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Assessment of the concentration of heavy metals in two vegetables in selected urban metropolises (Ilorin and Osogbo), Nigeria

A. E. Awe[1]*, G. O. Adesina[1], K.A. Adelasoye[1], S. O. Abiola[2] and A. A. Adeniji[3]

[1]Department of Crop and Environmental Protection, Faculty of Agricultural Sciences, Ladoke Akintola University of Technology, Ogbomoso, Nigeria.
[2]Department of Plant and Soil Sciences, Ferguson College of Agricultural Sciences, Oklahoma State University, Stillwater, United States of America.
[3]Department of Geography, Faculty of Social Sciences, University of Exeter, Penryn Campus, United Kingdom.

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This study analyzed heavy metal contamination in commonly consumed leafy vegetables grown on peri-urban farms in Osogbo and Ilorin, Nigeria. Across five neighborhoods in each city, fresh vegetable samples were collected and assessed for lead (Pb), copper (Cu), zinc (Zn), iron (Fe), and manganese (Mn) using atomic absorption spectrophotometry. Alarming Pb levels were discovered, with mean concentrations ranging from 0.01 to 0.26 mg/kg depending on the sampling site, up to 4 times above the WHO safety limit (0.05 mg/kg). Average Cu levels also exceeded guidelines at 0.17 mg/kg in Osogbo and 0.13 mg/kg in Ilorin. Likewise, average Fe surpassed recommended thresholds at 0.54 mg/kg and 0.52 mg/kg in the two cities, respectively. Chronic dietary exposure to these metals poses risks of lung, kidney, neurological and other organ damage among consumers. The contamination likely results from industrial emissions and vehicular pollution. Further research should identify specific entry points across the food production pipeline to guide targeted interventions. Additionally, alternative cultivation methods and consumer health advisories are needed to reduce toxicant exposures from urban-grown greens that many Nigerians rely on. Urgent multi-sectoral action must decrease heavy metal accumulation in vegetables from farms encircled by expanding cities.

Key words: Heavy metals, leafy vegetables, health risks, peri-urban farms, Nigeria.

INTRODUCTION

Leafy vegetables, also referred to as Indigenous vegetables, provide key micronutrients to most developing countries, including Nigeria. They constitute a major portion of the human diet worldwide and play a significant role in human nutrition, serving as sources of vitamins (C, A, B6, B9, E), minerals, dietary fiber, and phytochemicals (Khanthapok and Sukrong, 2019). Due to their nutritional importance, these vegetables are commonly used as

*Corresponding author. E-mail: sabiola@okstate.edu.

major ingredients in soups and are also utilized to garnish cereals, herbs, and aphrodisiacs, among other purposes (Mohammed and Sharif, 2011; Singh et al., 2020; Byrd and Dunn, 2020). Specifically, *Amaranthus hybridus and Corchorus olitorius* (commonly known as amaranth and jute mallow, respectively) are highly important vegetables in some parts of Nigeria due to their nutritious leaves, succulent stems, and cereal-like grains (Opega et al., 2016; Ogwu, 2020). However, the production of these nutritious vegetables in peri-urban sites poses contamination risks from various sources such as industrial pollution and transportation emissions (Anifowose et al., 2022; Agyeman et al., 2023; Onwuka et al., 2023).

