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HEAVY METAL CONTAMINANTS IN POPULARLY-CONSUMED VEGETABLES IN FREETOWN, SIERRA LEONE

ABSTRACT

The contamination of the environment with heavy metals is one of the challenges that makes 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 therefore assessed the level of concentration of heavy metals namely; chromium (Cr), iron (Fe), copper (Cu), zinc (Zn), and lead (Pb) in some commonly consumed vegetable samples 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) were all obtained at local market places in Freetown. The samples were analysed using an X-ray fluorescence machine (XRF) to determine their heavy metal concentration. The goals were to determine the food safety status of the vegetables by comparing the results to the maximum permissible limit (MPL) for vegetables 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 shows that the maximum is reached. 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 market sites 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, Maximum permissible limits, X-ray Florescence machine.

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 (US Environmental Protection Agency, 2003). Vegetable consumption on a regular basis is one of the possible health-improving practices, hence vegetables are regarded 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-

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related ailments (Prakash *et al.,* 2012). 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 (Siegel *et al.,* 2014). 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 (Marshall, 2004; Radwan and Salama, 2006; Wang *et al.,* 2005; Khan *et al.,* 2008). 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 (Radwan and Salama, 2006).

Waste water typically contains substantial levels of beneficial nutrients and heavy metals, which present both opportunities and challenges in agricultural production (Chen *et al.,* 2005). Based on earlier reports, the presence of heavy metals in waste water can reduce the quality and yield of plant produce (Fatoba *et al*., 2011). 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 (Monu *et al.,* 2008; Heidarieh *et al.,* 2013). 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 (Duran *et al.,* 2007; Tuzen and Soylak, 2007). 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. (Jarup, 2003).

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 (D'Mello, 2003; Latif *et al.,* 2009; Ismail and Rashid, 2017). There has been a slew of studies, and the literature is replete with them (McLaughlin *et al.,* 2000; Mecray *et al.,* 2001; Crusbery *et al.,* 2004; Cahosh and Singh, 2005; Isa and Jimoh, 2013; Chrome *et al.,* 2014). Similar investigations, however, have not been carried out widely in Sub-Saharan Africa. In Nigeria, certain research on heavy metal concentrations have been published (Ogbonna *et al.,* 2009; Fagbote and Olanipekun, 2010; Opaluwa *et al.,* 2012; Chibuike and Obiora, 2014). Ghana, too (Ampofo and Awortwe, 2017). Identifying the potential of some heavy metals

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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 to 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 a valuable guidance for future agricultural practices, land-use planning, and the development of prompt intervention techniques. 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.

MATERIALS AND METHODS

Study Area

The research was carried out in Freetown, Sierra Leone's capital. According to the 2015 population and housing census, Freetown is located in 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, the (Lumley Market) and (Aberdeen Market). Whereas in the Central, The (Congo Market) and (PZ Market).

Sample Collections

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 market places within the Freetown metropolis yielded a total of 320 vegetables. 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 labelled with the plant name, date of collection, part of the market from which they were purchased, and market location.

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Sample Preparation

To remove air contaminants, the vegetable samples were washed with tap water and deionised 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 analysed 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.

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. The 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 $P<0.05$ (significant).

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 (1985)/FAO (1996).

Means values of Heavy metals concentration in the vegetables investigated

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 95% confidence level (P<0.05), whilethose with the same alphabets are not statically significantly different at 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 95% confidence level (P<0.05), whilethose with the same alphabets are not statically significantly different at 95% confidence level (P<0.05).

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

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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 95% confidence level (P<0.05), whilethose with the same alphabets are not statically significantly different at 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 95% confidence level (P<0.05), whilethose with the same alphabets are not statically significantly different at 95% confidence level (P<0.05).

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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.

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 (Divrikli *et al.,* 2006). 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 (Colak *et al.,* 2005 and Narin *et al.,* 2005). Zn shortage due to ingestion of plant foods containing inhibitory components for Zn absorption is a growing concern in developing nations (Divrikli *et al.,* 2006). A result showed a relative increase of Zn contents in most vegetables reported by Singh *et al.,* (2004) and Itanna, (2002), who reported that Zn concentration (3.56 – 4.59 mg/kg-1) was within the recommendation international standards on the other hand, the other results were concordant with that obtained by Al Jassir *et al.,* (2005), 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 fertilizer, liming materials, and bio fertilizer. 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, (1985).

The results of the analysis revealed that the levels of Cr in all of the vegetables analysed ranged from 0.00 – 4.58 %, with the highest concentration recorded for *Solanum lycopersicum* at the Congo market on the roadside. 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.

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According to a recent study by Rahman *et al.,* (2013), the average Cr concentration in leafy and non-leafy vegetables from Bangladesh was 1.12 mg/kg (range: 0.35 – 4.50 mg/kg) and 0.84 mg/kg (range: 0.18 – 1.91 mg/kg), respectively. The current study's chromium concentration in vegetables was somewhat higher than previous research in Bangladesh and comparable to other studies from other countries. The frequent use of untreated or inadequately treated waste water from industrial establishments, as well as the use of chemical fertilizers and pesticides, are the main sources of Cr in agricultural soil in Bangladesh (Islam *et al.,* 2015b). 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 (Divrikli *et al.,* 2006).

