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BIOACCUMULATION OF HEAVY METALS IN SOME SELECTED VEGETABLES HARVESTED FROM THE SAUKA VILLAGE OF ABUJA NIGERIA

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Abstract

Food contamination by heavy metals has become a great challenge for agricultural producers and consumers. The main sources of heavy metals in vegetable crops are their growth media such as soil, air, and nutrient solutions from which the roots or foliage take up these heavy metals. The current study was aimed at determining the concentrations of heavy metals such as lead, chromium, cadmium, copper, and zinc in the soil and some selected vegetables like Ugwu, Waterleaf, Bitter leaf, Spinach, and Scent leaf gotten from Sauka Area, Abuja, Nigeria. The vegetable samples were air-dried and prepared into a powdered form, soil samples were also air-dried and prepared in powdered form, and heavy metals were estimated using an Atomic Absorption Spectrometer. The current study revealed that the concentrations of heavy metals such as copper, zinc, and lead, in all the vegetables harvested from the Sauka area of Abuja, Nigeria, were above the WHO permissible limits, except the concentration of copper in spinach sample, which was below the WHO permissible limit. Chromium and cadmium concentrations were below the WHO permissible limits in the vegetable samples except for cadmium concentration for waterleaf, which was above the permissible limit. Increases in the concentration of heavy metals assayed from the leaf samples were recorded, 13 out of 25 (52 %) leaf samples showed increases in the concentration of heavy metals in the leaf sample compared to their corresponding soil samples, with the least increase of 15.94 % lead concentration in Bitter leaf to 4,455.03 % increase in the zinc content of the waterleaf sample. In conclusion, the percentage increase in the concentrations of heavy metals in some of the harvested plants' leaves compared to the actual concentrations in the soil suggests evidence of bioaccumulation.

***Keywords**: Bioaccumulation, heavy metals, Sauka village, vegetables*

INTRODUCTION

Vegetables are among the important sources of protective foods (Sheela *et al*., 2004). Green leafy vegetables are succulent plant parts grown in gardens and consumed as a side dish or soup with starchy staples among the tribes in Nigeria (Sheela *et al*., 2004). The importance of dietary components of leafy vegetables is significant in the African population since they are generally comparatively fiber-rich. In contrast, cereals, root vegetables, and other foodstuffs are relatively poor sources (Fasuyi, 2006). Several vegetable species abound in Nigeria, utilized as condiments or spices in human diets or as supplementary feeds to livestock such as rabbits, poultry, swine, and cattle (Taiwo, 2007). Literature reported vegetables as good sources of vitamins, carotene, protein, iron, calcium, ascorbic acid, and a tangible concentration of trace minerals (Oladepo *et al*., 2018). The potassium content of leafy vegetables is good in controlling diuretic and hypertensive complications (George, 2003). Vegetable fats and oils are known to lower blood lipids, thereby reducing diseases associated with coronary artery damage (Adenipekun and Oyetunji, 2010). Leafy vegetables are highly beneficial for the maintenance of health and the prevention of diseases. They serve as a valuable source of food ingredients that can be utilized to build up and improve the body successfully (Hanif *et al*., 2006) For years, there has been increasing demand for fresh vegetables mainly because of their convenience as ready-to-eat products as well as the health benefits associated with their consumption (Ajayi *et al*., 2018). In Nigeria, and in most other tropical countries of Africa, where the daily diet is dominated by starchy staple foods, vegetables are the cheapest and most readily available source of important proteins, vitamins, minerals, and essential amino acids (Akubugwo et al., 2007). Leafy vegetables are

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important items of the diet in many Nigerian homes, apart from the variety which they add to the menu (Mephba et al., 2007), they are valuable sources of nutrients, especially in rural areas where they contribute substantially to protein, minerals, vitamins, and fibers. Nutrients are usually in short supply in daily diets (Mohammed and Sharif, 2011). Biochemical processes circulate metals. Some metals are essential and their deficiency results in the impairment of biological functions. When present in excess, essential metals may become toxic. Other metals not known to have crucial functions may give rise to poisonous manifestations when intakes are in excess (Friberg and Norberg, 1986).

