

SOURCES AND ENVIRONMENTAL IMPLICATION OF HEAVY METALS POLLUTION IN PLANTS GROWN AROUND CONTAMINATED SITE IN EDO STATE, NIGERIA

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ABSTRACT

Dietary exposure to heavy metals, namely Arsenic (As), Lead (Pb), Cadmium (Cd) and Chromium (Cr), has been identified in Oluku and Otofure in metropolitan Benin City, Nigeria, as a risk to human health through the consumption of food crops and other edible plants. This study investigates the sources and the magnitude of heavy metals contamination in soils and food crops, cultivated close to mechanic workshop, refuse and waste currency dumpsites; this will help in creating public awareness of the imminent danger of food crops grown around contaminated sites. Thirty six (36) samples of food crops (cassava tuber and plantain fruits) were analysed from three different sites using atomic absorption spectrometer (AAS) with the aim of determining the level of concentration and the magnitude of exposure of the heavy metals investigated to human health. The results obtained when compared to standards revealed that the metals investigated were above threshold value; consequently exposing humans that consume such food crops grown in the area of study to health risk. The decrease in concentration from around and away from the sites as well as correlation range $r = (P < 0.01-0.001)$ shows anthropogenic source of contamination. The results obtained are presented in tables as mean plus or minus standard deviation (mean $\pm$ SD) with super and subscript defining the degree of significant differences in distance. Temperature obtained from the soil range from 24-28⁰ C while the pH recorded was from 2.99-6.80.

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KEYWORDS: Health-Risk, Food Crops, Magnitude, Exposure and Anthropogenic

INTRODUCTION

The implications associated with metals (embracing metalloids) contamination is of great concern, particularly in agricultural production systems. Metals most often found as contaminants in vegetables include Arsenic, Cadmium and Lead. These metals can pose a significant health risk to humans, particularly in elevated concentrations above the very low body requirements, Gupta and Gupta (1998).

Interest has recently been stimulated in researches at evaluating the levels of heavy metals around refuse dumpsite due to the growing concerns expressed by the government, regulatory agencies and the public, Page and Change (1985); Feng et al; (1991); Anthony and Balwant, (2006); Tiller (1992); Ukpebor and Unuigbo (2003), over the large acres of land covered by these dumpsites, its relation to environmental and health implications, Imasuen and Omorogieva (2013). The quality of soil intended for agricultural use depends on the concentration of heavy metals in it, Ukpebor and Unuigbo (2003). Heavy metals have been identified as a silent killer of mankind and causes environmental depletion. Therefore heavy metals analyses form an important components needed for regular Environmental Impact Assessment

(EIA) in town and cities, Asuen et al; (2005). Numerous studies have been carried out on the assessment of environmental pollution during the last two decades and the results reveal that mining, spillage, solid waste, household/industrial effluent, automobile emission, combustion of fossil fuels, atmospheric metallic burden, mechanic workshop, waste currency dump site etc. which finally settle in soils constitute the major sources of heavy metals in sediments and soil, Browning (1969), Ndiokwere (1984), Ihenyen (1998), Page and Gange (1970); WHO (1972); Asuen et al; (2005); Ukpebor and Unuigbo (2003); Imasuen and Omorogieva (2013). The cultivated plants take up the metals either as mobile ions present in the soil solution through the roots, Davies (1983) or through foliar adsorption, Chapel and Alexander (1986). The uptake of the metals by crops results in the bioaccumulation of these metals in plant tissues, Amusan et al; (2005). It has been reported that plants grown on contaminated soils, enhanced metals concentration due to pollution which increased heavy metal ion contents, Davies and White (1981); Grant and Dobbs (1977). The area under investigation lies within the tropical rainforest, consequently the soil is highly leached and acidic with relatively high temperature, (Figs 1 & 2), Imasuen and Onyeobi (2013). Since man is the

ultimate target of chemical influences in the environment, the consumption of these heavy metals through plant sources should be carefully regulated otherwise it may lead to accumulation in man with attendant health hazards; it was on this note that this research was carried out. The significance of this research is to examine the level of exposure of the crops grown around these sites to heavy metal contamination and the resulting health implication as well as to provide information for appropriate legislature and guideline for environmental monitoring.

