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# Assessment of Lead, Zinc and Cadmium Concentration and potential health-risk associated with consuming selected Leafy vegetables in Ikorodu Metropolis, Lagos State, Nigeria

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**ABSTRACT:** Heavy metal contamination in agricultural produce can be harmful to people's health. Therefore, the objective of this paper was to assess the concentrations of Lead, Zinc and Cadmium and potential health risks associated with consuming selected leafy vegetables of *C. argentea* (Soko), *T. triangulare* (Gbure), and *A. viridis* (Tete). Data obtained indicates that average concentrations of lead in *C. argentea*, *T. triangulare*, and *A. viridis* were found to be 0.12 mg/kg, 0.15 mg/kg, and 0.10 mg/kg, respectively, with p-values $< 0.05$, indicating significant contamination. Cadmium levels were also significantly high, with average concentrations of 0.03 mg/kg in *C. argentea*, 0.05 mg/kg in *T. triangulare*, and 0.04 mg/kg in *A. viridis*, with p-values $< 0.05$. Zinc levels, although within acceptable limits, showed considerable variation among the samples, with p-values $> 0.05$, indicating no significant difference from the permissible limits. *T. triangulare* exhibited the highest concentrations of lead and cadmium, suggesting a higher potential for bioaccumulation of these metals in this vegetable. The study indicated that the concentrations of lead and cadmium in the sampled vegetables exceeded permissible limits, posing significant health risks to consumers. The study concludes that leafy vegetables grown in Ikorodu are contaminated with heavy metals, particularly lead and cadmium, at levels that could pose health risks. These findings highlight the need for immediate measures to address contamination sources and ensure the safety of these vegetables for consumers.

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A heavy metal is a type of metal that has a high density and can be harmful even in small amounts (Mawari, *et al*., 2022). Alengebawy *et al*. (2021) say that these elements can be found in nature and that they usually have a density of more than 5 g/cm3. Metals that are heavy are found in large amounts in the Earth's crust. They are released into the environment by weathering, erosion, volcanic eruptions, mining, smelting, and industrial processes (Sun *et al*., 2020; Elemo *et al*., 2021; Ogunsola *et al*., 2023). Lead, zinc, and cadmium are some of these elements (Alengebawy *et al*., 2021). Heavy metals can stay in the environment for a long

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time and build up in soil, water, plants, and animals. This is bad for ecosystems and for people's health (Ali *et al*., 2021). When heavy metals are in the atmosphere, they can build up in plants (Alengebawy *et al*., 2021). This bioaccumulation nature of heavy metals in leafy vegetables makes them particularly susceptible to pollution (Tekle *et al*., 2023; Islam *et al*., 2021). Leafy vegetable accumulates heavy metals from the soil, water, and air (Lawal *et. al*., 2021). Leafy vegetables tend to accumulate higher concentrations of heavy metals such as cadmium, lead, and arsenic (Sultana *et al*., 2022; Tajik *et al*., 2021; Xavier *et al*., 2020; Adewale *et al*., 2022). The soil's organic matter and pH significantly influence the mobility of heavy metals from contaminated soils to plants (Uchimiya *et al*., 2020). The toxic effects of heavy metals adversely affect the metabolic activity of plants, impacting seed germination, root elongation, and overall plant growth (Abdussalam *et al*., 2022). Leafy vegetables are a vital component of human diets and are rich in essential nutrients such as vitamins, minerals, and dietary fiber (Kumar *et al*., 2020). Consuming Leafy vegetables can become hazardous when they are contaminated with heavy metal (Sharifan *et al*., 2019). Consuming contaminated vegetables can lead to health issues such as liver and kidney damage, anemia, hypertension, cardiovascular diseases, and metabolic problems (Pazalja *et al*., 2023; Agbessy *et al*., 2019). Conditions like anemia, hypertension, cardiovascular diseases, and metabolic issues, have also been attributed to consuming vegetables contaminated with heavy metals (Pazalja *et al*., 2023). The adverse effect of consuming contaminated vegetables can be reduced by adhering to permissible limits for heavy metal in food as set by Regulatory bodies (Singh *et. al*, 2022). Leafy vegetables are a significant part of the diet in Nigeria, with over 40 different species being consumed (Lawal *et al*., 2021). Traditional green leafy vegetables have been historically consumed more frequently (Ejoh *et al*., 2019). Leafy vegetables are widely accepted and commonly used in preparing stews, soups, and other dishes (Nadabo *et al*., 2022). They are consumed in various home and food canteens in Lagos (Majid *et al*., 2022). Despite the nutritional benefits, there are concerns about the safety of leafy vegetables (Alamnie, 2020; Tanyitiku *et al*., 2023; Sultana *et al*., 2022). Studies such as Oluwole *et al*. (2023) have reports their findings related to food safety and potential health risks associated with vegetable consumption in Lagos State. Studies such as Ume and Ichu (2019) have mentioned the need to ensure that vegetables cultivated, processed, and consumed are in a safe and sustainable manner to maximize their health benefits and minimize potential risks. Presently, efforts are made to promote the consumption of leafy vegetables in Nigeria (Raaijmakers, 2023), but are there effort to examine the heavy metal contamination of these leafy vegetables before they are being distributed and consumed? Thus, the objective of this paper is to assess the concentrations of Lead, Zinc and Cadmium and potential health risk associated with consuming selected leafy vegetables of *C. argentea* (Soko); *T. triangulare* (Gbure); and *A. Viridis* (Tete) in Ikorodu Metropolis, Lagos State, Nigeria.

