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Original Research Article

Assessment of lead (Pb) uptake and hazard potentials of cassava plant (*Manihot esculentus cranz*), Dareta Village, Zamfara, Nigeria

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Lead (Pb) concentration in soil and cassava tissues from Dareta village was assessed using Shimadzu Atomic Absorption Spectrophotometer (model AA-6800, Japan) after wet digestion to evaluate uptake/accumulation and to estimate potential health risk due to consumption of edible tissues of the plant. The ranges of concentrations were 84.86 – 344.78 mg/kg, 1.19 – 3.75 mg/kg, 0.03 – 2.59 mg/kg and 0.02 – 0.43mg/kg for soil, cassava peels, peeled cassava roots (tubers) and cassava leaves respectively. Lead concentrations in soils were within WHO/FAO Maximum Permissible Limit. The average (Pb) concentration in peeled cassava tubers was found to be above WHO/FAO permissible limit for consumed food. Average values of Estimated Daily Intake (EDI) for cassava tubers were above the Recommended Daily Intake (RDI) and the Upper Tolerable intake (UL). Average Target Hazard Quotient (THQ) for cassava tubers was above 1.00 indicating that the perennial intake of cassava tubers from the village poses significant risk of lead Toxicity. The low mobility of (Pb) in cassava plant from root to leaves was reflected by low Translocation Factor. The large difference in lead concentrations between roots and leaves indicated an important restriction of the internal transport of the toxic metal from the roots towards the aerial parts.

Key words: Soil, lead, uptake/accumulation, permissible limits, potential hazard.

INTRODUCTION

The study of harmful effect of chemical substances present in the natural environment and its effects on organisms is the subject of environmental toxicology. Ecological or environmental toxicology is therefore concerned with harmful effects of chemicals that are present in the soil, water, air, food or other environmental vectors exposed to man and other biota (Hodgson, 2004). Living organisms in areas such as mines, smelters and waste dumping sites that are heavily polluted face serious risk of exposure to toxic chemicals. Of all environmental contaminants, heavy metals are of great concern due to their ability to persist in the environment (Corley and Mutiti, 2017). Most often, these substances are not biodegradable and are easily converted from one form to another depending on their chemical forms and prevailing environmental conditions. The science that deals with the aspect of chemical release, movements, uptake, degradation and effects is called chemodynamics (Hodgson, 2004). Proper understanding of chemodynamics of heavy metals must consider their transfers between the spheres of the environment. A very crucial aspect of the interchange is their transfer to organisms in the biosphere because each species of organism in a given ecosystem is in some way dependent upon another species and upon the non living components of their surrounding environment. Ecological exposure to a given heavy metal occurs when the metal reaches a location on or in the organism where it can illicit deleterious effect and is in the form that is bioavailable (NGCERA, 1999).

Acute widespread lead pollution and poisoning was reported in Zamfara state, Nigeria in 2010 with unprecedented environmental emergency of intense magnitude in affected villages of the Northern Nigerian state. The soaring price of gold in the international market compelled villagers prospecting for flakes of the precious metal. Unfortunately, what the local miners found was laced with lead, with concentrations as high as 10% in most cases. Consequently, thousands of villagers were exposed to mass lead contamination (PRI, 2012; Kabara, 2014). Inhalation of lead contaminated dust and ingestion of contaminated water and food were identified as the main reason for the high blood Pb levels in victims (udiba et al., 2012). Lack of awareness within the mining communities coupled with inadequate environmental and health regulations/enforcement regarding lead toxicities from the ore mining and processing operations, resulted in more deaths due to lead poisoning in the state than the whole world combined in the last forty years particularly amongst children who are uniquely susceptible to lead poisoning (Shiloh, 2010). Studies have reported a pre- remediation soil lead concentrations exceeding 100,000ppm in many areas and villages including residential compounds (Telmer, 2011; Joint UNEP/OCHA, 2010; UNICEF, 2011). An immediate medical response protocol was developed to provide oral Chelation therapy to vulnerable groups. In order not to compromise the efficacy of the chelation therapy, immediate remediation of the affected villages was carried out. Post remediation soil lead levels ranging from 81.65mg/kg to 684.27mg/kg have also been reported (Udiba et al*.,* 2012). In a general audit of lead in soil, Udiba et al*.* (2019) recorded average soil lead concentration ranging from 1029.42±98.50 mg/kg to 6724.68±184.00 mg/kg with a high percentage bioavailability/mobility (about 46%) indicating that lead may easily be transferred into the food chain by plant uptake or leaching into ground water aquifers. Cultivation of crops for human or animal consumption on soil with such high profile of bioavailable lead (Pb) could lead to uptake of dangerous concentrations and accumulation of the metal in edible crop tissues. Human exposure to very high concentration of the lead (Pb) over a short period or low concentration over a prolonged period can result to serious and in most cases irreversible health problems and even death. Food safety is therefore a significant aspect of any country's economic stability (Idakwoji, 2016). Lead pollution from ore mining and processing has been ranked 7th in the Black Smith Institute's top ten world worst toxic pollution problems (Black Smith Institute, 2011).

Lead is a classical or cumulative poison (Idakwoji, 2016). A substance is a poison only when it causes harmful effect at a particular concentration to organism to which it is exposed. In other words it is a dosage that makes a poison. However, there is no concentration below which lead is said to be safe (Ogabiela et al., 2011). Terrestrial plant may be exposed to this environmental pollutant in two ways. One is exposure of the shoot to the airborne pollutants; another is uptake of the pollutant by roots growing in contaminated soil. Studies have shown that crops grown in lead contaminated soil accumulate unhealthy amount of the toxic metals in their tissues (Addo et al*.,* 2013; MacBride, 2007). The rate of uptake and accumulation by plants is affected by a number of factors such as soil chemistry, chemical form of the metal, stages of plant growth, plant species, soil type etc (Sharma et al., 2009). A plant is classified as a hyperaccumulator of a given metal when the translocation factor is greater than one, when the bioaccumulation factor is greater than one and when the concentration of the metal is between 10 – 500 times the level in normal plant (plant grown in uncontaminated soil) (Hosman et al., 2017). Different plants have different capacity to absorb and accumulate different metals (Wilberforce, 2015).

Cassava is one of the most drought resistant crops. It can be successfully grown even in poor soils where many other crops do not grow well. World over, about 800 million people depend on cassava as their primary staple food (IFAD/FAO, 2005a). In 2016, the global production of cassava root was 277 million tones with Nigeria as the largest producer having about 21% of the world total (FAOSTAT, 2017). The crop is one of the most widely cultivated food crops in southern Nigeria where it is grown almost by every household. In recent years, it's production has also increased in the North central region of the country (middle belt). Although cassava cultivation is not highly popular in the north eastern and north western regions of Nigeria, the sweet cassava cultivar often boiled and consumed directly without any other form of processing, is a major delicacy amongst the hausa's of northern Nigeria particularly Zamfara state (IFAD/FAO, 2005a). Cassava varieties are usually classified as bitter and sweet cultivars depending on the presence or absent of cyanogenic glucosides (Gideon-Ogero, 2008). Several processing techniques are used to produce several products from cassava for human and animal consumption. It is a well established fact that exposure to toxic metals such as lead (Pb) through consumption of food products with elevated metal concentration can lead to serious health challenges in both humans and animals. Lead occupies position number 2 in the Agency for Toxic substances and Disease Registry (ATSDR) top 20 list. It interferes with the normal development of a child's brain and nervous system; therefore children are more at greater risk of Lead toxicity. The effect on peripheral nervous system on the other hand, is more pronounced in adults. Lead absorption constitutes serious risk to public health. It induces reduced cognitive development and intellectual performance in children, increased blood pressure, and cardiovascular diseases in adult as well as liver and kidney dysfunction (Ogabiela et al., 2011, ASTDR, 2008; Abdullah, 2011). Information about