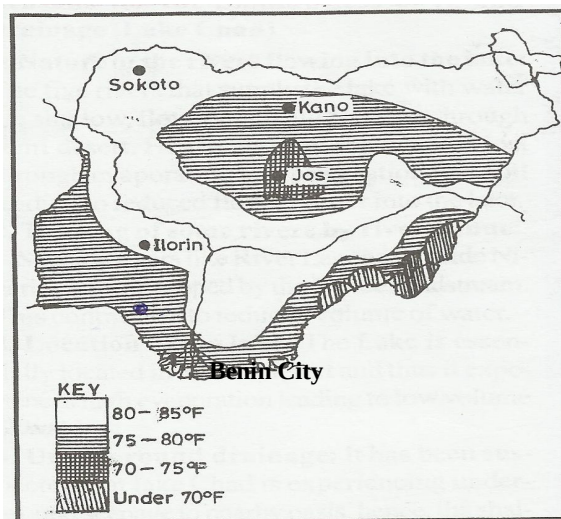


Fig 1: Map of Nigeria Showing Mean annual temperature (Adapted from Iwena, 2008).

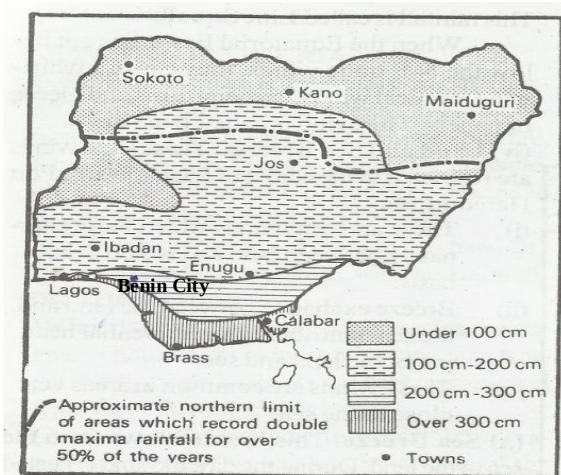


Fig 2: Map of Nigeria Showing monthly range of rainfall distribution in different Zones adapted from Iwena (2008).

MATERIALS AND METHODOLOGY

The materials used for accurate result in this research include; cassava tubers and plantain fruits, reagent of 20% diluted Hydrochloric acid, concentrated Nitric acid, perchloric acid and distilled water. The apparatus used are; Electric oven, weighing machine, pH meter, teflon crucible, stopwatch, 100ml

measuring cylinder, 250ml volumetric flask, knife, Global position system (GPS), desiccator and fume cupboard.

The study was carried out in Oluku which is a commercial and nodal town in metropolitan Benin City. It is strategically located on $06^{\circ} 27'14.8''N$, $05^{\circ} 35'35.2''E$ and a gateway to the western route in south-western Nigeria.(Fig 3). The population of the town is increasing per second as a result of the influx of migrants and land developers in and around Benin City.