Previous studies have identified the accumulation of heavy metals in vegetable crops cultivated near Nigeria's major urban centers (Afonne and Ifediba, 2020; Edogbo et al., 2020; Adewale et al., 2022). For example, a survey conducted in Lagos found that Pb levels in amaranth ranged from 3.2 to 4.8 mg/kg, which is up to 4 times the WHO limit of 1 mg/kg (Uzel, 2015). Similarly, Wilberforce and Nwabue (2013) revealed that the levels of lead, nickel, and cadmium in Enyigba topsoil in Ebonyi state were observed to be above the US-EPA regulatory limits. This indicates that the regular consumption of leafy vegetables by urban populations potentially contains unsafe levels of contaminants that could pose health risks. Furthermore, heavy metals such as lead, mercury, and cadmium have been implicated by the World Health Organization (WHO) as primary causes of cancer, mortality, livestock health problems, serious human health problems, and nerve damage (Balali-Mood et al., 2021; Munir et al., 2021; Mitra et al., 2022). Several researchers have highlighted that in agricultural ecosystems, where animal farming and related agricultural practices are intensive, heavy metals can reach the soil due to the application of commercial fertilizers, sewage sludge, and pesticides, which may contain a wide variation of heavy metals as impurities (Lin et al., 2022; Alsafran et al., 2023; Rashid et al., 2023). Therefore, to delve deeper into this matter, a quantitative analysis of heavy metals present in essential leafy greens cultivated in Ilorin and Osogbo, two significant cities in Nigeria, was conducted. The metals, namely Pb, Cu, Zn, Fe, and Mn, were chosen and examined due to their toxicological significance and their relationship with proximity to industrial and transportation sources (Kolakkandi et al., 2020; Kabir et al., 2022). The result of this analysis will assist in evaluating heavy metal accumulation in these commonly consumed vegetables and how they pose a significant public health issue that requires mitigation strategies.

MATERIALS AND METHODS

Study site

Five sites each from peri-urban metropolises of Ilorin (Location A: Ganmo, B: Adisco, C: Odo Efo, D: Jooro, E: Egbejila) and Osogbo (Location A: Ido Osun, B: Oke Onitii, C: Okinni, D: Ofatedo, E: Oju Irin Ilupeju) were selected for the study.

The study focused on five major vegetable farming sites around each city where the production of leafy greens like amaranth and jute mallow is most popular. These sites were selected due to their intensive cultivation patterns and common use of chemical inputs like fertilizers and pesticides, which can introduce heavy metal contaminants.

Collection of samples

Sixty fresh leafy vegetable samples were collected from five different sites in each of the two metropolitan towns (Osogbo and Ilorin) using multistage random sampling. Samples of the edible portions of vegetables (1 kg each) were collected once a month, with the samples being taken from a height above 10 cm from the soil surface. These samples were kept in polyethylene bags that were rinsed with pre-distilled water and pinned up to avoid excess deposition. Subsequently, the samples were transported to the laboratory for further examination.

Chemical analysis of leafy vegetables

Sample preparation and treatment

At the laboratory, the samples from each sampling location were separately divided into two groups. The first group was left untreated for oven drying, while the other group was washed with clean tap water using normal household techniques. After draining the excess water, the samples were chopped into small pieces and oven dried at 80ºC until a constant weight was achieved. The dry vegetable samples were powdered using a stainless steel blender and passed through a 2 mm size sieve. The samples were then stored at room temperature for further analysis.

Estimation of heavy metals in selected leafy vegetables

A 5 g dry-weight subsample was crushed in a mortar and ashed in a muffle furnace at 450ºC for 6 h. The ashes were not completely white. Then, 2 ml of concentrated HNO3 were added, and the mixture was heated to boiling point on an electric plate heater until the formation of nitrous fumes had stopped. Subsequently, the ashes were returned to the muffle furnace at 450ºC for a further 2 h (Ni et al., 2016). The resulting white ashes were digested with 3.60 mL of concentrated HNO_3 filtered through a 2 mm filter paper, transferred into a 25 mL flask, and brought to volume with ultrapure water to achieve a final concentration of 10% HNO_3. Analytical blanks were prepared in the same way but without the addition of any sample. Vegetable samples were measured in duplicate using a Graphite Furnace Atomic Absorption Spectrophotometer (GFAAS) (PerkinElmer Analyst 600) for Cu, Zn, and Pb quantification, whereas Fe and Mn concentrations were determined using a Flame Atomic Absorption Spectrophotometer (FAAS) (PerkinElmer AA3110).

Determination of soil pH

Soil samples were collected at a depth of 15 to 20 cm from each vegetable sampling site, concurrently with the vegetable sampling. Five soil samples were randomly collected from each site and homogenized into one composite sample per site. Soil sampling was conducted once at the beginning of the vegetable harvesting season to assess baseline heavy metal levels in the soil. The soil

Table 1. Heavy metals concentration (mg/kg) in vegetable samples from both metropolitan cities.

