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Assessment of the Health Risk of Some Heavy Metals in Cabbage Grown on Dumpsite at Hanwa in Zaria, Kaduna State, Nigeria

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Abstract

Pollution of soil with heavy metals can lead to high concentration of the metals in plants, consequently in animals and human body. Cadmium, Copper and Lead concentrations were determined in soil samples and cabbage (Brassica oleracea) grown on a dumpsite at Hanwa in Zaria, Nigeria. Both the soil and plant samples were digested using a mixture of Nitric acid and Perchloric acid (ratio 3:1). The metals concentrations in the samples were determined using Atomic Absorption Spectroscopy (AAS). Soil parameters like Particle Size, pH, Moisture Content, and Organic Matter were also evaluated using standard methods. The results indicated much higher concentrations of heavy metals in the soil than roots, stems and leaves of the analyzed cabbage sample. The Cd level in the plant samples ranged from 1.20 to 1.70mg/kg (site) and 0.80 to 1.00mg/kg (control). Concentration of Cu in the samples ranged from 15.50 to 35.90mg/kg (site) and 7.30 to 13.90mg/kg (control) and Pb: 19.40 to 42.70mg/kg (site) and 5.80 to 26.40mg/kg (control)were above the recommended limit by joint FAO/WHO. The Transfer Factor (TF) of the studied metals from soil to cabbage leaves were in the order of Cd (0.92) > Pb (0.58) > Cu (0.44).In this study, the Health Risk Index (HRI) for Pb (3.421) was found to be greater than 1, which indicates significant potential health risks. The high level of these heavy metals places the consumers of cabbages grown within the dumpsite area at health risk. Cultivation of vegetables on metal dumpsites should be discouraged as the soils are polluted with heavy metals.

Keywords: Cabbage, Dumpsite, Heavy metal, Health risk, Transfer factor

INTRODUCTION

The high concentration of heavy metals in the soil is reflected by higher concentration of metals in plants, consequently in animals and human body. The ability of some plants to absorb and accumulate xenobiotics makes them useful as indicators of environmental pollution (Buzewski *et al.*, 2002). The content of heavy metals in plant depends on the location of their growth and harvest, as well as on the capacity of the plants to accumulate various substances from soil, water and air (Anna *et al.*, 2011).

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Environmental pollution is the buildup of the concentration of toxic levels of chemicals on the air, water and land, which reduces the ability of the affected area to support life (Gathambo, 2002). Pollution generally is the introduction of harmful substances into the environment. As environmental pollutants, heavy metals toxicity causes major problem for ecological, evolutionary, nutritional and environmental balances. In soil, commonly found heavy metals include, cadmium, arsenic, chromium, lead, copper, zinc and nickel, all of these are causing risks to human health and the environmental balance by entering the surroundings via natural means and through the human activities (Showkat *et al.,* 2019).

Consumption vegetables regularly in diet can have many health benefits such as reducing many health-related diseases and enhancing the digestion of fats and carbohydrates. Unfortunately, harmful substances such as organic pollutants and heavy metals are found in these vegetables, and this may lead to harmful effects (Ambrose *et al*., 2022). Globally there is a significant increase in the demand and consumption of vegetable as it constitutes an important part of the human diet and nutrition. Cultivation of vegetables especially in urban areas are prone to anthropogenic contamination from various sources including: urban and industrial wastes, mining and smelting and metallurgical industries. As a result, food safety issues and potential health risk are becoming a major public concern worldwide and make it as one of the most serious environmental concerns (Hailu and Leta, 2020).The aim of this study is to determine heavy metal levels in cabbage and to evaluate the health risks that may arise in humans according to consumption scenarios.

MATERIALS AND METHODS

Sample Collection

Whole plant parts were collected at Hanwa dumpsite in Zaria, Nigeria. The plant samples were taken randomly. The morphological status of the plant based on colour of the leaves and stage of growth was taken into consideration (Ray, 1990). The samples were taxonomically authenticated and identified at the herbarium of the Department of Biological Sciences by U. S. Gallah as *Brassica oleraceae* with voucher no. 19012.

Soil samples were taken from the top to the depth of 15cm around each plant root zone into polythene bags using hand trowel. The soil samples collected were then mixed together and a composite sample was taken. Background soil and plant samples were obtained as control 5km away. Both plant and soil samples were collected separately in polythene bags, labeled and taken to the laboratory.

Sample Pretreatment

Soil samples were air-dried in a flat plastic tray for three days. Stones and pieces of macro-organism matter were hand-picked from the air-dried samples, and the samples ground in a mortar and sieved through 500µm laboratory test sieve. Sieved samples were dried in the oven at 65^oC for 16 hours and further kept in oven at the same temperature for 24 hours to obtain constant weight. Samples of dried plant were put in clean polythene bags and kept for analysis.

