*European Journal of Nutrition & Food Safety*

***Volume 15, Issue 3, Page 12-21, 2023; Article no.EJNFS.96232***
***ISSN: 2347-5641***

# Heavy Metal Contaminants in Popularly-consumed Vegetables of Freetown, Sierra Leone

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

***Article Information***

DOI: 10.9734/EJNFS/2023/v15i31297

**Open Peer Review History:**
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/96232

***Original Research Article***

***Received: 25/01/2023***
***Accepted: 25/03/2023***
***Published: 28/03/2023***

## ABSTRACT

The contamination of the environment with heavy metals is one of the challenges that make up Sierra Leone's environmental problem, with urbanization being one of the main causes; due to the lack of proper waste dumpsites and landfills for infrastructural development, rivers, and streams are polluted. The loss of biodiversity, but river and stream pollution have a significant impact on aquatic life. Animals and plants in contaminated water sources "may perish or reproduce improperly". This study assessed the level of concentration of heavy metals namely; chromium (Cr), iron (Fe), copper (Cu), zinc (Zn), and lead (Pb) in some commonly-consumed vegetables like *Manihot esculenta* (Cassava) leaves, *Ipomoea batatas* (Potato) leaves, *Amaranthus viridis* (African spinach), *Corchorus olitorius* (Krain krain); *Solanum lycopersicum* (Tomatoes); *Cucumis sativus* (Cucumber); *Brassica oleracea* (Cabbage); *Abelmoschus esculentus* fruits (Okra); *Capsicum annuum* (Bell Pepper); and *Lactuca sativa* (Lettuce) which were all purchased at local market places in Freetown.

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The vegetable samples were analyzed using an X-ray fluorescence machine (XRF) to determine their heavy metal concentration. The goal was to determine the food safety status of the vegetables by comparing the results to the maximum permissible limit (MPL) for vegetables, as set by WHO/FAO. The levels of Zn, Cr, Fe, Cu, and Pb in all vegetable samples varied from 4.70 – 5.69 %; 3.46 – 4.58 %; 4.00 – 4.52 %; 2.87 – 3.42 %; and 0.5 – 1.2 %, respectively. This result indicates that the metals were present at unsafe levels. According to the result, the maximum concentration values are much higher than the MPL value suggested by WHO/FAO for vegetables, implying that eating vegetables from the source market sites in this study may pose a health risk to humans. Heavy metals in vegetables should be monitored on a regular basis to prevent excessive accumulation of these heavy metals in the human food chain. When it comes to vegetable marketing, certain precautions should be implemented.

*Keywords: Heavy metals; vegetables; food safety; food; contamination and contaminants.*

## 1. INTRODUCTION

Food safety is a global concern since foods are poisoned and rendered unwholesome in many circumstances, with sources as diverse as the toxins themselves [1]. Vegetable consumption on a regular basis is one of the possible health-improving practices, hence vegetables are regarded as an important part of the human diet. People all around the world have recently begun to consume fresh vegetables rather than red meat in order to lower the occurrence of chronic diseases such as diabetes, cancer, cardiovascular disease, and other age-related ailments [2]. Vegetables are important for human nutrition and health, especially as sources of vitamin C, folic acid, a mineral, niacin, thiamine, and pyridoxine, as well as their biochemical role and antioxidative properties [3]. Pollution and contamination of the human food chain have become unavoidable as human activity grows, particularly with the use of contemporary technologies. One of the most critical areas of food quality assurance is heavy metal contamination in food [4]. As a result of greater knowledge of the risk that toxic metals represent to food-chain contamination, international and national food-quality rules have cut the maximum allowable quantities of toxic metals in food [5].

Wastewater typically contains substantial levels of beneficial nutrients and heavy metals, which present both opportunities and challenges in agricultural production [6]. Based on earlier reports, the presence of heavy metals in wastewater can reduce the quality and yield of plant produce [7]. Human health may also be endangered by the intake of heavy metal-contaminated plants. Because of their extended biological half-life, non-biodegradability, and ability to accumulate in various body areas, heavy metals are harmful [8]. The use of metal-based herbicides and fertilizers, irrigation with contaminated water, industrial pollutants, and the harvesting process are all elements that contribute to heavy metal pollution [9]. It is obvious that long-term use of foods containing dangerous levels of heavy metals can lead to chronic heavy metal accumulation in the kidney and liver of humans, resulting in a variety of biochemical malfunctions, including cardiovascular bone, renal, and liver disease [10].