Metropolitan cities	Pb	ZN	Fe	Cu	Mn
Ilorin	0.14	0.54	0.52	0.13	0.016
Osogbo	0.19	0.54	0.96	0.17	0.03
P-value	0.36 (ns)	0.97 (ns)	0.37 (ns)	0.37 (ns)	0.13(ns)
WHO standard	0.05	5.0	0.1	0.1	50

Table 2. Heavy metals concentration (mg/kg) in vegetable samples from Osogbo locations.

Sites	Pb	Zn	Fe	Cu	Mn
Ido Osun	0.22	0.57^{b}	0.49	0.3^{a}	0.02^{a}
Oke Onitii	0.31	0.4^{c}	0.53	0.08^{b}	0.01^{b}
Okinni	0.11	0.78^{a}	2.76	0.08^{b}	0.02^{a}
Ofatedo	0.23	0.58^{b}	0.48	0.32^{a}	0.02^{a}
Oju Irin Ilupeju	0.08	0.39^{c}	0.54	0.09^{b}	0.01^{b}
P_value (<0.05)	0.52	<0.01	0.37	<0.01	<0.01
WHO Standard	0.05 (ns)	5.0	0.1	0.1	50

^{abcd} means on the same column with different superscripts are significantly different ($P < 0.05$). ^{ns} means no significant. Pb-Lead, Cu-Copper, Fe-Iron, Zn-Zinc, Mn-Manganese.

samples were mixed with distilled water in a clean jar at a ratio of 1:1 to form an emulsion. After vigorous shaking, the mixture was allowed to stand for 5 to 10 min to facilitate the dissolution of soil salts in the distilled water. Soil pH was measured using an electronic pH tester.

Data analyses

All data were initially subjected to the Shapiro-Wilk test to check for normality. Significant means were separated by the Tukey Honestly Significant Difference (HSD) test. All statistical analyses were conducted at a significance level of 5% using R version 3.3.2, with the Lmertest package for statistical testing and the ggplot2 package for visualization. The estimated descriptive data for the heavy metal concentrations included means and ranges.

RESULTS

Heavy metal concentrations of site samples across the metropolitan cities

The concentrations of heavy metals (Pb, Zn, Fe, Cu, and Mn) obtained from selected commercial farms in the Osogbo and Ilorin metropolis were analyzed in this study, and the results are presented in Tables 1. The tested heavy metals were detected in both metropolitan cities with no significant difference between the overall metal levels in Osogbo and Ilorin. However, there were variable concentration patterns per dry weight of the tested samples across the different sampling sites within each city.

Heavy metal concentrations of sites sample in Osogbo

All sampled sites across Osogbo showed detectable levels of heavy metals (Table 2). Zinc (Zn) concentrations significantly varied by location, with the highest concentration observed in Okinnni (0.78 mg/kg) and the lowest in Oju Irin Ilupeju and Oke Oniti sites (0.39 mg/kg). Furthermore, the iron concentration was relatively consistent, ranging from 0.49-0.67 mg/kg, with the highest concentration in Okinni (0.67 mg/kg) and no significant differences among sites. Additionally, Copper (Cu) showed considerable variability, with significantly higher accumulations in Ido-Osun and Ofatedo (0.3 mg/kg) compared to the lowest levels in Okinni (0.08 mg/kg). Lastly, manganese (Mn) concentrations varied significantly across all five sites, ranging between 0.01-0.02 mg/kg. Ido Osun, Okinni, and Ofatedo contained the highest Mn concentrations (0.02 mg/kg), while Oke-Oniti and Oju Irin sites had the lowest concentrations (0.01 mg/kg).

Heavy metal concentrations of sites samples in Ilorin

Table 3 presents the results of the heavy metal analysis in vegetable samples collected from selected sites in Ilorin. Lead (Pb) concentration exhibited significant differences among the sampled sites, with the highest metal concentration observed in Ganmo at 0.26 mg/kg and Egbejila at 0.25 mg/kg, while the lowest was found

Table 3. Heavy metals concentration (mg/kg) in vegetable samples from Osogbo locations.