Digestion of Sample

Samples of sieved soil and plant (1g each) were weighed into separate digestion flasks. To each flask, 20cm^3 of the HNO_3-$HClO_4$ acid mixture (ratio 3:1 by volume) was added and the content was shaken and placed on the hot plate in fume cupboard. The temperature was set at 150^oC and the sample was digested for 1½hours. The temperature was gradually increased and the digestion continued until the solution became clear (the white fuming stage). The temperature was then reduced and 2cm^3 of conc. HCl was added and heated again. The flask was then removed from the hot plate and 60cm^3 of distilled water added within a few minutes. The content was filtered through a Whatman No. 41 filter paper into a 100cm^3 standard volumetric flask and then made up to the mark with distilled water (Zakka *et al*., 2014). The Cadmium, Copper and Lead concentrations were obtained by Atomic Absorption Spectroscopy method (AAS) (AAS-HP SN MY14470001 machine). The analysis was done in triplicate.

Soil Physicochemical Parameter Analysis
Soil parameters such as Particle Size, pH, Moisture Content, and Organic Matter were determined using standard method as described by Nura *et al*. (2021) and Nontobeko *et al*. (2021).

Particle size and soil texture: The soil was pulverized and filled in a 1000cm^3 measuring cylinder to about a one-quarter full of soil. Distilled water was added until the cylinder is three-quarter full. A teaspoon full of powdered, non-foaming dish washer detergent was added. After which the fitting lid was tightened, it was shaken for 10-15 minutes. The shaking breaks apart the soil aggregates and separates the soil individual mineral particles. The cylinder was then kept undisturbed for 2 to 3 days. The soil particles that settle after 1 minute according to its size and the depth marked as sand. After 2hours, the level of sediment was also marked on the cylinder depth as the silt. After the water became cleared (3 days), the level of clay was marked. The thicknesses of sand, silt and clay layers were added together as the total thickness.

Calculations:

$$\frac{\text{Thickness of sand}}{\text{Total Thickness}} \text{X } 100 = \% \text{ sand} \quad (1)$$

$$\frac{\text{Thickness of silt}}{\text{Total Thickness}} \text{X } 100 = \% \text{ silt} \quad (2)$$

$$\frac{\text{Thickness of clay}}{\text{Total Thickness}} \text{X } 100 = \% \text{ clay} \quad (3)$$

Determination of pH: Distilled water was added to the sieved soil sample in a ratio of 2.5:1, i.e. 25cm^3 of distilled water and 10g of soil sample. The suspension was shaken using mechanical shaker for thirty minutes and later stirred with glass stirrer. The pH was determined using a pH meter (Jenway pH meter–model 3505); by immersing the glass electrode into the partially settled suspension.

Determination of moisture content of soil: Two watch glasses were weighed and then 10g of soil samples each were weighed into different watch glasses. These were heated in an oven at 105^{o}C for 16hours, allowed to cool in a desecrator for 20minutes, and then weighed again. The samples were heated again until constant weight was obtained.

Calculation:

$$\% \text{ Moisture Content} = \frac{(X-Y)}{X} \text{X } 100 \quad (4)$$

where X = weight of air-dried soil
Y = weight of oven-dried soil

Determination of organic matter (Walkley-Black, Dichromate Oxidation Method): The 1 g soil sample has been treated with 5 mL of concentrated H_2SO_4 for 4 h, then with 5 mL of 0.5 M $K_2Cr_2O_7$. The mixture was heated at 150–160° C for 5 min and then allowed to cooled to room temperature. The solution was transferred into a conical flask with 100 mL deionized water. The excess $K_2Cr_2O_7$ was determined by titrating with 0.25 M $FeSO_4$. The change in colour of the solution from dark green to blue to reddish-brown colour signified the endpoint.

$$\text{Organic Carbon (\%)} = M \times \frac{(V1-V2)}{\text{Mass of Soil}} \times 0.39 \quad (5)$$

where M= concentration of $FeSO_4$,V1=Volume of blank,V2=Volume of $FeSO_4$, 0.39=constant

Transfer Factor (TF): The transfer factors of heavy metals from soil to vegetables, is one of the key components of human exposure to metals through the food chain. Transfer factor in this study was calculated based on the total metal content of the vegetable leaves(Eze *et al*., 2018).

$$TF = \frac{(\text{Concentration of metals in leaves})}{(\text{Concentration of metals in Soil})} \quad (6)$$

Risk Assessment of Heavy Metals in Vegetable Sample (Cabbage leaves)