Heavy metals are generally referred to as those metals that possess a specific density of more than 5 g/cm3 and adversely affect the environment and living organisms (Järup, 2003). They, without doubt, are important constituents for plants and humans, when present only in a small amount. Some micronutrient elements may also be toxic to animals and plants at high concentrations. For instance, copper (Cu), chromium (Cr), fluorine (F), molybdenum (Mo), nickel (Ni), selenium (Se), or zinc (Zn). Other trace elements such as arsenic (As), cadmium (Cd), mercury (Hg), and lead (Pb) are toxic even at small concentrations (Divrikli *et al*., 2006). Being persistent and non-biodegradable heavy metals can neither be removed by normal cropping nor easily leached by rainwater (Khadeeja *et al*., 2013). They might be transported from soil to ground waters or taken up by plants, including crops. For this reason, the knowledge of metal-plant interactions is also important for the environment's safety (Divrikli *et al.*, 2006). Increasing interest has been in determining heavy metal levels in public food supplies. However, their concentration in bio-available form is not necessarily proportional to the total concentration of the metal (Opaluwa *et al*., 2012; Nwachukwu *et al*., 2010). The quality of the ecosystem becomes altered, when heavy metals find their way, somehow, into it through human and natural activities. These activities are one of the most pressing concerns of urbanization in developing countries like Nigeria, which result in the problem of solid, liquid, and toxic waste management. Such waste may be poisonous or radioactive (Onibokun and Kumuyi, 1996; UNDP, 2006). Such waste management problems include heaps of uncontrolled garbage, roadsides littered with refuse, streams blocked with rubbish, the prevalence of automobile workshops and service stations, inappropriately disposed of toxic waste and disposal sites that constitute a health hazard to residential areas (Adewole and Uchegbu, 2005; Rotich *et al.*, 2006; Ebong *et a*l., 2008). The occurrence of uncontrolled urban sewage farming is a common site in African cities which exposes consumers of such products to poisoning from heavy metals (Ebong *et al*., 2008). Open dumps are a source of various environmental and health hazards. The decomposition of organic materials produces methane, which may cause explosions and produce leachates, which pollute surface and groundwater. It ruins the aesthetic quality of the land (Oyelola *et al*., 2009). Automobile wastes include solvents, paints, hydraulic fluids, lubricants, and stripped oil sludge; all results of activities such as battery charging, welding, and soldering, automobile body works engine servicing, and combustion processes (Adewole and Uchegbu, 2005; Utang *et al*., D2013). Soil is the most important component of the environment, but it is the most undervalued, misused, and abused of the earth's resources (Gokulakrishnan and Balamurugan, 2010). Soil contamination has become a serious problem in all industrialized areas of the country. Soil is equally regarded as the ultimate sink for the pollutants discharged into the environment (Shokoohi *et al*., 2009). Most plants and animals depend on the soil as a growth substrate for their sustained growth and development. In many instances, the sustenance of life in the soil matrix is adversely affected by the presence of deleterious substances or contaminants. The entry of the organic and inorganic forms of contaminants results from the disposal of industrial effluents (Gowd *et al*., 2010). The source of the organic and inorganic elements of the soil of the contaminated area was mainly the unmindful release of untreated effluent on the ground (Shetty and Rajkumar, 2009). The contamination of soils with heavy metals or micronutrients in phytotoxic concentrations generates adverse effects on plants and poses risks to human health (Murugesan *et al*., 2008). Afterwards, the consuming contaminated vegetables constitutes an important route of heavy metal exposure to animals and humans (Sajjad *et al*., 2009; Tsafe *et al*., 2012). Abandoned waste dumpsites have been used extensively as fertile grounds for cultivating vegetables, though research has indicated that the vegetables are capable of accumulating high levels of heavy metals from contaminated and polluted soils (Cobb *et al*., 2000; Benson and Ebong, 2005).

The aim of this research work was to ascertain the level of heavy metal contaminations in the soils and vegetables of some selected vegetable plantations in Sauka Village, Gui-Sauka District, Abuja Municipal Area Council (AMAC), FCT-Abuja, Nigeria.

Materials and Methods

Vegetable Samples

A simple Random sampling technique was employed to collect the vegetable samples of fluted pumpkin leaves (*Telfairia occidentalis*), African spinach, "Green" (*Amaranthus hybridus*), waterleaf (*Talinum triangulare*), Bitter leaves (*Vernonia amygdalina*) and Scent leaf, "Africa basil" (*Ocimum gratissimum*). The plants were identified by a Botanist at University of Abuja, Nigeria. The leaves of the vegetable samples were separated from the whole plants with the aid of a stainless-steel knife and labelled.

Soil Samples

Samples of soils were taken at a uniform depth of 15 cm around the vegetable roots with the aid of a hand trowel that had been pre-cleaned with concentrated nitric acid to prevent heavy metal contamination before analysis.

Preparation of Vegetable Samples

The vegetable samples were air dried and then pounded to obtain a fine sample, followed by sieving through a 0.5 mm mesh size sieve to obtain a uniform particle size. Each vegetable sample was labelled and stored in a dry plastic container that had been precleaned with concentrated nitric

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acid to prevent heavy metal contamination before analysis with atomic absorption spectrophotometry.