Sites	Pb	Zn	Fe	Cu	Mn
Ganmo	0.27[a]	0.66 [b]	0.5 [b]	0.23 [b]	0.02
Adisco	0.07 [b]	0.33 [e]	0.52 [ab]	0.06 [cd]	0.045
Odo Efo	0.04 [c]	0.54 [c]	0.54 [a]	0.27 [a]	0.02
Jooro	0.07 [bc]	0.37 [d]	0.52 [ab]	0.04 [d]	0.02
Egbejila	0.27 [a]	0.83 [a]	0.52 [ab]	0.07 [c]	0.02
P_value(<0.05)	<0.01	<0.01	<0.01	<0.01	0.37 (ns)
WHO Standard	0.05	5.0	0.1	0.1	50

[abcde] means on the same column with different superscripts are significantly different (P < 0.05). [ns] means no significant. Pb-Lead, Cu-Copper, Fe-Iron, Zn-Zinc, Mn-Manganese.

in Odo-Efo at 0.04 mg/kg.

Zinc (Zn) showed a significant presence across all sites, ranging between 0.33-0.83 mg/kg. Egbejila had the highest Zn level at 0.82 mg/kg, followed by Ganmo (0.65 mg/kg), Odo-Efo (0.53 mg/kg), Jooro (0.36 mg/kg), and Adisco (0.33 mg/kg). Iron (Fe) concentration significantly differed among sites, with Odo-Efo having the maximum at 0.54 mg/kg and Ganmo the minimum at 0.49 mg/kg. In contrast, Copper (Cu) concentration showed a different trend, with Odo-Efo having the highest concentration at 0.27 mg/kg compared to lower levels measured in Adisco (0.06 mg/kg), Jooro (0.05 mg/kg), and Egbejila (0.07 mg/kg). Lastly, Manganese (Mn) concentration showed no significant difference among the five sites, ranging between 0.01-0.02 mg/kg, with Adisco having the lowest manganese concentration at 0.01 mg/kg.

DISCUSSION

This study reports the concentrations of heavy metals content of Lead (Pb), Copper (Cu), Zinc (Zn), Iron (Fe), and Manganese (Mn) in the leaves of vegetables grown on five commercial vegetable farms in selected suburb of Ilorin and Osogbo, Nigeria.

Lead (Pb)

The concentration of lead in the areas sampled from the Ofatedo and Ido-Osun sites of Osogbo, as well as samples from Ganmo and Egbejila sites of the Ilorin location were observed to exhibit the highest lead contamination in the produced vegetables. The lead levels from these locations exceeded the WHO standard (0.05 mg/kg). Similarly, Wilberforce and Nwabue (2013) reported that the lead in garden egg and pig leaf collected from Enyigba exceeded the WHO maximum limit, which is 0.3 mg/kg. Meanwhile, plants usually show the ability to accumulate large amounts of lead without visible changes in their appearance or yield (Sharma et al., 2020; Duan et al., 2020; Ejaz et al., 2022). This indicates that the consumption of these vegetables will certainly lead to health issues. Consequently, several researchers have highlighted that a significant amount of accumulated lead is sequestered within the bones and teeth, leading to bone fragility and weakness in the wrists and fingers (Ghebreyessus and Sallee, 2019; Briffa et al., 2020). Furthermore, lead stored in the newborn can re-enter the bloodstream during phases of heightened bone mineral recycling, such as pregnancy, lactation, menopause, and advanced age (Pervin et al., 2020).