Health Risk Index (HRI): The health risk index through the consumption of contaminated Cabbage from the sites was assessed based on the food chain and the reference oral dose (R_fD). Values of HRI depend upon the daily intake of metals (DIM) and oral reference dose (R_fD) which was estimated per day exposure of metals to the human body. The DIM in this study was calculated using the average adult vegetable intake rate of 0.345 kg / person / day. Average body weight (BW) of adult consumers 60 kg (Eze *et al*., 2018).

$$DIM= \frac{\text{Conc. of metal X food weight consumed}(0.345)}{BW(60kg)} \quad (7)$$

The health risk index for heavy metals was evaluated using the expression;

$$HRI = \frac{DIM}{RfD} \quad (8)$$

R_fD for Cd = 0.01, Cu = 2 and Pb = 0.04 (mg / kg bw / day). If the health risk index value is < 1, then the exposed population is considered to be safe but where HIR is equal or greater than 1, the exposed population is considered to be very unsafe.

RESULTS AND DISCUSSION

Physicochemical Parameters of Soil

The results for physicochemical parameters of the analyzed sample are shown in Table 1.
The particle sizes (%) are 31, 38 and 31 for sand, silt and clay respectively, for both soil sample and soil control sample. The soil texture was found to be Clay-Loam. The pH values of soil sample and control sample are 6.78 and 7.12 respectively, which implies that both soil samples tend toward neutrality. The percentage moisture content for the soil sample is 3.00% and 4.00% for the control sample. The percentage organic matter of soil sample and control sample are 3.38% and 4.02% respectively.

Metal Content in Soil and Plant

In Table 2, the results showed that concentration of Cd in soil of the sample site was found to be 1.30mg/kg and the control site was gotten as 0.08mg/kg. The concentration of Cd in cabbage root of the sample site was found to be 1.70mg/kg and the control site was gotten as 0.09mg/kg. The concentration of Cd in cabbage stem of the sample site was found to be 1.30mg/kg and the control site was gotten as 0.80mg/kg. The concentration of Cd in cabbage leaves of the sample site was found to be 1.20mg/kg and the control site was gotten as 1.00mg/kg. The Cu level in soil of the studied site was found to be 35.60mg/kg and the control site was gotten as 12.00mg/kg. The concentration of Cu in cabbage root of the sample site was found to be 30.30mg/kg and the control site was gotten as 7.3mg/kg. The concentration of Cu in cabbage stem of the sample site was found to be 35.90mg/kg and the control site was gotten as 13.90mg/kg. The concentration of Cu in cabbage leaves of the sample site was found to be 15.50mg/kg and the control site was gotten as 9.20mg/kg. The Pb concentration in soil of the studied site was found to be 41.00mg/kg and the control site was gotten as 26.40mg/kg. The concentration of Pb in cabbage root of the sample site was found to be 19.40mg/kg and the control site was gotten as 5.80mg/kg. The concentration of Pb in cabbage stem of the sample site was found to be 42.70mg/kg and the control site was gotten as 11.50mg/kg. The concentration of Pb in cabbage leaves of the sample site was found to be 23.80mg/kg and the control site was gotten as 14.90mg/kg.

The concentration of heavy metals in all the cabbage samples were higher than the joint limit FAO/WHO (2012) of 0.02mg/kg Cd, 0.10mg/kg Cu and 0.10mg/kg Pb as reported by Ekweozor *et al.* (2017). The high levels of these heavy metals in the vegetable grown within the study area are at high risk to the consumers with time unless an urgent step is taken by relevant agencies. The high levels of heavy metals in the vegetable samples from the study area most likely attributed to anthropogenic activities in the area including the use of chemical fertilizers and/or the release of untreated solid wastes (Bernard, 2021).

It was observed that the average concentrations of heavy metals in the soil of the dumpsite compared to the control are higher. Also, the heavy metals in the plants grown on the dumpsite are higher than those from the control site. The concentration of Pb is highest, which implies that the environment where the soil and plant is located is polluted with lead. Copper is also present in high concentration and Cadmium is minimal in the environment.

Transfer Factor of Heavy Metals from Soil to Cabbage leaves

The metal transfer factor depends on the soil pH, soil organic matter, metals availability and soil particle size (Uwah, 2009). The metal transfer factor from soil to plants is a key module of human exposure to heavy metals through food chain. Transfer factor of metals is important to investigate the human health risk index. TF values close to or above 1 are considered to be high. This may indicate contaminations from anthropogenic sources and also increased bioaccumulation of heavy metals in the vegetable. Table 3 shows the TF of Cd, Cu and Pb from soil to cabbage leaves and in the order of Cd (0.92) > Pb (0.58) > Cu (0.44). High TF implies low retention of metals in soil while lower TF implies that the metals binds more to the soil and becomes unavailable for plants (Eze *et al.,* 2018). The soil-plant bioaccumulation relationships vary from element to element and plant to plants (plant parts also). Metals in soil are absorbed by the plant roots and passed to stems and then leaves. The concentration of these metals present in the different parts of a plant may depend on the concentration present in the soil (Bernard, 2021).

