered through Whatman No. 541 filter paper. The beaker was washed with successive small portions of 0.25M HNO_3 and filtered. Thereafter, the filtrate was transferred into 50cm^3 volumetric flask and diluted to the mark with water.

Five serial calibration standards were prepared for all the metals by diluting aliquots of the working metal solutions with 0.25M HNO_3 and the calibration standards were made to cover the optimum absorbance range of 0.2-10mg/L for the standard calibration curves.

Analyses of the Samples Extracts: Both the cassava roots and soil extracts were analyzed for their levels of chromium (Cr), lead (Pb), cobalt (Co), nickel (Ni), copper (Cu), cadmium (Cd), iron (Fe) and zinc (Zn) using an SP Pye (1900) Unicam Atomic Absorption Spectrophotometer equipped with air – acetylene burner.

Determination of Some Physicochemical Properties of the Farms Soils: Sample Preparation and Analysis: Bulk soil samples collected at the depth of 0-30cm in the farmers' fields and control farms were respectively homogenized and sieved (< 2.00mm) and laboratory analyses of the soil properties were carried out on the < 2.00mm particles using standard procedures. Particle size was determined using the hydrometer method, pH was measured in 1:2.5 suspension in water and organic matter was determined by dichromate oxidation method[16]. Effective Cation Exchange Capacity (ECEC) was determined by summation method following the determination of exchangeable cations[17] and the extraction of exchangeable acidity in 1N KCl[18]. The soil electrical conductivity was determined by a modified laboratory method[13].

Data Handling: The data generated from this study were subjected to statistical treatment such as mean, standard deviation, ANOVA, t-test and correlation analysis to determine the significance of data variation between sample locations as well as the relationship between variables.

Results and Discussion

Table-1 presents the concentrations (µg/g) of some trace metals in the roots of cassava obtained from selected farms in Otukpo, Ohimini and Kastina-Ala Local Government Areas of Benue State, Nigeria between June, 2008 and May, 2009. In the farmers' fields, the concentrations ranged from 0.036±0.001µg/g Cr to 0.840±0.230µg/g Pb in Otukpo while in Ohimini and Kastina-Ala, the concentrations varied between 0.032±0.006µg/g Ni to 0.850±0.270µg/g Pb and 0.031±0.003µg/g Cr to 0.870±0.250µg/g Pb respectively. The control farms results varied between 0.023±0.004µg/g Cr to 0.522±0.200µg/g Pb in Otukpo, 0.022±0.001µg/g Ni to 0.511±0.180µg/g Pb in Ohimini and 0.025±0.005µg/g Cr to 0.548±0.130µg/g Pb in Kastina-Ala L.G.A. The results differed significantly ($p < 0.05$) between sample locations and between farms. This may be due to the interactions of soil-plant root-microbes under different agricultural practices which played important roles in regulating trace metals movement from soil to the edible parts of crops.

Table-1
Concentrations (µg/g) of some heavy metals in roots of cassava grown in some farms in Otukpo, Ohimini and Kastina-Ala, Benue State