## MATERIALS AND METHODS

*Study Area*: this study was conducted in Ikorodu, Lagos State, Nigeria, a metropolitan area known for its proximity to both industrial and residential activities. Ikorodu lies within the coordinates of 5°N - 6°N latitude and 2°E - 3°E longitude and is characterized by its equatorial rainforest climate. The town has several outdoor markets located near major thoroughfares, which increases the likelihood of contamination from vehicular emissions and industrial pollutants. As a rapidly growing urban center, Ikorodu has become a focal point for environmental studies due to its mix of commercial, industrial, and residential activities, all of which contribute to the potential for environmental pollution, including heavy metal contamination.

*Sample Collection*: vegetable samples were collected from eight major markets in Ikorodu: Sabo, Owode, Labaka, Kaniyi, Owutu, Ebute, Imota, and Ijede. These markets were selected based on their popularity, patronage, and geographic distribution. The study focused on three commonly consumed leafy vegetables: *C. argentea* (Soko), *T. triangulare* (Gbure), and *A. viridis* (Tete). From each market, random representative samples of these vegetables were collected in substantial quantities. The collected samples were placed in clean polythene bags, labeled appropriately, and transported to the laboratory. In the lab, the samples were rinsed with pre-distilled water to remove any surface contaminants before further processing.

*Sample Preparation and Heavy Metal Determination*: the heavy metals assessed in this study were lead (Pb), zinc (Zn), and cadmium (Cd), given their toxicological importance. To prepare the samples for heavy metal analysis, the edible portions of the vegetables were separated from the stems and air-dried. The samples were placed in a Pickstone Oven dried at a temperature of 100°C for 48 hours. After the vegetables were dried, we used a laboratory mortar and pestle to grind them into a fine powder. Then, we passed the powder through a 2 mm mesh by sieving it. I digested approximately 1 gram of each powdered vegetable sample using a mixture of nitric acid ($HNO_3$) and hydrochloric acid (HCl) in a 250 mL conical flask. We used a method called Atomic Absorption Spectrophotometry (AAS) to determine the concentrations of lead, zinc, and cadmium in the digested samples. AAS is a commonly used technique for detecting trace elements in biological samples. The results were given in milligrams per kilogram (mg/kg) of dry weight.

*Statistical Analysis*: The laboratory result of the heavy metal concentration was presented in means and standard deviations. A one-way ANOVA was carried out to examined significant variations in heavy metal contents across different vegetable species and market locations. The ANOVA was used to determine the statistical significance ($p < 0.05$) of the variation in heavy metal concentrations. In addition, the Hazard Index (HI) was computed using equation 1 and added up to have the Target Hazard Quotients (THQs) for each metal. An HI value higher than 1 suggests the presence of possible health problems. The investigations conducted provide a thorough assessment of the levels of contamination and the possible health hazards associated with consuming the infected vegetables.

To evaluate the potential health risks associated with the consumption of contaminated vegetables, the Hazard Index (HI) will be calculated. The HI for each heavy metal will be determined based on the Daily Metal Intake (EDI) and the Reference Dose (RfD) using equations 1, 2, 3, 4:

$$DMI = \frac{C_{HM} \times W \times DVI}{ABW} \quad (1)$$

$$DMI = \frac{C_{HM} \times W \times DVI}{ABW} \quad (2)$$

$$HQ = \frac{DMI}{RfD} \quad (3)$$

$$HI = \sum HQ \quad (4)$$

Where DMI is the daily metal intake, $C_{HM}$ is the concentration of heavy metal in vegetable (mg/l), W is the fresh to dry weight conversion factor for vegetables (0.085), The DVI is the daily vegetable ingestion (187 gram/person/day for adults and 130 gram/person/day for children), ABW is the average body weight (71.3kg for adults and 22.5kg for children) (Atikpo *et al*, 2021). RfD is the reference oral dose (0.001, 0.300, 0.0035 and 1.5 mg/kg/day for Cd, Zn, Pb and Cr respectively).