Table 1: Physicochemical Parameters of Soil Samples

Parameters	Soil Sample			Soil Control Sample		
Soil Particle Size (%)	Sand 31	Silt 38	Clay 31	Sand 31	Silt 38	Clay 31
Soil Texture	Clay-Loam				Clay-Loam	
Soil pH	6.78			7.12		
% Moisture Content	3.00			4.00		
% Organic Matter	3.38			4.02		

Table 2: Concentration of Heavy Metals in Soil and Plant Samples

Element		Concentration (mg/kg)				FAO /WHO (mg/kg)
		Soil	Root	Stem	Leaf	
Cd	Site	1.30±0.03	1.70 ±0.02	1.30±0.02	1.20±0.01	0.02
	Control	0.80±0.02	0.90±0.04	0.80±0.03	1.00±0.02	
Cu	Site	35.60±0.03	30.30±0.03	35.90±0.01	15.50±0.02	0.10
	Control	12.00±0.03	7.30±0.02	13.90±0.02	9.20±0.04	
Pb	Site	41.00±0.03	19.40±0.02	42.70±0.01	23.8±0.05	0.10
	Control	26.40±0.04	5.80±0.01	11.50±0.02	14.90±0.01	

Risk Assessment of Heavy Metals in Cabbage leaves

If the health risk index (HRI) of metals are equal to or greater than 1, then population is considered to be unsafe and will experience potential health hazards through consumption of vegetables, and when is less than 1, then exposure to any significant potential health risks to the population will not be of any great concern from the intake of the vegetable. However, continuous accumulation of these metals over time may have a negative impact on the environment (Neclam *et al.,* 2014). In this study, the HRI for Pb (3.421) was found to be greater than 1 (Table 4), which indicates significant potential health risks. Lead is considered as potent carcinogenic and it affects major different parts of body because of its distribution in the body in the various tissues (Arif*et al*. 2015).Exposure to high lead levels can severely damage the brain, kidney and ultimately cause death (Abdullahi *et al*., 2022; Ahsan *et al*., 2018). The HRI for Cd (0.700) is reasonable high, though less than 1. Cadmium is considered to be "carcinogenic to humans" by the International Agency for Research on Cancer (IARC, 2010). Yashim *et al*. (2020) reported that ingestion of high levels of cadmium can lead to severe stomach irritation, vomiting and diarrhoea, while exposure to lower levels for a long time can lead to kidney damage, bone deformity, and the ability of bones to break easily.

Table 3: Transfer Factor (TF)

Metal	Soil (mg/kg)	Leaves (mg/kg)	TF
Cd	1.30	1.20	0.92
Cu	35.60	15.50	0.44
Pb	41.00	23.80	0.58

Table 4: Risk Assessment of Heavy Metals in Cabbage leaves

Metal	Conc.(mg/kg)	Av. Daily intake (kg)	Body wt kg	R_fD WHO (2011)	DIM	HRI
Cd	1.20	0.345	60	0.01	0.007	0.700
Cu	15.50	0.345	60	0.2	0.089	0.446
Pb	23.80	0.345	60	0.04	0.137	3.421

CONCLUSION

As stated in the result of analysis of soil and plant from Hanwa Area of Zaria, it has clearly shown that both the analyzed heavy metal contents and some values of physicochemical parameters are higher than that of the control samples.

The soils of the dumpsite in Hanwa appear to be enriched with some heavy metals which are potentially toxic elements. TF of Cd, Cu and Pb from soil to cabbage leaves were in the order of Cd (0.92) > Pb (0.58) > Cu (0.44). High TF implies low retention of metals in soil while lower TF implies that the metals bind more to the soil and become unavailable for plants This is as a result of high level of contamination from metal scraps and other materials disposed on the site, which allows deposit of such metals. The high levels of the metal in the plants grown on the dumpsite soil poses a significant chronic health problem to human. This showed that HRI for Pb (3.421) was found to be greater than 1, followed by that of Cd (0.700) and Cu (0.446), which indicates significant potential health risks. Consumption of cabbages grown within dumpsite area can be of health risk due to the high levels of heavy metals. Cultivation of vegetables on dumpsites, especially metal dumpsites should be discouraged as the soils of metal dumpsites are polluted with heavy metals.

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