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Original Research Article

Bioaccumulation and Health Risk Assessment of Heavy Metals in Three Vegetables Consumed in Lagos, South-West Nigeria

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ABSTRACT

Heavy metal contamination of vegetables is suspected to contribute to the global expansion of chronic diseases, necessitating safety evaluation of all vegetables. This study assessed the safety of lead (Pb), cadmium (Cd), cupper (Cu), chromium (Cr), and nickel (Ni) in moringa (*Moringa oleifera*), fluted pumpkin (*Telfairia occidentalis*) and roselle (*Hibiscus sabdariffa*) sold in Ketu, Ikorodu and Ogba markets in Lagos. After atomic absorption spectroscopy, the daily intake of metals (DIM), the Health Risk Index (HRI), and the Target Hazard Quotient (THQ) of the vegetables were determined. The results showed that the metals were within the World Health Organization (WHO) permissible limits. The vegetables from Ogba were the most contaminated, while Ketu were the least. The DIM of Cd from *M. oleifera* and *H. sabdariffa* as well as Pb through the consumption of all the vegetables exceeded the recommended limits. These showed that consumption of the three vegetables may predispose consumers to Pb and Cd toxicities. However, only Cd in *H. sabdariffa* and Pb in *T. occidentalis* had HRI of 1 and 2, respectively, which specifically indicated the potential toxicity of the two vegetables regarding Cd and Pb. But the THQ of Cd and Pb is less than 1, indicating that the vegetables may not induce a serious health problem in residents within the average life span of Nigerians (54 years). Overall, the results obtained showed that the three vegetables are not entirely safe. Therefore, there is a need to remove all sources of vegetable contamination in the studied areas.

Keywords: Daily Intake of Metals, Health Risk Index, Heavy metal, Toxicity, Vegetable.

Introduction

Heavy metals are metals with a specific gravity of 5 g/cm^3 or above.[1] They have a high atomic weight and are at least 5 times denser than water. The metals are toxic and have been linked with the increasing prevalence of chronic diseases worldwide. Heavy metals of primary concern to living organisms owing to their toxicological properties include lead (Pb), cadmium (Cd), mercury (Hg), arsenic (As), barium (Ba), zinc (Zn), copper (Cu), manganese (Mn) and iron (Fe).[2] Even at minute quantities, these metals can induce hematological, biochemical, histopathological, and genetic diseases, among others. However, the severity of damage caused by these metals depends on their form, concentration, duration of exposure, route of exposure, as well as the age, gender, genetics, and diets of exposed individuals. [3] Direct human exposure to heavy metals may occur through natural sources such as weathering and volcanic eruptions.[4] It may also occur from anthropogenic activities such as mining, oil refining, use of leaded petrol, airborne dust, arbitrary discarding and burning of toxic waste, among others.[5] Indirect exposure occurs when heavy metals in the environment build up in the food chain, predisposing humans to various diseases.[6] Among the sources of heavy metal build up in the food chain are vegetable species.

Vegetables are a group of food plants that are diverse and vary immensely in energy and nutritional content.[7] Vegetables are rich in dietary fiber, which is linked to reduced cases of cardiovascular disease and obesity.[7] They are also important sources of micronutrients such as vitamins, minerals and phytochemical[8] However, several studies, including Onakpa *et al*. [9] and Latif *et al*. [10] showed that some vegetables could accumulate metals beyond recommended levels if planted in polluted soil. Heavy metals from industries and automobile exhaust may also contaminate vegetables during developmental stages, transport and marketing. [11] Some heavy metals most often found in vegetables include Cu, As, Cd, Pb, and chromium (Cr).[12,13] These vegetables may cause a gradual accumulation of metals to toxic levels in consumers. Thus, strategies to reduce the incidence of chronic diseases worldwide should include determination of the safety status of vegetables consumed worldwide with regards to heavy metal accumulation. Some studies have assessed heavy metal profiles and health risks of some vegetables sold in some markets in Lagos, but the results are inconsistent and varied from market to market. For example, Adu *et al*.[14] reported abnormal concentrations of Cu, Cd, Fe and Zn in some vegetables purchased from Agboju and Iba markets in Lagos. Similarly, some vegetables collected along the Nigeria-Benin Seme border in Lagos revealed abnormal levels of Pb, Cu, Fe, and Cr.[15] However, Ladipo and Doherty. [16] reported normal concentrations of selected heavy metals in some vegetables collected across markets in Lagos, including Mushin, Oyingbo, Oshodi, Iyana-Paja and Shomolu. Collectively, these studies showed that the safety of vegetables consumed in Lagos depends on the location of purchase. Thus, there is a need to assess the safety of all vegetables sold across various markets in the city. Even for those markets that have been reported safe, there is a need for continuous