Trace metals	Sample farms	Concentration (µg/g)/sample location		
		Otukpo	Ohimini	Kastina-Ala
Cr	A	0.036^{a*}±0.001	0.038^{b}±0.004	0.031^{c}±0.003
	B	0.023^{a+}±0.004	0.026^{b}±0.007	0.025^{c}±0.005
Pb	A	0.840^{a}±0.230	0.810^{b*}±0.150	0.870^{c}±0.250
	B	0.522^{a}±0.200	0.511^{b+}±0.180	0.548^{c}±0.130
Co	A	0.052^{a}±0.007	0.050^{b}±0.004	0.055^{c*}±0.002
	B	0.043^{a}±0.001	0.045^{b}±0.003	0.046^{c+}±0.003
Ni	A	0.038^{a*}±0.005	0.032^{b}±0.006	0.042^{c}±0.002
	B	0.024^{a+}±0.005	0.022^{b}±0.001	0.026^{c}±0.007
Cu	A	0.117^{a}±0.016	0.130^{b*}±0.015	0.155^{c}±0.024
	B	0.053^{a}±0.013	0.057^{b+}±0.015	0.054^{c}±0.013
Cd	A	0.833^{a}±0.210	0.850^{b}±0.270	0.820^{c*}±0.210
	B	0.394^{a}±0.110	0.431^{b}±0.160	0.390^{c+}±0.114
Fe	A	0.633^{a*}±0.130	0.680^{b*}±0.100	0.693^{c}±0.150
	B	0.438^{a+}±0.070	0.410^{b+}±0.130	0.389^{c}±0.040
Zn	A	0.533^{a}±0.120	0.561^{b}±0.150	0.630^{c*}±0.200
	B	0.318^{a}±0.130	0.344^{b}±0.110	0.361^{c+}±0.150

Data presented are mean ± SD of 8 replicate analysis. Within columns, t-test of paired means with asterisk (*) and plus (+) are statistically significant ($p<0.05$). Within rows, ANOVA of means with different alphabets are statistically significant ($p<0.05$). **Key:** A = Farmer's Field, B = Control Farm.

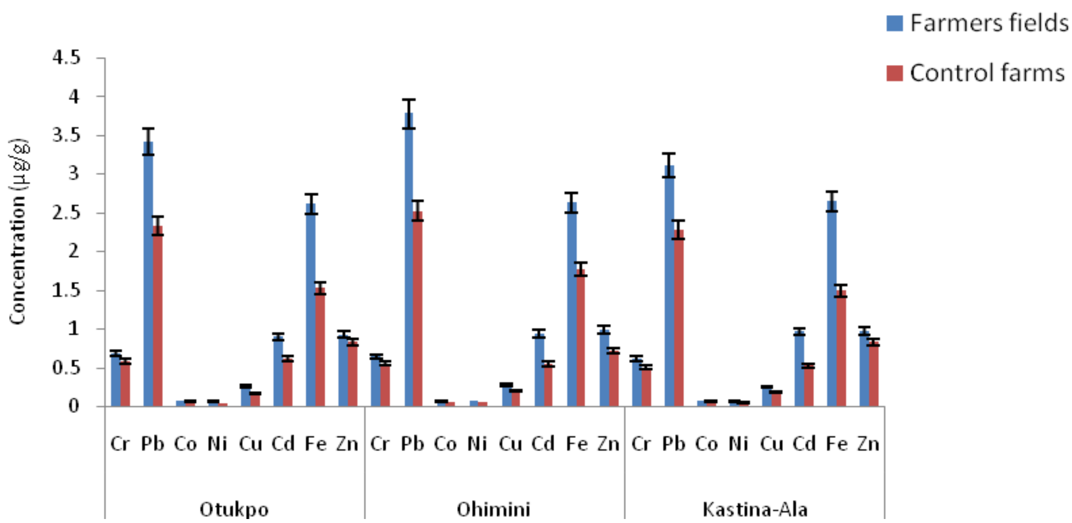

Figure-1
Concentrations (µg/g) of the trace metals in the farms soils at the sample locations