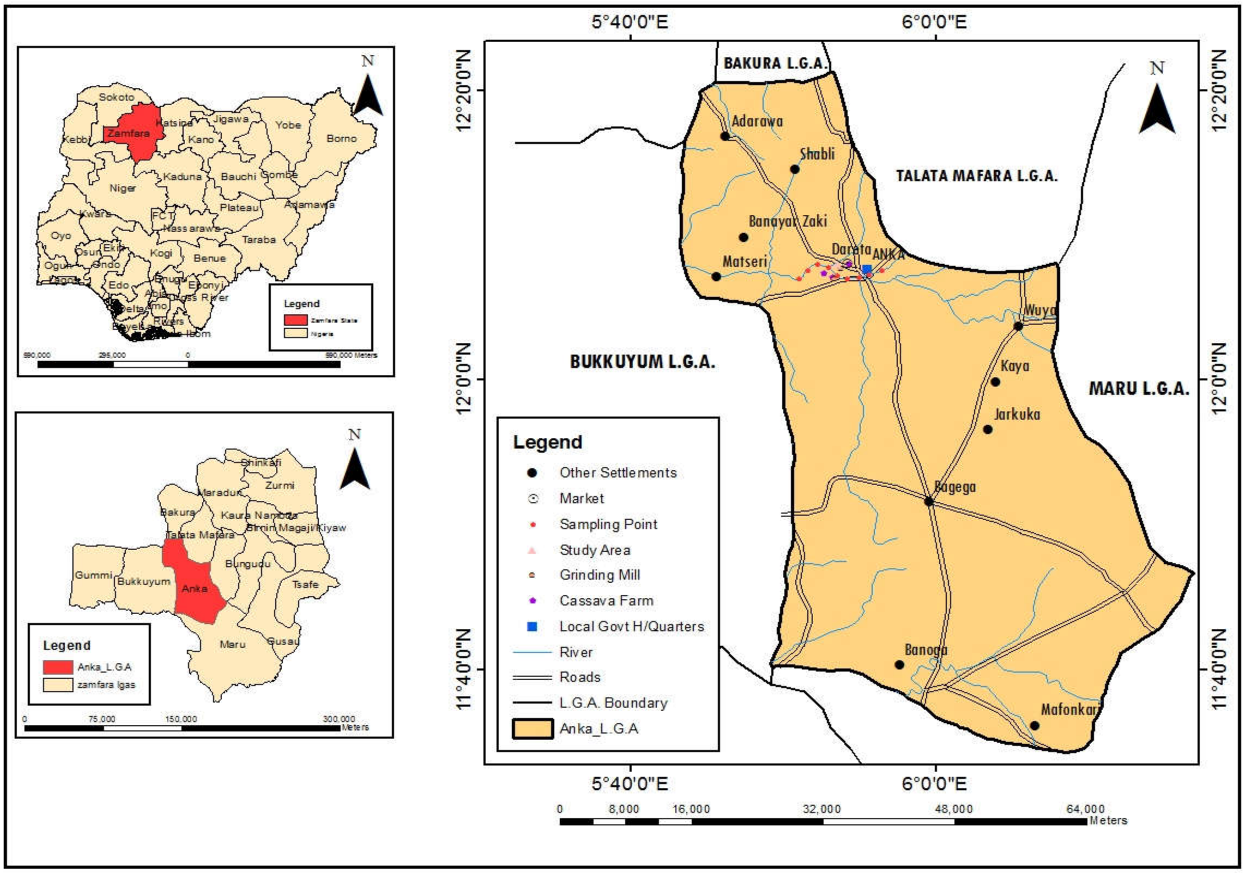

Figure 1: Map of Anka Local Government Area of Zamfara State, Nigeria: showing Dareta Village with sampling points
Source: Adopted and modified from Administrative map of Nigeria

heavy metal concentration in edible tissues of food crops and their dietary intake is therefore very important for assessing risk to human health (Addo et al., 2013, Zhuang et al., 2009). This study was designed to assess lead concentration in soil, uptake and accumulation by cassava tissues (root, stem and leaves), and most importantly to evaluate potential health risk due to the consumption of cassava tissues from Dareta village.

MATERIALS AND METHODS

Study Location

Zamfara State is located in the northwest geopolitical zone of Nigeria. It occupies a land mass of about 39,762 square kilometers and has the town Gusau, as its capital. The State shares boundaries with Sokoto, Niger, Kebbi, Katsina and Kaduna State within the country and an international boundary with Niger Republic (Joint UNEP/OCHA, 2010).

The estimated population of the State is 3,582,912 out of which 716,582 are estimated to be children under the age of five years and 143,316 children under the age of one year (Joint UNEP/OCHA, 2010; NPC, 2006). Farming is the major occupation of the people. More than 90% of the people are involved in one form of agriculture or the other.

The climate of the northwestern Nigerian State is warm and tropical, with temperatures sometimes rising up to 38 ^{o} C at the peak of the dry season (between March and April). The beginning of the rains is between mid-March and May, lasting for about six months up to the end of October, while the extremely dry, cold and dusty wind that blows from the Sahara towards the western coast of Africa (Harmattan) lasts from December to February. The mean annual rainfall in the area fluctuates between 36 and 80 millimeters, varying slightly, from the northern to the southern parts of the State.

The vegetation of the State is made up of Sudan and Guinea Savannah. The Sudan Savannah is found in the northern, western and eastern part of the State. The Northern Guinea Savannah is found in the southern part of the State. This vegetation type is largely found in the Gusau, Tsafe and Anka Local Government Areas (ZMoE, 2003).

Dareta village (the study area) is in Anka Local Government Area located on 12°06′30″ N 5°56′00″ E (Figure 1) with total area of about 2,746 sq km and total human population of about 142, 280 (NPC, 2006). Based on the 2006 Anka LGA census data, the estimated population of Dareta village is 1033 and number of children less than 5yrs based on 20% of population is 207. The village is primarily populated by the Hausa and Fulani peoples. Until recently; following the discovery of gold, the major activity of the people of Dareta village was farming. Recently artisanal mining activities engaged a large percentage of the population. Dareta, Abare, Tungan daji, Sunke, Tungar guru, Duza, Bagega are the major villages where the 2010 outbreaks of lead poisoning occurred (Blaksmith Institute, 2011).

Sample Collection, Preservation and Preparation

Procedure for sample collection preservation and preparation was adopted from Abida (2009). Five cassava farms in Dareta Village were randomly selected for the study. Each of the farms was divided into three sections of approximately equal size. The three sections were designated sampling point 1, 2 and 3 respectively. The crop was harvested from the three sampling points established in each farm after making arrangement with the respective farm owners through the village head. The harvest was done by cutting the cassava stem 10 cm from the ground before uprooting and separating the enlarged roots (tubers) from the stem using stainless steel knife. The leaves were also obtained using the knife. Both roots and leaves were stored in labeled black polyethylene bags. Soil samples were also collected from the points where crops were uprooted at debt between 1 and 10 cm using hand trowel into labeled black polyethylene bags. Soil and cassava samples were collected from three cassava farms in Basawa village, Zaria (a non mining community) as control. Collected samples were transported to the environmental laboratory of the National Research Institute for Chemical Technology (NARICT), Zaria for preparation and analysis.