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assessment because the ecosystem is dynamic and so also pollution. To the best of our knowledge, heavy metal profiles and health risk assessment of vegetables sold in Ogba, Ketu and Ikorodu in Lagos have not been evaluated. Therefore, this study was initiated to evaluate the levels and health risks of Cu, Pb, Cd, Cr and nickel (Ni) in moringa (*Moringa oleifera*), fluted pumpkin (*Telfairia occidentalis*) and roselle (*Hibiscus sabdariffa*) consumed in Lagos, Nigeria.

Materials and Methods

Description of the Study Site

This study was carried out in Lagos metropolis, Southwestern Nigeria. Lagos is the former capital of Nigeria, on latitude 6° 27' 55.5192" N and longitude 3° 24' 23.2128" E (Figure 1). Lagos is a major commercial hub in Africa and its economy would rank fifth largest if compared to countries in the continent. [17] According to Lagos State Government, Lagos is the most densely populated city in Nigeria. However, the Federal Government of Nigeria through a population census conducted in 2006 disputed this claim and ranked the city behind Kano. Lagos State shares boundaries with Ogun State in the north and east as well as the Republic of Benin in the west and the Atlantic Ocean in the south. The vegetation of the state is tropic with a short dry season between December and February and a long rainy season between March and November.

Ikorodu, one of the selected sites, is the headquarters of Ikorodu Local Government in the north-east of Lagos State. The town is steadily growing and is home to some heavily polluting industries such as textile and steel companies. Ketu, another study site, is in the Kosofe Local Government Area of the state. It is cosmopolitan and hosts the largest fruit and vegetable market in the state. Ogba, the third selected site, is densely populated and located in Ikeja Local Government Area. It is in the heart of Lagos and has a popular Sunday market patronized by people from all over Lagos. The traffic in the area is very heavy and is also home to some industries and shopping malls.