The results in figure-1 presents the concentrations (µg/g) of the trace metals in soils of the farmers' fields and control farms in the study area. The soils of the selected farmers fields recorded mean trace metal contents of 0.062±0.003µg/g Ni to 3.420±0.270µg/g Pb in Otukpo, 0.063±0.002µg/g Co to 3.780±0.420µg/g Pb in Ohimini and 0.058±0.002µg/g Ni to 3.110±0.212µg/g Pb in Kastina-Ala L.G.A. The mean levels of the trace metals in the control farms soil varied between 0.040±0.005µg/g Ni to 2.330±0.110µg/g Pb in Otukpo while in Ohimini and Kastina-Ala, the results ranged from 0.047±0.004µg/g Ni to 2.520±0.330µg/g Pb and 0.044±0.003µg/g Ni to 2.280±0.521µg/g Pb respectively. The results revealed significantly ($p < 0.05$) elevated levels of the trace metals in soils from the farmers' fields where chemical fertilizers (single superphosphate fertilizers) and herbicides (mostly diuron and paraquat) were applied to enhance soil fertility and control weeds respectively. This suggest an anthropogenically induced source. Phosphate fertilizers have been reported to be among the sources of heavy metals input into agricultural systems. On the average, it has been reported that phosphate rock contains 11, 25, 188, 32, 10, and 239 mg/kg of As, Cd, Cr, Cu, Pb and Zn, respectively[19]. Thus, repeated use of phosphate fertilizers, especially if abused as observed in the study area may result in accumulation of these elements and increase the contamination potential in soil. It has been reported that most farmers in Benue state applied agrochemicals randomly to crops without regard to the local environmental conditions and this has significant effect on the accumulation of agrochemical metabolites in soils and absorption by crops grown on such soil[10]. Careless and inappropriate agricultural practices can degrade and contaminate natural resources and in so doing, harm human health. The health impacts of agricultural chemicals (pre and post emergence herbicides, insecticides and pesticides) used in cassava production are a function of their degree of their accumulation in environmental sinks: soil, air, water, plants and the degree and form in which humans are exposed to them. It has been estimated, for example, that only 0.1 percent of pesticides actually reached pests, while the remainder stayed in the environment or on food[7]. The rampant uncontrolled agricultural practices in most parts of developing countries have been attributed to poverty, poor policy governing agriculture and land use as well as the low level of awareness on sustainable land use, agriculture and environmental management[20].

The overall mean concentrations of the trace metals in the farms soils and cassava roots presented in figures-2 and -3 respectively revealed high levels of Pb, Cd, Fe and Zn across the sample locations. The results in table-2 revealed that in both the farmers' fields and control farms; the soils and cassava roots content of the trace metals were strongly positively correlated. This suggests that the soil available trace metals have significant effect on the levels present in crops grown on the soil. The present levels of the trace metals in the cassava roots were lower than the available reported human toxicity levels of 1.00mgPb/day, 200mgFe/day, 200mgCr/day, 150-600mgZn/day[21] and 10mg/kg Cu[22]. High dietary contents of Lead and Cd are considered potential carcinogens and are associated with etiology of a number of diseases, especially cardiovascular, kidney, nervous system, blood as well as bone diseases[23].