Soil samples from each point were thoroughly mixed to obtain a representative sample, air dried, crushed and sieved with 2 mm mesh before wet digestion. I g of a well mixed sample from each sampling point was taken into a 250 mL glass beaker and digested with 10 mL of concentrated nitric acid, perchloric acid and hydrofluoric acid in the ratio 3:1:1 on a hot plate. After evaporating to near dryness, 10 mL of 2 % nitric acid was added, filtered into 50 mL volumetric flask and the made up to the mark with distilled deionized water (Udiba et al*.,* 2012).

Edible tissues (leaves and roots) were thoroughly washed so as to remove all adhered soil. Peeled Cassava tubers and leaves were cut into pieces. Leaves were also cut into pieces. All crop samples were air dried for 5 days in the laboratory. The dried samples were pulverized (ground into powder) using SON approved binatone electric blender (model BLG-401, China), passed through 1 mm sieve and digested. The digestion of 1g was carried out using 5 mL of concentrated nitric acid according to Awofolu (2005).

Sample Analysis

Lead concentration in the digests was determined by Atomic Absorption Spectrophotometry, using Shimadzu Atomic Absorption Spectrophotometer (model AA-6800, Japan) equipped with Zeaman background correction and graphite furnace at National Research Institute for Chemical Technology (NARICT), Zaria, Nigeria. The calibration curve was prepared by running different concentrations of the standard solution (lead II nitrate in nitric acid). The instrument was then set to zero by running the respective reagent blanks and lead (Pb) concentration determined at a wavelength of 283.3 nm. Average values of three replicates were taken for each determination.

Analytical Quality Assurance

Appropriate quality assurance procedures and precautions were taken to ensure the authenticity of the results. Samples were carefully handled to avoid cross-contamination. Glass wares were properly cleaned and distilled deionized water was used throughout the study. All the reagents used were of analytical grade. In order to check the reliability of the analytical method employed for lead (Pb) determination, one blank and combined standards were run with every batch of 10 samples to detect background contamination and monitor consistency between batches. The result of the analysis was validated by digesting and analyzing Standard Reference Materials (Lichens coded IAEA-336) following the same procedure. The analyzed values and the certified reference values of the elements determined were compared to ascertain the reliability of the analytical method employed.

Statistical Analysis

Test for normality was carried out using Shapiro Wilks test and Z-score test was used to check for outliers

Analysis of Variance (ANOVA) Test

Having passed the test for normality and outliers, data collected were subjected to statistical test of significance using the Analysis of Variance (ANOVA) test to assess significant variation in lead concentration in soil, cassava roots and leaves across the five different plots under study. Probabilities less than 0.05 ($p < 0.05$) were considered statistically significant. Independent t-test was used to compare lead content of edible cassava tissues from the study area and the lead content of edible cassava tissues from Zaria (control). Probabilities less than 0.05 ($p < 0.05$) were considered statistically significant. The analysis was done using SPSS software 23.00 for windows.

Translocation Factor (TF)

Translocation Factor (TF) was described as the ratio of lead concentration in plant shoot [$Lead_{shoot}$] to that in the plant root [$Lead_{root}$] as given in equation 1 (Malik et al*.,* 2010).

TF = [$Lead_{shoot}$] / [$Lead_{root}$] ----------------- (1)

Bioaccumulation Factor (BAF)

The ability of Plant (cassava) to accumulate metal (Pb) with respect to its concentration in soil is called index of bioaccumulation factor for lead (Addo et al., 2013; Zhuang et al., 2009). BAF was calculated according to Addo et al. (2013) as given in equation (2)

$$BAF = [Pb_{plant}] / [Pb_{soil}] \ldots\ldots\ldots\ldots (2)$$

Where, $[Pb_{plant}]$ represent lead concentration of lead in edible cassava tissues and $[Pb_{soil}]$ concentration of lead in soil. Bioaccumulation factor was therefore calculated for peeled cassava tubers as BAF_T and cassava leaves as BAF_L

Bioavailability factor (BF)

The bioavailability factor (BF) of lead in plants, also known as the bioavailability index, was calculated according to Malik et al., 2010 as:

$$BF = \frac{\text{mg lead per kg edible cassava tissue}}{\text{Total content of lead per kg Soil}} \times 100 \ldots (3)$$

Lead concentrations of soil and cassava tissues were calculated on dry weight basis.

Estimated Daily Intake (EDI)

The Estimated Daily Intake (EDI) of lead from edible cassava tissues in this study was determined following Addo et al. (2013) using equation (4)

$$EDI = (C_{Pb} \times DAC)/ Bw \ldots\ldots\ldots (4)$$

Where C_{Pb} (mg/kg) is lead concentration in edible cassava tissues, DAC represents the Daily Average Consumption of cassava tissues by Nigerians and Bw the body weight. The DAC for cassava tubers was adopted from IFAD/FAO, (2005b) as 226.93g/person/day while the DAC for cassava leaves was adopted from Adedokun et al. (2016) 65g/person/day. An adult's average body weight of 70 kg was used for the EDI evaluation. The estimated Daily Intake was calculated for each farm land and Zaria (control).

Target Hazard Quotient (THQ)

Estimation of potential hazard to human health (Target Hazard Quotient- THQ) through the consumption of edible tissues of cassava was computed using equation (5).

$$THQ = (Div \times C_{Pb})/ (RfD \times Bo) \ldots\ldots\ldots 5$$

Where (*Div*) is the daily intake of cassava (per day), C_{Pb} is the concentration of lead in edible tissues of cassava (mg/kg), R*f*D is the oral reference dose for lead (mg/kg body weight per day) and Bo is the human body weight (kg). RfD according to Guerra et al. (2012) is an estimate of daily oral exposure for the human population which does not cause harmful or damaging effect during life time. The methodology for estimation of target hazard quotients (THQ) was adopted from USEPA Region III Risk-Based Concentration Table, January–June 1996 cited in Guerra et al. (2012). The daily intake of cassava tubers was taken as 226.93grams/person/day and that of cassava leaves was 65g/person/day. The value of RfD for Pb (0.0035 per day) was taken from WHO (1993). The average Bo was taken as 70 kg for adults (WHO, 1993).

RESULTS

To evaluate the accuracy and precision of the analytical procedure employed standard reference materials of lichen coded IAEA - 336 was analyzed in like manner to the samples. The analyzed values were found to be within the ranges of the certified reference values for the elements determined suggesting the reliability of the method employed (Table 1).

Results from the determination of lead concentration in soil and cassava tissues are presented in Table 2. Translocation factor (TF), Bioaccumulation factor (BAF) and Bioavailability factor (BF) of the toxic metal across cassava farms were calculated and presented in Table 3. Estimated Daily Intake (mg/kg bw/day) and Target Hazard Quotient calculated for edible cassava tissues are presented in Table 4. Comparison of lead contents of edible cassava tissues from Dareta village (study area) and Zaria (control) is shown in Figure 2.