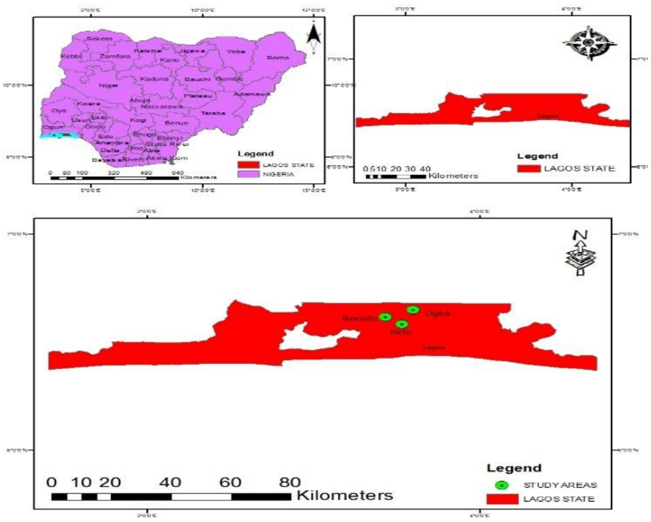

Figure 1: Maps of Nigeria and Lagos Showing the Study Areas

Collection and Preparation of Vegetable Samples

Ten (10) samples of each vegetable, *Moringa oleifera, Telfairia occidentalis* and *Hibiscus sabdariffa,* were purchased every other week between August and October 2019 from different markets in Ketu, Ikorudu and Ogba. In all, a total of 50 samples were collected for each vegetable in the various markets. The vegetables were carried to the laboratory in pre-washed polyethylene bags. The edible parts, including the leaves and young stems, were washed gently to remove impurities and subsequently sun dried for 14 days. [18] The dried materials were thereafter milled into a fine powder, labeled accordingly and kept in a desiccator for further analysis.

Heavy metal Analysis

One (1) g powder of each vegetable was transferred into a pre-washed 100 mL beaker containing analytical grade 25 mL aqua-regia and 5 mL 30% H_2O_2. [19] The mixture was digested at 80°C until a homogenous solution was obtained. The solution was allowed to cool, after which it was filtered and diluted to 50 mL with deionised water.[20] The filtrate was then subjected to atomic absorption spectroscopy using a spectrophotometer (UNICAM Model 969) to determine its levels of copper (Cu), lead (Pb), cadmium (Cd), chromium (Cr) and nickel (Ni).

Quality Control

Background contamination of the samples was checked to ensure accuracy of data. Blank samples were analyzed after five samples and all analyses were replicated six times. Precision and accuracy of analysed metals were checked against standard reference material for every heavy metal.

Health Risk Evaluation

The health risks of daily exposure to the selected heavy metals in the vegetables were determined by calculating daily intake of the metals (DIM), [21] as well as the health risk index (HRI)[22] and the target hazard quotient (THQ).[23, 24]

The DIM can be described as the concentrations of the metal lodged into the body based on the weight of the consumer and is calculated by the formula below:

$$DIM = \frac{CHM \times CF \times DIV}{ABV}$$

Where CHM is the concentrations of heavy metals in the vegetables (mg/kg), CF is the conversion factor, DIV is the daily intake of vegetables, and ABW is the average body weight of the consumers. The CF of 0.085 was used to convert the fresh vegetable weight to dry weight, [25] while 98 g per person per day and 65 kg body weight were considered for the DIV and ABW respectively.[26]

$$HRI = \frac{DIM}{RFD}$$

Where RFD is the oral reference dose. According to USEPA, [27] RFD for Pb, Cd, Cu, Cr and Ni are 0.0035, 0.001, 0.040, 1.5 and 0.020 mg/kg/day, respectively. A HRI value greater than 1 was considered not safe.

$$THQ = \frac{EF \times ED \times DIV \times CHM}{RFD \times ABW \times TA} \times 10^{-3}$$

Where EF is the exposure frequency (350 days/year), ED is the exposure duration in which 54 years was considered the average life span of Nigerian, [26] and TA is the average exposure time for non-carcinogens (ED x 365 days/year). THQ is the estimate of exposure to a pollutant and level at which no negative effects are expected. It is an estimate of the non-carcinogenic risk level of exposure to a single pollutant, and a THQ value greater than 1 is considered toxic.[28]

Statistical Analysis

Descriptive statistics were used to summarize data collected from sampling sites as mean ± standard errors (SE). The graphs were drawn using Minitab software, version 7.0.

Results and Discussion

Levels of Selected Heavy Metals in the Vegetable Species

Tables 1-3 show the levels of Cu, Cd, Ni, Pb, and Cr in the three vegetable species purchased from the markets in the studied areas.