Because there is such a high demand for food safety nowadays, many researchers are focusing their efforts on estimating the risks associated with consuming a variety of contaminated foodstuffs, such as heavy metals, pesticides, and/or toxins in vegetables [11]. There has been a slew of studies, and the literature is replete with them [12-15]. Similar investigations, however, have not been carried out widely in Sub-Saharan Africa. In Nigeria, certain research on heavy metal concentrations have been published [16-18]. Ghana, too [19]. Identifying the potential of some heavy metals toxicity in urban and peri-urban farming systems in Sierra Leone is one of the few studies of its kind done out in the country. As a country recuperating from the devastating effects of a civil war (1991–2002) and the deadly Ebola outbreak (2014 to 2015), which results in the destruction of yields and land plundering among others, Understanding the presence and concentration of potentially harmful heavy metals in vegetables from Freetown market sites will be valuable guidance for future agricultural practices, land-use planning, and the development of prompt intervention techniques [20-22]. Thus, using an X-ray fluorescence machine, this study was carried out to determine the rate of heavy metal accumulation in some commonly consumed vegetables from selected markets in Freetown, as well as to statistically compare heavy metal concentrations in vegetables for necessary inferences and recommendations [23,24].

## 2. MATERIALS AND METHODS

### 2.1 Study Area

The research was carried out in Freetown, Sierra Leone's capital. According to the 2015 population and housing census, Freetown is located at latitude 8.484'N and longitude -13.22994'W, with a population of 1,055,964. Western Area Urban and Western Area Rural are the two parts of Freetown. Two (2) from Westend and two (2) from central were chosen as study areas in the Western Area Urban. In the Westend, Lumley Market, and Aberdeen Market. Whereas in the Central, Congo Market and PZ Markets.

### 2.2 Sample Collection

The following popularly consumed vegetables were sampled in a randomized manner: *Manihot esculenta* (Cassava) leaves; *Ipomoea batatas* (Potato) leaves; *Amaranthus viridis* (African spinach); *Corchorus olitorius* (Krain krain); *Solanum lycopersicum* (Tomatoes); *Cucumis sativus* (Cucumber); *Brassica oleracea* (Cabbage); *Abelmoschus esculentus* fruits (Okra); *Capsicum annuum* (Bell Pepper); and *Lactuca sativa* (Lettuce) at each market sites and the collection was carried out between the hours of 10 am to 2 pm and was between February to March 2021.

The four separate marketplaces within the Freetown metropolis yielded a total of 320 vegetable samples; twenty (20) common vegetables were sampled from each of the four markets in four replicates. Each vegetable was collected from each market, placed in new polythene bags, and labeled with the plant name, date of collection, part of the market from which they were purchased, and market location.

### 2.3 Sample Preparation

To remove air contaminants, the vegetable samples were washed with tap water and deionized water, then air dried to remove moisture. To acquire a consistent particle size, the dry sample was pulverized using an agate pestle and mortar, then sieved using a 0.5 mm mesh size sieve. Before being analyzed with the X-ray fluorescence technique, each vegetable sample was labelled and placed in a dry plastic container that had been pre-cleaned with concentrated nitric acid to prevent heavy metal contamination.

### 2.4 Statistical Analysis

Each sample of the selected vegetables was examined separately. The concentration of heavy metals in the selected vegetable samples was represented as means and standard deviation. Minitab statistics software was used to conduct statistical analysis. Tukey's test was used to determine statistically significant differences between the means of the selected vegetable samples, and superscripts were used to show the significant difference between the means of the selected vegetable samples. A one-way ANOVA with replications was used to evaluate differences among vegetable samples, and the procedure's significance criterion was set at $P<0.05$.

## 3. RESULTS AND DISCUSSION

The heavy metal content of Cr, Fe, Cu, Zn, and Pb has been investigated in this study. Determined in popularly consumed vegetables from chosen market locations in Freetown, Sierra Leone. To determine the levels of food contamination, the detected quantities of Cr, Fe, Cu, Zn, and Pb in commonly consumed vegetables were compared to the recommended limit published by the WHO [25]/FAO [26].

This means values of Heavy metals concentration in the vegetables investigated.

Table 1 - 5 summarizes the mean heavy metal concentrations in vegetables. As a result of the findings, the trend for overall mean heavy metal levels of having metals examined in all of the different vegetables sampled from the four distinct market sites can be shown. Heavy metal concentrations in all vegetables studied were in the following order: Zn>Cr>Fe>Cu>Pb.

