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Investigating the Transfer of Metals to Carrots and Tomatoes from Soils of Old Mining Site of Jos Plateau, Nigeria

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Abstract: **The levels of the heavy metals; cadmium (Cd) and lead (Pb) were investigated in the vegetables (carrots and tomatoes) planted in farmlands around the old mine sites in Jos, Plateau State. These edible vegetables were planted and harvested at maturity. Atomic absorption spectroscopy was used for the analyses. The result reveals that cadmium concentrations ranged from 0.01 – 0.45mg/kg and lead concentrations ranged from 0.01 – 0.31mg/kg. The uptake of these metals by tomatoes was higher than that of carrots. The results further showed that concentrations of cadmium in some of the vegetables were above the Food and Agriculture Organization/ World Health Organisation (FAO/WHO) maximum permissible limit. The soil – plant transfer factor values of cadmium in tomatoes from two of the farms were higher than 1(TF>1), one farm had transfer factor of 1, this implied that there was soil –plant transfer of cadmium in the tomatoes that had TF greater than 1. While lead had soil – plant transfer values lower than 1(TF<1) in some of the vegetables, this implied that there was no soil - plant transfer of lead to these vegetables.**

Keywords: **Cadmium, lead, vegetables, transfer - factor.**

I. INTRODUCTION

Organized mining in Nigeria began in 1903 when Britain, the Colonial government, created the Northern protectorate for Mineral survey. Nigeria became a major producer of tin, columbite and coal in the 1940s while Oil was discovered in 1956 but the 1967 -1970 civil war made many of the expatriates including mining experts to leave the country [1]. It was reported that mining on the Plateau started around 1914 through the discovery of tin deposits by the British experts which subsequently led to the setting up of mineral survey team on mineral exploration in the Northern protectorate. Presently, there are more than 4000 abandoned mining sites and ponds [2].

Mining activities in Nigeria contributed to the problems of environmental pollution and land degradation because in most mining sites, unregulated mining activities were operational, leading to indiscriminate dumping of industrial waste. The Itakpe iron ore deposit in Nigeria had been reported to release Ti, Cr, Mn, Cd, Ta, Ca, Zn, Cu into the environment[3]. These wastes contaminate the soil, water and air with trace elements and could be retained within the soil matrix for long time ranging from hundreds to thousands of years. It was reported that Cd, Ni, and Zn had relatively shorter residence time in the soil when compared to Pb and Cr. Heavy metals which are major contaminant of the soil include Cu, Ni, Cd, Zn, Cr, Pb, Fe, Ca, Mg [4]. Ingestion of a very minute concentration of these metals (Cd, Pb,Hg) is highly toxic [5]. Heavy metals are very harmful to the ecosystem because of their non- biodegradable properties, long biological half lives and ability to accumulate in different parts of the body because of their solubility in water, of which most are very toxic. The human body mechanism does not have any definite route or system for the removal of these metals; as such they remain within the body [6].

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It was reported that accumulation of heavy metals within the food chain which is absorbed by plants pose serious health challenges to man [7]. It was further reported that ingestion of heavy metal contaminated food may deplete some essential nutrients in the human body which are further responsible for decrease in immunological defense system, intrauterine growth retardation, disabilities associated with malnutrition and high prevalence of upper gastrointestinal cancer rates. Also that the toxic effects become visible with serious consequences after several years of exposure as they are usually stored on the soft tissues Furthermore, heavy metals affect the brain because the brain tissues have attraction for them, especially lead (Pb), Mercury (Hg), Cadmium (Cd) and Aluminum (Al) [8]. Cadmium (Cd) targeted organs for its poisoning are reported to be liver, placenta, kidneys, lungs, brain and bones [9]. Lead (Pb) is reported to be physiologically and neurologically toxic to man. Effect of Lead poisoning is more serious in children, as it usually attacks their Central Nervous System (CSN), destroys the development of fetal organs, causes neurological deficits and reduces their mental abilities [10].

SOIL – PLANT TRANSFER FACTOR (TF):

Soil – Plant Transfer Factor (TF) describes the amount of an element expected to enter a plant from its substrate, under equilibrium conditions that assumes a linear relationship between the concentrations of a certain element in the plant with that in the soil. It is the ratio of the concentration of metal in the plant to that of the soil [11].

The aim of this research study is to determine if the metals discovered in the vegetables were transferred from the soil of the old mining sites or got into the vegetables through other sources.

II. DESCRIPTION OF THE STUDY AREA

Jos, the capital of Plateau State popularly refers to as tin city is found between latitude 9^0 50'N and 1^0 05' and longitude 8^0 50'E and 8^0 55'E. It is about 300km North-East of Abuja, 400km South of Kano and 600km South West of Maiduguri with an average elevation of about 1238 meters above mean sea level and highest peak of some 20km East ward from Jos Shere Hills rising to about 1777 meters above sea level [12].