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Except for Cd which was absent in the *T. occidentalis* samples, the metals were recorded at permissible limits in the three vegetable species across the markets. These results agree with Ladipo and Doherty [16] who detected permissible levels of Cd and Zinc (Zn) in *T. occidentalis* collected in some markets in Lagos. Adu *et al.* [14] also found traces of some heavy metals, including Pb, Cd, Cu, and Cr in some vegetables consumed in Lagos. However, the results contradict Atayese *et al*. [29] who reported abnormal concentrations of Pb and Cd in Amaranthus purchased along two major highways in Lagos. Abnormal concentrations of Pb in some fruits collected from markets in Ketu and Ikorodu were also reported by Ogunkunle *et al*. [30] Though the results of the current study suggest the vegetables may pose no risk to consumers regarding the evaluated metals, in a strict term, there are no safe levels for most heavy metals. Heavy metals may accumulate gradually to toxic levels in biological systems. As such, consumers, farmers, and marketers in the areas should ensure that all sources of heavy metal exposures are removed. One important route of heavy metal contamination is the use of wastewater for irrigation. Some other important sources of heavy metals in vegetables are their growth media, including soil, air, and nutrient solutions. [31] Heavy metal contaminations of vegetables can also occur through atmospheric pollution in the form of metal containing aerosols. [32] Vegetable grown in industrial areas and along roadsides may also be contaminated with heavy metals.

Figures 1-3 compared the three studied areas based on the concentrations of the heavy metals in each vegetable species. Figure 1 shows *M. oleifera* from Ketu had the highest concentrations of Pb, while Cd, Ni, and Cr were highest in *M. oleifera* from Ogba. *M. oleifera* from Ikorodu had the highest concentrations of Cu. These show that *M. oleifera* from Ogba were more contaminated than other markets. In Figure 2, *T. occidentalis* from Ikorodu had the highest concentrations of Cu, Ni, Pb and Cr, making *T. occidentalis* from the area the most contaminated among the three studied areas. Figure 3 reveals that *H. sabdariffa* from Ikorodu had the highest concentrations of Cu, while Cd, Ni, Pb, and Cr were highest in *H. sabdariffa* from Ogba, making Ogba samples the most contaminated. These observations show that the vegetable species from Ogba were more contaminated than others, while Ketu were the least. This is understandable because Ogba is more cosmopolitan with more traffics and small-scale industries than other studied areas. This suggests that transportation and marketing could be the major entry points of heavy metals. One would have expected the vegetables from Ikorodu to be more contaminated than others because the town has more big companies. This could mean that the vegetables in Ikorodu markets are grown far away from the town or companies.

Health Risk Assessment of Daily Consumption of the Vegetables

The daily intake of the metals by residents of Ogba, Ikorodu, and Ketu in Lagos via the consumption of the vegetables is presented in Table 4. The daily intake of Cd through the consumption of *M. oleifera* and *H. sabdariffa* exceeded the recommended limits and so did the daily intake of Pb through the consumption of all the vegetable samples. Other variables were within the recommended limits. These show that consumption of the vegetables may predispose consumers to Pb and Cd toxicities. However, Table 5 reveals that only Cd in *H. sabdariffa* and Pb in *T. occidentalis* had HRI of 1 and 2, respectively, suggesting that the two vegetables might pose a health threat. Lead toxicity can affect every organ and enzyme system, particularly in children.[34, 35] Cadmium poisoning can also cause multi-organ damage and death.[36, 37] However, the THQ of all the metals through the consumption of the vegetable species are less than1. This indicates that all the vegetables may not induce a serious health problem in residents of the areas aged 54 or less (average life span of Nigerians). But in reality, many Nigerians live far above 54 years, and this subgroup might be at an increased risk.