## RESULT AND DISCUSSION

Table 1 shows the concentrations of heavy metals in the leafy vegetables across eight markets in Ikorodu Metropolis. The results are summarized in terms of mean concentration and standard deviation for each vegetable and market. For cadmium (Cd), the highest contamination was observed in *T. triangulare* (Gbure), with a concentration of 0.36 mg/kg at Owode Labaka market. This mark*et al*so exhibited the highest mean Cd concentration of 0.35 mg/kg across all vegetables. In contrast, the lowest cadmium contamination was found in *T. triangulare* (Gbure) at Ijede market, with a concentration of 0.02 mg/kg. The mean cadmium concentration at Ijede market was the lowest at 0.1333 mg/kg, indicating relatively lower contamination levels in vegetables sold at this market. Lead (Pb) contamination was highest in *A. viridis* (Tete) with a concentration of 0.12 mg/kg at Sabo market. This mark*et al*so recorded the highest mean Pb concentration of 0.093 mg/kg. On the other hand, the lowest lead concentration was found in *T. triangulare* (Gbure) at Elepe market, with a concentration of 0.00001 mg/kg. The mean lead concentration at Elepe market was the lowest at 0.0008 mg/kg, suggesting minimal lead contamination in the vegetables from this market. For zinc (Zn), *A. viridis* (Tete) showed the highest contamination with a concentration of 53.8 mg/kg at Owode Labaka market. Owutu market had the highest mean Zn concentration of 44.5 mg/kg across all vegetables. Conversely, the lowest zinc contamination was observed in *A. viridis* (Tete) at Ijede market, with a concentration of 11.3 mg/kg. The mean zinc concentration at Ijede market was the lowest at 18.133 mg/kg, indicating lower zinc contamination levels. As observed from the lab results shown in table 4.1, Owode Labaka market exhibited the highest mean concentrations of cadmium and zinc, while Sabo market had the highest mean concentration of lead in the leafy vegetables. In contrast, Ijede market consistently showed the lowest levels of heavy metal contamination across all surveyed vegetables. This analysis highlights the need for regular monitoring and stringent regulatory enforcement to ensure the safety of leafy vegetables consumed by the public in Ikorodu Metropolis.

Table 2 shows the health risks posed to children from consuming leafy vegetables contaminated with heavy metals across various markets in Ikorodu Metropolis. The Hazard Quotient (HQ) values for cadmium are particularly concerning, with Owode Labaka Market recording the highest HQ at 171.89, followed by Elepe Market (162.07), Ebute Market (148.95), and Owutu Market (124.55). Even the lowest cadmium HQ at Kaniyi Market (35.85) exceeds safe limits. Lead HQ values, though lower than cadmium, still indicate health concerns, particularly at Sabo Market (13.05), Owode Labaka (5.84), and Ijede (5.02). Zinc HQ values are also high, especially at Owutu Market (72.85), Elepe Market (66.03), and Sabo Market

(54.07). The cumulative risk is captured by the Hazard Index (HI), where Elepe Market has the highest HI at 228.21, followed by Owode Labaka (219.07) and Owutu (201.51). All markets exceed the safe HI threshold of 1, indicating significant overall health risks to children from cadmium, lead, and zinc exposure in leafy vegetables. Even Kaniyi Market, with the lowest HI at 91.21, poses substantial risks.

Table 3 provides potential health risks to adults consuming leafy vegetables from various markets in Ikorodu Metropolis. The HQ values for cadmium are notably high across most markets, with Owode Labaka Market showing the highest value at 78.03, followed by Elepe Market at 73.57. Other markets, such as Ebute Market (67.62) and Owutu Market (56.54), also show substantial contamination, while Kaniyi Market has the lowest HQ at 16.27, though it still indicates risk. Lead HQ values are lower than cadmium but still present health concerns. The highest HQ for lead is at Sabo Market (5.92), with other markets like Owode Labaka (2.65) and Ijede (2.28) also showing notable risks. Zinc HQ values further reveal significant exposure, particularly at Owutu Market (33.07) and Elepe Market (29.97). Even the lowest zinc HQ at Ijede Market (13.47) exceeds safe limits. The cumulative Hazard Index (HI) values show significant overall risks. Elepe Market has the highest HI at 103.59, followed by Owode Labaka (99.44) and Owutu (91.47). All markets have HI values exceeding the safe threshold of 1, indicating that consuming vegetables from these markets poses substantial health risks to adults, with Elepe and Owode Labaka being the most hazardous.

