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Determination of Some Heavy Metals in Soil and Edible Vegetables Grown in Two Different Farms in Damaturu Metropolis, Yobe State, Nigeria

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Abstract

Vegetables comprise an important part of our daily foods that contribute some minerals and other nutrients to human body. Consumption of contaminated vegetables by heavy metals results in bioaccumulation of these harmful elements in the body. Therefore, this study is designed to examine the amount of heavy metal concentrations (Nickel, Copper, Cadmium and Zinc) in soil and edible parts of four vegetables namely Amaranthus hybridus (spinach), Hibiscus sabdariffa (roselle), Urena lobata (caesar weed) and Ceratotheca sesamoides (false sesame) grown in two farms. Transfer factor of heavy metals from soil to the plants was also evaluated. Samples were prepared and analysed using Atomic Absorption Spectrophotometry (AAS). The mean concentrations of all the vegetables in the both farms for Ni, Cu, Cd and Zn were obtained as 0.215, 2.341, 0.023 and 2.251 mg/Kg respectively. Whereas, the mean concentrations in the soils were 0.317, 7.560, 0.071 and 9.910 mg/Kg for Ni, Cu, Cd and Zn respectively. The levels of the above heavy metals in almost all the samples from those farms were below the maximum allowable limits recommended by WHO/FAO and therefore, they had acceptable conditions for human consumption. The exception was Ni which was slightly above the (0.1 mg/Kg) WHO/FAO permissible limit in the samples of both farms excluding Urena lobata of Custom Farm. In Bin Bukar, the trend of the transfer factor was in rank of Ni > Cd > Cu > Zn, whereas, in Custom Farm the transfer factor was sort as Cu > Ni > Cd. The highest Transfer Factor (TF) value was 1.464 found in Ceratotheca sesamoides for Ni in Bin Bukar Farm and 0.627 in Urena lobata for Cu in Custom Farm. The Transfer Factor values for Cd, Cu and Zn for the range of vegetables were not substantially high, except for Ni which the ratio was greater than one indicating that the plants have accumulated elements.

Keywords: Heavy metals, Transfer Factor, AAS, Bin Bukar Farm, Custom Farm

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INTRODUCTION

Heavy metals are considered as one of the major environmental issues currently. This causes serious health threat to the pollution in the environment. Metal with a density greater than 5g/cm^3 are consider as heavy and may have some harmful effects to human cells (WHO, 2000; Alqosouimi, 2006). At present, pollution resulting from heavy metal is one of the scariest environmental problem globally. These metals mostly pile up in the leafy part of the vegetables which is mostly consumed, this is different with the case of grains and fruits (Mapanda*et al.,* 2005). Vegetables are important to human diet as they supplement so many minerals and vitamins like retinol, ascorbic acid, cholecalciferol, thiamine, niacin, biotin, and riboflavin. However, most of our vegetables grown in urban areas are irrigated with contaminated water bodies either from sewage or industrial effluents. The contaminated water may contain toxic chemicals that are lethal to man. So, the safety of these vegetables is not guarantee as the quality of these foodstuffs has to be ascertain (Khan *et al.,* 2009; Radwan and Salama, 2006; Wang *et al.,* 2005).

Rapid industrialization as well as some modern agricultural practices which include the use of inorganic fertilisers, herbicides, rodenticides, pesticides contribute to soil, water and air pollution. Indiscriminate dump of refuse also contaminates soil and water in our environment (Zheng*et al.,*2010; Zhuang*et al.,* 2009). The major route in which man is exposed to heavy metals is through the biological ecosystem in which heavy metals form part of the niche (Ahmad and Goni, 2010; Calderon *et al.,* 2003).

Urbanization and other human activities cause the environmental pollution by the accumulation of harmful chemicals from industrial effluents in the soil. Heavy metals mostly found everywhere in nature and form parts of these chemicals that causes serious damage to human (Nies, 1999). Most plants response to light, water and gravity. Water dissolves most of the mineral elements needed by plants including the heavy metals which are absorbed via the roots and transported to the other parts of the plant. The uptake of these metals alters the general mineral composition of the plant (Olajire and Ayodele, 2003). The concentration of heavy metals in plants depend on factors like bioavailability and amount of heavy metal present in the soil, acidity or alkalinity of the soil, amount of organic matter and self-standing performance (Nwoko and Mgbeahuruike, 2011). Generally, only a small amount of heavy metals is transported to the shoot part of the plant as compare to the amount initially in the soil, because root opposes this transport (Sunitha *et al.,* 2013). However, plants with high transfer factor can absorb a significant amount of the metal. Such plants are good for phytoremediation and can be used for purification. Heavy metals can easily get into our bodies because they are water soluble and we use water for many of our activities. Most of the industrial products contain these metals which are non-biodegradable in human system and are dangerous even at low concentrations because there is no appropriate process of removing them from body (Olowu *et al.,* 2012; Olowu *et al.,* 2010).