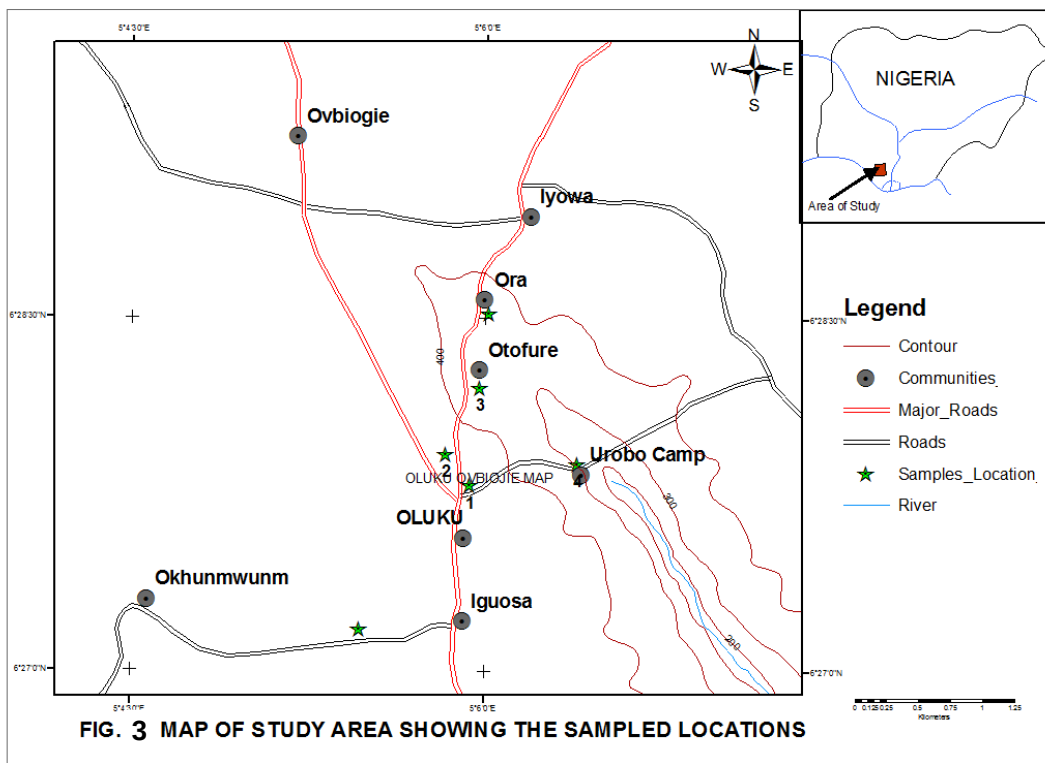
Cassava tuber and plantain samples were obtained from the farm at a distance of 20m away from waste currency dumpsite, mechanic workshop a refuse dumpsite and at a control distance of 1000m (1km) away. The farms are owned by some of the inhabitants of the communities where they derive their food from.

The cassava tubers and plantain fruits were taken to the laboratory; the samples were washed with distilled water and sliced carefully and then rapped with foil paper and placed in the oven at a steady temperature of $70^{\circ}C$ for three days. The dried samples of each food crop investigated was then ground in an agate mortar with pestle. 0.5g each of the prepared sample of cassava tuber and plantain fruit was weighed into a teflon crucible and placed in a desiccator at $300^{\circ}C$ for three hours for proper ashing.

The samples were allowed to cool for 24 hours after which 10ml of 20 percent diluted Hydrochloric acid was added and filtered into 250ml volumetric flask and transferred into 100ml rubber bottle. Distilled water was added to make-up and the content was thoroughly mixed by shaking.

Liquid digested plants (cassava tuber and plantain fruits) were analysed using Atomic Absorption Spectrometer (ASS) model 969 Unicam series.

The result of the analysis was further subjected to statistical treatment at $p < 0.05$ (95%) confidence level using SPSS.