The farm lands were: Farm A, at Danjuma farm, Hollaza settlement near F.G.C, Jos in Jos north, Farm B at Gurum near Mistaali and Farm C at Tsaya both in Bassa L.G.A. while the control samples were collected from West African Milk (WAMCO) farm at Vom, Jos South L.G.A. The Figure below shows the map of Plateau state indicating the three local government areas (L.G.As) where the research studies' farmlands are located.

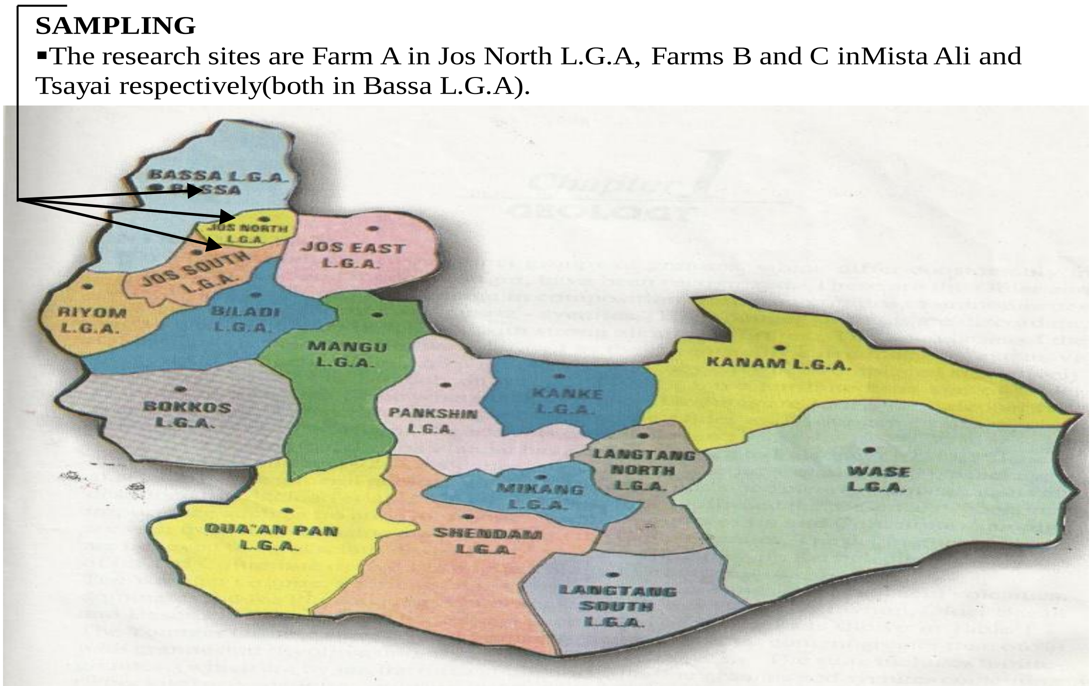

Fig. 1

III. MATERIALS AND METHODS

SAMPLING:

Three samples were obtained from each site namely: Whole fresh plants of tomatoes, *Lycopersicum esculentum,* (a fruit vegetable); carrots, *Daucus carrota* (a root vegetable) and soil. Planting and harvesting of the vegetables were done during the dry and raining seasons of 2014 from the three farm lands near the old mininig site. The soil samples were taken at the depth of 2- 20cm. Sabbe and Marx sampling method was employed for every sample [13]

TREATMENT OF SAMPLES:

The vegetable samples were washed, separated, cut and air-dried. The dried samples were ashed at 550^o and stored in air tight covered plastic containers for elemental analyses. One gram (1g) of each of the soil and ashed plant sample were digested with 40 ml of aqua regia (a mixture of 3 parts concentrated HCl to 1 part concentrated HNO_3) on a hot plate in a fume cupboard, until the digested sample was dried and baked. The baked sample was re dissolved with 10ml 1 : 1 HCl. To the hot solution, 30 ml of deionized water was then added and filtered through a Whatman number 41 filter paper into a 100 ml standard volumetric flask and the solution made up to the mark with distilled water. All the reagents used were of analytical grade. Cadmium and lead were determined in the plant and soil samples using a SOLAAR ice 3000AA01122804v1.30 Atomic Absorption Spectrophotometer (AAS).

DETERMINATION OF SOIL – PLANT TRANSFER FACTOR (TF):

The metal concentrations in the extracts of the soils and plants are calculated on the basis of dry weight using the following simplified equation:

TF= Cp / Cs

where, Cp and Cs are the concentration of heavy metals analyzed in plant and soil samples respectively

TF>1 means the plant accumulated the element; TF = 1 means the plant is not influenced by the element; TF< 1 means the plant avoids the element from the uptake [11].