**Table 1. Mean values of Chromium (Cr) concentration in the vegetables investigated**

| Vegetables Investigated | Interior % | | | | Roadside % | | | | WHO, (1996). Permissible Limits % | FAO, (1985). Permissible Limits % |
|---|---|---|---|---|---|---|---|---|---|---|
| | Lumley Market | Congo Market | Aberdeen Market | PZ Market | Lumley Market | Congo Market | Aberdeen Market | PZ Market | | |
| *M. esculenta* | 0.61±1.21$^{bc}$ | 0.18±0.35$^{b}$ | 0.00±0.00$^{a}$ | 0.00±0.00$^{a}$ | 0.66±1.32$^{bc}$ | 0.02±0.05$^{b}$ | 0.00±0.00$^{a}$ | 0.00±0.00$^{a}$ | 0.01 | 0.01 |
| *I. batatas* | 0.00±0.00$^{c}$ | 0.41±0.83$^{ab}$ | 0.00±0.00$^{a}$ | 1.67±2.01$^{a}$ | 0.00±0.00$^{c}$ | 0.33±0.68$^{b}$ | 0.00±0.00$^{a}$ | 1.69±2.03$^{a}$ | 0.01 | 0.01 |
| *C. olitorius* | 0.00±0.00$^{c}$ | 1.14±1.35$^{ab}$ | 0.15±0.30$^{a}$ | 0.02±0.04$^{a}$ | 0.00±0.00$^{c}$ | 1.30±1.46$^{ab}$ | 0.16±0.32$^{a}$ | 0.02±0.05$^{a}$ | 0.01 | 0.01 |
| *A. viridis* | 0.93±0.47$^{bc}$ | 0.45±0.44$^{ab}$ | 1.17±0.37$^{a}$ | 1.11±0.00$^{a}$ | 1.60±0.31$^{bc}$ | 0.48±0.46$^{b}$ | 1.16±0.36$^{a}$ | 1.21±0.02$^{a}$ | 0.01 | 0.01 |
| *L. sativa* | 1.77±1.18$^{b}$ | 2.04±1.36$^{a}$ | 1.51±1.21$^{a}$ | 1.97±1.32$^{a}$ | 1.96±1.31$^{b}$ | 2.10±1.40$^{ab}$ | 1.92±1.27$^{a}$ | 2.00±1.34$^{a}$ | 0.01 | 0.01 |
| *B. oleracea* | 0.82±0.56$^{bc}$ | 0.24±0.41$^{ab}$ | 0.46±0.31$^{a}$ | 0.05±0.04$^{a}$ | 1.05±0.76$^{bc}$ | 0.41±0.47$^{b}$ | 0.48±0.32$^{a}$ | 0.07±0.05$^{a}$ | 0.01 | 0.01 |
| *S. lycopersicum* | 3.46±0.02$^{a}$ | 3.33±1.04$^{a}$ | 0.00±0.00$^{a}$ | 2.35±2.07$^{a}$ | 4.58±0.01$^{a}$ | 3.48±0.89$^{a}$ | 0.00±0.00$^{a}$ | 2.44±2.09$^{a}$ | 0.01 | 0.01 |
| *C. sativus* | 1.25±0.01$^{bc}$ | 0.89±1.08$^{ab}$ | 1.53±0.91$^{a}$ | 1.95±1.47$^{a}$ | 1.33±0.05$^{bc}$ | 1.49±2.03$^{ab}$ | 1.81±0.91$^{a}$ | 2.13±1.43$^{a}$ | 0.01 | 0.01 |
| *C. annuum* | 0.00±0.00$^{c}$ | 0.19±0.39$^{ab}$ | 0.54±1.07$^{a}$ | 0.00±0.00$^{a}$ | 0.00±0.00$^{c}$ | 0.22±0.45$^{b}$ | 0.66±1.33$^{a}$ | 0.00±0.00$^{a}$ | 0.01 | 0.01 |
| *A. esculentus* | 0.06±0.00$^{c}$ | 0.25±0.40$^{ab}$ | 1.02±1.34$^{a}$ | 0.07±0.01$^{a}$ | 0.07±0.01$^{c}$ | 0.43±0.42$^{b}$ | 1.25±1.48$^{a}$ | 0.1±0.03$^{a}$ | 0.01 | 0.01 |

*Mean values in the column with different superscripts of alphabets are statically significantly different at 95% confidence level (P<0.05), whilethose with the same alphabets are not statically significantly different at 95% confidence level (P<0.05)*

