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Heavy Metal Concentrations in Yam and Cassava Tubers from Enyigba Lead-Zinc Mining Site in South Eastern Nigeria.

Nworu, J. S[1]* Ogbolu,B.O[1]Nwachukwu, S.O[2]Izomor, R.N[3]Oghonyon, E.I[3]
[1]* *Department of Chemistry, Nigeria Maritime University, Okerenkoko, Delta State.*
[2]*Department of Chemistry, Alex Ekwueme-Federal University, Ndufu-Alike, Ebonyi State*
[3]*Department of Biology, Nigeria Maritime University, Okerenkoko, Delta State.*
Correspondence Author: Nworu, Jerome Sunday

Abstract: *Heavy metal concentration in yam and cassava tubers from Enyigba Lead-Zinc mining site in South Eastern Nigeria has been studied. Results obtained were compared with those from control site where there is no mining activity. This study analysed the presence of Zn, Pb, Fe, Mn, Cu, As, Cd, Cr and Ni on cassava and yam tubers from contaminated soil caused by Lead-Zinc miningusing Atomic Absorption Spectrometer (Buck Scientific 210 VGP model).The metal concentrations in both yam and cassava samples are all above the WHO permissible limits from both affected locations except Chromium metal which falls within the WHO permissible/consumable limit.The variations of the level of heavy metals in cassava and yam tubers were analysed using the analysis of variance (ANOVA) in excel, at 0.05 significance levels (p<0.05).*

Keywords: *Heavy Metal, Yam tuber, Cassava Tuber, Lead-Zinc Mine*

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I. Introduction

Heavy metals are highly poisonous. The most poisonous heavy metals include Cadmium, Lead, Arsenic and Mercury. They are non-biodegradable and can easily bio-accumulate on soil. Absorption of these heavy metals by plants occurs through Chemophytostabilisation due to remediation nature of most plants. The roots of plants are the major route for uptake of chemicals from soil (Musah*et al.*, 2008). Within a local mining sites, most agricultural practices take place. Crops planted on such soils accumulate large amount of heavy metals resulting from the mining operation. Chemophytostabilisation is a process in which soil amendments are distributed/accumulated in the topsoil (Park *et al.*, 2011). The bioavailability, distribution and bioaccumulation of metals (and metalloids) in the soil environment is defined as a fraction of the total metal content in the soil solution and the soil particles that are available to the receptor (Naidu *et al.*, 2008). Apart from the natural activities, most human activities also have potential contribution to produce heavy metals as side effects. Migration of these heavy metals into non-contaminated soils as dust or leachates and spreading of heavy metals containing sewage sludge are a few examples of events contributing towards pollution of the ecosystems (Gaur and Adholeya, 2004).

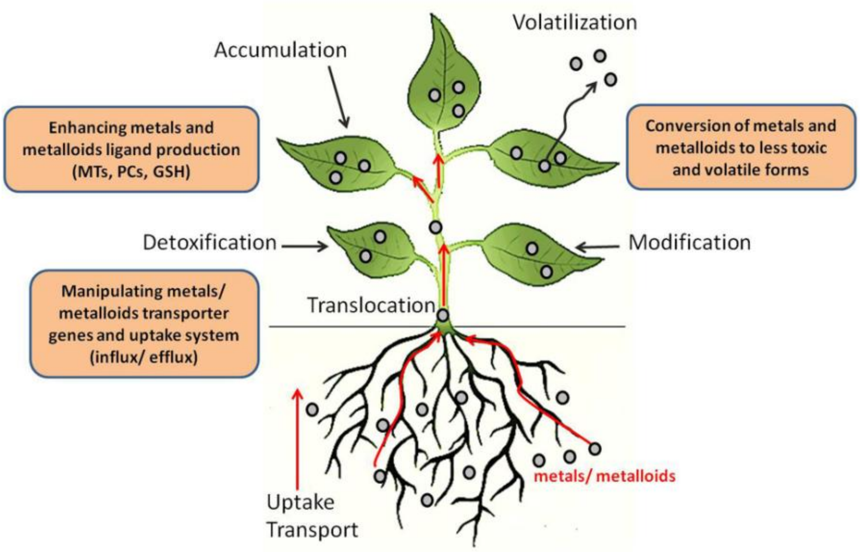

Figure 1: The mechanisms of heavy metals uptake by plant

Several plants do not only bio-accumulate heavy metals in the roots but also translocate from roots to the shoots (Baker et al., 2000). The high level of heavy metal in the soil could indicate similar concentration in plant by accumulation at a concentration that could causes serious risk to human health when consumed (Singh *et al.*, 2010). Metal bio-accumulation in plants (consumable plants) is really of great concern as their concentration/dosage may exceed WHO recommended safety levels thereby posing health hazards to man and environment. This research work is aimed at obtaining the current heavy metal deposit level on the soil around the mining site where agricultural practices are still taking place using Atomic Absorption Spectrometer after proper digestion of the samples. The interest for this work came as a result of incessant death of children between 3-9years in the community as a result of the increased level of Lead-Zinc mine which caused large deposit of these heavy metals on their soils and water within the environment. The crops planted on these soils easily bio-accumulates these heavy metals and can be transported through the whole plants. Upon consumption of these foods it gets directly into the body system and are very poisonous.