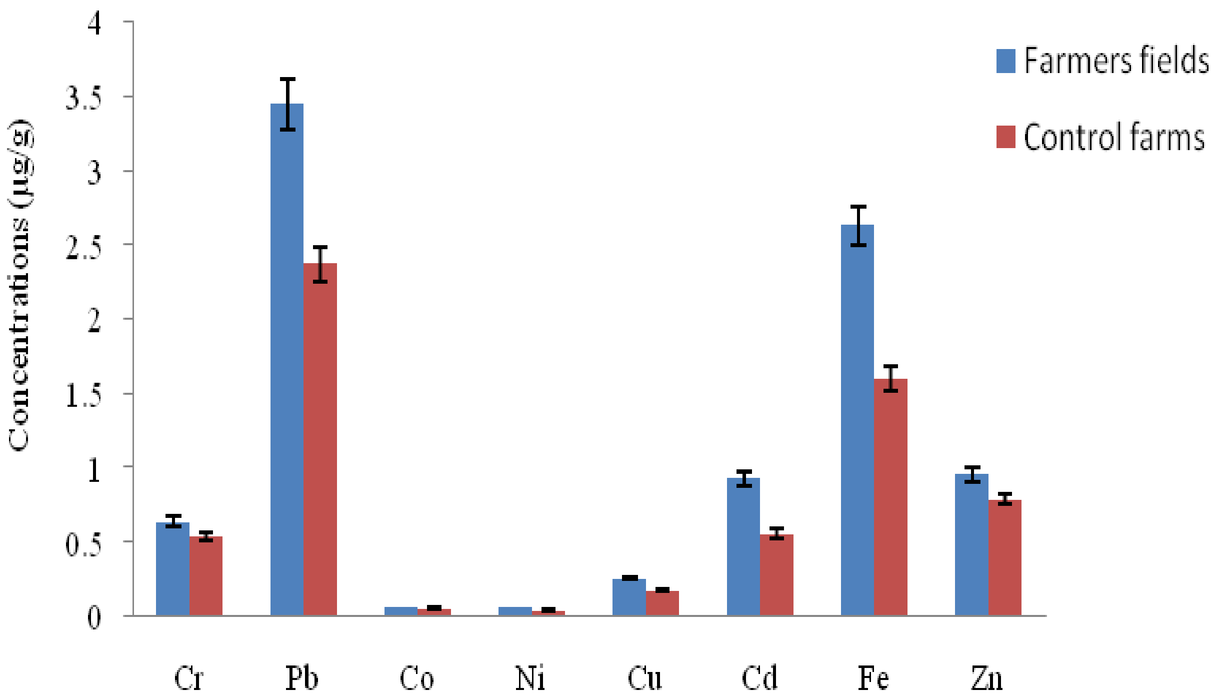

Figure-2

Overall mean concentrations (µg/g) of the trace metals in the farms soils

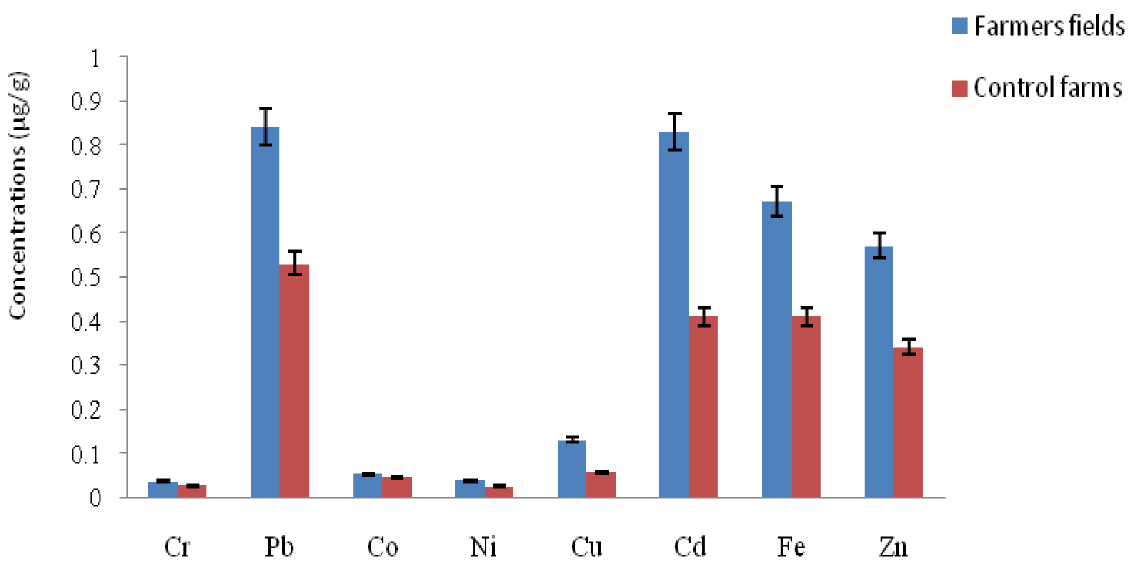

Figure-3
Overall mean concentrations (µg/g) of the trace metals in the cassava roots

Table-2
Correlation coefficients between the mean concentrations (µg/g) of the trace metals in soils and cassava roots