**Table 2. Mean values of Iron (Fe) concentration in the vegetables investigated**

| Vegetables Investigated | Interior % | | | | Roadside % | | | | WHO, (1996). Permissible Limits % | FAO, (1985). Permissible Limits % |
|---|---|---|---|---|---|---|---|---|---|---|
| | Lumley Market | Congo Market | Aberdeen Market | PZ Market | Lumley Market | Congo Market | Aberdeen Market | PZ Market | | |
| *M. esculenta* | 1.58±0.47$^{bcd}$ | 1.90±0.36$^{abc}$ | 1.74±0.08$^{a}$ | 1.52±0.23$^{bcd}$ | 2.06±0.48$^{abcd}$ | 2.34±0.35$^{abc}$ | 2.21±0.45$^{a}$ | 1.77±0.13$^{bcd}$ | 0.04 | 0.04 |
| *I. batatas* | 1.26±0.03$^{cd}$ | 0.92±0.18$^{c}$ | 1.24±0.74$^{a}$ | 1.21±0.66$^{bcd}$ | 2.00±0.50$^{abcd}$ | 1.49±0.78$^{bc}$ | 1.65±0.67$^{a}$ | 1.36±0.70$^{bcd}$ | 0.04 | 0.04 |
| *C. olitorius* | 1.79±0.39$^{abcd}$ | 2.09±1.74$^{abc}$ | 1.23±0.81$^{a}$ | 1.21±0.61$^{bcd}$ | 1.84±0.51$^{bcd}$ | 2.89±2.02$^{abc}$ | 1.82±0.29$^{a}$ | 1.25±0.64$^{bcd}$ | 0.04 | 0.04 |
| *A. viridis* | 1.60±0.26$^{bcd}$ | 1.48±0.05$^{abc}$ | 1.43±0.27$^{a}$ | 1.36±0.25$^{bcd}$ | 1.64±0.25$^{bcd}$ | 1.84±0.49$^{abc}$ | 1.63±0.22$^{a}$ | 1.64±0.47$^{bcd}$ | 0.04 | 0.04 |
| *L. sativa* | 0.89±0.66$^{cd}$ | 1.05±0.90$^{bc}$ | 1.78±2.19$^{a}$ | 0.75±0.27$^{cd}$ | 1.32±0.97$^{cd}$ | 1.48±0.87$^{bc}$ | 2.24±2.38$^{a}$ | 0.77±0.28$^{cd}$ | 0.04 | 0.04 |
| *B. oleracea* | 1.39±0.26$^{bcd}$ | 1.13±0.75$^{abc}$ | 1.96±0.93$^{a}$ | 1.73±0.49$^{bcd}$ | 1.64±0.27$^{bcd}$ | 1.02±1.20$^{abc}$ | 2.26±1.26$^{a}$ | 1.86±0.54$^{bcd}$ | 0.04 | 0.04 |
| *S. lycopersicum* | 3.25±0.05$^{ab}$ | 3.33±1.04$^{a}$ | 1.85±1.85$^{a}$ | 2.55±1.53$^{ab}$ | 3.47±0.06$^{ab}$ | 3.98±1.21$^{ab}$ | 2.03±1.81$^{a}$ | 2.75±1.72$^{ab}$ | 0.04 | 0.04 |
| *C. sativus* | 3.62±2.20$^{a}$ | 3.22±0.99$^{ab}$ | 4.00±2.15$^{a}$ | 3.98±1.19$^{a}$ | 3.97±2.39$^{a}$ | 4.48±1.69$^{a}$ | 4.52±2.43$^{a}$ | 4.04±1.12$^{a}$ | 0.04 | 0.04 |
| *C. annuum* | 0.13±0.18$^{d}$ | 0.43±0.82$^{c}$ | 1.73±1.97$^{a}$ | 0.11±0.01$^{d}$ | 0.06±0.02$^{d}$ | 0.52±1.00$^{c}$ | 1.96±1.85$^{a}$ | 0.11±0.01$^{d}$ | 0.04 | 0.04 |
| *A. esculentus* | 2.27±0.45$^{abc}$ | 0.54±0.54$^{abc}$ | 1.97±0.76$^{a}$ | 2.32±0.49$^{abc}$ | 0.95±1.26$^{abc}$ | 2.33±0.34$^{abc}$ | 2.33±0.57$^{a}$ | 2.39±0.49$^{abc}$ | 0.04 | 0.04 |

