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Assessment of Heavy Metal Residues in Soil and Leaves of Vegetables Along Urban and Peri-Urban Gradient of Lagos State Nigeria

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Abstract

Several studies have been carried out on leafy vegetables but many did not assess the heavy metals residue in soil and leafy vegetables along the urban and peri-urban gradient of Lagos State. The study assessed the level of heavy metals residue in the soil and leaves of three commonly consumed vegetables - Celosia argentea, Amaranthus hybridus and Corchorus olitorius - in Lagos State. Sampling was conducted in 2019 and 2020. Fe, Pb, Cu and Cd residues in the soil and the leafy vegetables samples were digested and determined in the laboratory using Atomic Absorption Spectrophotometer (AAS). Data were analyzed using simple descriptive statistics and Analysis of Variance (ANOVA). The range of values for the mean concentrations of the heavy metals in soil showed that Fe = 20.76 ± 0.20 mg/kg – 107.83 ± 17.02 mg/kg, Pb = 0.13 ± 0.07 mg/kg –2.47 ± 0.45 mg /kg, Cd = 0.08 ± 0.02mg/kg – 6.07 ± 2.90 mg/kg and Cu = 0.24 ± 0.11mg/kg – 40.20 ± 4.90 mg/kg. The range of values for the mean concentrations of the heavy metals in the leafy vegetables showed that Fe = 113.10 ± 14.05 mg/kg – 1.51 ± 0.02 mg/kg, Pb = 0.51 ± 0.09 mg/kg - 0.001 ± 0.001 mg/kg, Cd = 0.51 ± 0.01mg/kg - 0.001 ± 0.01 mg/ kg, Cu = 7.54 ± 0.97 mg/kg - 0.36 ± 0.03 mg/kg. The concentration of heavy metals residues in soil and the three vegetables were at safe levels set by WHO/FAO except for Pb and Cd found in vegetables in Ketu and Yaba study locations.

1. Introduction

Vegetables supply diets with crude protein, crude fiber and minerals needed by man for healthy living (Houngla et al., 2020). Recently, leafy vegetable (*Corchorus olitorius, Amaranthus hybridus* and *Celosia argentea*) production have become an important aspect of social and economic activity in the city of Lagos (Adewale et al., 2022). However, there are possibilities that the production of these vegetables may turn out to affect the local environment in some negative ways due to industrial activities, carbon monoxide from passing vehicles, application of chemical fertilizer, indiscriminate dumping of refuse and other toxic waste around the urban farms (Adewale et al., 2022). These activities increase the chances of heavy metal accumulation in the soil and the growing vegetables.

Heavy metals are naturally occurring elements that have a high atomic weight and a high density greater than that of water by about five times (Tchounwou, 2012; Koller and Saleh, 2018). They can contaminate the food supply and may be regarded as the most important problem for our environment (Rai et al., 2019). Heavy metals in vegetables can directly threaten human health causing neurological, reproductive and respiratory illnesses. These metals are not biodegradable. They can accumulate in important organs of man and animals causing serious health problems (Shah et al., 2015). Thus, there is a need for proper management of vegetable production activities along Lagos urban and peri-urban gradient. Therefore, this study assessed the level of heavy metals concentration in the soil and leaves of three commonly consumed vegetables (*Celosia argentea*, *Corchorus olitorius* and *Amaranthus hybridus*) in Lagos State.

2. Materials and Methods

2.1 The Study Location

This study was conducted in Lagos, Nigeria with five study sites (vegetable farms) (Fig. 1). The five study locations were selected for this purpose namely: Yaba, Ketu, Ikorodu, LASU and Ibeju Lekki Farms. Yaba Farm here referred to urban vegetable gardens located in the densely populated residential area of Lagos and also close to the Ijora Railway terminal, National Stadium Lagos and Yaba/Tejuosho markets. Ketu Farm here referred to the urban vegetable garden located within the city of Lagos. The farm was surrounded by residential buildings and very close to a major road in the area. LASU Farm here is referred to as the peri-urban vegetable farm that surrounded Lagos State University. Ikorodu Farm here is referred to as the peri-urban vegetable garden located within Lagos (Ikorodu) Farm Settlement. Ibeju-Lekki Farm here referred to Peri-urban community vegetable gardens located in Ibeju-Lekki. A sparsely populated community of Epe Division of Lagos.