Table 1: Levels of the Selected Heavy metals (mg/kg) in the Vegetables Purchased from Ketu Markets

Vegetable	Cu	Cd	Ni	Pb	Cr
M. oleifera	0.414 ± 0.001	0.002 ± 0.000	0.004 ± 0.000	0.063 ± 0.0003	0.023 ± 0.0003
T. occidentalis	0.218 ± 0.0003	ND[a]	0.005 ± 0.000	0.032 ± 0.0003	0.019 ± 0.0003
H. sabdariffa	0.336 ± 0.0003	0.003 ± 0.0003	0.002 ± 0.000	0.032 ± 0.0003	0.169 ± 0.0003
Standard [33]	40	0.1	5.0	0.3	2.30

Values were expressed as Mean ± SE; a = Not Detected; 33 = World Health Organization

Table 2: Levels of the Selected Heavy metals (mg/kg) in the Vegetables Purchased from Ikorodu Markets

Vegetable	Cu	Cd	Ni	Pb	Cr
M. oleifera	0.443 ± 0.0007	0.002 ± 0.000	0.002 ± 0.000	0.028 ± 0.0003	0.032 ± 0.0006
T .occidentalis	0.222 ± 0.0007	ND[a]	0.008 ± 0.000	0.036 ± 0.0007	0.020 ± 0.0003
H. sabdariffa	0.43 ± 0.0003	0.002 ± 0.0003	0.003 ± 0.000	0.013 ± 0.0003	0.232 ± 0.0003
Recommended [33]	40	0.1	5.0	0.3	2.30

Values were expressed as Mean ± SE; a = Not Detected; 33 = World Health Organization

Table 3: Levels of Selected Heavy metals (mg/kg) in the Vegetables Purchased from Ogba Markets

Vegetable	Cu	Cd	Ni	Pb	Cr
M .oleifera	0.398 ± 0.0005	0.003 ± 0.000	0.005 ± 0.000	0.016 ± 0.0003	0.033 ± 0.0003
T. occidentalis	0.202 ± 0.0007	ND[a]	0.006 ± 0.000	0.033 ± 0.0003	0.016 ± 0.0003
H. sabdariffa	0.177 ± 0.0003	0.012 ± 0.0003	0.011 ± 0.000	0.039 ± 0.0003	0.271 ± 0.0003
Recommended [33]	40	0.1	5.0	0.3	2.30

Values were expressed as Mean ± SE; a = Not Detected; 33 = World Health Organization

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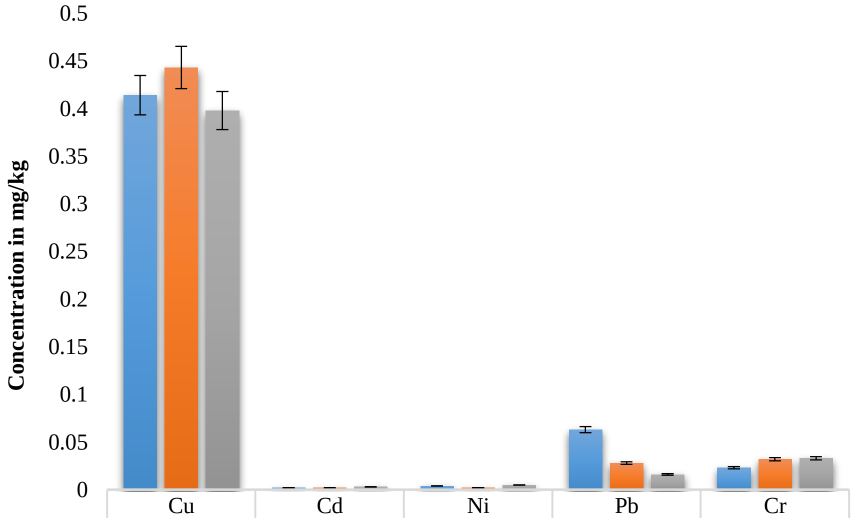
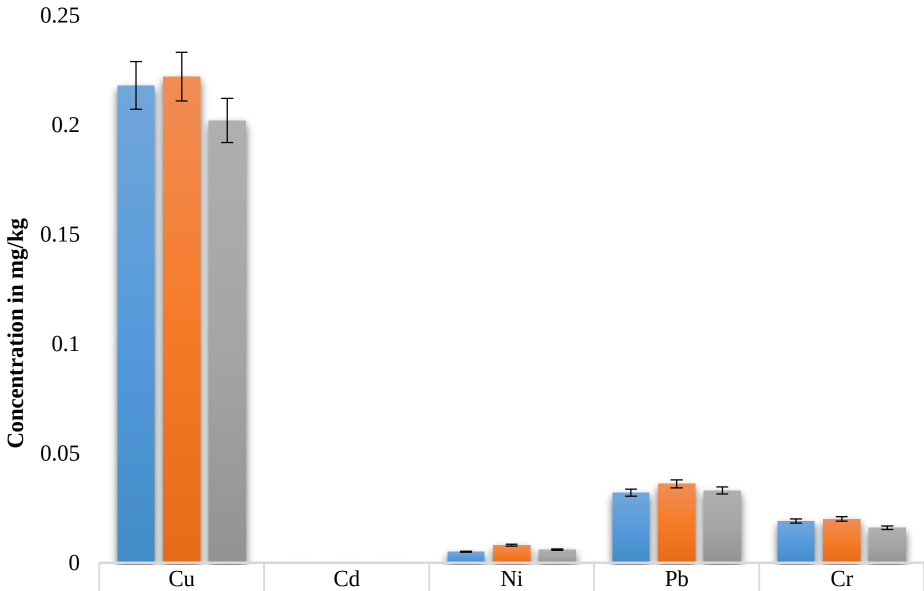


