Determination of Heavy Metals Concentration in Soil and Leafy Vegetables in Urban Expressway and Peri-urban Road Farms of Lagos State, Nigeria

Peter Sanjo Adewale[1*], Sunday Clement Olubunmi Makinde[2], Victor Owolola Kusemiju[3], Olawole O. Obembe[4]

[1]Centre for Environmental Studies and Sustainable Development, Lagos State University, Lagos, Nigeria
[2]Department of Botany, Lagos State University, Lagos, Nigeria
[3]Department of Zoology, Lagos State University, Lagos, Nigeria
[4]Department of Biological Sciences, College of Science and Technology, Covenant University, Ogun, Nigeria

**Corresponding author: sanjoadewale@gmail.com*

Abstract: Farmers have long considered urban agriculture as a panacea to urban food insecurity. However, growing food in cities is faced with many challenges like food contamination. Past studies on leafy vegetables focused on vegetables cultivated in urban centres. However, this paper aimed to determine and compare the level of heavy metals concentrations in soil and leafy vegetables in Urban Expressway Farms (UEF) and Peri-urban Road Farms (PRF) in Lagos, Nigeria. These two locations were purposefully selected. Soil Auger was used to drill holes to the required soil depth to collect soil samples. Sample of *Amaranthus hybridus*, *Celosia argentea* and *Corchorus olitorius* were collected using "envelope" principle. Pb, Cd and Mn residues in the samples were digested and determined using Atomic Absorption Spectrophotometer. The collected data were analysed using mean, standard deviation and Analysis of Variance. The mean pH value for UEF soil is 6.5 while PRF soil is 6.6. The highest Pb (0.93±0.06) was recorded in *Celosia argentea* at UEF. The highest mean concentration of Cd (0.51±0.11) was recorded in *Amaranthus hybridus* at UEF. The highest concentration for Mn was recorded in *Amaranthus hybridus* (0.98±0.02) at UEF. The concentrations of Pb in *Celosia argentea* at UEF 5 m from the expressway and Cd concentration in *Amaranthus hybridus* at 10 m from expressway were above the WHO/FAO permissible levels in vegetables. Level of heavy metal residue observed in soil and vegetables under this study were mostly influenced by the location of the farm-environment and not mainly the vegetable type. The relative concentrations of Pb and Cd in all the three leafy vegetables raise some serious environmental concerns and need to be monitored regularly to prevent consumption of contaminated leafy vegetables. Farmers are encouraged to cultivate in fields far away from expressway.

Keywords: *Amaranthus hybridus, Celosia argentea, Corchorus olitorius, Heavy metals, Soil*

Received 28.03.2022; Revised 07.05.2022; Accepted 18.05.2022

Cite This Article: Adewale, P.S., Makinde, S.C.O., Kusemiju, V.O. & Obembe, O.O. (2022). Determination of Heavy Metals Concentration in Soil and Leafy Vegetables in Urban Expressway and Peri-urban Road Farms of Lagos State, Nigeria. *Journal of Sustainability and Environmental Management*, 1(2), 241-246.

1. Introduction

Sources of heavy metals in the environment include pesticides, fertilizer, fuel, wastewater, sewage, vehicular exhaust, industrial effluents and agricultural waste (Gjorgieva-Ackova, 2018). Other studies like that of Bett et al., (2019). Gabrielyan et al., (2018); Musa, et al., (2018) have also reported that the use of spray paint, chemical fertiliser and burning of tyres are sources of heavy metals in urban gardens. Other sources of heavy metals contamination include storm water runoff, improperly treated wastewater, soil amendments and the food system (Carvalho, 2017; Springmann et al., 2018). Heavy metals are naturally occurring elements that have a high atomic weight and a high density greater than that of water (Koller and Saleh, 2018; Tchounwou, 2012). They can contaminate food supply and may be regarded as the most important problem for our environment (Rai et al., 2019). Both lead and cadmium are toxic to man. The liver and kidney are known to contain half the total cadmium in the body and its bioaccumulation in the system have been related to hypertension and cardiovascular diseases (Zhou et al., 2016). Acute effects of Pb poisoning could lead to constipation, vomiting, anaemia, swelling of the brain, paralysis and even death. Lead is also known to interfere with the function of the mitochondria and impair respiration. As a result of environmental pollution in cities, heavy metals find their ways into soil and vegetables cultivated closed to roads. Although, vegetables are known to enrich diets with nutrients including crude protein, crude fibre and minerals, continuous consumption of heavy metal contaminated vegetables could have serious health implications in cities where leaded fuel is very much in use (Aletor and Adeogun, 1995; Houngla et al., 2020).