Sampling was done in 2019 and 2020. Samples of soil and vegetable were collected from the farms. At each location under the study, 5 sub-sampling points at a distance of 5m from each other were identified and from which soil and vegetable samples were collected. The subsamples collected were put into one representative sample (Adewale et al 2022 & Baltrėnas et al., 2003).

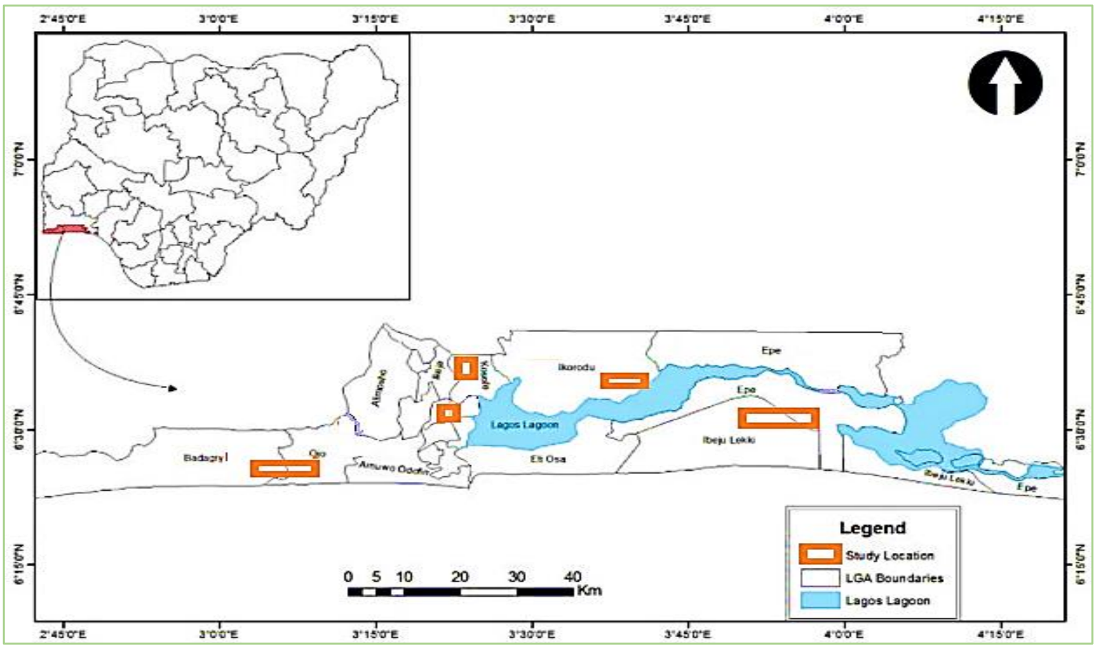

Figure 1: Geographical Map of Lagos State showing the study sites

2.2 The Experimental Soil and Plants

The soil sample were collected three times (September 2019, December 2019 and March 2020) from depth of 0-5cm as this was the region where root of the vegetable plants derived nutrients. (Adewale et al., 2022). Soil auger was used for soil sample collection. Each sample of the soil was stored in double sealable polythene bags and kept in a cool container during transport to the Laboratory. The leafy vegetables (*Celosia argentea*, *Corchorus olitorius* and *Amaranthus hybridus*) were harvested freshly from the farm locations three times (September 2019, December 2019 and March 2020). These vegetables were selected because they were the commonly consumed vegetables in Lagos State Nigeria (Onwordi et al., 2009).