	Cu	Cd	Ni	Pb	Cr
Ketu Market	0.414	0.002	0.004	0.063	0.023
Ikorodu Market	0.443	0.002	0.002	0.028	0.032
Ogba Market	0.398	0.003	0.005	0.016	0.033

Ketu Market Ikorodu Market Ogba Market

Figure 1: Concentrations (mg/kg) of Heavy Metals in *M. oleifera* from Ketu, Ikorodu and Ogba Markets.



	Cu	Cd	Ni	Pb	Cr
Ketu Market	0.218	0	0.005	0.032	0.019
Ikorodu Market	0.222	0	0.008	0.036	0.02
Ogba Market	0.202	0	0.006	0.033	0.016

Ketu Market Ikorodu Market Ogba Market

Figure 2: Concentrations (mg/kg) of Heavy Metals in *T. occidentalis* from Ketu, Ikorodu and Ogba Markets.

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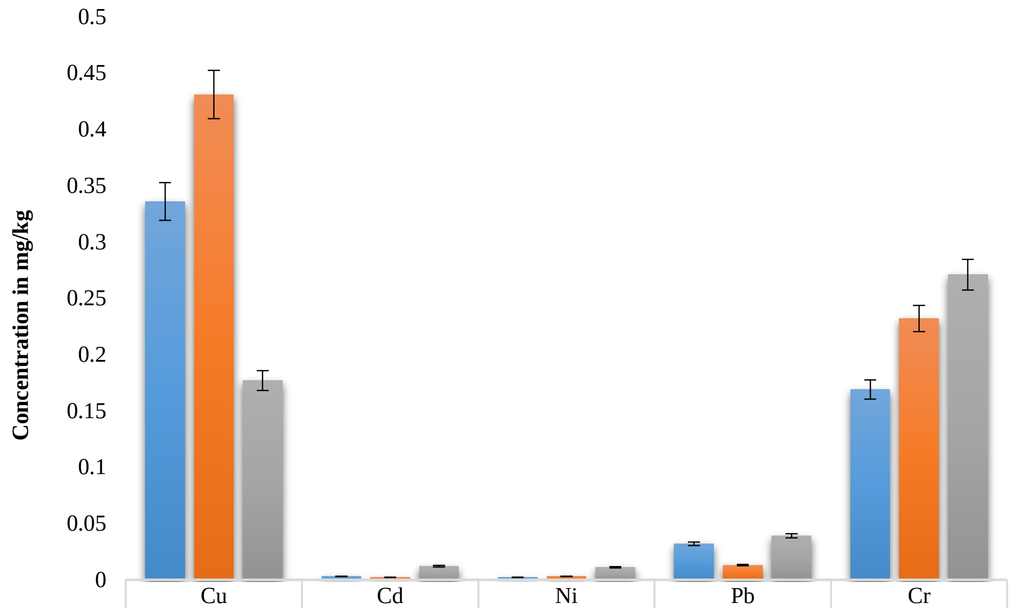