Recently, urban and peri-urban leafy vegetable production of *Amaranthus hybridus* L. (African Spinach commonly called *Efo Tete* in Yoruba) *Celosia argentea* L. (Lagos Spinach commonly called *Efo Soko*), and *Corchorus olitorius* L. (Jute Mallow commonly called *Ewedu*), which are commonly consumed in Lagos State have become important economic (income generating) and social activity. However, chances are that urban and peri-urban vegetable production (UPVP) may impact man and the local environment in some negative ways as there are growing concerns with the continuous use of fertilizers as the nutrition resources of plant growth and indiscriminate use of some other agrochemicals such as pesticides in urban and peri-urban vegetable farms. Consequently, contaminations of the human food chain with the heavy metals and reduction of soil quality and its effects on human health have now become inevitable (Yang, 2016).

Heavy metals in vegetables can cause a direct threat to human health. They are not biodegradable and accumulate in vital organs of man and animals causing serious health problems (Shah et al., 2015). There is need for open space vegetable production in Lagos urban (Ikeja and Lagos divisions) and peri-urban (Badagry, Ikorodu and Epe divisions) farms to be well managed so that the production of vegetable in these areas will not become a setback to achieving a sustainable environment as summarised in the Sustainable Development Goals (SDGs) (CAFOD, 2015). This paper evaluated and compared the level of heavy metals concentrations in soil and leafy vegetables in Urban Expressway Farms (UEF) and Peri-urban Road Farms (PRF) in Lagos State, Nigeria.

2. Materials and methods

The study was conducted in Lagos urban expressway farms (UEF) and peri-urban road farms (PRF) (Table 1). These two study locations were purposeful selected because vegetables are mostly cultivated along road setbacks in Lagos State. Soil and vegetable samples were collected from the farms in 2019 and 2020. Soil sampling is most often accomplished by selecting, according to the "envelope" principle, i.e., 5 sub-sampling sites within the representative area of the single sampling. Having multiple subsamples does provide a more accurate picture of the entire study area and prevent an irregular area from skewing the results of the findings. Sub-sampling sites are selected at a distance of 5m from each other, and the subsamples collected were put into one representative sample (Baltrėnas et al., 2003).

Surface soils (0–5 cm) (Ondo et al., 2014) were collected. This procedure was repeated three times at each site (Ondo et al., 2014) and the mean concentration of each heavy metal was calculated. This depth was chosen as a zone of the most active root system of vegetable crops. The samples were taken using a soil drill and stored in sealable polythene bags. Samples of the three leafy vegetables (*Amaranthus hybridus* L. (African Spinach locally called *Efo Tete* in Yoruba), *Celosia argentea* L. (Lagos Spinach locally called *Efo Soko* in Yoruba) and *Corchorus olitorius* L. (Jute Mallow locally called *Ewedu* in Yoruba) were collected randomly from actively growing plants at each location and stored in sample bags properly labelled before taking to Laboratory for heavy metals detection. These three leafy vegetables were selected for this study because they are the leafy vegetables that most 'Lagosians' normally consume (Onwordi et al., 2009).