*Mean values in the column with different superscripts of alphabets are statically significantly different at a 95% confidence level (P<0.05), while those with the same alphabets are not statically significantly different at a 95% confidence level (P<0.05)*

**Table 3. Mean values of Copper (Cu) concentration in the vegetables investigated**

| Vegetables Investigated | Interior % | | | | Roadside % | | | | WHO, (1985). Permissible Limits % | FAO, (1996). Permissible Limits % |
|---|---|---|---|---|---|---|---|---|---|---|
| | Lumley Market | Congo Market | Aberdeen Market | PZ Market | Lumley Market | Congo Market | Aberdeen Market | PZ Market | | |
| *M. esculenta* | 0.22±0.11[b] | 0.20±0.12[a] | 1.05±1.86[a] | 0.28±0.02[a] | 0.74±0.52[cd] | 0.28±0.80[a] | 1.25±1.89[a] | 0.53±0.44[ab] | 0.01 | 0.01 |
| *I. batatas* | 0.04±0.01[b] | 0.86±1.64[a] | 0.58±0.96[a] | 0.53±0.99[a] | 0.22±0.35[d] | 0.92±1.65[a] | 0.63±1.02[a] | 0.58±1.66[ab] | 0.01 | 0.01 |
| *C. olitorius* | 0.04±0.01[b] | 1.68±1.83[a] | 0.98±1.90[a] | 0.88±1.68[a] | 0.05±0.03[d] | 2.03±2.17[a] | 1.07±2.01[a] | 0.91±1.73[ab] | 0.01 | 0.01 |
| *A. viridis* | 0.99±1.88[ab] | 0.61±1.08[a] | 0.11±0.10[a] | 0.05±0.01[a] | 0.99±1.79[bcd] | 0.87±1.57[a] | 0.12±0.12[a] | 0.07±0.01[b] | 0.01 | 0.01 |
| *L. sativa* | 0.19±0.20[b] | 0.15±0.11[a] | 0.81±1.45[a] | 0.05±0.02[a] | 0.43±0.62[d] | 0.18±0.12[a] | 0.88±1.45[a] | 0.08±0.05[ab] | 0.01 | 0.01 |
| *B oleracea* | 2.59±1.49[a] | 1.40±1.63[a] | 2.87±1.90[a] | 1.73±1.81[a] | 2.72±1.25[ab] | 0.68±1.19[a] | 3.08±2.02[a] | 1.78±1.88[ab] | 0.01 | 0.01 |
| *S. lycopersicum* | 2.71±0.15[a] | 2.64±0.46[a] | 2.13±0.43[a] | 1.63±1.08[a] | 2.88±0.44[a] | 2.70±0.48[a] | 2.37±0.38[a] | 1.77±1.16[ab] | 0.01 | 0.01 |
| *C. sativus* | 2.52±1.50[a] | 1.42±1.60[a] | 2.24±1.45[a] | 2.40±0.27[a] | 3.42±0.10[a] | 1.47±1.61[a] | 2.33±1.45[a] | 2.71±0.48[a] | 0.01 | 0.01 |
| *C. annuum* | 1.91±0.15[ab] | 1.84±0.42[a] | 2.13±0.43[a] | 1.54±0.01[a] | 2.36±0.40[abc] | 2.39±0.42[a] | 2.38±0.38[a] | 1.62±0.01[ab] | 0.01 | 0.01 |
| *A. esculentus* | 0.16±0.01[b] | 0.20±0.12[a] | 0.15±0.08[a] | 1.05±1.56[a] | 0.31±0.06[d] | 0.18±0.11[a] | 0.26±0.16[a] | 1.10±1.58[ab] | 0.01 | 0.01 |

*Mean values in the column with different superscripts of alphabets are statically significantly different at a 95% confidence level (P<0.05), while those with the same alphabets are not statically significantly different at a 95% confidence level (P<0.05)*

