

An Assessment of the Health Risks of Trace Element Exposure from Consuming Leafy Vegetables

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ABSTRACT

Leafy vegetables are a source of many nutrients needed for growth. However, they could pose health risks when contaminated with trace elements. Several studies have evaluated the concentration of trace elements in leafy vegetables. However, their health risks to humans are less evaluated. Thus, this study assessed the potential health risks of consuming *Telfairia occidentalis*, *Celosia argentea*, *Corchorus olitorius*, *Talinum triangulare*, and *Vernonia amygdalina*, based on trace element content reported by selected studies in Lagos State, Nigeria, sourced from academic databases. Cadmium (Cd), lead (Pb), chromium (Cr), copper (Cu), zinc (Zn), and iron (Fe) were evaluated. Daily Intake (EDI) of these trace elements and Target Hazard Quotient (THQ) were estimated. The averages of the results were also mapped at the LGA level in Lagos state to present a spatial view of where the results were obtained. The results showed that the EDIs were below the Maximum Tolerable Daily Intake (MTDI) except for Fe and Ni. However, the estimated THQs were generally greater than one. THQ values for Cu and Zn ranged between 0.8 and 2. Zn THQ was less than 1 in *T.occidentalis* and *C. olitorius*. A THQ greater than one implies that the vegetable poses non-carcinogenic risks. Hence, these vegetables pose potential health risks if consumed at the estimated quantity and rate. Thus, continuous monitoring of these vegetables and their sources of contamination is necessary. Also, there is a need for public awareness of the vulnerability of leafy vegetables to trace metal contamination, and mitigation measures should be explored.

Keywords: Leafy vegetables, Trace elements, Health risks

Introduction

Leafy vegetables are a source of essential vitamins that supplement other food nutrients. However, leafy vegetables are highly vulnerable to trace metal contamination because trace metals are major contaminants of leafy vegetables.

Insufficient or excessive dietary intake of essential nutrients has been identified as the cause of malnutrition (Elsa *et al.*, 2023). This is described as inadequate, surplus, or imbalanced nutrient range influencing regular body composition and function, resulting in adverse health outcomes (Younis *et al.*, 2015). Excessive dietary intake of trace elements poses several human health risks (Gebeyehu and Bayissa,

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2020). Cd competes with divalent elements (Cu, Zn, or Fe) and can accumulate in the kidney, resulting in renal toxicity (EFSA, 2015). Lead can result in headache, irritability, and abdominal pain, affect the central nervous system, and can be more impactful in children (Mishra *et al.*, 2023). Chromium can result in cardiovascular diseases such as bronchitis and asthma (Shekhawat, 2015). Nickel causes kidney, lung, cardiovascular diseases, and nasal and lung cancer (Genchi *et al.*, 2020). Copper, Zinc, and Iron are essential elements, but at high concentrations could also have toxic effects by altering the functions of several organs and systems (Ohiagu *et al.*, 2022).

Previous studies have examined trace element levels in vegetables in Lagos state (Sobukola *et al.*, 2010; Ladipo & Doherty, 2011; Doherty *et al.*, 2012; Babatunde *et al.*, 2014; Adesuyi *et al.*, 2015; Adewale *et al.*, 2023). Most reported that trace element concentrations in leafy vegetables in Lagos were below the existing permissible limits, while a few reported higher values (Alani *et al.*, 2020; Adewale *et al.*, 2023). However, these studies did not evaluate the health risks associated with their consumption. Several factors have been identified to assess the health risks of trace elements from food. This includes body weight, age, exposure length, quantity, acquisition method, health status, and the number of heavy elements that one is exposed to (Mishra *et al.*, 2023).

Some studies have evaluated the trace elements' health risks with some measurable parameters, which were adopted in this study (Gebeyehu & Bayissa, 2020; Gupta *et al.*, 2021; Ojiego *et al.*, 2022). In addition, research on health risks can express the need to review the guidelines' values if there are health risks from concentration values that are even below permissible limits.