Table 1: Study locations

Farm	Location	Water source for irrigation	Prevailing land use and vegetable production management practices
1.	Urban Expressway Farm (UEF): Ketu Expressway farms in Ikeja division of Lagos state	Shallow well	Farms located at 5 m, 10 m and 15 m from the Lagos major expressway. Organic+Inorganic fertilizer+Herbicides+Pesticides
2.	Peri-urban Road Farm (PRF): LASU/Iyana Iba Road farms in Badagry division of Lagos state	Borehole + shallow well	Farms located at 5 m, 10 m and 15 m from major road in Badagry division of Lagos State. Organic fertilizer + Inorganic fertilizer+Herbicides+Pesticides are used.

Soil and vegetable samples were air-dried in the laboratory. The samples were crushed and sieved using 2 mm sieve. Particles greater than 2 mm were discarded. Each sample (0.25 g) was then placed into 50 ml flask and 10 ml concentrated HNO3 was added. The mixtures were left in a fume cupboard to cold digest overnight. The following morning the mixture was heated for about half an hour in a microwave.

The mixture was then allowed to cool at room temperature for some minutes after which 10 ml of double distilled H_2O was added filtered via 0.45 μm cellulose. The concentrations of the heavy metals- Lead, Cadmium and Manganese-in each sample were then determined using atomic absorption spectrophotometer following American Public Health Association procedures and standard.

Primary data of heavy metal residue in soil and vegetable samples were checked and analysed. Mean and standard deviation of each heavy metal was calculated. Heavy metal concentrations in analyzed soil and vegetables samples from the study locations were analysed through one-way Analysis of Variance (ANOVA) test.

3. Results

3.1. Heavy metals contents in the soil

All soil samples across the farm locations contained different mean concentrations of Pb, Cd and Mn as shown in Table 2. The results showed that the soils were slightly acidic with pH ranging from 6.50- 6.70. The pH of soil samples from urban expressway farms (UEF) was lower (6.50-6.60) compared with pH of soil from peri-urban road farms (PRF) (6.60-6.70) (Table 2). The soil from UEF had a mean pH of 6.5, while that of PRF had mean pH of 6.6 (Table 2). The highest Pb (0.66 mg/kg) was recorded in soil at UEF. The highest mean concentration of Cd (0.18) was recorded in soil at UEF. In this same vein, the highest concentration for Mn (8.22 mg/kg) was recorded in soil at UEF. The concentration of the heavy metal residues found in the soil at the different sampling points of the two study sites varied significantly.

The concentrations of Pb and Cd in UEF decreased significantly with increased distance from the expressway and the road. (Table 2). Similar pattern was recorded for the concentrations of Cd and Mn at PRF (Table 2).

3.2. Heavy metals contents in the leafy vegetables

All vegetable samples contained different concentrations of Pb, Cd and Mn as shown in Table 3. The highest Pb (0.93±0.06) was recorded in *Celosia argentea* at UEF. The highest mean concentration of Cd (0.51±0.11) was recorded in *Amaranthus hybridus* at UEF. In this same vein, the highest concentration for Mn (0.98±0.02) was recorded in *Amaranthus hybridus* at UEF. The concentration of the heavy metal residues found in the three leafy vegetables at the different sampling points of the two study sites varied significantly.

In *Amaranthus hybridus* at UEF, mean concentrations of Pb and Mn followed the order UEF -5 m > UEF -10 m (Table 3) except in Cd where the Cd concentration in *Amaranthus hybridus* showed no trend. In PRF mean concentrations in *Amaranthus hybridus* for Pb and Cd followed the decreasing order from 5 m to 15 m (PRF-5 m >PRF-10 m >PRF-15 m (Tables 3). No specific pattern was observed for Mn in PRF for *Amaranthus hybridus*. The occurrence of Pb and Mn in *Amaranthus hybridus* at 10 m and 15 m distances from the expressway at UEF area, did not differ significantly (p>0.05) (Table 3).