**Table 4. Mean values of Zinc (Zn) concentration in the vegetables investigated**

| Vegetables Investigated | Interior % | | | | Roadside % | | | | WHO, (1985). Permissible Limits % | FAO, (1996). Permissible Limits % |
|---|---|---|---|---|---|---|---|---|---|---|
| | Lumley Market | Congo Market | Aberdeen Market | PZ Market | Lumley Market | Congo Market | Aberdeen Market | PZ Market | | |
| *M. esculenta* | 0.38±0.23[b] | 0.40±0.27[b] | 0.38±0.17[b] | 0.64±0.04[b] | 1.11±0.54[b] | 0.58±0.45[b] | 1.05±0.51[bc] | 1.14±0.59[b] | 0.02 | 0.02 |
| *I. batatas* | 0.65±0.01[b] | 0.51±0.05[b] | 0.93±0.32[bc] | 1.24±0.68[b] | 0.93±0.48[b] | 0.51±0.10[b] | 1.36±0.39[b] | 1.31±0.73[b] | 0.02 | 0.02 |
| *C. olitorius* | 0.22±0.01[b] | 1.43±2.29[b] | 0.26±0.13[cd] | 0.97±0.66[b] | 0.40±0.29[b] | 1.47±2.30[b] | 1.01±0.79[bc] | 1.3±0.73[b] | 0.02 | 0.02 |
| *A. viridis* | 0.24±0.15[b] | 0.69±0.50[b] | 0.34±0.07[cd] | 0.34±0.10[b] | 0.36±0.23[b] | 0.74±0.54[b] | 0.47±0.12[bc] | 0.65±0.44[b] | 0.02 | 0.02 |
| *L. sativa* | 4.69±2.92[a] | 3.89±0.9[a] | 4.70±0.47[a] | 4.08±2.24[a] | 5.13±3.04[a] | 4.30±1.14[a] | 5.69±0.46[a] | 4.35±2.42[a] | 0.02 | 0.02 |
| *B. oleracea* | 0.1±0.16[b] | 0.15±0.27[b] | 0.02±0.00[d] | 0.42±0.62[b] | 0.34±0.62[b] | 1.11±0.98[b] | 0.04±0.01[c] | 0.51±0.64[b] | 0.02 | 0.02 |
| *S. lycopersicum* | 0.05±0.00[b] | 1.07±0.71[b] | 0.46±0.49[bcd] | 0.29±0.32[b] | 0.06±0.01[b] | 0.39±0.6[b] | 0.80±0.85[bc] | 0.32±0.30[b] | 0.02 | 0.02 |
| *C. sativus* | 0.3±0.05[b] | 1.14±0.51[b] | 0.31±0.00[cd] | 0.28±0.15[b] | 0.6±0.44[b] | 0.88±1.11[b] | 0.44±0.01[bc] | 0.32±0.18[b] | 0.02 | 0.02 |
| *C. annuum* | 1.23±0.01[b] | 1.07±0.71[b] | 0.56±0.57[bcd] | 1.43±0.05[b] | 1.40±0.10[b] | 1.21±0.68[b] | 0.82±0.57[bc] | 1.54±0.06[b] | 0.02 | 0.02 |
| *A. esculentus* | 1.73±0.09[b] | 1.14±0.51[b] | 1.20±0.35[cd] | 1.17±0.77[b] | 2.07±0.37[b] | 1.04±0.62[b] | 1.34±0.51[b] | 1.4±0.95[b] | 0.02 | 0.02 |

*Mean values in the column with different superscripts of alphabets are statically significantly different at a 95% confidence level (P<0.05), while those with the same alphabets are not statically significantly different at a 95% confidence level (P<0.05)*