Table 2 indicates that, the concentration of lead in the soil, Cassava peels, peeled cassava tubers and cassava leaves showed the following ranges 84.86 – 344.78 mg/kg, 1.19 – 3.75 mg/kg, 0.03 – 2.59 mg/kg and 0.02 – 0.43mg/kg respectively. The highest soil lead concentration (344.78mg/kg) was recorded in cassava farm 5 while the lowest (84.86mg/kg) was recorded in cassava farms 2. The highest concentration of lead (37.52 mg/kg) in cassava peels was recorded in farm 1 and the lowest (1.19mk/kg) in farm 4. The highest (2.59 mg/kg) and lowest (0.03 mg/kg) lead concentration of peeled cassava tubers were recorded in cassava farm 2 and cassava farm 3 respectively. Cassava leaves recorded the highest (0.43mg/kg) lead concentration in cassava farm 2 and the lowest (0.02mg/kg) lead concentration in cassava farms 1. The order of concentration was as follows: soil > Cassava peel > peeled cassava tuber > Cassava leaves. The difference in the concentration of lead between the soil, cassava peels, peeled cassava tubers and cassava leaves was found to be statistically significant (ANOVA, $p < 0.05$), Lead concentration in soil being significantly higher than Cassava peels, peeled cassava tubers and cassavas leaves. The concentration of lead in cassava peels was also significantly higher than that of cassava tubers and cassava leaves. Similarly lead concentration in peeled cassava tubers was found to be significantly higher than that of cassava leaves at 95% confidence level. The differences in lead contents of soils and cassava tissues (Table 2) between the farms under study were found to be statistically significant (ANOVA, $p < 0.05$).

Table 1. Results of analyzed reference material (Lichen IAEA - 336) compared to the certified reference values (mg/kg)

Element (mg/kg)	Pb	Cd	Cu	Mn	Zn
Analyzed value	5.25	0.140	4.00	55.78	29.18
Reference value	4.2-5.5	0.1-2.34	3.1- 4.1	56-70	27-33.80

Table 2. Lead levels of Cassava soil, tubers, peels and leaves across five cassava farms in Dareta village (mg/kg)

Cassava Farm	Sampling point	Soil	Peeled Tuber	Peels	Leaves
1	1	168.22	1.25	3.75	0.02
	2	171.88	1.29	3.46	0.03
	3	166.78	1.22	3.12	0.04
	Mean ±SD	168.96±2.6[a]	1.25±0.31[a]	3.45±0.36[a]	0.03±0.07[a]
2	1	90.96	0.03	3.14	0.43
	2	100.67	0.12	2.94	0.25
	3	84.86	0.15	3.01	0.37
	Mean ±SD	92.16±7.9[b]	0.10±0.66[b]	3.03±0.83[b]	0.35±0.94[a]
3	1	136.95	2.59	2.02	0.08
	2	133.71	2.42	1.93	0.09
	3	141.90	2.57	1.50	0.09
	Mean ±SD	137.52±4.1[c]	2.53±8.6[c]	1.81±0.27[c]	0.09±0.07[b]
4	1	190.44	1.11	1.26	0.07
	2	201.99	1.06	1.19	0.07
	3	187.62	1.10	1.33	0.09
	Mean ±SD	193.35±7.6[a]	1.09±0.26[d]	1.26±0.74[d]	0.08±0.09[b]
5	1	340.83	1.35	1.39	0.06
	2	344.78	1.28	1.32	0.15
	3	338.94	1.37	1.21	0.25
	Mean ±SD	341.52±2.9[d]	1.33±4.6[d]	1.31±0.87[d]	0.15±0.91[b]
Zaria (Control)	1	58.58	0.16	0.35	0.02
	2	86.41	0.16	0.44	0.03
	3	60.56	0.13	0.23	0.03
	Mean ±SD	68.51±1.51[b]	0.15±0.19[e]	0.34±1.05[e]	0.03±0.59[a]
Standards			*0.025mg/kg	10.00mg/kg	**0.30mg/kg

** JECFA, 2007; ** Commission of the European Communities (2006) and Cordex Standards 1995*
Means with the different superscripts along the column indicates significant ($p < 0.05$, ANOVA) difference in lead (Pb) concentration

Table 3. Translocation factor (TF), Bioaccumulation Factor (BAF) and Bioavailability Factor (BF) across cassava farms

Farms	Translocation Factor (TF)	(BAF_L)	(BF_L)	(BAF_T)	(BF_T)
1	0.009	0.00018	0.018	0.00740	0.740
2	0.116	0.00380	0.380	0.00108	0.108
3	0.050	0.00065	0.065	0.01840	1.840
4	0.063	0.00041	0.041	0.05640	5.640
5	0.115	0.00044	0.044	0.00389	0.389
Average	**0.051**	**0.00110**	**0.110**	**0.01743**	**1.743**
Control	0.008	0.00044	0.044	0.00219	0.219

Figure 2 shows that the mean lead concentrations of cassava tissue from the Dareta village (study area) were higher than the mean lead concentrations of cassava tissues from Zaria (control). The differences were found to be statistically significant ($p < 0.05$).

Table 3 shows that, the highest translocation factor (TF) was obtained for lead in cassava farm 2 and the lowest in cassava farm 1. Translocation factor followed the trend: cassava farm 2 > cassava farm 5 > cassava farm 4 > cassava farm 3 > cassava farm 1. The highest bioaccumulation factor (BAF_T) and bioavailabilty factor (BF_T) for peeled cassava tubers were obtained in cassava farm 2 and the lowest in cassava farm 1. Both (BAF_T) and (BF_T) followed the trend: cassava farm 2 > cassava farm 3 > cassava farm 5 > cassava farm 4 > cassava farm 1. The highest and the lowest bioaccumulation factor (BAF_L) and bioavailabilty factor (BF_L) for cassava leaves were recorded at cassava farm 4 and 2 respectively. (BAF_L) and (BF_L) followed the

Table 4. Estimated Daily Intake (mg/kg bw/day) and Target Hazard Quotient

Farms	EDI_T	EDI_L	THQ_T	THQ_L
1	4.052	0.0279	1.158	0.008
2	0.324	0.3252	0.093	0.093
3	8.202	0.0836	2.343	0.023
4	3.534	0.0743	1.010	0.021
5	4.312	0.1393	1.231	0.020
Average	**4.048**	**0.1300**	**1.179**	**0.037**
Control	0.486	0.0279	0.138	0.007