So many researches have been conducted in the study area to determine the levels of heavy from roadside dust (Verma, 2015), sachet water (Waziri & Bomoi, 2012), soil (Usman & Bashir, 2020), commercial eggs (Galadima *et al*., 2018), fish gills and water (Katuzu *et al*., 2020). However, exhaustive search show that there are few research on vegetable around the study area. This research intent to determine the levels of heavy metal concentrations (Nickel, Copper, Cadmium and Zinc) in soil and leaves of four vegetables namely; *Amaranthus hybridus* (spinach), *Hibiscus sabdariffa* (roselle), *Urena lobata* (caesar weed) and *Ceratotheca sesamoides* (false sesame) grown in Bin Bukar Farm along Gujba Road and Custom Farm along Potiskum Road. The results obtained will be compared with the standard permissible limit set by

WHO/FOA. Moreover, the transfer factor of heavy metals from soil to the plants was also evaluated.

Materials and Methods

The Study Area

The study was carried out at Damaturu in Bin Bukar Farm and Custom Farm on December, 2014. Damaturu is the capital city of Yobe State of Nigeria, which is located on coordinates of 11°44' 55" N, 11°57' 50"E in the north-eastern part of Nigeria, with an area of 2,366 km².The textural class of the soil was Clay loam. The vegetation of this area falls within the sudan savannah.

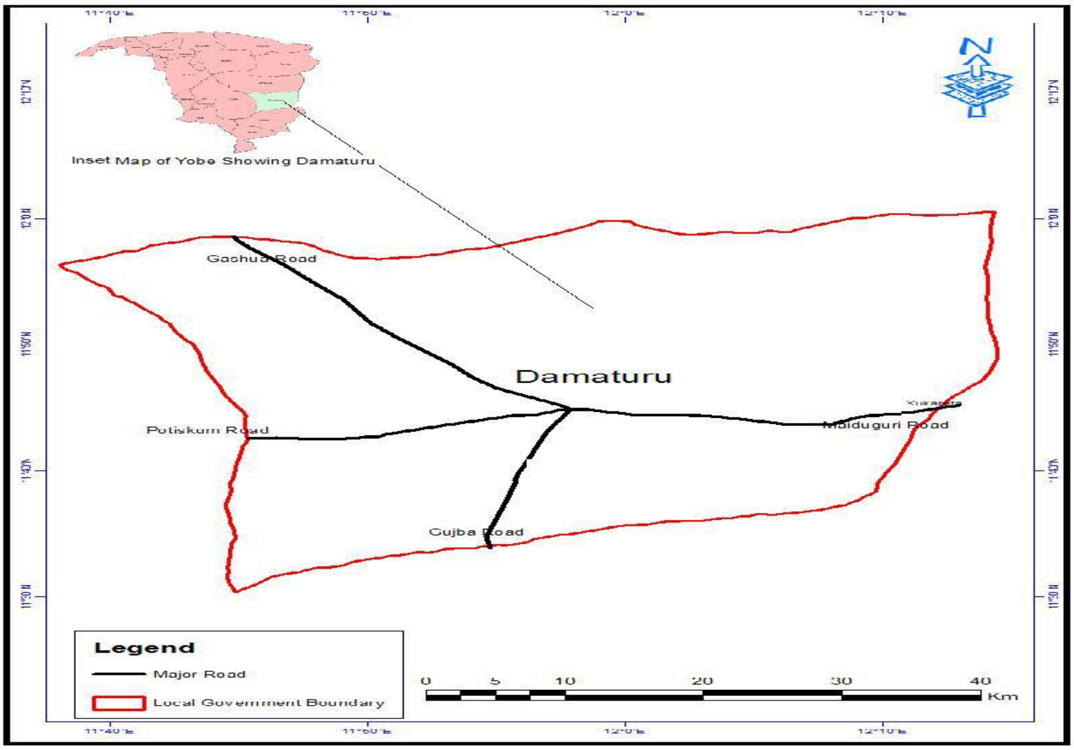

Fig.1: Map the study area (Adapted from Galadima, 2018)

Reagents and Standards

Chemicals used were of analytical grade; nitric acid (HNO_3) was from M&B while perchloric acid ($HClO_4$) was from BDH. Known concentrations of the metals were used as control.