In *Corchorus olitorus*, mean concentration recorded in UEF for Pb has no specific pattern (Tables 3). In PRF, it was observed that the mean concentrations of heavy metals in *Corchorus olitorus* followed the order of decreasing mean concentration with increasing farm distance from the road (PRF-5 m > PRF-10 m > PRF-15 m) (Tables 3). For both *Amaranthus hybridus* and *Corchorus olitorus*, the concentrations of Mn at 10 m and 15 m distances from the Expressway at UEF did not differ significantly (p>0.05) (Table 3).

For *Celosia argentea* in UEF, the mean concentrations for Pb and Cd at the 5 m distance were significantly higher than for the 10 m and 15 m distances (Tables 3). At the PRF area, the mean concentrations for Cd and Mn at the 5 m distance were significantly higher than for the 10- and 15 m distances. However, the concentrations of the heavy metals in *Celosia argentea* at the 10 m and 15 m distances at both study locations did not differ significantly, except for Pb in PRF area (p>0.05) (Table 3).

Table 2: Mean concentration of heavy metals in soil at the study locations

Distance (m)	Urban expressway farms				Peri-urban road farms			
	Heavy Metals (mg/kg)				Heavy Metals (mg/kg)			
	pH	Pb	Cd	Mn	pH	Pb	Cd	Mn
5	6.50a	0.66c	0.10a	0.61c	6.60a	0.36 c	0.18c	8.22a
10	6.60b	0.45b	0.07ab	0.52b	6.60 a	0.32b	0.15b	6.21c
15	6.50a	0.35a	0.06b	0.48a	6.70 b	0.31a	0.12a	4.52b
FAO/WHO (MPL)	-	100	3	2000	-	100	3	2000

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

Table 3: Heavy metal concentration in vegetables at various distances from farm edge in Urban Expressway and Peri-urban Road Farms (values are means of three replicates)

	Urban Expressway Farm			Peri-urban Road Farm		
Farm Distance from Express-way/Road	Pb (mg/kg) Mean ±SD	Cd (mg/kg) Mean ±SD	Mn (mg/kg) Mean ±SD	Pb (mg/kg) Mean ±SD	Cd (mg/kg) Mean ±SD	Mn (mg/kg) Mean ±SD
	Amaranthus hybridus			***Amaranthus hybridus***		
5	0.06±0.02b	0.02±0.01a	0.98±0.02a	0.12±0.01a	0.12±0.02c	0.05±0.01a
10	0.05±0.01a	0.51±0.11b	0.59 ±0.95b	0.06±0.01b	0.01±0.01b	0.89±0.06c
15	0.05±0.02a	0.13±0.02a	0.55±0.13b	0.04±0.01c	0.00±0.00a	0.69±0.20b
	Celosia argentea			***Celosia argentea***		
5	0.93±0.06b	0.01±0.01a	0.54±0.23a	0.00±0.00a	0.04±0.04b	0.46±0.16c
10	0.06±0.02a	0.002±0.0b	0.52±0.09a	0.01±0.01b	0.01±0.01a	0.15±0.00b
15	0.06±0.00a	0.002±0.0b	0.52±0.11a	0.00±0.01a	0.01±0.01a	0.17±0.08a
	Corchorus olitorus			***Corchorus olitorus***		
5	0.01±0.02a	0.02±0.01a	0.66±0.01b	0.02±0.02c	0.23±0.02c	0.73±0.08c
10	0.01±0.01a	0.03±0.02b	0.43±0.06a	0.01±0.01b	0.17±0.02b	0.63±0.05b
15	0.01±0.01a	0.02±0.01a	0.49±0.01a	0.00±0.00a	0.11±0.02a	0.56±0.03a
WHO/FAO (MPL)	**0.30**	**0.20**	**500.00**	**0.30**	**0.20**	**500.00**

4. Discussion

The location of the farms is a major factor found to influence the concentration of metals in the soils of the farm in the study. The amount of these heavy-metals in each soil varied among sampling sites in the study locations. The concentrations of Pb and Cd in UEF decreased significantly with increased distance from the expressway and the road. Similar pattern was recorded for the concentrations of Cd and Mn at PRF. The increased Pb and Cd concentration in the soils of sites near the road could probably result from the lubricating oil and/or old tires of vehicles used on the roads (Sürücü et al., 2018). However, the concentrations of each of these metals in the soil were below the permissible limit set out by WHO/FAO (2011).