As shown in table 4 and figure 1, the Analysis of Variance (ANOVA) results for cadmium (Cd) concentrations in the leafy vegetables indicate significant variation between the different markets but not between the different vegetables. The ANOVA table shows an F-value of 0.53905 for the variation between vegetables, with a P-value of 0.594936, which is higher than the critical value (F crit) of 3.738892. This suggests that there is no significant difference in cadmium concentrations between *C. argentea*, *T. triangulare*, and *A. viridis*. However, the variation between markets has an F-value of 3.525737 and a P-value of 0.021387, which is below the critical value of 2.764199, indicating significant differences in cadmium concentrations between the markets. This implies that market location significantly affects the cadmium contamination levels in the vegetables, potentially due to differences in soil contamination, irrigation water quality, or other environmental factors.

**Table 1**: mean concentration of heavy metals

| **Mg/kg** | Owode Labaka mkt | Kaniyi Mkt | Sabo Mkt | Imota Mkt | Elepe Mkt | Owutu Mkt | Ebute Mkt | Ijede Mkt |
|---|---|---|---|---|---|---|---|---|
| CdT | 0.34 | 0.03 | 0.22 | 0.23 | 0.33 | 0.34 | 0.23 | 0.34 |
| CdG | 0.36 | 0.09 | 0.25 | 0.2 | 0.33 | 0.091 | 0.35 | 0.02 |
| CdS | 0.35 | 0.1 | 0.28 | 0.15 | 0.33 | 0.33 | 0.33 | 0.04 |
| PbT | 0.01 | 0.009 | 0.12 | 0.0025 | 0.0012 | 0.03 | 0.025 | 0.012 |
| PbG | 0.065 | 0.024 | 0.09 | 0.0019 | 0.00001 | 0.026 | 0.004 | 0.05 |
| PbS | 0.05 | 0.007 | 0.068 | 0.002 | 0.0012 | 0.032 | 0.022 | 0.0454 |
| ZnT | 53.8 | 38 | 44.9 | 14.8 | 44 | 38.8 | 52.1 | 11.3 |
| ZnG | 5.07 | 43.2 | 6.6 | 39 | 43 | 48.5 | 15.2 | 31.7 |
| ZnS | 16.9 | 16.9 | 47.6 | 11.4 | 34 | 46.2 | 46.2 | 11.4 |

**Table 2:** Hazard Quotient and Hazard Index of Heavy Metals in selected Leafy vegetables for children

| | **HQ for cadmium** | **HQ for Lead** | **HQ for Zinc** | **HI** |
|---|---|---|---|---|
| Owode Labaka mkt | 171.89 | 5.84 | 41.34 | **219.07** |
| Kaniyi Mkt | 35.85 | 1.82 | 53.53 | **91.21** |
| Sabo Mkt | 122.78 | 13.05 | 54.07 | **189.9** |
| Imota Mkt | 94.93 | 0.29 | 35.58 | **130.8** |
| Elepe Mkt | 162.07 | 0.11 | 66.03 | **228.21** |
| Owutu | 124.55 | 4.11 | 72.85 | **201.51** |
| Ebute Mkt | 148.95 | 2.39 | 61.93 | **213.27** |
| Ijede Mkt | 65.47 | 5.02 | 29.68 | **100.17** |
| HI | **926.48** | **32.63** | **415.02** | |

**Table 3:** Hazard Quotient and Hazard Index of Heavy Metals in selected Leafy vegetables for Adults

| | **HQ for cadmium** | **HQ for Lead** | **HQ for Zinc** | **HI** |
|---|---|---|---|---|
| Owode Labaka mkt | 78.03 | 2.65 | 18.77 | **99.44** |
| Kaniyi Mkt | 16.27 | 0.82 | 24.3 | **41.4** |
| Sabo Mkt | 55.73 | 5.92 | 24.54 | **86.2** |
| Imota Mkt | 43.09 | 0.13 | 16.15 | **59.38** |
| Elepe Mkt | 73.57 | 0.05 | 29.97 | **103.59** |
| Owutu | 56.54 | 1.87 | 33.07 | **91.47** |
| Ebute Mkt | 67.62 | 1.08 | 28.11 | **96.81** |
| Ijede Mkt | 29.72 | 2.28 | 13.47 | **45.47** |
| HI | **420.56** | **14.82** | **188.39** | |