II. Materials and Methods

Yam and cassava tuber were randomly selected in triplicates from four different locations (A, B, C and D) within a locally mined lead village in Ebonyi state, Nigeria. Control samples of yam and cassava were gotten from River state, Nigeria. Proper identification of samples was carefully made and transported to the laboratory in a polyethylene bag.

Pre-treatment

Samples (yam and cassava) were subjected to laboratory washing to remove surface dirt, dust and other deposits which may cause contamination.

Digestion process

For every 2g of each ground sample, the tubers were weighed into a separate beaker containing 30ml of three different acid mixtures consisting of concentrated HNO_3 (21ml), concentrated $HClO_4$ (4.5ml) and concentrated H_2SO_4 (4.5ml) at 5:1:1 ration. The mixture of the acid and the sample were heated to 90˚C for 45 minutes until a transparent solution appeared (Osu*et al.*,2015). The digested samples were allowed to cool and filtered with whatman No 42 filter paper. The filtrates were transferred into a 100ml volumetric flask and made up to mark with distilled water.

Preparation of analytical grade standard solutions

Analytical grade reagents of salts of Zn, Pb, Fe, Mn, Cu, As, Cd, Cr and Ni were prepared in 1000ppm to pre-standardize the Atomic Absorption Spectrometer before sample analysis.

AAS Sample Analysis

Heavy metals present in the digested samples were analysed using Atomic Absorption Spectrometer (Buck Scientific 210 VGP model). In all analysis, blank determination was included and analysis were made in triplicates.

Statistical/Data analysis

The variations of the level of heavy metals in cassava and yam tubers were analysed using the analysis of variance (ANOVA) in excel, at 0.05 significance levels ($p<0.05$).

III. Results

Table 1: Heavy metal concentration on cassava tuber (mg/kg)

Locations/Metals	Zn	Pb	Fe	Mn	Cu	As	Cd	Cr	Ni
A	72.00	0.84	16.00	40.00	15.00	0.20	0.80	0.06	24.00
SD±	2.01	0.01	2.00	3.00	2.10	0.01	0.01	0.00	1.00
B	84.00	0.76	12.00	38.00	18.00	0.40	0.60	0.05	36.00
SD±	1.85	0.02	1.50	2.50	3.25	0.03	0.00	0.00	1.50
C	80.00	0.90	18.00	48.00	17.00	0.60	0.70	0.09	42.00
SD±	2.00	0.01	2.02	2.00	1.50	0.05	0.01	0.01	2.65
D	75.00	0.90	14.00	34.00	16.00	0.40	0.50	0.04	53.00
SD±	1.50	0.03	1.50	1.50	2.00	0.03	0.01	0.00	3.40
Average	77.75	0.85	15.00	40.00	16.50	0.40	0.65	0.06	38.75
Control site	12.00	0.01	10.00	18.00	5.00	0.01	0.01	0.01	14.00
SD±	1.00	0.02	2.00	1.80	1.00	0.01	0.01	0.01	3.00

SD= Standard Deviation

Table 2: Heavy metal concentration on yam tuber (mg/kg)

Locations/Metals	Zn	Pb	Fe	Mn	Cu	As	Cd	Cr	Ni
A	65.00	0.55	12.00	25.00	10.00	0.20	0.50	0.02	15.00
SD±	2.00	0.03	1.50	2.01	1.00	0.02	0.07	0.00	0.80
B	48.00	0.55	12.00	19.00	15.00	0.40	0.50	0.02	21.00
SD±	1.50	0.03	2.00	1.50	1.00	0.01	0.02	0.00	2.50

C	54.00	0.50	10.00	24.00	16.00	0.60	0.70	0.05	30.00
SD±	3.50	0.01	1.30	2.00	1.50	0.03	0.08	0.01	2.01
D	68.00	0.60	14.00	20.00	10.00	0.60	0.30	0.08	46.00
SD±	3.50	0.01	2.20	2.50	1.00	0.05	0.04	0.00	2.00
Average	58.75	0.55	12.00	22.00	12.75	0.45	0.50	0.043	28.00
Control site	6.00	0.01	11.00	12.00	7.00	0.05	0.02	0.01	14.00
SD±	0.14	0.04	1.00	1.50	1.00	0.01	0.01	0.02	2.05