2.3 Determination of heavy metal content in Soil and plants

The soil and the edible part of the vegetable plants were first dried in the laboratory. The dried samples were crushed and sieved using a 2 mm sieve in the laboratory. For each sample, 0.25g was transferred into a 50 ml flask and 10 ml concentrated HNO3 (10 ml only) was added to each flask. The digestion of the mixture was done in a fume cupboard overnight and later heated for about an hour (Adewale et al., 2022). The mixture was left to cool for about an hour at room temperature. Thereafter, 10 ml of double distilled H2O was added and filtered via 0.45 µm cellulose. The filtrate was then analyzed for Iron, Lead, Cadmium and Copper by Atomic Absorption Spectrometer (AAS). This procedure was followed for both plants and soil samples.

2.4 Data Analysis

The primary data of heavy metal residue from the AAS analysis were cross-checked and thereafter analyzed using descriptive statistics tools (mean and standard deviation). Further analysis of variance (ANOVA) was conducted. ANOVA for each vegetable and soil was performed separately using variables such as locations and vegetable types as locations and vegetable types tested varied. Duncan's Multiple Range Test was used as a post hoc test to determine where significant differences exist.

3. Results and Discussions

3.1 Level of heavy metal concentration in soil along the urban and peri-urban gradient of Lagos

Levels of concentrations of the four heavy metals (Fe, Pb, Cd and Cu) in the soil from the study sites were given in (Table 1). The range of values of the mean concentrations of the heavy metals as presented in Table 2 such that Fe = 20.76 ±0.20 mg/kg –107.83 ±17.02mg/kg, Pb = 0. 13 ±0.07mg/kg – 2.47 ±0.45mg/ kg, Cd = 0.08±0.02mg/kg–6.07 ±2.90mg/kg, and Cu = 0.24±0.11mg/kg–40.20±4.90mg/kg. The obtained results of this study showed that the level of Fe in the soil of LASU was highest when compared with soil samples from other locations in this study. However, Yaba has the lowest concentration of Fe.

The concentration of Pb in the soil samples collected from Yaba has the highest value of 2.47 ±0.45 mg/kg followed by Ketu with a value of 0.49±0.14mg/kg. Ibeju-Lekki recorded the lowest Pb with 0.13±0.07/kg (Table 1). Pb content found in Yaba soil was significantly ($p< 0.05$) higher as compared to those in the other soil samples from other farms in this study. Cadmium values showed low levels in soil samples across all locations except at Yaba.

The concentration of Cu in the soil samples in Yaba and Ketu were 40.20±4.90mg/kg and 0.43±0.11mg/kg, respectively while the concentration of Cu in LASU, Ikorodu and Ibeju-Lekki amounted to 27.22±7.07mg/kg, 27.67±1.47mg/kg, 0.24±0.11mg/kg respectively (Tables 1). The low Cu value (0.29mg/kg) was recorded in Ikorodu (Table 1). The concentration of Cu in the study locations varied significantly ($p <0.05$).

Table 1: Mean concentrations of Fe, Pb, Cd and Cu (mg/kg) in the soil along Lagos urban- peri-urban gradient

Sample Location	Fe ± SD (mg/kg)	Pb ± SD (mg/kg)	Cd ± SD (mg/kg)	Cu ± SD (mg/kg)
Yaba	20.76±0.20a	2.47±0.45c	6.07±2.90b	40.20±4.90c
Ketu	36.04±10.76a	0.487±0.14b	0.08±0.02a	0.43±0.11a
LASU	107.83±17.02c	0.33±0.06ab	0.15±0.03a	27.22±7.07b
Ikorodu	76.84±12.45b	0.13±0.07a	0.10±0.02a	27.67±1.49b
Ibeju-Lekki	24.71±4.19a	0.12±0.01a	0.09±0.03a	0.24±0.11a
FAO/WHO	50000.00	100.00	3.00	100.00