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.,* (2009), examined various vegetable samples and found a significant concentration of Fe in Pakistan. Waheed *et al.,* (2003), looked into the concentration of Fe (17.0 – 35.60 g/g) in certain raw foodstuff 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 analysed was 0.04 – 3.42 %. *Cucumis sativus* on the roadside near PZ market had the highest concentration, while *Ipomoea batatas* and *Corchorus olitorius* in 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 (FAO/WHO, 1988), as well as leaves being entrance routes for heavy metals from the air (FAO/WHO, 1988). (Demirezen and Aksoy, 2006).

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.,* (2003). From the Bangladeshi village of Samta, which was higher than the current study. However, the Cu content in the current study's vegetables was

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equivalent to that found in a study in Varanasi, India (Sharma *et al.,* 2007), 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 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 (Divrikli *et al.,* 2003). 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 (Qui *et al.,* 2000), 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*. (2012) suggested that the concentration of heavy metals can only be raised to a toxic level over a period of consistent though inconspicuous accumulations.

Conclusion

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.,* (2006) 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 waste water and sewage was greater than the WHO acceptable limit (2 mg/kg-1).

REFERENCES

Alam, M.M., Snow E.T. and Tanaka, A. (2003) Arsenic and heavy metals contamination of vegetables grown in Samta village, Bangladesh. *Sci. Total Environ.* 308, 83–96

Al Jassir, M.S., Shaker, A. and Khaliq, M.A. (2005) Deposition of heavy metals on green leafy vegetables sold on roadsides of Riyadh City, Saudi Arabia. Bull. Environ. Cont. Toxicol. 75, 1020–1027.

Chen, Y., Wenyou H., Biao H., Weindorf D. C., Nithya R., Xiaoxiao L. and Silvana N. (2013). Accumulation and health risk of heavy metals in vegetables from harmless and organic vegetable production systems of China. *Ecotoxicology and Environmental Safety* **(98)**: 324–330.

Chen Y, Wang C, Wang Z. (2005). Residues and source identification of persistent organic pollutants in farmlands soils irrigated by effluents from biological treatment plants *Environ Int.* 2005; 31:778-83.

Colak, H., Soylak, M. and Turkoglu, O. (2005). Determination of trace metal content of herbal and fruits teas produced and marketed from Turkey *trace Elem. Electroly*. 22: 192-195.

`

Crusberg T.C., Mark, S.,&Dilorio, A., (2004) Biomineralization of Heavy metals in Arora, K., Bridge, P., & Bhatnagar, D. (ed.) *Fungal Biotechnology in Agricultural food Environmental Applications* CRC Press. Pp 674-691.

D'Mello, J.P. (2003) "Food safety: Contaminants and Toxins", pp. 191–215. Cambridge, CABI Publishing.

Demirezen, D., Aksoy, A. (2006). Heavy metal levels in vegetables in Turkey are within safe limits for Cu, Zn, Ni and exceeded for Cd and Pb. *Journal of Food Quality*. **(29)**: 252265.

Divrikli, U., Saracoglu, S., Soylak, M. and Elci, L. (2003) Determination of trace heavy metal contents of green vegetables samples from Kayseri- Turkey by flame atomic absorption spectrometry. *Fresen Environ. Bull*. 12, 1123–1125.

Divrikli U., Horzum N., Soylak M. and Elci L. (2006). Trace Heavy Metal Contents of Some Spices and Herbal Plants from Western Anatolia, Turkey, *International Journal of Food Science Technology*, 41: 712-716.

Demirezen, D. and Aksoy, A. (2006) Heavy metal levels in vegetables in Turkey are within safe limits for Cu, Zn, Ni and exceeded for Cd and Pb. *Journal of Food Quality*, 29, 252–265.

D'Mello, J.P. (2003) "Food safety: *Contaminants and Toxins*", pp. 191–215. Cambridge, CABI Publishing.

Duran, A., Tuzen, M. and Soylak, M. (2007) Trace element levels in some dried fruit samples from Turkey. Int. J. Food Sci. Nutr. 59, 581–589.

FAO, 1969. Permissible safe Limits of Heavy metals in vegetables.

FAO/WHO (1988) Codex committee on food additives and contaminants, thirty-first session, The Hague, The Netherlands, 22-26 March 1999. Joint FAO/ WHO Food Standard Programme, Geneva, Switzerland.

Fagbote, E.O., and Olanipekun, E.O (2016) Evaluation of the status of Heavy metal pollution of soil and Plant (*Chromolaena odorata*) of Agbabu Bitumen Deposite Area Nigeria. American-Eurasian Journal of Dcientific Research 5(4), 241-248.

Fatoba, P.O., Adepoju, A.O. and Okewole, G.A. (2011). Heavy metal accumulation in the fruits of tomato and okra irrigated with industrial waste effluents. J. Ind. Pollution Control 28(2): 103-107

Fatoba, P.O., Adepoju, A.O. and Olorunmaye, K.S. (2012). Effects of soaps and Detergents wastes on seed germination, flowering and fruiting of Tomato (Lycopersicon esculentum) and Okra (Abelmoschus esculentus) plants. Eco., Env. and Cons. 17(1): 6-10.