Thus, this study investigated the health risks of consuming selected leafy vegetables in Lagos State. The evaluated trace metals were Cd, Cr,

Pb, Ni, Cu, Zn, and Fe. The objectives were to estimate the daily intake of trace metals from these leafy vegetables and evaluate their non-carcinogenic hazard risks.

2.0 Materials and Methods

The study was based on the results of previous studies on trace elements' concentration in *T. occidentalis*, *C. argentea*, *C. olitorius*, *T. triangulare*, and *V. amygdalina* in Lagos state. Hence, research articles on trace metals assessment in leafy vegetables in Lagos were consulted from academic databases from 2010–2023 [Sobukola *et al.*, (2010), Ladipo and Doherty, (2011), Doherty, *et al.*, (2012), Oluwole *et al.*, (2013), Babatunde *et al.*, (2014), Adesuyi *et al.*, (2015), Adewale *et al.*, (2022), Alani *et al.*, (2020), Ebabhi *et al.*, (2020), Adewale *et al.*, (2023)].

The selected studies were also limited to studies that used atomic absorption spectrophotometry (AAS). The data from all selected articles were averaged for each vegetable type. The EDI, THQ, and HRI were calculated. Also, studies within a local government area of the state were averaged irrespective of the vegetable type to present the spatial distribution of the evaluated parameters using the ArcGIS software.

The intake of trace metals daily from vegetable consumption was estimated according to Equation 1 (Gupta *et al.*, 2021).

$$EDI = \frac{C \times IR \times EF \times ED}{BW \times AT} \times 10^{-3} \dots\dots \text{Eqn 1}$$

EDI is the estimated daily intake of metals (mg person⁻¹ day⁻¹), C is the average trace metals' concentration in the same vegetable type (mg kg⁻¹), IR is ingestion rate (g person⁻¹ day⁻¹), EF is exposure frequency (day year⁻¹), ED is the exposure duration (years), BW is the mean adult body weight (Kg), and AT is average time (NCR) (days). The values adopted were based on previous studies and guidelines, as shown in Table 1.

Table 1: Exposure variables with the values adopted in this study and references

Variables	Values	References
C (mg/Kg dry weight)	Average value for each vegetable type	Selected studies in Lagos state from 2011 to 2023
IR (g/day)	90	FAO/WHO 1999
EF (days)	365	Gupta <i>et al.</i> , 2021, Gebeyehu & Bayissa, 2020.
ED (years)	70	Gupta <i>et al.</i> , 2021
BW (Kg)	60	FAO/WHO 1999, WHO 1996
AT (days)	70*365 (25550)	Gupta <i>et al.</i> , 2021

The human health risk to metals is expressed as the “Target Hazard Quotient” (THQ_M) as described by Gebeyehu & Bayissa (2020), and it is calculated as:

$$THQ_M = \frac{EDI}{RfD_M} \dots\dots\dots \text{Eqn 2}$$

THQ_M is the target hazard quotient from the ingestion of specific trace metals. EDI is the estimated daily intake of the metals (mg kg⁻¹ d⁻¹), and RfD_M is the metal oral reference dose (mg kg⁻¹ d⁻¹), with values shown in Table 2. A potential risk is indicated for each metal when the THQ_M value exceeds the corresponding maximum tolerable daily intake (MTDI) or THQ_M > 1 (Gupta *et al.*, 2021).

Table 2: Trace metals and their oral reference doses

Trace metals	Oral reference dose (mg kg ⁻¹)	References
Copper (Cu)	0.04	Javed & Usmani, 2016
Zinc (Zn)	0.3	Javed & Usmani, 2016
Cadmium (Cd)	0.001	Antoine <i>et al.</i> , 2017
Lead (Pb)	0.0035	Chang <i>et al.</i> , 2014
Chromium (Cr)	0.003	Chang <i>et al.</i> , 2014
Iron (Fe)	0.7	Javed & Usmani, 2016
Nickel (Ni)	0.008	Haber <i>et al.</i> , 2000

Results

The estimated daily intake of trace metals (EDI) in mg day⁻¹ kg⁻¹ body weight, as described in Equation 1, is presented in Table 3.