SD= Standard Deviation

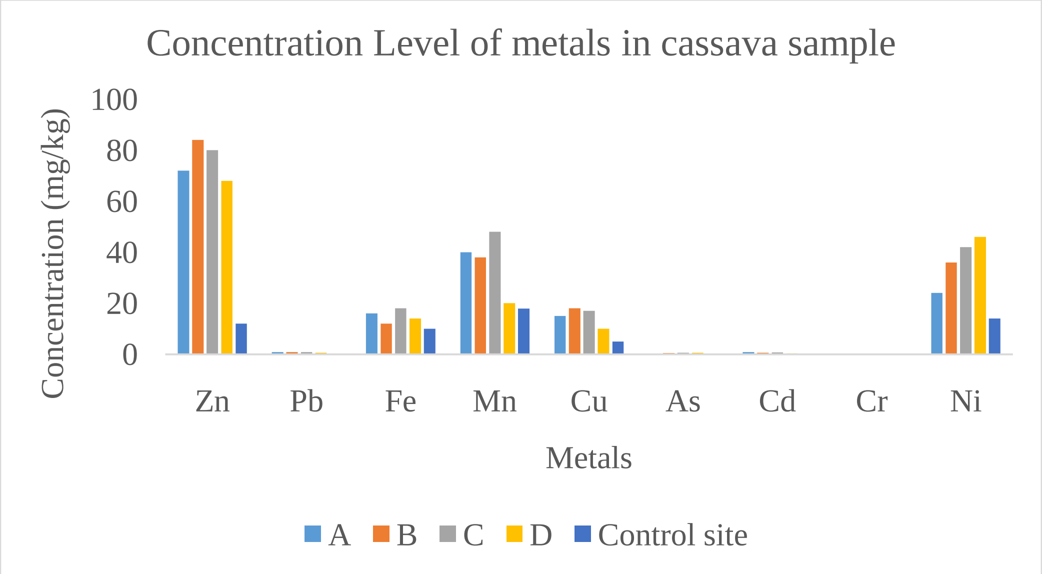

Figure 2: Concentration Level of metals in cassava sample

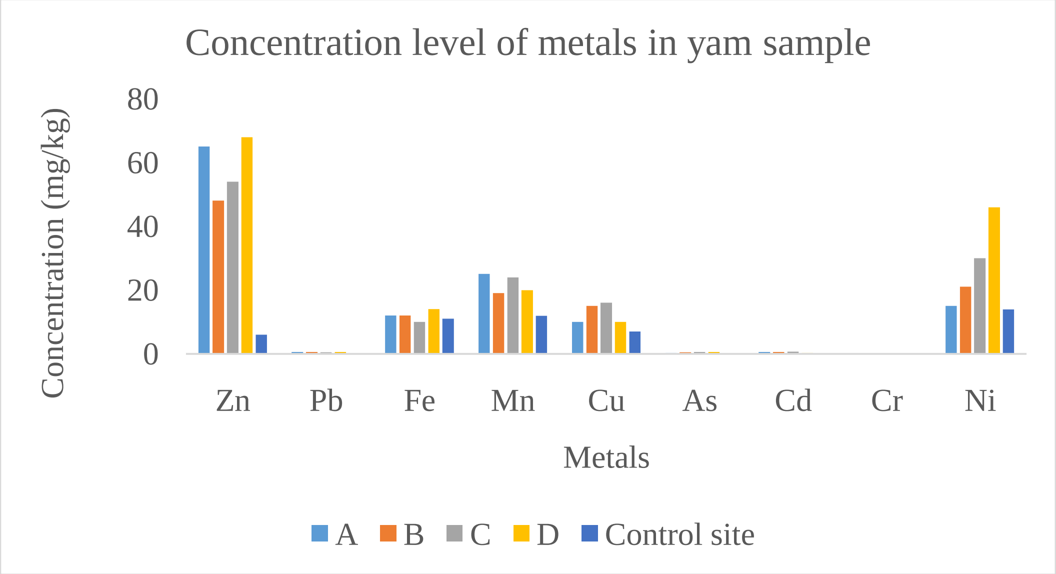

Figure 3: Concentration level of metals in yam sample

IV. Discussion

The quantitative metal concentration (mg/kg) of the cassava sample from location A, B, C and D and that from the control site are represented in Table 1 and Figure 1. The standard deviations of the generated data from both sites are also represented accordingly in Table 1. From location A, the order of the heavy metal distribution in the yam tuber is Zn (72.00mg/kg)>Mn (40.00mg/kg)>Ni (24.00mg/kg)>Fe (16.00mg/kg)>Cu (15.00mg/kg)>Pb (0.84mg/kg)>Cd (0.80mg/kg)>As (0.20mg/kg)>Cr (0.06mg/kg). The heavy metal concentrations on the cassava samples from location C occurred in same order as those from location A though with variable concentrations. The metal distribution in the cassava from location B is in the order Zn (84.00mg/kg)>Mn (38.00kg/mg)>Ni (36.00mg/kg)>Cu (18.00mg/kg)>Fe (12.00mg/kg)>Pb (0.76mg/kg)>Cd (0.60mg/kg)>As (0.40mg/kg)>Cr (0.05mg/kg). From location D, the concentration of the heavy metal is as follows; Zn (68.00mg/kg)>Ni (46.00mg/kg)>Mn (20.00mg/kg)>Fe (14.00mg/kg)>Pb = As (0.60mg/kg)>Cd (0.30mg/kg)>Cr (0.08mg/kg). have

The range of Zn, Pb, Fe, Mn, Cu, As, Cd, Cr and Ni concentrations on the cassava tuber is 68-84 mg/kg, 0.6-0.9 mg/kg, 12-18 mg/kg, 20-48 mg/kg, 10-18 mg/kg, 0.2-0.6 mg/kg, 0.3-0.8, 0.05-0.09 mg/kg and 24-46 mg/kg respectively as compared with the Zn, Pb, Fe, Mn, Cu, As, Cd, Cr and Ni concentrations from the control site, 12 mg/kg, 0.01 mg/kg, 10 mg/kg, 18 mg/kg, 5 mg/kg, 0.01 mg/kg, 0.01 mg/kg, 0.01 mg/kg, and 14 mg/kg respectively.