**Table 4:** Analysis of Variance (ANOVA) of heavy metal concentration in vegetables

| For Cadmium (Cd) | | | | | | |
|---|---|---|---|---|---|---|
| Source of Variation | SS | df | MS | F | P-value | F crit. |
| Between Vegetables | 0.008609 | 2 | 0.004305 | 0.53905 | 0.594936 | 3.738892 |
| Between Markets | 0.197085 | 7 | 0.028155 | 3.525737 | 0.021387 | 2.764199 |
| Error | 0.111798 | 14 | 0.007986 | | | |
| Total | 0.317493 | 23 | | | | |
| For Lead (Pb) | | | | | | |
| Source of Variation | SS | df | MS | F | P-value | F crit. |
| Between Vegetables | 0.000169 | 2 | 8.44E-05 | 0.286799 | 0.754968 | 3.738892 |
| Between Markets | 0.018499 | 7 | 0.002643 | 8.977692 | 0.000292 | 2.764199 |
| Error | 0.004121 | 14 | 0.000294 | | | |
| Total | 0.02279 | 23 | | | | |
| For Zinc (Zn) | | | | | | |
| Source of Variation | SS | df | MS | F | P-value | F crit. |
| Between Vegetables | 366.0952 | 2 | 183.0476 | 0.641855 | 0.541122 | 3.738892 |
| Between Markets | 1811.024 | 7 | 258.7177 | 0.907191 | 0.528148 | 2.764199 |
| Error | 3992.595 | 14 | 285.1854 | | | |
| Total | 6169.715 | 23 | | | | |

The study revealed that leafy vegetables (*C. argentea, T. triangulare, and A. viridis*) sampled from various markets in Ikorodu Metropolis contained varying levels of cadmium, lead, and zinc, with cadmium levels in some cases exceeding permissible limits.

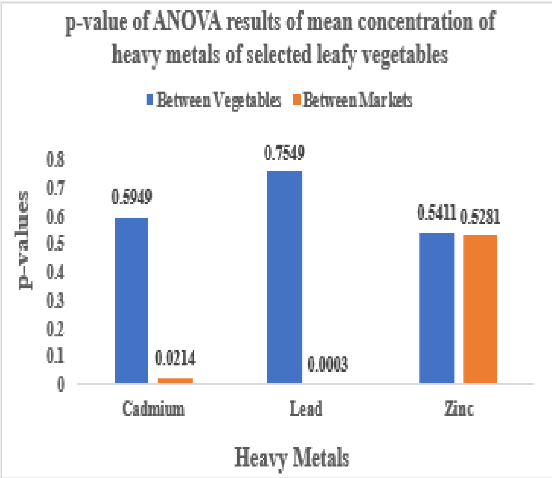


**Fig 1:** ANOVA result of heavy metal concentration of selected leafy vegetables

These findings align with earlier studies by Adu *et al*. (2022), Ebabhi *et al*. (2020), and others, which also reported the presence of these heavy metals in Nigerian vegetables, raising concerns about persistent contamination. Similar contamination in *C. argentea* and *T. triangulare* was reported by Isiuku and Enyoh (2020), Yaradua *et al*. (2019), and Otugboyega *et al*. (2023), while *Amaranthus spp*. contamination was confirmed by Ogwu (2020) and Balali-Mood *et al*. (2021). These studies highlight the widespread issue of heavy metal contamination in leafy vegetables, posing a significant threat to food safety and public health. The study confirmed that the heavy metal concentrations, particularly cadmium, exceeded WHO limits in all sampled vegetables. The elevated cadmium levels are especially concerning due to cadmium's toxicity and long biological half-life, which poses serious health risks such as kidney damage, neurological disorders, and cardiovascular diseases. Consistent with previous research, the study underlines the need for stringent regulatory oversight and frequent monitoring to mitigate these risks.

*Conclusion:* In conclusion, this study highlights significant levels of cadmium contamination in leafy vegetables across various markets in Ikorodu Metropolis, Nigeria, with *T. triangulare* (Gbure) consistently exhibiting the highest concentrations. Lead concentrations showed variability among markets, with *A. viridis* (Tete) recording the highest levels. Zinc levels were within safe limits across all vegetables studied. The Hazard Index (HI) calculations revealed substantial health risks associated with cadmium exposure, particularly concerning for children. Urgent interventions are necessary to improve agricultural practices, monitor soil and water quality rigorously, and enforce stricter food safety regulations to mitigate these risks.

*Declaration of Conflict of Interest:* authors declare no conflict of interest

*Data Availability Statement:* Data are available upon request from the first author or corresponding author

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