*Fe= Iron, Pb= Lead, Cd= Cadmium, Cu= Copper, FAO= Food and Agriculture Organization, *WHO= World Health Organization, MPL = Maximum Permissible Limit, Means having the same letter(s) in the same column are not significantly ($P < 0.05$) different

3.2 Level of heavy metal concentration in leafy vegetables along Lagos urban and peri-urban gradient

The mean concentration of heavy metals in the three leafy vegetable types in this study is shown in Table 2 below. Fe contents were found to be highest in Ibeju-Lekki (99.95±10.85mg/kg), LASU (83.88±4.26mg/kg) and Ikorodu (113.10±14.05mg/kg) for *Amaranthus hybridus*, *Celosia argentea* and *Corchorus olitorius* respectively (Table 2). Fe concentration was found to be the lowest of the three vegetable types under study in Yaba when compared with other farm sites. The concentration of Fe levels in *Amaranthus hybridus, Celosia argentea* and *Corchorus olitorius* collected all varied significantly ($p< 0.05$) across the farms.

From Table 2, the highest level of Pb means concentration (0.51 ± 0.09 mg/kg) in *Amaranthus hybrid* was recorded in Yaba. The same trend was observed in Yaba for *Celosia argentea* and *Corchorus olitorius* (0.27 ±0.08mg/kg and 0.33±0.011mg/kg respectively). The results revealed that Lead concentrations in *Celosia argentea, Corchorus olitorius* and *Amaranthus hybridus* were higher in urban farms (Yaba and Ketu) when compared with peri-urban farms (LASU, Ikorodu and Ibeju-Lekki).

The highest level of Cd concentrations (0.51 ±0.01mg/kg) for *Amaranthus hybridus* was found in Yaba followed by Ketu with Cd mean concentration of 0.22±.23mg/kg (Table 2). *Celosia argentea* and *Corchorus olitorius* have the highest level of Cd mean concentration in LASU. The lowest concentration of Cd in the 3 leafy vegetables was found in Ibeju-Lekki. The mean concentration of Cd level in *Celosia argentea, Corchorus olitorius* and *Amaranthus hybridus* collected all varied significantly ($p< 0.05$) across the farms. Specifically, when comparing urban and peri-urban farms there was significant variation ($p< 0.05$) in the level of Cd concentration in the three leafy vegetables.

From Table 2 the mean of Cu in *Amaranthus hybridus* was found to be highest in Ikorodu (3.70±0.20mg/kg). The mean of Cu (6.04±2.48mg/kg) in *Celosia argentea* was found to be highest in LASU. The same trend was observed for *Corchorus olitorius* as the highest level of Cu concentrations (7.54±0.97mg/kg) for this vegetable was found in LASU. There are significant variations ($p< 0.05$) in the level of Cu concentration across the urban and peri-urban farms.

3.3 Two-ways Analysis of Variance for Location x Vegetable Type Interactions Effect on Heavy Metals Contamination in the study locations

A test of between-subjects (location x vegetable types) effects was performed on heavy metal contaminations in vegetables. The result showed that location has a significant effect (0.00) on the level of heavy metal contaminations in vegetables at $p < 0.05$. However, vegetable types have no significant effect (0.255) on the level of heavy metal contaminations in vegetables at $p < 0.05$. Location x vegetable type has a significant effect (0.001) on the level of heavy metals contamination in the vegetables at $p < 0.05$ (Table 3).

Table 2: The Mean concentration of heavy metals (mg/kg) in three leafy vegetables along Lagos urban- peri-urban gradient

Sample Location/	Fe (mg/kg) Mean ± SD	Pb (mg/kg) Mean ± SD	Cd (mg/kg) Mean ± SD	Cu (mg/kg) Mean ± SD
		Amaranthus hybridus		
Yaba	5.11 ±1.11a	0.51 ±0.09d	0.51 ±0.01c	3.25 ±0.15b
Ketu	33.19±1.9b	0.06±0.02b	0.22±.23b	0.611±0.10a
Lasu	52.20±9.58c	0.10±0.40b	0.01±0.16ab	1.23±0.82a
Ikorodu	99.95±10.85d	0.17±0.00c	0.15±0.23ab	3.70±0.20b
Ibeju-Lekki	9.80 ±1.00a	0.002 ±0.00a	0.001±0.01a	0.98 ±0.11a