Zinc (Zn)

The concentration of zinc in both metropolitan cities across various areas was shown to be relatively higher among all heavy metals analyzed. According to Silva et al. (2019), zinc is regarded as the least harmful and essential component of the human diet, supporting the immune system's healthy operation. A diet lacking in zinc can be more harmful to a person's health than a diet high in zinc. High quantities of zinc can be built up in vegetables cultivated in soil polluted with heavy metals, possibly causing major health concerns to consumers. However, the zinc content range seen in this study is far lower than the advised safe level, indicating that the veggies are safe (FAO/WHO, 2011). Additionally, several studies have shown significant zinc concentrations in *C. olitorius*, including 4.71 ± 0.01 mg/100g (Idirs et al., 2009) and 0.090-0.942 g/100g (Isuosuo et al., 2019). The area's main zinc source is probably tire wear and tear from motor vehicles, which is accelerated by bad road conditions and trash incineration.

Iron (Fe)

An important micronutrient called iron is needed for the body's ability to transport oxygen. Since it actively participates in a variety of metabolic activities, including oxygen transport, deoxyribonucleic acid (DNA) production, and electron transport, it is essential for almost all living things (Abbaspour et al., 2014). Iron concentrations in the examined samples varied, with Okinni sites having the highest Fe concentration. Due to their high iron content, vegetables are frequently advised for anemic patients (Mantadakis et al., 2020; Cappellini et al., 2020). Meanwhile, the iron levels in the studied vegetables were lower than those discovered in several green vegetables sourced from specific Ethiopian farmlands and below the advised upper limit for vegetables (Wilberforce and Nwabue, 2013). In research on the effects of heavy metal pollution in soil and grown vegetable crops, Daulta et al. (2023) found that a high amount of iron over allowed limits may cause leaf chlorosis owing to iron toxicity. In humans, high iron consumption has been linked to symptoms such as vomiting, upper abdominal discomfort, pallor, cyanosis, diarrhea, disorientation, shock, hemochromatosis, diabetes, liver, lung, and kidney problems, hematoma, and cardiomyopathy, according to Abbaspour et al. (2014).

Copper (Cu)

Copper is essential for maintaining a healthy central nervous system, avoiding anemia, and interacting with the activities of zinc and iron in the body (Mezzaroba et al., 2019). However, excessive intake can lead to toxicity symptoms. In our study, Cu levels in Ganmo and Ofatedo sites exceeded the WHO guideline of 0.1 mg/kg Cu in vegetables.

Consequently, localized contamination from machinery or agrochemicals may have significantly contributed to the accumulation patterns observed. Given the importance of copper in human metabolism, further investigation of exposure sources is recommended to balance the nutritional benefits and toxicity risks among consumers of these urban vegetables.

Manganese

Unlike other metals examined, the concentration of manganese in all vegetable sampling sites fell below the WHO-recommended maximum concentration of 50 mg/kg. According to Filippini et al. (2018), no health risk has been associated with food containing high manganese concentration, which contrasts with the results of vegetable samples from Ilorin and Osogbo metropolises. However, toxicity symptoms can still manifest at doses only moderately exceeding nutritional requirements, so continued monitoring is advisable given manganese's growing use in industry and agrochemicals.

Conclusion

This study discovered concerning levels of Pb, Cu, and Fe contamination in vegetables grown in peri-urban farms across neighborhoods of Osogbo and Ilorin. Mean Pb concentrations reached up to 0.26 mg/kg, four times higher than the WHO limit of 0.05 mg/kg. Localized accumulation likely results from industrial activities and vehicular emissions within the urban environment. Prolonged dietary exposures to heavy metals could promote bone fragility, neurotoxicity, metabolic disruption, and other health effects among consumers relying on these greens. Children and pregnant women in low-income groups with limited nutritional alternatives may face particular risks. Further investigation should identify contaminated sites and likely pollution sources to guide localized remediation efforts. Additionally, authorities should implement regulatory programs to monitor urban farm soil and produce, enable access to safer cultivation zones, and protect vulnerable consumer groups through market restrictions or health advisories. Mitigating heavy metal contamination requires coherent policies across industrial, transport, agricultural, and public health sectors.

Government, farmers, consumers, and other stakeholders must collaboratively balance nutritional demands and contamination risks related to essential leafy vegetables produced in Nigerian cities. This will become increasingly critical as climate change and food insecurity amplify dependence on local greens.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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