RESULTS AND DISCUSSION

ARSENIC: Arsenic with chemical formula (As) found in group five and period four of the periodic table of an element; has atomic weight of 74.9 and atomic number thirty three (33). The average crustal abundance of Arsenic is 1.5 mg kg^{-1} ; Plant et al; (2004). From the analytical and statistical treatment the results show that from the three sites and two food crops (cassava and plantain fruits) investigated, a concentration level of $13.20 \pm 0.01 \text{ mg kg}^{-1}$ was recorded for plantain fruits grown around mechanic workshop while $2.54 \pm 0.01 \text{ mg kg}^{-1}$ was recorded for cassava tuber in the same site. Other values of arsenic recorded around waste currency and refuse dumpsite for cassava range from $2.36 \pm 0.01 \text{ mg kg}^{-1}$ to $2.54 \pm 0.01 \text{ mg kg}^{-1}$ and of plantain fruit was $2.85 \pm 0.01 \text{ mg kg}^{-1}$ – $13.20 \pm 0.01 \text{ mg kg}^{-1}$. At a distance of 1000m away from contaminated site, the results obtained show that there was a significant decrease compared to the value obtained around the site. This in addition to the strong positive correlation at $p < 0.001$ two tailed buttress that the metals are from same origin. Tables 1-4 show the results obtained from each site and the correlation of plants to plants. The result obtained from both food crops shows that there is a high risk of exposure and threat of arsenic in food crops sampled as the level of concentration far exceed the recommended threshold value of 0.2 mg kg^{-1} by Vinogradov (1959), Taylor (1964), Bear (1964) and Bowen (1966). Arsenic is highly toxic and can lead to a wide range of health problems in humans. It is carcinogenic, mutagenic and terratogenic, National Research Council (1999).

Other health effects include cardiovascular and peripheral vascular diseases, neurobehavioral disorders, diabetes, hearing loss e.t.c Robert et al (2005).

Cadmium: Cadmium was highest in mechanic workshop (table 2) with concentration level of $21.90 \pm 0.10 \text{ mg kg}^{-1}$ in plantain fruit. At the waste currency dumpsite, concentration level of $10.21 \pm 0.01 \text{ mg kg}^{-1}$ was recorded in cassava tuber (table 1), $7.21 \pm 0.01 \text{ mg kg}^{-1}$ in plantain fruit respectively (table 3). The values obtained from both sites revealed a significant decrease away from the sites. The correlation coefficient range of ($r=0.50-0.95$) was recorded for cadmium at $p < 0.01$ to $p < 0.001$ two tailed showing a positive correlation (table 4). When the result was compared to (table 5) permissible limit of 0.6 mg kg^{-1} heavy metals Cadmium in plant, there was a high rate of exposure and threat to the health of innocent residents' peasant farmers who consumed these food crops and the uninformed citizen who bought such food for consumption within the locality and elsewhere. Health impact of cadmium has been reported from several parts of the world. The most popular one being itai-itai, a Japanese word meaning pains in the bones; central nervous system disorder, cancer, mutation, Manahan (2000).

Chromium: Across the three sites investigated, the highest concentration of chromium was found in plantain fruit grown around the mechanic workshop with a value of $37.71 \pm 0.01 \text{ mg kg}^{-1}$. Cassava tuber recorded the second highest with a concentration of $12.13 \pm 0.01 \text{ mg kg}^{-1}$ around the currency waste

dumpsite and then cassava tuber around the refuse dumpsite which recorded $10.10 \pm 0.01 \text{ mg kg}^{-1}$. The range across the sites for cassava tuber was from $8.13 \pm 0.01 \text{ mg kg}^{-1}$ to $37.71 \pm 0.01 \text{ mg kg}^{-1}$ and for plantain fruits from $9.14 \pm 0.01 \text{ mg kg}^{-1}$ to $37.17 \pm 0.01 \text{ mg kg}^{-1}$. By comparing the results obtained in this research to an established standard of 0.2 mg kg^{-1} of table 5 it was observed that both crops sample were above the permissible threshold value recommended for food crops, suggesting a high level of exposure and health risk to humans that consume the food. Chromium correlate positively with other metals studied in this research at $p < 0.001$ two tailed except for Nickel which correlate poorly at $p < 0.05$ with a correlation coefficient, $r = 0.44$. The positive correlation shows that the metals are from similar origin absorbed by plants root from the soil. Medical reports and literature have pointed out havoc done by chromium accumulation in human body tissues and blood around the world. Popular among them is cancer, nervous disorder, WHO (1972).