Preparation of Soil Samples

The soil samples were air dried for 48 hours, ground, and sieved using a 0.5 mm mesh size sieve to have uniform particle size. Each sample was labelled and stored in a dry plastic container that had been pre-cleaned with concentrated nitric acid before analysis with atomic absorption spectrophotometry

Determination of heavy metals

The experimental studies of both soil and vegetable samples were carried out at the Shedda Science and Technology Complex in Kwali Area Council, F.C.T, Abuja, Nigeria. The concentrations of heavy metals in the soil and vegetable samples were determined using atomic absorption spectrophotometry (AAS). Two grams of powdered sample from both soil and vegetables was digested into 20 ml of concentrated Nitric acid until a clear solution was obtained. The digest was cooled and it was then filtered into a 100 ml standard flask, deionized water was added to make it up to mark and the heavy metals were analysed using Atomic Absorption spectrophotometer Ice 3000AA02134104vl.30.

Data Analysis

The data obtained was analysed using Excel 2013 version, and the results obtained are presented as the mean concentration of heavy metals. The percentage of the heavy metal concentration in the vegetables relative to the concentrations of heavy metals in the soil was calculated, correlation between the soil heavy metal concentrations and that of the vegetables was analysed with the aid of a Pearson correlation.

RESULT

The concentrations (mg/kg) of copper (Cu), cadmium (Cd), Zinc (Zn), Lead (Pb), and Chromium (Cr) of both vegetables and soil (Bitter leaf, Scent leaf, Ugwu, Spinach, Water leaf) are depicted in Tables 1 and 2 respectively. The percentage concentrations of heavy metals in the vegetables relative to the concentrations of heavy metals in the soil are presented in Table 3. Positive correlations were revealed between the heavy metal concentrations in the vegetable and soil samples, this was established using a Pearson correlation, the result is presented in Table 4.

Table 1: Concentrations of the heavy metals in the vegetables

S/NO	Heavy metals (mg/kg)	Bitter leaf (mg/kg)	Scent leaf (mg/kg)	Ugwu leaf (mg/kg)	Spinach (mg/kg)	Waterleaf (mg/kg)	*WHO permissive limits (mg/kg)
1	Copper	16.88	31.44	22.91	0.37	31.21	10.0
2	Cadmium	-0.93	-0.30	-2.16	-1.32	0.25	0.02
3	Zinc	25.64	29.41	25.09	23.91	144.85	0.60
4	Lead	15.78	6.78	18.92	24.47	4.40	2.00
5	Chromium	-53.31	-46.06	-40.79	-50.39	-53.76	1.30

*Source: WHO (1998)

Table 2: Concentrations of the heavy metals in the soil samples

S/NO	Heavy metals (mg/kg)	Bitter leaf (mg/kg)	Scent leaf (mg/kg)	Ugwu leaf (mg/kg)	Spinach (mg/kg)	Waterleaf (mg/kg)	a*WHO permissive limits (mg/kg)
1	Copper	8.71	5.743	8.65	9.4	5.68	36.0
2	Cadmium	0.18	-0.05	-0.22	-0.41	-0.05	0.80
3	Zinc	26.55	58.14	12.50	10.83	3.18	50.0
4	Lead	13.61	14.08	14.69	12.67	9.39	85.0
5	Chromium	-16.03	-9.23	-4.88	-9.21	-1.66	100.0

[a] Target values are specified to indicate desirable maximum levels of elements in unpolluted soils (Denneman and Robberse 1990)
*Source: WHO (1998)

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Table 3: Percentage concentrations of heavy metals in the vegetables compared to the concentration of heavy metals in the soil
Key:

S/NO	Heavy metals (mg/kg)	Bitter leaf (mg/kg)	Scent leaf (mg/kg)	Ugwu leaf (mg/kg)	Spinach (mg/kg)	Waterleaf (mg/kg)
1	Copper	100.00↑ %	447.45↑ %	164.86↑ %	96.066↓ %	449.47↑ %
2	Cadmium	616.67↓ %	500.00↑ %	881.82↑ %	221.95↓ %	600.00↑ %
3	Zinc	-3.43↓ %	49.42↓ %	100.72↑ %	120.78↑ %	4,555.03↑ %
4	Lead	15.94↑ %	51.85↓ %	28.80↑ %	193.13↑ %	53.14↓ %
5	Chromium	232.56↓ %	399.02↓ %	735. 86↓ %	447.12↓ %	3, 138.55↓ %

↑ Denotes an increase in the concentration of heavy metal in the leaf compared to the soil
↓ Denotes a decrease in the concentration of heavy metal in the leaf compared to the soil