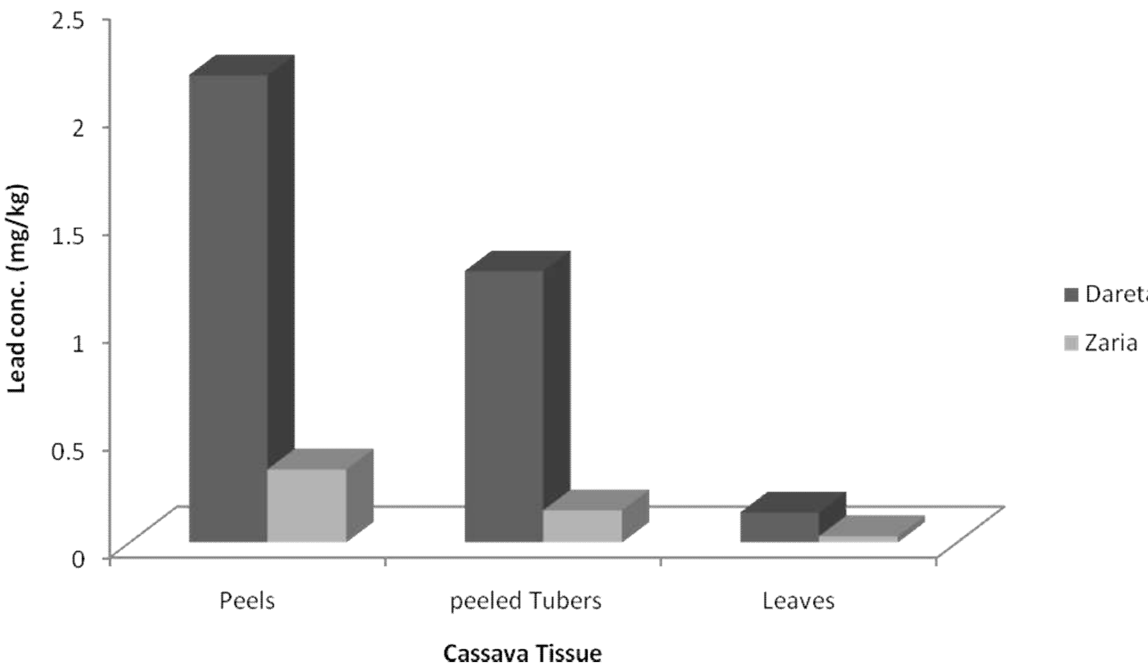

Figure 2: Comparison of lead contents of edible cassava tissues from Dareta village (study area) and Zaria (control)

sequence: cassava farm 4 > cassava farm 3 > cassava farm 1 > cassava farm 5 > cassava farm 2.

Table 4 indicates that the average estimated daily intake for cassava tuber (EDI_T) and cassava leaves (EDI_L) expressed in milligram per kilogram body weight were 4.048 and 0.1300 respectively. Average target hazard quotients for the two edible cassava tissues (peeled tubers and leaves) were 1.179 and 0.037 respectively.

DISCUSSION

Lead concentration in soils across the five cassava farms in this study were all within WHO/FAO 1992/1993 guideline for Maximum Permissible Limit (MPL) values (90 - 400 mg/kg) of lead (Pb) in agricultural soils (Duressa and Leta, 2015). The values were also within European Commission (EC) and United State MPL values of 50 – 300 mg/kg for agricultural soils (Duressa and Leta, 2015), cassava farm 5 being the only exception. Nigeria has no standards for soil lead levels but the Department of Petroleum Resources (DPR) adopts the Dutch standards for the assessment of soil pollution in the country. The Dutch soil remediation policy uses target and intervention values to assess soil contamination. The remediation intervention value which is used to indicate the Pb level at which the functional properties of the soil to support human, animal and plant life are seriously threatened or impaired is 530 mg/kg for lead. This value represents soil lead concentration above which the soil is said to be seriously contaminated. The target value (85 mg/kg) indicates soil lead level below which there is a sustainable soil quality. It is the soil Pb level that must be attained to fully recover all the functional properties of the soil for humans, animal and plant life, thus the bench mark for environmental quality on the assumption of negligible risk to the ecosystem (Dutch Target and Intervention Values, 2000). Soil lead levels recorded in the study were found to be above the Dutch target value but below the intervention values. This result was therefore in agreement with Joint UNEP/ OCHA, (2010) environmental emergency response mission, Zamfara State, Nigeria, report which states that, lead pollution and poisoning crisis was confined to areas where processing of the lead rich gold ore had taken place and has not spread extensively to other areas such as farm lands. Lower mean soil lead level of 8.40±2.48mg/kg had been reported for cassava farms within the vicinity of cement factory in north central Nigeria (Idakwoji, 2016). A mean soil lead level of 1.37µg/g was reported for cassava farms near cement processing facility in the Volta Region area of Ghana (Addo et al., 2013) and 22.99mg/kg for irrigated farm lands at Koka village Orioma State, East Ethiopia (Duressa and Leta, 2015).

The range of concentration (0.03mg/kg – 2.59mg/kg) of peeled cassava tubers (Table 2) in this study is a serious cause for concern. Joint FAO/WHO Expert Committee on food additives established the highest tolerable daily and weekly intake limits used for assessing health risk linked with the intake of metals through the consumption of contaminated food. The weekly maximum tolerable limit for lead corresponds to 0.025 mg/kg/human body weight (JECFA, 2007). The weekly tolerable limit for an average adult of 70 kg body weight is therefore 1.75 mg/kg. This intake limits apply to fresh vegetables, the contents of metals referred to in this study referring to dry weight (dw) were not recalculated to fresh weight (fw) due to lack of available information on the mean water contents of leaves and tubers of cassava from the area but it does gives clear indication of serious contamination of cassava tubers from the area. The obtained concentrations were compared to the European Commission Regulation (EC) NO 1881/2006 maximum permissible level of lead (0.20 mg/kg dry weight) in consumed vegetables (Commission of the European Communities. 2006) and were found to be higher. The concentrations of lead in the cassava tubers recorded in the study were also higher than the available reported human toxicity levels of 1.00 mgPb/day (Abah et al., 2013). Consumption of cassava tubers from Dareta thus poses significant risk of lead toxicity. The high lead content of cassava tubers observed despite the fact that soil lead levels were found to be within the acceptable limit might be attributed to the fact the over 45% of lead in Dareta soil is present in the mobile phase and is readily available for uptake by plants (Udiba et al., 2019). Lower lead concentration ranging from 0.012 mg/kg to 0.018 mg/kg have been reported for peeled cassava tubers from oil spills and gas flaring zones of Delta State, Nigeria (Osabohien et al., 2013). Nwocha et al., (2011) reported a range of 2.00 – 2.41 mg/kg for cassava tubers grown around oil flow stations in Bayelsa state, Nigeria. A mean value of 76.6±19.94 mg/kg was reported for cassava tubers from an abandoned municipal waste dump site in Umuahia, Nigeria (Okoronkwo et al., 2005). Mean values of 0.840±0.230 mg/kg, 0.850±0.270 mg/kg and 0.870±0.250 mg/kg were also recorded for cassava tubers from selected farms in Otukpo, Ohimini and Kastina-Ala Local Government Areas of Benue State, Nigeria (Abah et al., 2013). A median lead value of 0.7 mg/kg has been reported in literature for peeled cassava tubers in Zambian copper belt mining district (IGCP/SIDA, 2012). Dispersal of lead dust from ore mining and processing activities have been reported as the source of elevated lead levels in Dareta and its environs (Joint UNEP/OCHA, 2010; UNICEF, 2011; Udiba et al., 2012). Uptake of this metal from the soil might account for the significantly higher lead concentrations recorded for cassava tubers from Dareta village compared to Bassawa village, Zaria (control) a non mining community.