Nickel: Nickel was more concentrated in cassava tuber and plantain fruits sampled around the currency waste dumpsite with a value of $19.59 \pm 0.01 \text{ mg kg}^{-1}$ and $9.18 \pm 0.01 \text{ mg kg}^{-1}$ (table 1) respectively. Refuse dumpsite recorded $6.67 \pm 0.01 \text{ mg kg}^{-1}$ and $6.07 \pm 0.01 \text{ mg kg}^{-1}$ respectively, for cassava tuber and plantain fruits (tables 2-3) recorded $5.33 \pm 0.11 \text{ mg kg}^{-1}$ and $7.73 \pm 0.15 \text{ mg kg}^{-1}$ for mechanic workshop. All the values obtained were higher than the required standard for food crops. Associated health impact of Nickel is similar to those of chromium.

Lead: Of the two crops sampled (tables 1-3), plantains have the highest concentration of lead across the three sites with a value of $46.46 \pm 0.01 \text{ mg kg}^{-1}$ from the mechanic workshop. This was followed by $10.69 \pm 0.0 \text{ mg kg}^{-1}$ from refuse dumpsite and $8.34 \pm 0.0 \text{ mg kg}^{-1}$ from waste currency dumpsite respectively. Cassava tuber concentration value range from 6.42 ± 0.01 to $9.92 \pm 0.01 \text{ mg kg}^{-1}$ with the highest correlation coefficient $r = 0.98$ at $p < 0.001$ recorded for lead in plantain. However, there is an inverse correlation between lead and Nickel. It is important to state here, that all the values recorded across the sampled sites were above the permissible limit of 2.7 mg kg^{-1} for food crops set by Vinogradov, (1959), Bear (1964), Taylor (1964) and Bowen (1966) (Table 4). The high accumulation of lead above threshold limit calls for concern, since lead has been reported by medical experts, health workers and food nutritionist around the world to have effect on human health, National Research Council (1999). This is because of its bioaccumulation in the tissue and blood causing such ailment as dysfunction of the kidneys, reproductive system, liver, brain and the central nervous system.

CONCLUSION

Over seventy percent (70%) of the food crops sampled shows that food crops (cassava tuber and plantain fruits) obtained around mechanic workshop

have the highest concentration of the heavy metals studied across the various sites. Imasuen and Omorogevia (2013) made a similar report on soils around this site. A sharp decrease from the results obtained around the sites and at a distance of 1000m away from sites coupled with the strong positive correlation coefficient at $p < 0.001$ two tailed indicates a similar anthropogenic origin. Plantain fruits appear to accumulate a higher percentage of the heavy metals (table 2); this could be attributed to foliar uptake of heavy metals by plants and affinity, Rahlenbeck et al; (1999), Finster et al; (2004). The study also revealed that the acidic nature of the soil as a result of the leaching effect caused by heavy rainfall could be attributed to the high cadmium content in the food crops which were directly absorbed from the soil or by foliar absorption as a result of air pollution caused by burning of waste currency solid waste as well as vehicular emission. This could be remedied by Chemical Productivity Index (CPI) suggested for agricultural soil in tropical rainforest by Imasuen and Onyeobi (2013), and Imasuen (1987) as well as the use of sanitary land fill. The ultimate result show that there is a high risk of exposure to human health of the diseases caused by the heavy metals as enumerated in the discussion above. While appreciating the natural fertility of crops grown around waste dumpsite, we should also be conscious of the health implications and consequently the overall effects of such so called nutrients on the environment.

It is therefore suggested that farming around waste dumpsite should be discouraged; standard guidelines established should be fully enforced by law enforcement agencies. Compliance should be adhered to, those behind environmental pollution should be probed and damages paid for. Public enlightenment should be a routine event in areas of such practices. Finally, thorough remediation should be done in the parcel of land where such activities are taking place if it is so desired for agricultural purpose.