Ghosh, M., & Sigh S.P (2005). A review of Phytoremediation of Heavy metals and utilization of it's by products. *Applied Ecology and Environmental Research*, 3(1), 1-18.

Isa, K., &Jimoh, W.L.O., (2013). Determination of heavy metals in soils from dumpsites of tanneries and farmlands in Challawa Industrial Estates ano, Nigeria. Bayero*Journal of Pure and Applied Sciences,* 6(2), 57-64.

Ismail, A.S. and Rashid, M.S. (2017) Health risk assessment of heavy metals for population via consumption of vegetables collected from Khassa River, Kirkuk City, Northern Iraq. *Int. J. Curr. Res. Acad. Rev.* 5, 104–110.

Islam, E.U., X.Yang, Z He and Q. Mahmood, 2007. Assessing potential dietery toxicity of heavy metals of heavy metals in selected vegetables and food crocks. J. Zhejiang Univ. Sci., 9:210:220.

Jarup, L. (2003). Hazards of heavy metal contamination. *British Medical Bulletin*, **(68)**: 167–182.

`

Khan, S., Cao, Q., Zheng, Y.M., Huang, Y.Z. and Zhu, Y.G. (2008). Health risk of heavy metals in contaminated soils and food crops irrigated with waste water in Beijing, China. Environmental Pollution Series, 152(3):686-692.

Latif, A.G., Ardalan, A.M., Mohammadi, M.T., Hosseini, H.M. and Karimian, N. (2009) Solubility test in some phosphate rocks and their potential for direct application in soil. *W. Appl. Sci. J*. 6, 182–190

Marshall, (2004). Enhancing food chain integrity. Quality assurance mechanism for air pollution impacts on fruits and vegetables systems. Crop Post Harvest Program, Final Technical Report (R7530).

McLaughlin, M.J., Hamon, R.E., McLaren, R.G., Speir, T.W. and Rogers, S.L. (2000) Review: a bioavailability-based rationale for controlling metal and metalloid contamination of agricultural land in Australia and New Zealand, Australian Journal of Soil Research, 38(6):1037–1086.

Monu A, Bala K, Shweta R, Anchal R, Barinder K, Neeraj M (2008) Heavy metal accumulation in vegetables irrigated with water from different sources.

Mubofu– *Heavy Metal Contents in Some Commonly Consumed Vegetables* Tanz. J. Sci. 38(3), 2012

Narin, I., Tuzen, M., Sari, H. and Soylak, M. (2005) Heavy metal content of potato and corn chips from Turkey*. Bull. Environ. Contam. Toxicol*. 74, 1072– 1077

Ogbonna, D.N., Kil. B.L., &Youdeowei, P.O (2009). Some Physico-chemical and heavy metal levels in soils of waste dumpsite in Port Harcourt Municipality and Environs. *Journal of Applied Science and Environmental Management* 13(4): 65-70.

Opaluwa, O.D., Aremu, M.O., Ogbo, L.O., Abiola, K.A., Odiba, I.E. Abubakar M.M., and Nweze, N.O (2012). Heavy metal concentrations in soils, plants leaves and crops grown around dumpsite in Lafia metropolis, Nasarana State, Nigeria, Advances in Applied Science Research, 3(2), 780-784.

Prakash, D., Upadhyay, G., Gupta, C., Pushpangadan, P. and Singh, K.K. (2012) Antioxidant and free radical scavenging activities of some promising wild edible fruits. Int. Food Res. J. 19, 1106–1116.

Qui, X.X., Huang, D.F., Cai, S.X., Chen, F., Ren, Z.G. and Cai, Y.C. (2000) Investigations on vegetables pollution and pollution sources and its control in Fuzhou, Fujian Province*. Fuj. J. Agricult. Sci*. 15, 16–21

Radwan, M.A and A.K. Salama, (2006). Market basket survey for some heavy metals in Eygptian fruits and vegetables. Food Chem. Toxicol., 44:1273-1278.

Sharma, R. K., Agrawal M. and Marshall F. M. (2008). Heavy metal (Cu, Zn, Cd and Pb) contamination of vegetables in urban India: A case study in Varanasi. *Resource Journal of Environmental Toxicology* **(2)**: 92-99.

Siegel, K.R., Ali, M.K., Srinivasiah, A., Nugent, R.A. and Narayan, K.M. (2014) Do we produce enough fruits and vegetables to meet global health need? PloS One, 9, e104059.

Singh, K. P., Mohon, D., Sinha, S. and Dalwani, R. (2004). Impact assessment of treated/untreated waste water toxicants discharge by sewage treatment plants on health, agricultural and environmental quality in waste water disposal area. *Chemosphere* **(55)**: 227-255.

USEPA (2003). Strategy to Prevent Food borne Disease. http: www.epa.gov/agriculture/tfsy.html

WHO, 1985. Permissible Safe Limits of heavy metals in vegetables.