Lead concentration of cassava peels (1.19 – 3.75 mg/kg) was found to be higher than lead concentration of peeled cassava tubers (1.19 – 3.75 mg/kg) and Cassava leaves (0.02 – 0.43mg/kg) indicating significant accumulation of the toxic metal in the peels. Cassava peels may therefore be said to be the major storage organ for lead in Dareta Cassava. A similar observation of higher mean lead levels of cassava peels (1.8 mg/kg) than peeled cassava tubers (0.7 mg/kg) was found in literature (IGCP/SIDA, 2012). Cassava peels is not part of the human diet so that direct toxicity does not pose any significant risk. In an animal rearing community such as Dareta, cassava peels is a major animal feed. The Maximum tolerable level of lead in complete feed is 10 mg/kg (Commission of the European Communities, 2006). Lead concentration in cassava peels recorded in the study is lower than the Maximum tolerable limits. This concentration is not enough to cause acute toxicity. However, chronic poisoning may not be ruled out. In Dareta village, cassava peels are feed directly to livestock. The metal is thus introduced into the food chain through livestock. After absorption and distribution in the blood, Pb is initially distributed to soft tissues throughout the body. Eventually the bones accumulate the toxic metal over a much longer period (Idakwoji, 2016). As it is the custom to consume the whole animal when slaughtered, the consumption of edible tissues of food animals fed with cassava peels from the area over time might cause high accumulation of the lead despite the fact that concentration of the metal in the cassava peels is lower than the maximum tolerable limit. In Nigeria and many other countries of the world, meat and milk from cattle, goats and sheep are some of the most common sources of animal protein (Ogabiela et al., 2011). Consumption of food animals from the area thus poses serious threat to public health.

The large difference in lead concentrations between cassava root and cassava leaves indicates an important restriction of the internal transport of the toxic metal from the roots towards the aerial parts. The low mobility of lead in cassava plant from root to leaves was reflected by the low Translocation Factor observed across the farms (Table 3) Translocation factor mirrors the plant's ability to transport the metal from the root to harvestable part (leaves) and is mainly controlled by the pressure of roots, leaves transpiration and solubility of the metal in soil. Translocation Factor (TF) values lower than or equal to 1.033 suggested that Plants grown on highly metal contaminated soils behaved as tolerant plants or excluders. Metal excluders accumulate heavy metals from the surrounding medium into their roots but exclude their transport and entry into the aerial parts. Where the TF is greater than 1.033, the plant species is a hyperaccumulator of the metal (Hosman et al., 2017; Gennaro et al., 2012; USEPA, 2000). TF values recorded in this study were far below 1.033. The plant might therefore be said to be tolerant to the lead but not a hyperaccumulator of the metal with respect to the aerial part. The relatively higher levels of lead in cassava leaves from cassava farm 2 and farm 5 might be due to the presence of a highly mobile lead fraction in the soil, soil chemistry, the species of cassava or the stage of maturity of the cassava from the farm. Cassava is very well known for the presence of free and bound cyanogenic glucosides- linamarin and totaustralin, which are converted to hydrocyanic acid (HCN) in the presence of linamarase a naturally occurring enzyme in cassava. All plant parts contain cyanogenic glucosides with the leaves having the highest concentration (Gideon-Ogero, 2008). Cassava may be broadly classified as either bitter or sweet, signifying the presence or absence of toxic level of cyanogenic glucosides. Sweet cultivar can produce as little as 20 mg/kg of hydrocyanic acid per kg of fresh roots while bitter ones may produce more than 50 times as much (Gideon-Ogero, 2008). Young immature cassava tubers contain more HCN than matured tubers. The higher the concentration of HCN in the cassava tissue, the higher the ability to accumulate toxic metals (Gideon-Ogero, 2008). Osabohien et al., (2013) reported 0.041 mg/kg for cassava leaves and 0.032 mg/kg for peeled cassava tuber around oil spills and gas flaring zones of Delta State, Nigeria. Idakwoji, (2016) reported an average lead concentration of 0.03 mg/kg for cassava leaves cultivated within the vicinity a cement factory in North central, Nigeria. A mean lead concentration of 111.57 mg/kg was reported for cassava leaves and 76.6 mg/kg for peeled cassava tubers from an abandoned municipal waste dump site in Umuahia, Nigeria (Okoronkwo et al., 2005). The concentrations of lead in cassava leaves measured in this study were below the European Commission Regulation (EC) No 1881/2006 maximum permissible limit for lead (0.20 mg/kg dry weight) in leafy vegetable (Commission of the European Communities (2006) except at cassava farm 2. The observed levels of lead in the cassava leaves were also lower than the available reported human toxicity levels of 1.00mgPb/day (Abah et al., 2013). Young cassava leaves are regularly picked and cooked for human consumption. The tender leaves contain up to 25 percent protein, on a dry matter basis, and are a valuable source of iron, calcium, and vitamins A and C_3. The essential amino acid content of cassava leaf protein is similar to that found in hens's egg (IGCP/SIDA, 2012). People consuming cassava leaves from cassava farm 2 are ingesting high concentration of the toxic metal. Animals fed with cassava leaves may also ingest considerable amounts over time.

Soil to plant transfer is one of the major components of human exposure to metals through the food chain. Soil to plant transfer is a function of both soil and plant properties and is a good indicator of how much of the metal is bioavailable. In an audit report of soil lead concentration in Dareta, Udiba et al. (2019) revealed that over 46% of lead in Dareta geochemical environment was bioavailable. The potential of cassava plant to uptake and retain this bioavailable lead in its edible tissues was considered in this study as bioaccumulation. Bioaccumulation factor identifies the efficiency of a given plant species to accumulate a given metal. In this case it is the progressive increase in the concentration of lead in cassava tissues because the rate of intake exceeds the ability of the plant to eliminate the metal. The acceptable range of accumulation factor suggested by Kloke et al. (1984) for Cu and Pb (0.01- 0.1) in a normal plant was used as generalized range for comparison. These factors were based on the roots uptake of the metal and surface absorption of atmospheric metal deposits. The obtained bioaccumulation factors as shown in Table 3 were far lower than the value indicated by Kloke. The concentration of the toxic metal in edible cassava tissues (tuber and leaves) did not follow the trend of the metal in soil (Cassava farm 5 > Cassava farm 4 > Cassava farm 1 > Cassava farm 3 > Cassava farm 2) across the farms. Cassava farm 3 recorded the highest mean lead level in peeled cassava tubers while cassava farm 2 with the least soil lead level in the study recorded the highest mean Lead (Pb) concentration in the leaves (Table 2). This observation might therefore be attributed to differences in the chemical form of Pb present in soil at the different farms, the soil chemistry, species of cassava plant and the age of the plant. The findings of this study therefore agree with Yusuf, (2007) study on the sequential extraction of lead, copper, cadmium, and zinc in soils near Ojota waste site. The study stated that; the total concentration of a given metallic element in soil or sediment provides a useful and easier way of stating clearly, pollution due to the metal but generally inadequate in predicting the toxicity of the metal pollutant. The chemical form of the metal is of great importance in determining its potential bioavailability and remobilization from the soil to the other components of the ecosystem such as water, plants and animals when physico-chemical conditions are favourable. The observed significantly higher lead concentration in edible tissues of cassava from the study area (Dareta village) compared to those from the control (Basawa village, Zaria) was an indication of the presence of lead pollution due to mining activities Dareta village (Figure 2).