Table 4: Correlation between heavy metals content of vegetable and soil samples

S/N	Vegetable Samples	Soil sampled around the vegetables	Correlation coefficient	Remarks
1	Bitter leaf-heavy metal content	Bitter leaf soil with heavy metal content	0.929181	A very highly positive correlation
2	Scent leaf-heavy metal content	Scent leaf soil with heavy metal content	0.644115	Moderate positive correlation
3	Ugwu leaf-heavy metal content	Ugwu leaf soil with heavy metal content	0.90584	Moderate positive correlation
4	Spinach leaf-heavy metal content	Spinach leaf soil with heavy metal content	0.931904	A very highly positive correlation
5	Waterleaf-heavy metal content	Waterleaf soil with heavy metal content	0.267213	Low positive correlation

DISCUSSION

Food contamination by heavy metals has become a great challenge for agricultural producers and consumers. The main sources of heavy metals in vegetable crops are their growth media such as soil, air, and nutrient solutions from which these heavy metals are taken up by the roots or foliage (Lokeshwari and Chandrappa, 2006).

The current study revealed that the concentrations of heavy metals such as copper, zinc, and lead, in all the vegetables harvested from the Sauka area of Abuja, Nigeria, were above the WHO permissible limits, except the concentration of copper in spinach sample, which was below the WHO permissible limit. Chromium and cadmium concentrations were below the WHO permissible limits in the vegetable samples except for cadmium concentration for waterleaf, which was above the permissible limit. Increases in the concentration of heavy metals assayed from the leaf samples were recorded, 13 out of 25 (52 %) leaf samples showed increases in the concentration of heavy metals in the leaf sample compared to their corresponding soil samples, with the least increase of 15.94 % lead concentration in Bitter leaf to 4,455.03 % increase in the zinc content of the waterleaf sample. It should be noted that where non-significant increases were recorded in leaf samples, the soil sample heavy metal concentrations were either close to zero or below zero in negativity.

This finding aligns with earlier findings by Kadijat, (2022), who reported high levels of Zinc and Lead above the WHO permissible limits in the Vegetables and the high level of copper in bitter leaf and Ugwu leaf. However, the finding disagrees with that of Khadijat, (2022) who reported higher than permissible levels of cadmium and chromium concentrations. The percentage concentrations of heavy metals in the harvested plants' leaves compared to the actual concentrations in the soil suggests evidence of bioaccumulation. This finding agrees with an earlier report by Alia *et al*., (2015) that plants bioaccumulate heavy metals from the soil.

The contamination of vegetables and soil by heavy metals could also be attributed partly to the fact that vegetables are grown in polluted and degraded environmental conditions in peri-urban, or urban fringe zones and are subjected to further pollution from vehicles and industries during marketing. They

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are often irrigated with contaminated water and the addition of fertilizers and metals-based pesticides to boost production (Radwan and Salama, 2006). The pollution of soils by heavy metals from automobile sources is a serious environmental issue; these metals are released during different operations of road transport such as combustion, component wear, fluid leakage, and corrosion on metals. Lead, cadmium, copper, and zinc are the major metal pollutants of the roadside environments and are released from fuel burning, wear out of tires, leakage of oils, and corrosion of batteries and metallic parts such as radiators, etc., (Dolan *et al*., 2006). Most heavy metals are toxic to living organisms; even those considered essential can be toxic if present in excess. For instance, Lead is a well-known neurotoxin reported to have an impairment of neurodevelopment in children is the most critical effect. In many plants, lead accumulation can exceed several hundred times the threshold of maximum level permissible for humans (Wierzbieka, 1995). It has been suggested that lead on a cellular and molecular level may permit or enhance carcinogenic events involved in DNA damage, DNA repair, and regulation of tumour suppressor and promoter genes.

Various kinds of heavy metals are absorbed by plants when available in the soil or irrigation water (Fusconi, *et al*., 2006), thus, with an increase in heavy metal concentration within the roots, its corresponding concentration in the shoots also increases. Is important to note that metals like magnesium (Mg), manganese (Mn), iron (Fe) and copper (Cu) are classified as plant essential metals. They are required in a specific amount, and their elevated concentrations or deficiency will result in unwanted effects and reduce plant productivity (Wang et al., 2009). Whereas, Chemicals like Cd, Pb, Ti, and Hg have no known nutritional value in plants; however, when taken up even in trace quantities they could be detrimental to human health (Farombi *et al*., 2007)

Valko *et al*. (2005); reported that heavy metals interact with nuclear proteins; and DNA causing site-specific damage. Heavy metals also cause the production of reactive oxygen and nitrogen species comprising hydroxyl, and superoxide radicals, nitric oxide, hydrogen peroxide and other endogenous oxidants. He also reported them to activate signalling pathways (Valko *et al*., 2005).

Conclusion

The current investigation suggests that plants absorb and bioaccumulate heavy metals from the soil as revealed by our experimental findings.

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