Celosia argentea				
Yaba	3.26 ±0.04a	0.27 ±0.08c	0.26 ±0.01b	0.36±0.03a
Ketu	21.03±2.59b	0.061±0.23ab	0.12±0.17ab	0.57±0.22a
Lasu	83.88±4.26d	0.01±0.01a	0.017±0.02a	6.04±2.48b
Ikorodu	48.39±13.17c	0.15±0.02b	0.004±0.005a	4.04±0.06b
Ibeju-Lekki	8.96 ±.94a	0.001±0.01a	0.002 ±0.01a	0.49 ±0.11a
Corchorus olitorus				
Yaba	1.51±0.02a	0.33±0.011c	0.079±0.01b	5.11±1.1c
Ketu	15.81±3.34b	0.02±0.01a	0.02±0.02a	0.46±0.35a
Lasu	91.86±5.97c	0.01±0.01a	0.17±0.05c	7.54±0.97c
Ikorodu	113.10±14.05 d	0.002b	0.03±0.00a	1.96±0.17b
Ibeju-Lekki	7.90 ±0 .61ab	0.001±0.001a	0.001±0.005a	0.38 ±0.04a
WHO/FAO (MPL)	425.00	0.30	0.20	73.30

FAO= Food and Agriculture Organization, *WHO= World Health Organization, MPL = Maximum Permissible Limit, Means having the same letter(s) in the same column are not significantly ($P < 0.05$) different

Table 3: Tests Of Between Subject Effects (Location X Vegetable Types Interactions) On Vegetable Heavy Metals Contamination (Two-Way Anova)

Tests of between subjects' effects					
Dependent Variable: Average heavy metals					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1630.932[a]	14	116.495	19.063	.000
Intercept	2439.533	1	2439.533	399.208	.000
Location	1241.442	4	310.360	50.788	.000
Vegetable type	18.757	2	9.378	1.535	.255
Location * Vegetable type	361.971	8	45.246	7.404	.001
Error	73.331	12	6.111		
Total	5696.087	27			
Corrected Total	1704.263	26			
a. R Squared = .957 (Adjusted R Squared = .907)					

4. Discussion

4.1 Heavy Metals Residue in Soils

Soils of Yaba, LASU and Ketu hold a high level of heavy metals which can be attributed to agrochemical applications, and vehicular and industrial emissions. In addition, the high level of Pb and Cd observed in soil samples from the Ketu and Yaba (Urban farms) can be attributed to high levels of agrochemical applications like chemical fertilizers, pesticides and herbicides. This result agrees with that of Fang *et al.* (2011), in China where heavy metal residues in the soil of vegetable farms were found to be on an increasing trend along the rural-urban gradient. The same trend was reported by Makanjuola *et al.* (2019).

Considering the influence of prevailing agricultural practices (land uses) on heavy metal concentrations in the soil, there was a clear distinction between the soil samples. Metal concentrations in the soil's samples varied widely in concentration across the experimental sites, reflecting an array of anthropogenic impacts such as traffic emissions, industrial emissions, waste disposal, soil transport and redistribution. The heavy metal concentrations were consistently highest in Yaba (Urban farm) samples for Pb and Cd than in soils collected from LASU, Ikorodu and Ibeju-Lekki. This observation agrees with the findings of Akhtar *et al.* (2014).