From Table 2 and Figure 2, the heavy metal concentrations on the yam tubers from the mining environment and the concentrations of heavy metals from the control site are represented. The standard deviations of the values are also stated in the table 2 accordingly. The heavy metal distribution in the yam tuber from location A varies thus; Zn (65.00mg/kg)>Mn (25.00 mg/kg)>Ni (15.00 mg/kg)>Fe (12.00 mg/kg)>Cu (10.00 mg/kg)>Pb (0.55 mg/kg)>Cd (0.50 mg/kg)>As (0.20 mg/kg)>Cr (0.02 mg/kg). From location B, Zn (48.00 mg/kg)>Ni (21.00 mg/kg)>Mn (19.00 mg/kg)>Cu (15.00 mg/kg)>Fe (12.00 mg/kg)>Pb (0.55 mg/kg)>Cd (0.50 mg/kg)>As (0.40 mg/kg)>Cr (0.02 mg/kg). From location C, Zn (54.00mg/kg)>Ni (30.00mg/kg)>Mn (24.00mg/kg)>Cu (16.00mg/kg)>Fe (10.00mg/kg)>Cd (0.70mg/kg)>As (0.60mg/kg)>Pb (0.50mg/kg)>Cr (0.05mg/kg). While the heavy metal distribution in the location D is Zn (68.00mg/kg)>Ni (46.00mg/kg)>Mn (20.00mg/kg)>Fe (14.00mg/kg)>Cu (10.00mg/kg)>Pb = As (0.60mg/kg)>Cd (0.30mg/kg)>Cr (0.08mg/kg).

The range of Zn, Pb, Fe, Mn, Cu, As, Cd, Cr and Ni concentrations on the yam tuber is 48-68 mg/kg, 0.5-0.55 mg/kg, 10-14 mg/kg, 19-25 mg/kg, 10-16 mg/kg, 0.2-0.6 mg/kg, 0.3-0.7 mg/kg, 0.02-0.08 mg/kg and 15-46 mg/kg respectively as compared with the Zn, Pb, Fe, Mn, Cu, As, Cd, Cr and Ni concentrations from the control site, 6 mg/kg, 0.01 mg/kg, 11 mg/kg, 12 mg/kg, 7 mg/kg, 0.05 mg/kg, 0.02 mg/kg, 0.01 mg/kg and 14 mg/kg respectively.