Estimated Daily Intake

The potential health risk of lead to residents of Dareta associated with the consumption of cassava was assessed by estimating the level of exposure. This was achieved by evaluating the daily intake. The estimated daily intake (EDI) of metals was used to describe the safe level of metallic intake through food consumed by several researchers (Guerra et al., 2012; Lanre-Iyande and Adekunle, 2012). EDI depends on both metal concentration in edible portion of food crop and the amount of food consumed (Ado et al., 2013; Guerra et al., 2012). The EDI in this study thus combines data on Pb levels in edible cassava tissues with quantities of cassava tissues consumed on daily basis. The approximate daily lead intake for people living in Dareta and its environs through the consumption of enlarged cassava roots (tubers) and cassava leaves estimated, were compared with the Recommended Daily Intake/or allowance (RDI) of 0.00 mgPb/day and the upper tolerable daily intake (UL) of 0.240 mgPb/day. The estimated daily intake for lead is the amount of the metal in air, drinking water or food that can be taken daily over life time without appreciable health risk. The average values of the estimated daily intake of lead from both cassava tubers and cassava leaves were found to be above the recommended daily intake for the metal Table 4. The average value of the estimated daily intake of lead for cassava tubers was also found to be above the upper tolerable intake (UL) for the metal. The average estimated daily intake of lead for cassava leaves on the other hand was lower than the upper tolerable daily intake. The estimated daily intake of lead computed in this study were expressed milligram per kilogram body weight per day (mg/kg b.w./day) so that for an average adult of 70 kg body weight, the average EDI for cassava tuber (4.048) and cassava leaves (0.1300) multiplied by 70 amount to 283.37 mg/day and 9.1 mg/day respectively. The results obtained from the estimation of daily intake (EDI) of lead in the study implies that perennial intake of cassava tissues especially the tubers for Dareta village is likely to induce serious adverse health effects.

Target Hazard Quotient (THQ)

Risk to human health through the consumption of lead contaminated cassava was also characterized using target hazard quotient which is the ratio between exposure and the reference oral dose (RfD). THQ has been used by several researchers to indicate risk level due to exposure to contaminants (Ado et al., 2013; Guerra et al., 2012; Charry et al., 2008). When the ratio is less than one (1), there is no obvious risk from substance over a life time of exposure while THQ greater than 1 indicates that the contaminant may produce an adverse effect. The higher the THQ value, the higher the probability of experiencing long term deleterious effects. THQ in this study provides an indication of risk level due to exposure to lead through the consumption of edible cassava tissues (tubers and leaves) without taking into consideration other exposure routes such as dermal contact, inhalation and incidental ingestion of soil, water and other food sources. The THQ for cassava leaves cross the farms were all below 1 with an average of 0.037 while that of cassava tubers were all above 1 except for cassava farm 2. The average THQ for cassava tubers across the farms was 1.179 with the highest value recorded for cassava farm 3. THQ based risk assessment in this study indicated that the consumption of cassava tubers from Dareta village poses toxicological risk with respect to lead toxicity.

Conclusion

Cultivation of crops for human or animal consumption in soils with elevated metal levels could lead to uptake and accumulation of dangerous concentrations of the metal in edible crop tissues. In this study lead concentrations in soil across the cassava farms studied were all within WHO/FAO Maximum Permissible Limit (90 - 400 mg/kg) for agricultural soil. The average lead concentration of peeled cassava tubers was found to be above WHO/FAO permissible limit. The average values of Estimated Daily Intake (EDI) of lead from cassava tubers cross the farms were above the Recommended Daily Intake (RDI) and the Upper Tolerable intake (UL) for the metal. The average value of EDI of lead from cassava leaves was also found to be above RDI but lower than UL. The average Target Hazard Quotient for cassava tubers was above 1.00, thus indicating potential health risk. The low mobility of lead in cassava plant from root to leaves was reflected by the low Translocation Factor (0.009-0.116). The study concluded that ore mining and processing activities might be responsible for the significant difference observed between lead concentration in soil and cassava tissues from the Dareta village and Basawa village, Zaria (control). The large difference in lead concentrations between cassava root and cassava leaves indicates an important restriction of the internal transport of the toxic metal from the roots towards the aerial parts and that the perennial intake of cassava tubers from Dareta poses significant risk of lead toxicity.

Conflict of interest

No conflict of interest exits in the submission of this manuscript.

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REFERENCES

Abah J, Ubwa ST, Audu SI, Malu SP (2013). 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. Res. J. Chem. Sci., 3(5):63-70.

Abdullah MIM (2011). Evaluation of some heavy metals residue in whole milk powder used at confectionary plant regarding the public health significance, Animal research institute, agricultural research center, Giza Egypt.

Abida BM, Ramaiah H, Khan I, Veena K (2009). Analysis of heavy metals concentration in soil and litchens from various localities of hosur road, Bangalore, Indian E- J. Chem., 1:13-22.

Addo MA, Darko EO, Gordon BJB, Nyarko (2013). Heavy Metal Contaminations in soil and cassava harvested near cement processing facility in the Volta Region, Ghana: Implications of Health risk for the Population living in the Vicinity. e-journal of Sci. Tech. 3(8):71-83.

Adedokun AH, Njoku KL, Akinola MO, Adesuyi AA, Jolaoso AO (2016). Potential Human Health Risk Assessment of Heavy Metals Intake via Consumption of some Leafy Vegetables obtained from Four Market in Lagos Metropolis, Nigeria. J. Appl. Sci. Environ. Manage, 20 (3):530-539.

ATSDR, 2008. Draft toxicological profile for cadmium. Atlanta: US Department of Health and Human Services, Agency for Toxic Substances and Disease Registry. http://www.atsdr.cdc.gov/toxprofiles/tp5-p.pdf.

Awofolu OR (2005). A Survey of trace metals in vegetation, soil and lower animals along some selected major roads in Metropolitan City of Lagos. Environmental Monitoring and Assessment, 105:431-447.

Blacksmith Institute (2011). Environmental remediation – lead poisoning in Zamfara, final report. Retrieved January 20, 2012, from www.blacksmithinstitute.org.

Blacksmith Institute (2011).The World's Worst Toxic Pollution Problems Report. Retrieved January 28, 2012, from www.worstpolluted.org

Chary NS, Kamala CT, Raj DSS (2008). Assessing risk of heavy metals from consuming food grown on sewage irrigated soils and food chain transfer. Ecotoxicol. Environ. Safety 69 (5):13-24.

CODEX (1995). Codex General standard for contaminants and toxins in food and Feed. Codex Stan, 193:1-41

Commission of the European Communities (2006). Commission Regulation (EC) No 1881/2006. Official Journal of the European Union, 364:5-24.

Corley M, Mutiti S (2017). Effects of Lead Species and Growth Time on Accumulation of Lead in Chinese Cabbage. Retrieved March 2018 from *www.advancedsciencenews.com*

Duressa TF, Leta S (2015). Determination of Levels of As, Cd, Cr, Hg and Pb in Soils and Some Vegetables Taken from River Mojo Water Irrigated Farm land at Koka Village, Oromia State, East Ethiopia. Int. J. Sci. Basic Appl. Res. 21(2):352-372.