**Table 5. Mean values of Lead (Pb) concentration in the vegetables investigated**

| Vegetables Investigated | Interior % | | | | Roadside % | | | | WHO, (1985). Permissible Limits % | FAO, (1996). Permissible Limits % |
|---|---|---|---|---|---|---|---|---|---|---|
| | Lumley Market | Congo Market | Aberdeen Market | PZ Market | Lumley Market | Congo Market | Aberdeen Market | PZ Market | | |
| *M. esculenta* | 0.07±0.52[a] | 0.08±0.05[a] | 0.03±0.03[b] | 0.03±0.02[de] | 0.34±0.37[a] | 0.06±0.05[b] | 0.37±0.67[a] | 0.03±0.02[c] | 0.01 | 0.01 |
| *I. batatas* | 0.22±0.01[a] | 0.16±0.08[a] | 0.19±0.09[ab] | 0.13±0.01[bcd] | 0.53±0.50[a] | 0.19±0.07[ab] | 0.29±0.17[a] | 0.29±0.08[ab] | 0.01 | 0.01 |
| *C. olitorius* | 0.30±0.04[a] | 0.17±0.15[a] | 0.27±0.14[a] | 0.31±0.00[ab] | 0.54±0.49[a] | 0.23±0.22[ab] | 0.81±0.86[a] | 0.35±0.01[a] | 0.01 | 0.01 |
| *A. viridis* | 0.00±0.00[a] | 0.03±0.06[a] | 0.00±0.00[b] | 0.00±0.02[e] | 0.00±0.00[a] | 0.04±0.08[b] | 0.00±0.00[a] | 0.01±0.03[c] | 0.01 | 0.01 |
| *L. sativa* | 0.28±0.07[a] | 0.15±0.11[a] | 0.17±0.05[ab] | 0.40±0.01[a] | 0.53±0.35[a] | 0.28±0.18[ab] | 0.22±0.04[a] | 1.22±1.86[ab] | 0.01 | 0.01 |
| *B. oleracea* | 0.00±0.00[a] | 0.13±0.25[a] | 0.00±0.00[b] | 0.05±0.09[de] | 0.00±0.00[a] | 0.33±0.66[ab] | 0.00±0.00[a] | 0.05±0.11[c] | 0.01 | 0.01 |
| *S. lycopersicum* | 0.12±0.01[a] | 0.23±0.05[a] | 0.11±0.12[ab] | 0.33±0.13[ab] | 0.16±0.04[a] | 0.27±0.03[ab] | 0.11±0.13[a] | 0.37±0.08[a] | 0.01 | 0.01 |
| *C. sativus* | 0.17±0.11[a] | 0.28±0.16[a] | 0.14±0.10[ab] | 0.2±0.02[ab] | 0.68±1.05[a] | 0.59±0.41[a] | 0.16±0.11[a] | 0.29±0.08[ab] | 0.01 | 0.01 |
| *C. annuum* | 0.00±0.00[a] | 0.00±0.00[a] | 0.12±0.14[ab] | 0.00±0.00[e] | 0.00±0.00[a] | 0.00±0.00[b] | 0.13±0.15[a] | 0.00±0.00[c] | 0.01 | 0.01 |
| *A. esculentus* | 0.56±0.84[a] | 0.19±0.12[a] | 0.19±0.10[ab] | 0.12±0.08[cde] | 0.68±1[a] | 0.08±0.07[b] | 0.17±0.05[a] | 0.13±0.09[bc] | 0.01 | 0.01 |

*Mean values in the column with different superscripts of alphabets are statically significantly different at a 95% confidence level (P<0.05), while those with the same alphabets are not statically significantly different at a 95% confidence level (P<0.05)*

The mean concentration of the highest level of metal Zn in all of the vegetables studied ranged from 0.02 – 5.69 %, with the lowest concentration recorded for *Brassica oleracea* in Aberdeen market and the greatest concentration recorded for *Lactuca sativa* on the roadside at Aberdeen market. Zinc is an essential nutrient for human growth and development [27]. Its deficiency could be caused by a variety of factors, including low dietary intake, zinc metabolic diseases such as poor absorption or excessive excretion, or hereditary metabolic deficiencies [28,29]. Zn shortage due to the ingestion of plant foods containing inhibitory components for Zn absorption is a growing concern in developing nations [30]. A result showed a relative increase of Zn contents in most vegetables reported by Singh et al. [31]. WHO's standards show that Zn concentration (3.56 – 4.59 mg/kg-1) was within the recommended international standards [25]. On the other hand, the other results were concordant with that obtained by Al Jassir et al. [32], who reported the level of Zn between 14.14 and 76.28 µg/g in some vegetables and they found to be higher in the Purslane vegetable species for both washed and unwashed samples. Due to the long-term usage of fertilizer, Zn has a higher potential for accumulating in agricultural soil. Inorganic fertilizers that contribute to the release of heavy metals in agricultural soil and are taken up by plants include phosphate fertilizers, liming materials, and biofertilizers. As a result, they make their way into the food chain, where they eventually reach animals and people. In general, the current study found that Zn concentrations are higher than WHO/FAO-set international standards. (World Health Organization [25].

The results of the current work revealed that the levels of Cr in all of the vegetables analyzed ranged from 0.00 – 4.58 %, with the highest concentration recorded for *Solanum lycopersicum* obtained from the roadside of Congo market. At some point in time, no heavy metals were detected in some of the vegetables sampled, including *Manihot esculenta*, *Ipomoea batatas*, *Corchorus olitorius*, *Solanum lycopersicum*, and *Capsicum annum* at the different market sites.