The EDI, as shown in Table 3, showed that Cd, Pb, Cu, and Zn were below the maximum tolerable daily intake, while Cr, Fe, and Ni had higher values above the MTDI. Cd, Cr, and Pb are highly toxic and cause diverse health problems even at low concentrations (Rajkumar *et al.*, 2022). The target hazard quotients (THQ_M) calculated from the estimated EDI are presented in Table 4.

The metals' THQ values as presented in Table 3, were above one (1) except for the THQ of Zn in *T. occidentalis* and *C. olitorious*, with values of 0.33 and 0.8, respectively. A THQ index greater than one > 1 implies a non-carcinogenic risk.

Moreover, a spatial representation of the levels of trace elements in the vegetables is presented in Figure 1. This summarizes the trace metal levels irrespective of the vegetables. The mapped EDI and THQ, as presented in Figures 2 and 3, respectively, varied across the LGAs. The EDI depends on trace metal concentration, while the THQ depends on the oral reference dose, which is determined by the toxicity of each element. The HRI is the average of all THQs in a specific vegetable sample and was also presented based on the different LGAs, as shown in Figure 4. Places with THQs and HRIs greater than one (1) have potential health risks.

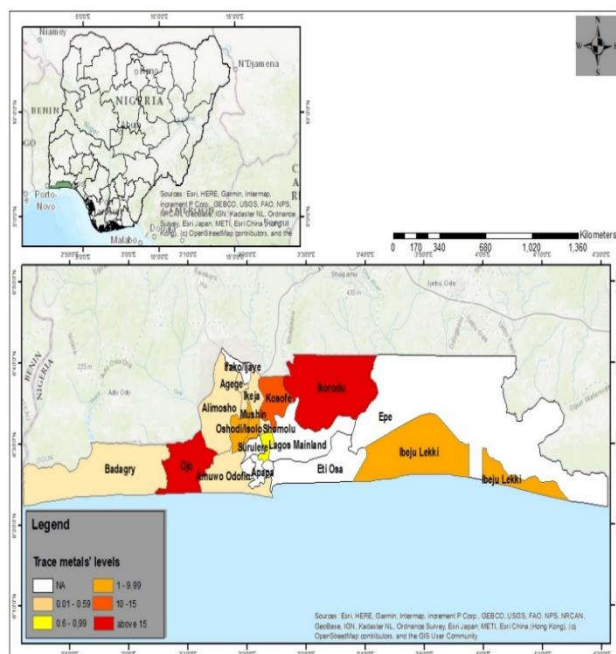
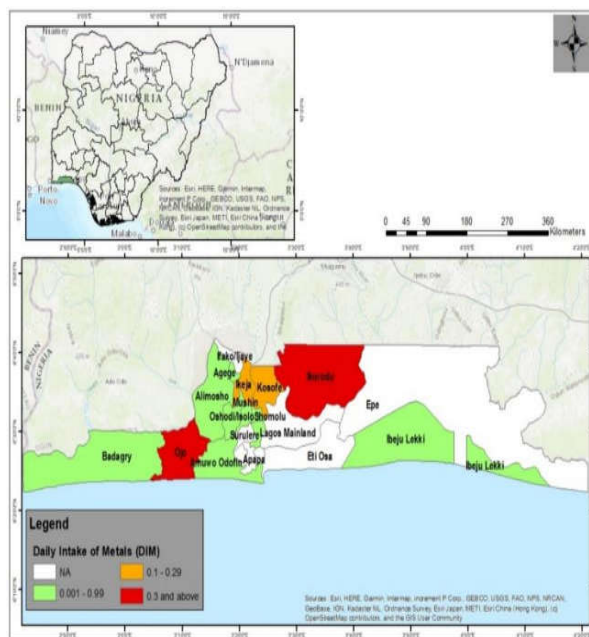
Table 3: Estimated daily Intake (EDI) of metal concentrations in leafy vegetables based on previous studies in Lagos state