4.2 Level of Heavy Metal Residue in Vegetables

The concentration of heavy metals in vegetables collected from Yaba, Ketu, Ikorodu, LASU and Ibeju-Lekki showed significant variation. This can be attributed to differences in location (distance from the city centre) and other farming practices. The finding from the current study revealed that the level of Pb and Cd in vegetables in Yaba and Ketu was found to the toxic level. According to FAO/WHO standards, the permissible level of Pb for vegetables is 0.3 mg/kg. It was found that in all vegetables in Yaba except for *Corchorus olitorus* whose concentration was almost at WHO standard, Pb concentration in other vegetables was higher than the permitted level. The level of Pb concentration that was observed in the vegetables could be a result of anthropogenic (human) activities such as solid waste combustion, agrochemicals-use such as pesticides- and vehicular exhaust.

However, the level of lead in vegetables in LASU, Ketu and Ikorodu is not above the WHO/FAO (2011), permissible standard, yet it is worthy of note that weak significance differences were recorded for Pb levels in vegetables on these farms. The implication of this is that regions/places called peri-urban are also undergoing a lot of development leading to high vehicular traffic and emissions on the roads and industrial pollution.

Generally, the level of Cu concentrations was higher in vegetables obtained from the LASU, Ikorodu and Ibeju-Lekki farm sites compared to those from the urban farm sites. These variations can be attributed to a lot of industrial and residential building development going on in these areas which are usually called peri-urban. A lot of people are moving so fast into this location making the vehicular traffic along the Lekki-Epe corridor becoming higher than that of Lagos Mainland. Also, the prevailing vegetable production management practices such as the use of copper-based fungicides on the farms.

Although the concentrations of copper in all three leafy vegetables from the study sites varied yet it was a very weak significant variation that was observed. This observation indicates that the level of heavy metals in the three vegetables was below the safe limits of 73.30 for Cu set by the WHO/FAO (2011). However, this result was higher than what Nisa *et al.* (2020) and Sayo *et al.* (2020) reported in Kenya. The varying concentrations of Copper in all the study locations may be due to their different uptake rate and the prevailing farm management system. The higher concentration of Cu detected in Ikorodu in this study may be due to developing industrial and residential development going on around the farms. The long age of farming in this peri-urban farm settlement which accounts for over 50 years of continuous farming system in the area (prevailing farm management) may also be responsible for this high Cu concentration in the three vegetables studied.

Fe is an important trace metal needed for the cellular functions of the body (Lopez et al., 2016). Fe levels in the three vegetables in this study were below the WHO / FAO (2011), stipulated limit. This suggests that Fe concentration in the various vegetables was safe for consumption. However, In Pakistan, Nisa *et al.* (2020), reported low Fe concentration in vegetables contrariwise, to the Fe concentration reported by Eid *et al.* (2020), in *Corchorus olitorius* L. cultivated in Abha - Saudi Arabia.

5. Conclusion

The finding of this study revealed that the highest level of Pb and Cd residues were found in urban farms surrounded by major city markets, the national stadium, railway terminals and densely populated residential and industrial areas. Metal concentrations in the soil samples varied in concentrations across the urban and peri-urban farms, reflecting an array of agricultural practices and the vegetable gardens' locations.

Nevertheless, the results obtained from this study for all the heavy metals in each category of soil and vegetable samples were below the WHO/FAO standard except for Pb in the three vegetables at Yaba study site. Also, Cd in soil, *Amaranthus hybridus and Celosia argentea* at Yaba study site and Cd in *Celosia argentea* at Ketu study site were found to be higher than the permissible level recommended by WHO/FAO. The high contents of Pb and Cd in vegetables under the prevailing management practices in urban areas of Lagos State revealed that continuous use of chemical fertilizer and other agrochemicals in vegetable gardens may result in the accumulation of heavy metals in the garden soil and in vegetables. Farmers should carry out soil tests before embarking on vegetable production to prevent growing vegetables in contaminated soil. They should reduce the use of agrochemicals in the production of vegetables. Importantly, they should adopt new practices of growing vegetables in cities. Such systems include hydroponic farming and vertical-soilless farming systems. Adopting these practices may reduce heavy metals contaminations in vegetables.

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