Sampling and Sample Preparation

Four different vegetable samples and one soil were collected randomly from the two farms, making the total of ten samples. The vegetables were irrigated with borehole water. The edible vegetables *Amaranthus hybridus* (spinach), *Hibiscus sabdariffa* (roselle), *Urena lobata* (caesar weed) and *Ceratotheca sesamoides* (false sesame) were collected in polythene bags. So also, the two samples of the soil from each of the two farms. Vegetable samples were selected on the ground that they are the most commonly used by the local communities.

The distilled water was used to wash the edible parts of the vegetables thoroughly (samples) and were cut into tiny pieces. The samples were then air dried under shade and kept at 100 ± 1°C in an oven in order to obtain constant weight. The vegetables were then ground into fine powdered form using pestle, mortar and siever. The soil samples were made into fine powdered form using room temperature as well.

Table 1: Vegetables used

S/N	Hausa Name	Code	Common Name	Scientific Name	Part of Vegetable used
01	Alayyafu	AL	Spinach	*Amaranthus hybridus*	Leaf
02	Yakuwa	YK	Roselle	*Hibiscus sabdariffa*	Leaf
03	Rama	RM	caesar weed	*Urena lobata*	Leaf
04	Karkashi	KK	false sesame	*Ceratotheca sesamoides*	Leaf

Samples Digestion and Analyses

Nitric-perchloric acid digestion was adopted (A.O.A.C 1990). One gram of grounded sample was transferred into 250mL digestion tube and 10mL of HNO_3 was added. The mixture was boiled gently for 30 – 45minutes.5ml of 70% $HClO_4$ was added after cooling, and boiled gently again until dense white fumes appeared. 20mL of distilled water was added after cooling, and the mixture was boiled further to release any fumes. The solution was then filtered after cooling using Whatman No. 42 filter paper and <0.45 um Millipore filter paper and quantitatively taken to a 25mL volumetric flask by adding distilled water.

The levels of Ni, Cu, Cd and Zn in the digested samples were determined using atomic absorption spectrophotometer (AAS Hitachi Z 1800, Japan).

Determination of Transfer Factor (TF)

The ratio of heavy metal in vegetables to that of the soil gives the transfer coefficient which determine the extent to which metal is transfer from the root to other parts of the plant.

$$\textbf{Transfer Factor (TF)} = C_{vegetable} / C_{soil}$$

Where, $C_{vegetable}$ = concentration of metal in plant sample(mg/kg) fresh weight and C_{soil} = concentration of metal in soil sample(mg/kg) dry weight (Ghosh *et al.,* 2012).

The levels of metals in both samples were calculated at dry weight condition. There are three conditions with respect to the TF value. If the value is greater than one, which signifies that the plant has aggregated elements. Value equal to one shows that the plant is not control by the elements. TF value less than one indicate that the plants didn't allow the intake of some elements into the plant tissues (Olowoyo*et al.,* 2010). Plants with significant TF ratio can be used for phytoremediation to absorbed toxic elements in the environment.

Data analysis

Data obtained from AAS analysis were presented as mean ± standard deviation (SD). Deviations within the sampling areas were analysed by one-way analysis of variance (ANOVA), taking $p<0.05$. All statistical calculations were accomplished with Statistical Package for Social Sciences (SPSS) V.15 for windows.