According to a study by Islam *et al*. [33], the mean concentration of Cr ranged from 0.88 (*S. lycopersicum*) to 2.1 mg/kg (*A. Gangeticus*) in leafy and non-leafy vegetables from Bangladesh. The current study's chromium concentration in vegetables are somewhat comparable to similar studies from other countries. The frequent use of untreated or inadequately treated wastewater from industrial establishments, as well as the use of chemical fertilizers and pesticides, are the main sources of Cr in agricultural soil in Bangladesh [34]. Cr is a non-essential element found in foods and natural fluids that builds up in the human body, mostly in the kidneys and liver. Various sources of pollution in the environment have been identified. Its prevalence in foods has been linked to a variety of causes of environmental pollution [30].

The mean Fe concentration in all the vegetables studied ranged from 0.06 – 4.52 %, with *Cucumis sativus* on the roadside at Aberdeen market having the greatest mean concentration and *Capsicum annuum* on the roadside at Lumley market having the lowest mean concentration. Zahir et al. [35], examined various vegetable samples and discovered the presence of a significant concentration of heavy metals in them. Ali and Al-Quatani. [36], looked into the concentration of Fe in certain raw foodstuffs grown in wastewater industrial medium in another study. When compared to the other vegetables studied, the amount of Fe in leafy greens was higher. The reasonable explanation for this condition is that Fe uptake can be accelerated and accumulates in the leaves, which are thought of as food production factories in plants.

In the present study, the mean concentration of Cu in all the vegetables analyzed was 0.04 – 3.42 %. *Cucumis sativus* on the roadside near the PZ market had the highest concentration, while *Ipomoea batatas* and *Corchorus olitorius* in the Lumley market had the lowest concentration. Cu is required for regular plant growth; hence vegetables have some in their tissues. However, the high level of Cu in vegetables may be attributable to the use of copper-based fertilizers, as well as leaves being entrance routes for heavy metals from the air [37,38].

Copper concentrations of 8.50 mg/kg and 15.50 mg/kg in leafy and non-leafy vegetables, respectively, were reported by Alan et al. [39]. From the Bangladeshi village of Samta, which was higher than the current study. However, the Cu content in the current study's vegetables was equivalent to that found in a study in Varanasi, India [40], where the mean copper concentration was 36.4 mg/kg (range: 20.5 – 71.2 mg/kg).

The mean content of Pb in all of the vegetables tested ranged from 0.00 – 1.22 %, with the greatest mean concentration, found on the roadside at the PZ market for *Lactuca sativa*. Pb is a significant cumulative body poison that enters the body through the air, water, and food and is not removed by washing fruits and vegetables [30]. The high levels of Pb in some of these plants are likely due to pollutants in irrigation water, farm soil, or pollution from highway traffic [41], however, no heavy metal detection was recorded for *Amaranthus viridis, Brassica oleracea*, and *Capsicum annuum* within and along the roadside at this time. Fatoba et al. [6] suggested that the concentration of heavy metals can only be raised to a toxic level over a period of consistent though inconspicuous accumulations.

Furthermore, when comparing vegetables taken on the roadside to those sampled in the market, an overall increase in metal levels was noted. This could be because Pb pollution was previously linked to heavy traffic in the area, which resulted in the accumulation of Pb emitted by automobile exhausts. Sharma et al. [32] revealed a Pb concentration (17.54 – 25.00 mg/kg-1) in vegetables grown in industrial locations. Muchuweti et al. (2006) found that the amount of Pb (6.77 mg/kg-1) in Zimbabwean crops irrigated with wastewater and sewage was greater than the WHO acceptable limit (2 mg/kg-1).

## 4. CONCLUSION AND RECOMMENDATION

The results of this study is indicative of heavy metal concentration in some generally-hawked vegetables in the study area, and this can lead to heavy metal poisoning (a health threat) in the consumers of such food materials. It can also be concluded that certain heavy metals such as Lead (Pb) tend to abound more on vegetables hawked nearer to the road sides where heavy vehicular traffic exist.

The authors recommend the regular check of food materials by public health officials of the country, for possible contaminants before they are released to the public for consumption. Such checks should also include those of irrigation water sources and soils for agricultural purposes. It is also recommended that food materials be moved away from regions of possible Pb emission such as fossil fuel burning. Food materials should not be left open while hawking, but protected with transparent screens, to prevent contamination.

## ACKNOWLEDGEMENT

The authors are grateful to Mr Anthony Kamara who assisted in carrying out the heavy metals analysis at the Department of Physics, Fourah Bay College, University of Sierra Leone. The authors are also grateful to AME University, Monrovia, Liberia, for providing financial support towards the publication of this article.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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