Leafy vegetables	EDI Cd	EDI Cr	EDI Pb	EDI Cu	EDI Zn	EDI Fe	EDI Ni
<i>T. occidentalis</i>	0.01	0.46	0.13	0.06	0.10	16.90	0.09
<i>C. argentea</i>	0.01	0.63	0.10	0.06	0.32	25.07	0.13
<i>C. olitorius</i>	0.01	0.35	0.09	0.06	0.24	11.18	0.14
<i>T. tiangulare</i>	0.01	0.27	0.11	0.08	0.54	62.88	0.18
<i>V. amygdalina</i>	0.00	NA	0.00	0.00	0.00	NA	0.00
MTDI (MG/DAY)	0.02-007	0.035-0.2	0.21	2.5-3	60-65	15	0.04

NA Not Available; *Maximum Tolerable Daily Intake (MTDI); Source: Gebeyehu & Bayissa 2020

Table 4: The THQ of trace metal concentrations in leafy vegetables based on previous studies in Lagos state

Leafy vegetables	THQ Cd	THQ Cr	THQ Pb	THQ Cu	THQ Zn	THQ Fe	THQ Ni
<i>T. occidentalis</i>	10	153.33	37.14	1.5	0.33	24.14	11.25
<i>C. argentea</i>	10	210	28.57	1.5	1.07	35.81	16.25
<i>C. olitorius</i>	10	116.67	25.71	1.5	0.8	15.97	17.5
<i>T. tiangulare</i>	10	90	31.43	2	1.8	89.83	22.5
<i>V. amygdalina</i>	0	NA	0	0	0	NA	0.01

**Figure 1:** Average trace metal levels in leafy vegetables by selected studies in Lagos State**Figure 2:** Estimated daily intake of trace metals from selected studies in Lagos State.

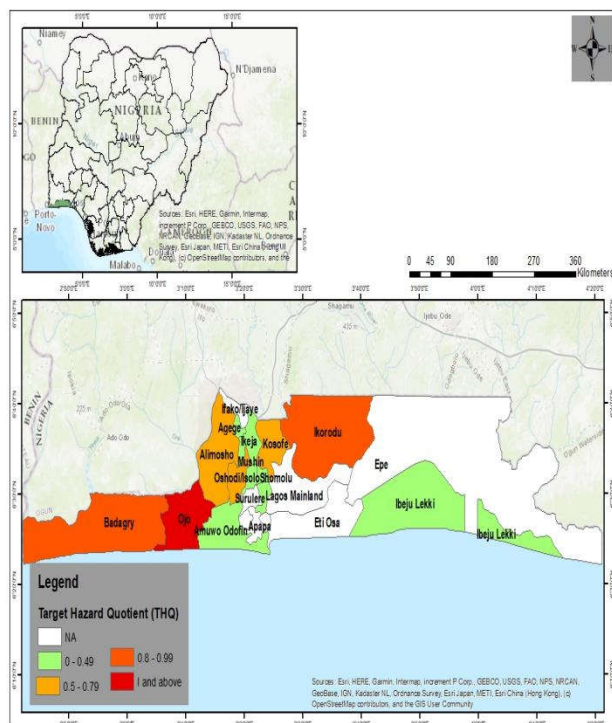


Figure 3: Target Hazard Quotient from the consumption of leafy vegetables in Lagos State