Dutch Target and Intervention Values (2000). Dutch soil remediation policy. Retrieved January 20, 2012, from www.esdat.net

FAOSTAT (2017). Cassava production in 2016, Crops/World Regions/Production Quantity from pick lists". Retrieved March 2018 *from UN* Food and Agriculture Organization Corporate Statistical Database

Gennaro B, Karam F, Pedro SR, Massimo F, Franco N Nicola S (2012). Heavy metals accumulation and distribution in durum wheat and barley grown in contaminated soils under Mediterranean field conditions. J. Plant Interactions.7(2):160-174

Gideon-Ogero JE (2008). Levels of heavy metals (lead, cadmium, zinc, magnesium and copper) in cassava from Niger Delta of Nigeria, an Indication of Soil Environmental pollution. Retrieved January 28, 2012, from http/www.ncbi.nlm.nih.gov/pmc

Guerra F, Trevizam AR, Muraoka T, Marcante NC, Canniatti-Brazaca SG (2012). Heavy metals in vegetables and potential risk for human health. Sci. Agric. 69 (1):54-60.

Hodgson E (2004). A Textbook on Modern Toxicology. John Willey and Sons Inc., Hoboken, New Jerasey

Hosman ME, El-Feky SS, Elshahawy MI, Shaker EM (2017). Mechanism of Phytoremediation Potential of Flax (*Linum usitatissimum* L.) to Pb, Cd and Zn. Asian J. Plant Sci. Res. , 7(4):30-40.

Idakwoji PA (2016). Assessment of heavy metal contamination of soil and cassava plants within the vicinity of a cement factory in north central, Nigeria. Advances in Appl. Sci. Res., 7(3): 20-27

IFAD/FAO (2005a). A review of cassava in Africa with country case studies on Nigeria, Ghana, the United Republic of Tanzania, Uganda and Benin, Proceedings of the Validation Forum on the Global Cassava Development Strategy,Volume 2]

IFAD/FAO (2005b). The Global Cassava Development Strategy: A Cassava Industrial Revolution In Nigeria, Information Division, Fao, Rome, Italy

IGCP/SIDA (2012). *Project 594* (pp 781-789). Windhoek, Czech Geological Survey,

Joint FAO/WHO Expert Committee on Food (JECFA) (2007): Database of Food Additives and Pollutants. Retrieved October 10, 2011, from http://jecfa.ilsi.org/search.cfm, visited 10-10-2011

Joint UNEP/OCHA Environment Unit, (2010). Lead pollution and poisoning crisis, environmental emergency response mission, Zamfara State, Nigeria. Switzerland: Joint UNEP/OCHA Environment Unit,

Kabara AA (2014). Zamfara lead poison update: 735 Child Deaths Recorded, 1450 on Treatment-MSF. Leadership Online News Paper, August 3rd 2014.

Kloke A, Sauerbeck DR, Vetter H (1984). The Contamination of Plants and Soils with Heavy Metals and the Transport of Metals in Terrestrial Food Chains. In 'Changing metal cycles and human health: report of the Dahlem Workshop on Changing Metals Cycles and Human Health, Berlin, Germany'. Ed J.O Nriagu Springer-Verlag: Berlin, pp: 113-141.

Lanre-Iyanda TY, Adekunle IM (2012). " Assessment of heavy metals and their estimated daily intakes from two commonly consumed foods (Kulikuli And Robo) found In Nigeria", African J. Food, Nutri. Develop., 3(12):6157-6169.

Malik RNS, Husain Z, Nazir I (2010). Heavy Metal Contamination and Accumulation in Soil and Wild Plant Species from Industrial Area of Islamabad, Pakistan. Pak. J. Bot., 42(1): 291-301.

McBride MB (2007). “Trace metals and sulfur in soils and forage of a chronic wasting disease locus”. Environ. Chem., 4:134–139.

National Population Commission (2006). Social Statistic in Nigeria (pp 300). Nigeria: National Beaureu of Statistics.

NGCERA (1999). Navy Guidance for Conducting Ecological Risk Assessment: Fundamentals of Ecology and Ecotoxicology, Ecorisk Fundamentals, 1:1 -30.

Nkwocha EE, Pat-Mbano EC, Tony-Njoku NF (2011). Assessment of Heavy Metal Concentration in Food Crops Grown Around Etelebou Oil Flow Station in Bayelsa State, Nigeria, Int. J. Sci. and Nature, 2(3):665- 670.

Ogabiela EE, Udiba UU, Adesina OB, Hammuel C, Ade-Ajayi FA, Yebpella GG, Mmereole UJ Abdulahi M (2011a). Assessment of Metal levels in Fresh Milk from Cows Grazed around Challawa Industrial Estate of Kano, Nigeria. J. Basic Appl. Sci. Res., 1 (7):533-538.

Okoronkwo NE, Ano AO, Onwuchekwa EC (2005). Environment, Health and Risk Assessment: A Case Study of the Use of an Abandoned Municipal Waste Dump Site for Agricultural Purposes. Afr. J. Biotechnol. 4 (11):1217-1221.

Osabohien E, Otutu OJ, Otuya OB (2013). Concentration of Heavy Metals in Soils, Tubers and Leaves of Cassava Plants Grown around some Oil Spill and Gas Flaring Zones in Delta State, Nigeria. Appl. Sci. Res. J., 1(1):1 – 6.

PRI (2012), Lead Poisoning from Gold Mining. Environmental News Magazine, April 2012

Sharma RK, Agrawal A, Mrshal FM (2009). Heavy metals in vegetable collected from production and market sites of a tropical urban area of india. Chem Toxicl. 47(3):582

Shiloh, (2010). Lead poisoning in kills over 160 people in Nigeria’s Northern zamfara state. Retrieved January 28, 2012 from http://www.apanews.net/apa.php?page=...article=125692.

Telmer K (2011). Assessment of the artisanal and small scale gold mining in Anka and Bukkuyum LGAs, Zamfara State, Nigeria, retrieved January 28, 2012, from www.artisanalgoldcouncil.org.

Udiba UU, Akpan ER, Antai EE (2019). (2018). Soil lead concentration in Dareta village, Zamfara, Nigeria (2019). J. Health Pollution. 9(23):1-15.

Udiba UU, Ogabiela EE, Hammuel C, Magomya AM, Yebpella GG, Ade-Ajayi AF, Odey MO, Gauje B (2012). Post remediation assessment of contaminants levels in soil, Dareta Village, Zamfara, Nigeria. J. Trends in Advanced Sci. and Engineering Tase, 4(1):70-79.

UNICEF Programme Cooperation Agreement (2011). Environmental remediation – lead poisoning in Zamfara FINAL REPORT September 2010 – March 2011. Retrieved January 28, 2012 from www.blacksmithinstitute.org.

United States Protection Agency (USEPA). 2000. Introduction to Phytoremediation. EPA 600/R-99/107. U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, OH.

Wilberforce JOO (2015) Heavy Metal Accumulation in Tubers Grown in a Lead-zinc Derelict Mine and their Significance to Health and Phytoremediation, American Chemical Sci. J. 8(3): 1-9.

World Health Organization WHO (1993). Evaluation of Certain Food Additives and Contaminants. In: Forty-First Report of the Joint FAO/WHO Expert Committee on Food Additives., WHO, Geneva, Switzerland. (WHO Technical Series, 837).

Yusuf KA (2007). Sequential extraction of lead, copper, cadmium and zinc in soil near Ojota Waste Site. J. Agron., 6 (2):331-333.

Zamfara State Ministry of Environment (2003). *Geographic data on zamfara state.* Zamfara, Govt. press.

Zhuang P, McBride MB, Xia H, Li N, Li Z, (2009). “Health risk from heavy metals via consumption of food crops in the vicinity of Dabaoshan mine, South China”, Sci. the Total Environ., 1551-1561.