Results and Discussion

Table 2: Mean concentration of heavy metals in vegetable and soil samples collected from Bin Bukar Farm

	Concentration (mg/Kg)			
Sample	Ni	Cu	Cd	Zn
Soil	0.293±0.001	10.750±1.707	0.038±0.001	9.910±1.490
Amaranthus hybridus	0.249±0.001	1.650±0.670	0.030±0.001	3.649±0.001
Hibiscus sabdariffa	0.251±0.001	2.100±0.900	0.028±0.001	2.055±0.001
Urena lobata	0.178±0.001	3.470±0.880	0.027±0.001	1.881±0.001
Ceratotheca sesamoides	0.429±0.001	4.370±0.890	0.026±0.001	1.659±0.001

Table 3: Mean concentration of heavy metals in vegetable and soil and samples collected from Custom Farm

	Concentration (mg/Kg)			
Sample	Ni	Cu	Cd	Zn
Soil	0.340±0.003	4.370±0.890	0.103±0.005	ND
Amaranthus hybridus	0.170±0.001	1.330±0.490	0.027±0.001	1.881±0.001
Hibiscus sabdariffa	0.146±0.001	1.650±0.670	0.016±0.001	2.055±0.001
Urena lobata	0.085±0.001	2.740±1.270	0.015±0.001	1.179±0.001
Ceratotheca sesamoides	ND	1.420±0.730	0.016±0.001	3.649±0.001

ND = Not Detected

Table 4. Transfer factor (TF) for heavy metals in vegetable samples from Bin Bukar Farm

	Metal			
Sample	Ni	Cu	Cd	Zn
Amaranthus hybridus	0.849	0.153	0.789	0.338
Hibiscus sabdariffa	0.857	0.195	0.737	0.207
Urena lobata	0.608	0.323	0.711	0.199
Ceratotheca sesamoides	1.464	0.407	0.684	0.167

Table 5: Transfer factor (TF) for heavy metals in vegetable samples from Custom Farm

	Metal			
Sample	Ni	Cu	Cd	Zn
Amaranthus hybridus	0.500	0.304	0.262	-
Hibiscus sabdariffa	0.429	0.378	0.155	-
Urena lobata	0.250	0.627	0.146	-
Ceratotheca sesamoides	ND	0.325	0.155	-

Concentration of heavy metals in vegetables and the soils

Table 2 and 3 present results of different concentrations obtained from AAS analysis of soil and vegetable samples from Bin Bukar Farm and Custom Farm. The samples were analysed for Ni, Cu, Cd and Zn. Cu was found to have the highest concentration of 10.75 ± 1.707 mg/Kg and Cd the least (0.038±0.001 mg/Kg) in soil. While in the samples of the vegetables Cu is still the highest with concentration of 4.37±0.89 mg/Kg in *Ceratotheca sesamoides* and Cd still the least with 0.026±0.001 mg/Kg for same *Ceratotheca sesamoides.* From table 3 also the concentrations of the aforementioned metals in soil and the vegetable samples collected from Custom Farm were also obtained and Cu was found to be the highest concentration (4.37±0.89 mg/Kg) and Cd the least (0.103±0.005 mg/Kg) for the soil sample. While, in the vegetable samples Zn was the overall with the concentration of 3.649±0.001 mg/Kg in *Ceratotheca sesamoides* and Cd the least with 0.015±0.001 mg/Kg for *Urena lobata.*

The above results showed a significance variation in the level of heavy metals content among the vegetables analysed in two different farms. The difference in the level of heavy metals content can be attributed to differences in the plants physical structure and the ability to transport the metals, shutting out, pile up or withholding (Singh *et al*., 2010).

In this study, the concentrations of Ni, Cu, Cd and Zn in the soils of both the Bin Bukar and Custom Farm and almost all the samples collected from those farms were in line with the minimum allowable limits set by WHO/FAO. The exception was nickel which was slightly higher than the threshold (0.1 mg/Kg) WHO/FAO in the samples of both the farms excluding *Urena lobata* of Custom Farm.

In Bin Bukar Farm, the level of nickel range between 0.178 – 0.429 mg/Kg and the concentration of Ni accumulation in vegetables is the order of *Ceratotheca sesamoides*>*Hibiscus sabdariffa* > *Amaranthus hybridus* >*Urena lobata*. While in Custom Farm the range of Ni was

0.085 – 0.170 mg/Kg and the order of the accumulation has the trend *Amaranthus hybridus* >*Hibiscus sabdariffa*>*Urena lobata* and Ni was below detection limit in *Ceratotheca sesamoides*. Nickel is a poisonous heavy metal which can lead to generation of free radical species in the cells and tissues of animals. These free radicals are very reactive as they possess free electron which can cause mutation in the cells, changes in DNA bases, influence lipid peroxidation and changes in calcium and sulphhydryl regulation (Das *et al*., 2008).