Zinc was observed to have the highest concentrations in both tuber crops from different locations. Zinc is the least toxic metal among other metals identified in the samples. Zinc is one of the essential elements in diets which enhances the essential functioning of the immune system. It is also essential for the growth and development of the foetus, and the normal functioning of the brain cells (Oti*et al.,*2013). The range of concentrations of Zinc (68-84mg/kg) on both samples from the four locations were far higher than the concentration/consumable limit of Zinc on food samples according to WHO which is 5-15mg/kg. The WHO acceptable limit for human consumption of Zn is 150 mg/kg (Demirezen and Ahmet, 2006). The average human intake of Zinc on daily basis is 7-16.3mg/day (Ajiwe*et al.,* 2018; ATSDR, 1994). High concentration of Zinc in human diets is more beneficial than its deficiency as it is detrimental to human health, causing birth defects, stomach cramp, skin irritation, anaemia and vomiting (Oti*et al.,* 2013; Radwan*et al.,* 2006).

Lead among other heavy metals analysed is the major toxic, harmful and concern for the contamination of food substances planted on the Enyigba Lead-Zinc mining site. Plants readily bio-accumulate large quantity of Lead through their roots without much changes in their total yield and appearances (Musah*et al.,* 2008; Park *et al.,* 2011; Oti*et al.,* 2013). The range of concentrations of Lead (0.60-0.90mg/kg) on both samples from the four locations were far higher than the concentration/consumable limit of Zinc on food samples according to WHO which is 0.001-0.3mg/kg. This shows that the consumption of these tuber crops will certainly cause much health issues. Accumulated Pb on food samples when consumed are being sequestered in the tooth and bones, this leads to weakness and brittleness of tooth and bones (Osteoporosis of the bone). Research on the field have also shown that Lead accumulation could be anthropogenic, can also be very chronic when occurred above permissible limits, causes body ailments and easily leads to the weariness of the body tooth and bones (Oti*et al.,* 2013; Ogbonna*et al.,* 2015; Onyedika*et al.,* 2008; Ezeh*et al.,* 2011 and Nnabo*et al.,* 2015).

The concentration of Chromium was recorded to have the least concentration across the locations in both yam and cassava samples. Its concentration ranges from 0.04-0.09mg/kg. among the metals studied, Chromium is the only one within the WHO permissible limit of 0.05-0.1mg/kg. This implies that, Chromium is not one of the heavy metals that could have led to the incessant ailments and deaths of underage children in the community. This finding does not agree with other researches from the affected area on consumable vegetables (Oti*et al.,* 2013).

Cadmium is highly mobile element and can easily be transported through the shoots of plants and uniformly distributed throughout the affected plant (Baker *et al.,* 2000 and Sekara*et al.,* 2005). The Cadmium concentration in both samples from the investigated sites ranges from 0.3-0.8mg/kg, which are above the WHO permissible limit of 0.003-0.05mg/kg. Researches showed that high concentration of Cadmium could cause reproductive failure, stomach pains, diarrhoea and severe vomiting, bone fracture, damage of central nervous system and DNA, in addition to cancer development (Oti*et al.,* 2013; Ogbonna *et al.,* 2015).

Iron, Manganese, Copper, Arsenic and Nickel concentrations in both cassava and yam tubers (Table 1 and 2; Figure 1 and 2) are above the WHO permissible limits of 0.3mg/kg, 0.05mg/kg, 0.05-1.50mg/kg, 0.05mg/kg and 0.01mg/kg respectively. Their high concentration could have resulted from the industrial mining of Lead and Zinc from the site. Since these metals occurs in association with others, they tend to be distributed with Pb and Zn. The ailment among the underage children within the environment can also be traced to their consumption of these tuber crops that are highly rich in these toxic metals.

V. Conclusion

This study analysed the presence of Zn, Pb, Fe, Mn, Cu, As, Cd, Cr and Ni on cassava and yam tubers from contaminated soil caused by Lead-Zinc mining. Samples from non-mining site were used as control. The metal concentrations in both yam and cassava samples are all above the WHO permissible limits from both affected locations except Chromium metal which falls within the WHO permissible/consumable limit. The ailment and incessant death of the underage children from the community could be traced to the health implications associated with these heavy metals as they are mostly chronic, harmful and could be lethal at elevated concentrations. It is observed that the industrial mining activities in the studied area have caused the mobility and transportation of these metals across the farm lands. It was observed that the wastes from the mining sites are not properly managed and are indiscriminately disposed in any available lands.I would recommend that underage children should not be raised in that environment. Also, agricultural practices should not be encouraged in that area as it has been covered with industrial activities. Government should also support the indigene to alleviate their poverty, because they carried out the agricultural activities and still lived there because they cannot afford other better places. Government should also provide a better mining facilities and technology to manage the wastes from the mining sites so as to avoid further environmental contamination.

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