NOTE: For the Table 1 shown below;

Means $\pm$ SD of the same column with similar superscript lowercase alphabet (aa or bb) are not significantly different while those with dissimilar superscript lowercase alphabet (ab or ba) are significantly different at $P < 0.05$

Means $\pm$ SD of the same row with similar subscript uppercase alphabet (AA or BB) are not significantly different while those with dissimilar subscript uppercase alphabet (AB or BA) are significantly different at $P < 0.05$

SEM: Standard minimum error to declare significance and it is calculated as $\sqrt{(\text{EMS}/nr)}$ where EMS is the Error Mean Square and nr is the number of variables

Table 1. Effect of location and concentration of heavy metals on plant in and around Currency Waste Dumpsite

Element	Type of food crop	Distance (m)		SEM
		20	1000	
Cr (mg kg ⁻¹)	Cassava (tuber)	12.13 ± 0.01 ^a _A	3.75 ± 0.05 ^a _B	0.01
	Plantain (fruit)	9.35 ± 0.01 ^b _A	1.67 ± 0.01 ^b _B	0.00
	SEM	0.00	0.01	
Cd (mg kg ⁻¹)	Cassava (tuber)	10.21 ± 0.01 ^a _A	4.41 ± 0.01 ^a _B	0.02
	Plantain (fruit)	5.21 ± 0.01 ^b _A	2.03 ± 0.06 ^b _B	0.01
	SEM	0.01	0.00	
Ni (mg kg ⁻¹)	Cassava (tuber)	19.59 ± 0.01 ^a _A	2.66 ± 0.01 ^a _B	0.02
	Plantain (fruit)	9.18 ± 0.01 ^b _B	1.35 ± 0.01 ^b _B	0.01
	SEM	0.00	0.02	
Pb (mg kg ⁻¹)	Cassava (tuber)	6.42 ± 0.01 ^a _A	5.41 ± 0.01 ^a _B	0.04
	Plantain (fruit)	8.34 ± 0.01 ^b _B	1.50 ± 0.01 ^b _B	0.01
	SEM	0.01	0.04	
As (mg kg ⁻¹)	Cassava (tuber)	2.44 ± 0.01 ^a _A	0.60 ± 0.01 ^a _B	0.00
	Plantain (fruit)	4.03 ± 0.06 ^b _B	0.71 ± 0.01 ^b _B	0.02
	SEM	0.01	0.04	

Table 2. Effect of location and concentration of heavy metals on plant in and around Heavy duty mechanic workshop

Element	Type of food crop	Distance (m)		SEM
		20	1000	
Cr (mg kg ⁻¹)	Cassava (tuber)	8.13 ± 0.01 ^a _A	3.75 ± 0.05 ^a _B	0.02
	Plantain (fruit)	37.71 ± 0.01 ^b _B	1.67 ± 0.01 ^b _A	0.02
	SEM	0.02	0.01	
Cd (mg kg ⁻¹)	Cassava (tuber)	6.11 ± 0.01 ^a _A	4.41 ± 0.01 ^b _A	0.01
	Plantain (fruit)	21.90 ± 0.10 ^b _B	2.03 ± 0.06 ^b _B	0.02
	SEM	0.01	0.02	
Ni (mg kg ⁻¹)	Cassava (tuber)	5.33 ± 0.11 ^a _A	2.66 ± 0.01 ^b _B	0.04
	Plantain (fruit)	7.73 ± 0.15 ^b _B	1.35 ± 0.01 ^b _B	0.01
	SEM	0.00	0.04	
Pb (mg kg ⁻¹)	Cassava (tuber)	9.92 ± 0.01 ^a _A	5.41 ± 0.01 ^b _B	0.04
	Plantain (fruit)	46.40 ± 0.10 ^b _B	1.50 ± 0.01 ^b _B	0.02
	SEM	0.00	0.01	
As (mg kg ⁻¹)	Cassava (tuber)	2.54 ± 0.01 ^a _A	0.60 ± 0.01 ^a _B	0.00
	Plantain (fruit)	13.20 ± 0.01 ^b _B	0.71 ± 0.01 ^b _A	0.01
	SEM	0.00	0.01	