Though, almost all the heavy metals concentrations in the soils and the vegetable samples were below the WHO/FAO tolerable limit except for Ni. It is worth noting that Cd and Ni are extremely toxic unlike Cu and Zn which are needed in small amount for normal body balance (Iatrou*et al.,* 2015) and other homeostasis adjustment needed for certain metabolic process in plants and animals' system (Veronique and Schuyler, 1994). Cervantes *et al.,* (2001) reported that Cu play a major role in the physiology of red blood cells and respiration, good nerves, good response to taste and bone development. Whereas Zn is required to strengthen the defence mechanism of the body (Rai *et al.,* 2004).

The concentrations of Nickel were in line with that of Opaluwa, *et al.,* (2012) with 0.42 mg/Kg in soil and 0.04 mg/Kg in Okro cultivated around dump sites in Lafia, Nasarawa State, Nigeria. The result revealed no significant difference in Nickel (Ni) content at $p<0.05$ for the vegetables.

Transfer factor (TF) from soil to vegetables

The transfer coefficient determined the changes in bioconcentration between metals in the soil and in the plants tissues. The bioavailability of the metals depends on the different individual properties of the plant and the soil. Large transfer coefficient value represents higher affinity of the plant to uptake the metals into its tissues. Low coefficient demonstrates good absorption of metals to the soil matrix (Coutate, 1992).

Transfer factor of metal is one of the determining factors which allows heavy metals into the food chain and endanger humans to many carcinogenic and non-carcinogenic health risks due to long term exposure. Parameters like transfer factor (TF), estimate daily intake (EDI), target hazard quotient (THQ) and target cancer risk (TCR) can be used to estimate the health risk assessment (Cui *et al*., 2004; Mahmood and Malik, 2014).

The ranges of the transfer factors were Ni 0.608 – 1.464, Cu 0.153 – 0.407, Cd 0.684 – 0.789 and Zn 0.167 – 0.338 in Bin Bukar Farm with trend of the transfer factors in order of Ni > Cd > Cu > Zn. Whereas the ranges of the transfer factors in Custom Farm were Ni 0.250 – 0.500, Cu 0.304 – 0.627 and Cd 0.146 – 0.262 with the trend of the transfer factors in order of Cu > Ni > Cd. The highest TF value was 1.464 found in *Ceratotheca sesamoides* for Ni in Bin Bukar Farm and 0.627 in *Urena lobata* for Cu in Custom Farm. The TF levels for Cd, Cu and Zn for most vegetables were highly insignificant, except for Ni which the ratio was greater than one indicating that the plants have accumulated elements. Abdul *et al.,* 2018 reported as high as (21.73) TF value for Ni in pumpkin and Nataša *et al.,* 2015 reported almost similar result for Cu (>0.5) in cabbage. These may be due to metals translocation from soil to plants which is determine by the general properties of the plants type and soil and can be change by environmental or human influence (Alloway and Ayres, 1997).

Table 6: Range of heavy metal in the study and that of WHO/FAO standards

Metal	Range of estimated heavy metals of the study in (mg/Kg)	WHO Limits (mg/Kg) For Vegetables	WHO Limits (mg/Kg) For Soils
Soil	0.038 – 10.750		
Nickel	0.085 – 0.429	0.1	≤50
Copper	1.330 – 10.750	73	100
Cadmium	0.015 – 0.103	0.2	3.0
Zinc	1.179 – 9.910	99	300

Conclusion

In this study, the outcome of the analyses when compared with WHO/FAO values showed that the mean concentrations of Ni, Cu, Cd and Zn in the soils of both the Bin Bukar and Custom Farm were below the minimum allowable limit as recommended by World Health Organization/Food and Agricultural Organization (WHO/FAO) and therefore, they had acceptable conditions for human consumption. This is not unconnected with the fact that both the farms depend on boreholes and annual rainfall which is virtually clean, as the sources of water. The exception was Nickel which was slightly higher than (0.1 mg/Kg) WHO/FAO permissible limit in the samples of both the farms excluding *Urena lobata* of Custom Farm. However, routine investigation for the contamination of vegetables and some foods by heavy metals is indispensable in order to protect and curtail them from entering the food cycle. It has been therefore, recommended in this study that all vegetables must be hygienically washed using water before eaten in order to stay safe. The transfer factors for Cd, Cu and Zn for most of the vegetables were insignificantly high, except for Ni which the ratio was greater than one indicating that the plants have accumulated elements.

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