	Cu	Cd	Ni	Pb	Cr
Ketu Market	0.336	0.003	0.002	0.032	0.169
Ikorodu Market	0.431	0.002	0.003	0.013	0.232
Ogba Market	0.177	0.012	0.011	0.039	0.271

Ketu Market Ikorodu Market Ogba Market

Figure 3: Concentrations (mg/kg) of Heavy Metals in *H. sabdariffa* from Ketu, Ikorodu and Ogba Markets.

Table 4: Daily Intake Rate (mg person-^{1}day-^{1}) of Heavy Metals in *M. oleifera*, *T. occidentalis* and *H. sabdariffa* in Ketu, Ikorodu, and Ogba, Lagos

Vegetable	Cu	Cd	Ni	Pb	Cr
M. oleifera	0.418	0.002	0.004	0.036	0.029
T. occidentalis	0.214	0.000	0.006	0.079	0.018
H. sabdariffa	0.315	0.006	0.005	0.028	0.201
Recommended [38]	0.900	0.000	0.500	0.000	-

Table 5: Health Risk Index (HRI) and Target Hazard Quotient (THQ) of the Heavy Metals in *M. oleifera*, *T. occidentalis* and *H. sabdariffa* in Ketu, Ikorodu, and Ogba, Lagos

Vegetable	Cu		Cd		Ni		Pb		Cr	
	HRI	THQ	HRI	THQ	HRI	THQ	HRI	THQ	HRI	THQ
M.oleifera	0.90	0.010	0.20	0.002	0.02	0.00	0.86	0.010	0.001	0.00
T.occidentalis	0.45	0.005	0.00	0.00	0.05	0.0003	2.00	0.022	0.001	0.00
H..sabdariffa	0.66	0.008	1.00	0.006	0.02	0.0002	0.57	0.008	0.011	0.00

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Conclusion

The results showed that *M. oleifera*, *T. occidentalis*, and *H. sabdariffa* sold in selected markets in Ogba, Ikorodu and Ketu in Lagos contain traces of Pb, Cu, Cd, Cr, and Ni. Health risk assessment of these metals showed that prolonged consumption of the vegetables may predispose consumers in the areas to Pb and Cd toxicity. However, the THQ of all the metals were less than 1, indicating that the metals may not induce a serious biological effect in residents aged 54 or below (the average life span of Nigeria). But practically, many Nigerians, including residents of the studied areas live above 54 years, thus this subgroup may be at an increased risk of heavy metal exposure from the vegetables. The longer a resident lives, the greater the risk. On average, the vegetables from Ogba were more contaminated than others, maybe because the area is more cosmopolitan. Though all the metals are recorded at permissible levels, in strict terms, most heavy metals have no safe doses. Thus, farmers, marketers and consumers in the city should ensure all entry points of heavy metals in the vegetables are removed. These can be achieved by reducing exposure of the vegetables to automobile exhausts, remediating the farmlands, not planting the vegetables close to roads, industries and dumpsites. Marketing of vegetables should not be done in or close to dirty environments such as mechanic workshops and battery chargers, among others. While we recommend confirmatory studies, agencies in charge of public and environmental health in the studied areas should ensure the safety of vegetables and other foods sold in the selected markets. Similar studies should be carried out periodically because ecosystem is dynamic and so does environmental pollution. Studies should also be done on metals and vegetables not evaluated in this study.

Conflict of interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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