		Cr	Pb	Co	Ni	Cu	Cd	Fe	Zn
Samples from famers' fields	Cr	1.0000							
	Pb	0.9967	1.0000						
	Co	0.9916	0.9777	1.0000					
	Ni	0.9981	0.9998	0.9818	1.0000				
	Cu	0.9546	0.9757	0.9081	0.9711	1.0000			
	Cd	0.9750	0.9899	0.9381	0.9868	0.9969	1.0000		
	Fe	0.9959	0.9999	0.9757	0.9996	0.9778	0.9912	1.0000	
	Zn	0.9933	0.9994	0.9701	0.9985	0.9825	0.9941	0.9997	1.0000
Samples from control farms		Cr	Pb	Co	Ni	Cu	Cd	Fe	Zn
	Cr	1.0000							
	Pb	0.9908	1.0000						
	Co	0.9993	0.9848	1.0000					
	Ni	0.9932	0.9998	0.9880	1.0000				
	Cu	0.9922	0.9999	0.9867	0.9999	1.0000			
	Cd	0.9756	0.9964	0.9665	0.9945	0.9954	1.0000		
	Fe	0.9774	0.9970	0.9686	0.9954	0.9961	0.9999	1.0000	
	Zn	0.9998	0.9929	0.9985	0.9950	0.9941	0.9792	0.9809	1.0000

The soil-root transfer factors of the trace metals presented in figure-4 indicated that cassava has high potentials to absorb cobalt and cadmium and bio-accumulate them into root tissues but low potential for lead and iron absorption. It has been noted that exposure of humans and animals to levels of cobalt normally found in the environment is not harmful[24]. However, chronic ingestion of minute amount of heavy metals may have damaging effects on human beings and other animals, since there is no good mechanism for their elimination. The high transfer factor of Cd recorded in this study could become a source of concern due to the reported health effects when dietary threshold limits are exceeded. Dietary Cd absorption rate in humans has been estimated at 5%[25] but the rates increase to 20–30% in some individuals[26, 27]. Furthermore, it has been reported that Cd-linked kidney toxicity occurred in higher-than-expected frequencies in human populations whose dietary Cd intakes were well within the current Provisional Tolerable Weekly Intake (PTWI); 7µg/kg body weight/week, corresponding to 1µg/kg body weight/day[28], which suggests that the current PTWI is not sufficiently restrictive to protect the general population[29]. It was also reported that the levels of Cd in organs such as liver and kidney cortex increase with age because of the lack of an active biochemical process for its elimination coupled with renal re-absorption[29].

The results of some physicochemical properties of the farms soils shown in table-4 revealed that both the farmers' fields and control farms are acidic (pH of 5.50±1.00-6.40±0.70) within the 0-30cm soil depth. In a study on commercial cassava production, it was observed that cassava tolerated soils within a wide pH range (4.0 to pH 8.0) but the best pH range for growing cassava is 5.5–6.5[30]. Based on USDA's soil classification triangle, the particle size distributions of the farms soils revealed loam textural class in Otukpo, sandy-silt-loam in Ohimini and clay-loam in Kastina-Ala. Both the electrical conductivities and cation exchange capacities of the soils are moderate but the organic matter content was high. These properties showed that the soils have good potential for retaining nutrients elements and trace metals within the top soil layer and this has implication for crops grown on contaminated soil. Under trace metals contamination, crops may absorb and bio-accumulate high amount of trace metals which may be transferred into the human food chain.