IV. RESULTS AND DISCUSSION

RESULTS:

The concentrations of cadmium (Cd)and lead (Pb) are presented on Tables 1 and 2.

TABLE 1 Concentration of metals (mg/kg)

		Cadmium (Cd)		Lead (Pb)	
		RAINING SEASON	DRY SEASON	RAINING SEASON	DRY SEASON
FARMS IDENTITY	CONTROLLED SOIL	BDL		BDL	
	FARM A	0.04±0.03		0.03±0.05	
	FARM B	0.07±0.03		0.14±0.04	
	FARM C	0.06±0.01		2.21±0.05	
	CONTROLLED CARROT	0.16±0.02		0.01±0.01	
	FARM A 2014	0.45±0.02	0.03±0.02	0.18±0.01	0.08±0.03
	FARM B 2014	0.01±0.01	BDL	0.28±0.02	BDL
	FARM C 2014	0.02±0.01	BDL	0.01±0.01	BDL
	CONTROLLED TOMATOES	0.18±0.01		0.05±0.01	
	FARM A 2014	BDL	0.08±0.002	BDL	0.07±0.02
	FARM B 2014	0.35±0.01	BDL	0.31±0.04	BDL
	FARM C 2014	0.68±0.03	0.23±0.01	0.03±0.01	0.10±0.07

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TABLE 2 Mean concentrations of metals (mg/kg)

		MEAN CONCENTRATION Cadmium (Cd)	MEAN CONCENTRATION Lead (Pb)
FARMS IDENTITY	**CONTROLLED SOIL**	BDL	BDL
	FARM A	0.04±0.03	0.03±0.05
	FARM B	0.07±0.03	0.14±0.04
	FARM C	0.06±0.01	2.21±0.05
	CONTROLLED CARROT	0.16±0.02	0.01±0.01
	FARM A 2014	0.24	0.13
	FARM B 2014	0.01	0.14
	FARM C 2014	0.01	0.01
	CONTROLLED TOMATOES		
	FARM A 2014	0.04	0.04
	FARM B 2014	0.18	0.16
	FARM C 2014	0.46	0.07

BDL : BELOW THE DETECTION LIMIT

TABLE 3 Soil – Plant Transfer Factor (TF)

FARMS	**Cadmium (Cd)**		**Lead (Pb)**	
	RAINING SEASON	DRY SEASON	RAINING SEASON	DRY SEASON
DANJUMA CARROT	11.25	0.75	6.00	2.67
GURUM CARROT	0.14	-	1.29	-
TSAYA CARROT	0.13	-	0.01	-
DANJUMA TOMATOES	-	2.00	-	2.33
GURUM TOMATOES	5.00	-	2.22	-
TSAYA TOMATOES	11.33	3.38	0.01	0.05

TABLE 4 Mean Soil – Plant Transfer Factor (TF)

FARMS	**Cadmium (Cd)**	**Lead (Pb)**
	MEAN TF	MEAN TF
DANJUMA CARROT	6.00	4.34
GURUM CARROT	0.07	1.00
TSAYA CARROT	0.07	0.01
DANJUMA TOMATOES	1.00	1.17
GURUM TOMATOES	2.50	1.11
TSAYA TOMATOES	7.36	0.03

DISCUSSION:

SOIL SAMPLES:

The results in table 1 showed that cadmium (Ca) and Lead (Pb) concentrations were below the detection limit in the control soil sample. Farm A, at Danjuma's farm had 0.04mg/kg of cadmium and 0.03mg/kg of lead; these had the lowest metal concentrations. Farm B's soil had cadmium concentration of 0.07mg/kg and lead was 0.14mg/kg. Lastly the soil from farm C at Tsaya followed with 0.06mg/kg of cadmium and 2.21mg/kg of lead. All the concentrations were below the Maximum Permissible Limit (MPL) when compared with the International Standards [14].

The result showed that Cd had mean concentration of 0.24mg/kg in carrots of farm A, 0.01mg/kg in carrots of farm B and 0.01mg/kg in carrots of farm C. The maximum permissible limit for Cd is 0.10mg/kg [15], as such only carrots from farm A with such cadmium concentration may be unsafe for human consumption.

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The mean concentration of cadmium in tomatoes was 0.04mg/kg for farm A, 0.18mg/kg in farm B and farm C had 0.46mg/kg. The maximum permissible limit is 0.10mg/kg, thus, it could be seen that only farm A with values lower than the permissible level could be recommended for human consumption.