The mean concentrations of Cd in the vegetables at the two study locations do not follow any specific trend. However, it is important to note that Pb concentrations in *Amaranthus hybridus* and *Celosia argentea* at UEF and *Amaranthus hybridus* and *Corchorus olitorus* at PRF 5 m from the road varied significantly when compared with 10 m and 15 m from the road. This can be attributed to emission from passing vehicles on the road and traffic density. Ogunyemi et al. (2003), observed the same trend in a study in Ibadan. This observation also agreed with the findings of Sürücü et al., (2018). The same trend was reported by Chen et al. (2010). Similar trend was observed for Mn in the three vegetables at PRF and for *Amaranthus hybridus* and *Corchorus olitorus* at UEF. This might be due to application of agrochemicals like pesticides and chemical fertilizers at the study locations.

The overall Pb, Cd and Mn concentrations in the soil were highest at the Urban Expressway Farm. This indicates heavy metals relation to traffic. Sharma and Prasad (2010) and Naser et al. (2012). The variation in concentrations of Pb and Cd among UEF and PRF can be explained by differences in density of the vehicular traffic on the expressway and the road. *Amaranthus hybridus* in UEF exceeded the tolerable recommended maximum value by FAO/WHO for the amount of Cadmium. *Celosia argentea* at UEF exceeded the tolerable recommended maximum value by FAO/WHO for the amount of Lead. The relative concentrations of Pb and Cd in all the three leafy vegetables at both UEF and PRF raise some serious environmental concerns and needs to be monitored regularly to prevent consumption of contaminated leafy vegetables.

5. Conclusion and recommendation

Soil pH in the study locations was generally slightly acidic yet the values varied. The differences in pH value can be attributed to the location of the farms. Also, level of heavy metal residue observed in soil and vegetables under this study were mostly influenced by the location of the farm-environment and not mainly the vegetable type. The mean concentration of heavy metals in UEF and PRF vegetable species depend on the level of anthropogenic activities and vehicular traffic density. The three vegetable types cultivated in the farms were safe for consumption except for Amaranthus hybridus and Celosia argentea in UEF with high heavy metal residues. These two vegetables at UEF are not safe for consumption. Continuous cultivation of vegetable by roadsides is a drawback to achievement of Sustainable Development Goal 3 of ensuring healthy living and promotion of well-being for all. High level of Pb and Cd in vegetables are potential health problem for human. Heavy metals can accumulate in the body tissue for a long time especially accumulation of Pb in body tissues can cause heart diseases and impair lung's functions. High level of Cd in blood can disrupt liver functions.

It is essential that the farmers be educated and encouraged to cultivate in fields far away from expressways as the distribution of heavy metals in the soil and the vegetables types studied were found to be mostly influenced by distance of the farms from the road. They are encouraged to carry out soil test before planting and adopt new practices of hydroponic and soilless farming systems in order to reduce heavy metals contaminations in vegetables. The Lagos State Environmental Protection Agency (LASEPA) should set and enforce strict regulations for different urban and peri-urban agriculture practices for safe vegetable production practices. Researchers should consider bio-monitoring of heavy metals in vegetables as a continuous needed activity so as to forestall possible consumption of contaminated vegetables.

Acknowledgements

This work is funded by Tertiary Education Trust Fund (TETFUND), Institutional–Based Research (IBR). Opinions, findings, conclusions and recommendations expressed in this article are those of the authors and do not necessarily reflect the views of TETFUND.

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