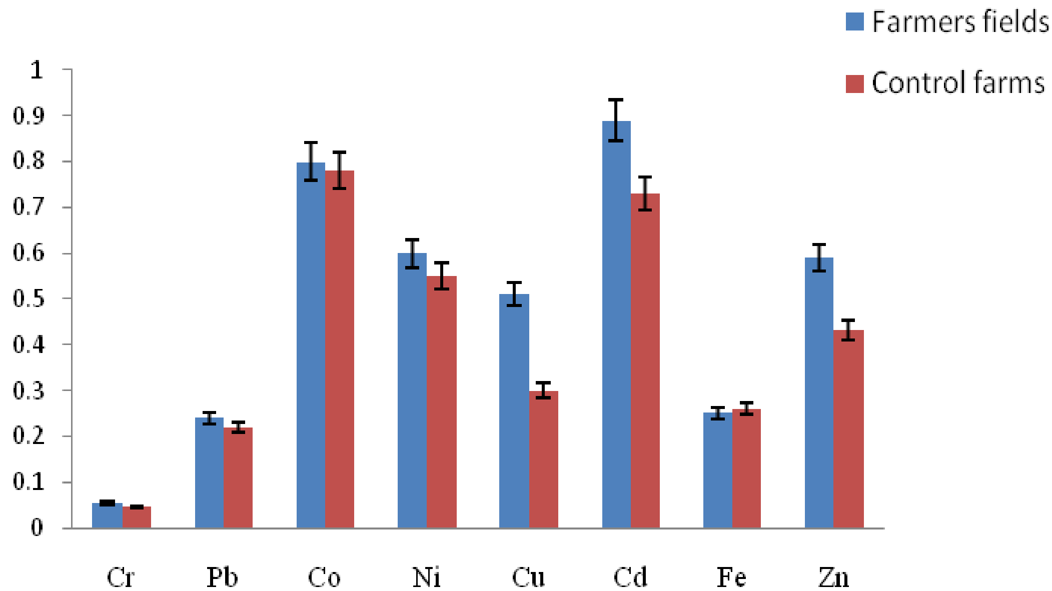

Figure-4
Transfer factors of the trace metals in the cassava roots
Tranfer factor = Trace metal concentration in cassava root/ Trace metal concentration in soil

Table-3
Some physicochemical properties of the soils in the sample locations

Soil physicochemical properties	**Sample locations/soil depth**					
	Otukpo		**Ohimini**		**Kastina-Ala**	
	A (0-30cm)	**B (0-30cm)**	**A (0-30cm)**	**B (0-30cm)**	**A (0-30cm)**	**B (0-30cm)**
pH (1:2.5 H_2O)	6.00±0.10	5.50±1.00	6.30±0.30	6.40±0.70	6.15±1.20	6.20±1.16
EC (mmho/cm)	0.25±0.02	0.22±0.03	0.20±0.04	0.22±0.05	0.25±0.01	0.20±0.05
ECEC (cmol/Kg)	7.66±1.10	7.20±1.50	8.20±0.54	7.80±1.20	8.15±0.80	7.90±0.46
Organic matter (%)	2.10±0.30	2.60±0.40	2.40±0.12	2.68±0.25	3.48±0.28	2.70±0.33
Sand (%)	33.40±1.80	30.70±2.10	35.10±1.30	32.00±1.07	36.20±1.90	34.30±2.20
Silt (%)	49.70±3.11	52.10±2.22	48.60±1.30	49.20±3.00	46.44±1.40	50.40±0.80
Clay (%)	16.90±0.20	17.20±1.16	16.30±0.60	18.80±0.40	17.36±0.21	15.30±0.40
Textural class	Loam		Sandy-silt-loam		Clay-loam	

Data presented are means ± SD of 8 replications. A = Farmers' Fields, B = Control Farms, K-Ala = Kastina-Ala

Conclusion

The result of this study revealed that the improper usage of chemical fertilizers and herbicides in the current effort to enhance cassava productivity contributed to anthropogenic build up of the trace metals in soils and cassava roots. Exposure of consumers to excess dietary (cassava roots) contents of trace metals may lead to risk of food poison. Therefore, farmers should be educated on the proper methods and time of applications of chemical fertilizers and herbicides to minimize the indiscriminate usage of these agrochemicals in cassava production and limit consumers' exposure to chemical contaminants.

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