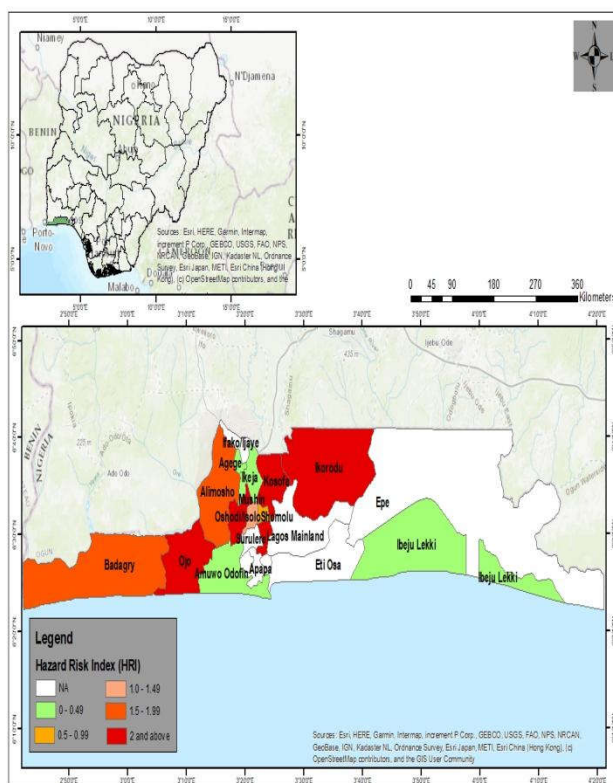


Figure 4: Hazard risk index of selected leafy vegetables in Lagos state.

Discussion

The EDIs of the trace metals were above the oral reference dose except for Zn. The oral reference dose represents the maximum oral intake of these metals that can be tolerated daily without side effects (USEPA, 2002; Anjum *et al.*, 2021). However, they were below the Maximum Tolerable Daily Intake (MTDI). The MTDI represents the maximum daily amount of metal that is safe for human consumption (Shaheen *et al.*, 2016). Humans are exposed to trace metals through ingestion, inhalation, and dermal contact (Shahid *et al.*, 2015). Thus, the MTDI considers other pathways of exposure to trace metals. The non-carcinogenic human health risks expressed as THQ_M were higher than one (1), except for the THQ of Zn. The THQ of Cr was the highest, followed by Ni. This is because Cr and Ni are highly toxic and, hence, pose greater risks even at lower concentrations. The observed THQ values greater than one (1) of the vegetables differ from studies on leafy vegetables in other countries (Ape, 2018; Gupta *et al.*, 2021). The hazard rises as the THQ increases (Anthoine *et al.*, 2017). The observed concentration levels could be associated with farming practices and environmental contamination. It is also worth noting that these vegetables had more than one metal, which increases the HRI. However, the number of trace metals examined in different studies was not the same, and this is acknowledged as a limitation of the study.

The map provides information on areas explored and their trace metal levels. Therefore, the high-risk areas are Ikorodu and Ojo Local Government Areas of Lagos State. These areas are associated with high traffic and industrial activities, which may contribute to the high contamination with trace metals, in addition to farming practices. The micronutrients (Cu, Zn, and Fe) were above the oral reference doses. However, Cu and Zn were below the MTDI.

Conclusion

Assessment of metals in leafy vegetables is necessary for public health and safety. This should not be limited to the concentration levels of the elements. This study showed that leafy vegetables in Lagos pose potential health risks of trace metals and require regular monitoring. Thus, studies on the different sources of contamination and farming practices should be explored. Also, there is a need for public awareness of the vulnerability of leafy vegetables to trace metal contamination. This will guide

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- farming practices to mitigate contamination. Moreover, improvement in pollution control measures, policy reviews, and intervention on environmental assessment are necessary. The development of strategies to mitigate the contamination of food resources should be explored, as this is one of the primary pathways of human exposure to trace metals.
- Conflict of Interest:**
The authors declared no conflict of interest.
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