Lead (Pb):

Carrots farm A had a mean concentration of 0.13mg/kg while that of farm B had 0.14mg/kg as the mean concentration and farm C had mean concentration of 0.10mg/kg. The maximum permissible limit for lead (Pb) is 0.30mg/kg. Based on these values,; carrots from all the farms were safe for human consumption as the concentrations were all below the maximum permissible limit. The mean concentration of lead (Pb) in tomatoes from farm A was 0.04mg/kg which was the lowest concentration obtained. Farms B and C had mean concentration of 0.16mg/kg and 0.07mg/kg respectively. The three tomatoes samples from the three farms were lower than the maximum permissible limit of 0.30mg/kg and hence safe for human consumption. This result was encouraging because the effect of lead poisoning could not be under estimated.

From the results, tomatoes from farm A was the safest followed by farm C and finally farm B. The results showed that the concentrations of cadmium in the vegetables from the three farmlands were higher than the maximum permissible limit. This finding corresponds to the research study by Duressa and Leta [11] on the levels of As, Cd, Cr, Hg and Pb in soils and some vegetables which showed that the mean concentration of metals in the analysed sample were above the maximum permissible limit. It was also observed that the concentrations of cadmium in tomatoes were higher than that of carrots, this means that up take of metals by tomatoes was higher than in carrots. This may be due to plant's selectivity of absorption of metals [11]. In the research studies of Jimoh and Mohammed [16], it was also observed that uptake of cadmium by tomatoes was higher than the maximum permissible limit.

Cadmium (Ca):

Tables 3 and 4 showed that the average Transfer Factor for carrot from farm A (6.00), was the only one above 1, as such it meant that the plant accumulated cadmium from the soil. Transfer Factor of carrots from farms B and C at both raining and dry seasons were below 1, the average Transfer factor 0.07 and 0.17, still below 1, thus impling that these carrots avoided cadmium uptake. The tomatoes plants from the three farms at both seasons of year 2014 had Transfer Factor of 1 for farm A, while farms B and C' s Transfer factors were higher than 1. This implied that for farm A, the tomatoes were not influenced by the metal but tomatoes from farms B and C had transfer of cadmium from the soil to the plant. This result agrees with that of Duressa and Leta [11], which showed low concentration of Cd and Cr in soil samples, while there were relatively high quantities in the plant samples. The Transfer factors of Cd in tomatoes from the three farms (farm A:1, farm B: 2.50 and farm C: 7.36) agreed with the research results of [17], who reported that Cd was one of the elements that could intensively be accumulated in plant bodies with TF = 1.00 – 10.00 and further classified some metals as having less, medium and high potential to be accumulated in plants: As>Pb> Hg were the metals showing medium accumulation with TF = 0.01 – 1.00, Cd was one of the elements reported to be intensively accumulated with TF = 1.00 – 10.00. Once these metals were uptaken by the plants, they accumulate in different tissues of the plants. This continuous uptake and translocation could increase the concentrations of metals in plant tissues despite low metal concentrations in the soils. On the contrary, As and Pb which showed large concentration in soil samples, had registered very low quantities in plants. This may be reasoned that at higher pH, the availability of As and Pb in solution form is less which hindered the soil – plant transfer.

Lead (Pb):

The mean transfer factor of lead for carrots from farm A was higher than 1 (4.34), implying that there was accumulation of the metal in the plant from the soil. For carrots from farms B, the transfer factor was 1.00 which implied that the plant was not influenced by lead. Farm C carrots had a transfer factor of 0.01 which was lower than 1, this implied that there was no transfer of the metal from the soil to the plant, the plant avoided the metal. The tomatoes from farms A and B had transfer factor higher than 1 which implied that there was accumulation of the metal in the plant from the soil. Tomatoes from farm C had a transfer factor that was less than 1; 0.03. This implied that the plant avoided the metal lead. Results of carrots and tomatoes from farm C in which the soil lead concentration was 2.21mg/kg but the vegetables had mean concentrations of 0.01mg/kg and 0.07mg/kg respectively agreed with the observation of Brain, 2005 that Pb which showed large concentration in soil samples, registered very low quantities in plants. This may be reasoned that at higher pH, the availability of As and Pb in solution form is less which hindered the soil – plant transfer.

The research work suggest that there was no soil – plant transfer in carrots of farms B and C but there was in carrots from farm A. Tomatoes from farms A and B had soil – plant transfer while farm C tomatoes had no soil – plant transfer.

V. CONCLUSION

Cadmium contaminations in some of the vegetables from the old mining sites were confirmed by the observed results in which their concentrations were higher than the FAO/WHO maximum permissible limit. The research results showed that carrots from farms B and C did not uptake both cadmium and lead while farm A carrots and tomatoes uptook the two studied metals.

Tomatoes from farms B and C uptook cadmium so also did tomatoes from farms A and B uptook lead, however, it was observed that there was no possibility of lead poisoning as all the observed results were less than the maximum permissible limit. But the continued consumption of these vegetables may be dangerous to the society because of cadmium poisoning which could be as a result of bioaccumulation of cadmium in the body system with serious health complications and even death.

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