Means ± SD of the same column with similar superscript lowercase alphabet (aa or bb) are not significantly different while those with dissimilar superscript lowercase alphabet (ab or ba) are significantly different at P<0.05

Means ± SD of the same row with similar subscript uppercase alphabet (AA or BB) are not significantly different while those with dissimilar subscript

uppercase alphabet (AB or BA) are significantly different at P<0.05

SEM: Standard minimum error to declare significance and it is calculated as $\sqrt{(EMS/nr)}$ where EMS is the Error Mean Square and nr is the number of variables

Table 3. Effect of location and concentration of heavy metals on plant in and around Otofure Waste Dumpsite

Element	Type of food crop	Distance (m)		SEM
		20	1000	
Cr (mg kg ⁻¹)	Cassava (tuber)	10.10 ± 0.01 ^a _A	3.75 ± 0.05 ^a _B	0.04
	Plantain (fruit)	9.14 ± 0.01 ^b _B	1.67 ± 0.01 ^b _B	0.01
	SEM	0.00	0.02	
Cd (mg kg ⁻¹)	Cassava (tuber)	7.21 ± 0.01 ^a _A	4.41 ± 0.01 ^b _B	0.01
	Plantain (fruit)	7.52 ± 0.01 ^a _B	2.03 ± 0.06 ^b _A	0.00
	SEM	0.01	0.02	
Ni (mg kg ⁻¹)	Cassava (tuber)	6.79 ± 0.01 ^a _A	2.65 ± 0.01 ^b _B	0.03
	Plantain (fruit)	6.07 ± 0.01 ^a _B	1.35 ± 0.01 ^a _B	0.04
	SEM	0.00	0.00	
Pb (mg kg ⁻¹)	Cassava (tuber)	8.61 ± 0.01 ^a _A	5.41 ± 0.01 ^a _B	0.00
	Plantain (fruit)	10.69 ± 0.01 ^b _B	1.50 ± 0.01 ^b _A	0.03
	SEM	0.02	0.01	
As (mg kg ⁻¹)	Cassava (tuber)	2.36 ± 0.01 ^a _A	0.60 ± 0.01 ^a _B	0.04
	Plantain (fruit)	2.85 ± 0.01 ^a _B	0.71 ± 0.01 ^b _A	0.01
	SEM	0.00	0.02	

Means $\pm$ SD of the same column with similar superscript lowercase alphabet (aa or bb) are not significantly different while those with dissimilar superscript lowercase alphabet (ab or ba) are significantly different at $P < 0.05$

Means $\pm$ SD of the same row with similar subscript uppercase alphabet (AA or BB) are not significantly different while those with dissimilar subscript

uppercase alphabet (AB or BA) are significantly different at $P < 0.05$

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Table 4: Permissible limit of heavy metals in plants

Heavy Metals Concentration in plants					
<----- (mg/kg) ----->					
Cr	Cd	Ni	Pb	As	Hg
0.2	0.6	0.23	2.7	3	15

Culled from Chemical Element Contents of the Lithosphere, Soils and Plants (mg/kg) from Vinogradov, (1959); Taylor, (1964); Bear, (1964) and Bowen, (1966).

Table 5: Correlation of various heavy metals in the Plant

	Cr _{pt}	Cd _{pt}	Ni _{pt}	Pb _{pt}	As _{pt}
Cr _{pt}	1.00	0.99***	0.44*	0.98***	0.97***
Cd _{pt}		1.00	0.50**	0.95***	0.94***
Ni _{pt}			1.00	0.24 ^{NS}	0.33*
Pb _{pt}				1.00	0.98***
As _{pt}					1.00

$P < 0.05 = *$ is poorly significant,

$P < 0.01 = **$ is significant

$P < 0.001 = ***$ is highly significant

$P < 0.05 = NS$ Not Significant, Pt= Plant

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