© 2017 IJSRST | Volume 3 | Issue 3 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X
Themed Section: Science and Technology

Assessment of Lead and Cadmium Residues in Assorted Vegetables Collected from Markets in Monrovia, Liberia

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ABSTRACT

Vegetables are considered as important dietary components because they often contain essential vitamins, minerals, and fibers that are protective against chronic diseases. Despite the nutritional importance of vegetables, they are quite susceptible to heavy metals contamination. Vegetable contamination by heavy metals can result into bioaccumulation of these toxic contaminants in body tissues of consumers. The current study, therefore, sought to investigate the levels of some toxic heavy metals (lead and cadmium) in edible vegetables sold in major markets in Monrovia, Liberia. A total of thirty-six vegetable samples belonging to six plant species were randomly sampled from the markets. After sample preparation, flame atomic absorption spectroscopy (FAAS) was used for the determination of heavy metal concentrations. The concentrations of the heavy metals (mg kg-1) ranged as follows: lead (Pb) 0.093-0.470 and cadmium (Cd) 0.042-0.131. The metal levels in the vegetable samples were generally below the FAO/WHO maximum permissible limits, indicating that, at the moment, the tested vegetable samples are safe for human consumption with respect to levels of Pb and Cd. However, considerable attention should be paid to the potential health risk of heavy metals via other exposure pathways and other regions of Liberia.

Keywords: Vegetables, Cadmium, Lead, Atomic Absorption Spectroscopy, Monrovia, Liberia

I. INTRODUCTION

The past few decades have witnessed a growing interest in assessing the levels of heavy metals in food including vegetables, fruits, meat, and fish. Such interests were geared towards ensuring the safety of the general food supply in order to minimize the potential hazardous effect on human health.

Vegetables are important components of a healthy diet (Shagal *et al*., 2012). Studies have shown that the consumption of various types of vegetables can significantly prevent chronic heart diseases and some types of cancers, especially cancers of the gastrointestinal tract (Lawal and Audu, 2011; Temple *et al*., 2012).

Heavy metals are considered as one of the most significant environmental concerns because of their toxicity and accumulation in the tissues of living organisms which even at low concentrations can endanger human health (Sharma *et al*., 2006). The existence of heavy metals in the food chains and their critical concentration can have adverse metabolic and physiological effects on the human body (Rowland and McKinstry, 2006). The absorption of metals, humans can be affected by several factors such as pH, ionic concentration of the solution, the presence of competitive metal cations, and organic and inorganic ligands (Gupta *et al*., 2012). Moreover, the shapes and different species of plants can create differences in their ability to absorb and accumulate heavy metals (Nazemi and Khosravi, 2011).

Lead (Pb) is a toxic metal that occurs naturally in the environment. However, most lead concentrations that are found in the environment are a result of anthropogenic activities. Due to the application of lead in gasoline, an unnatural lead-cycle has consisted. In car engines lead is burned and lead salts are generated. These lead salts enter the environment through the exhausts of cars. The larger particles drop to the ground immediately and pollute soils or surface waters, while the smaller particles travel long distances through air and remain in the atmosphere to later fall as rain. This lead-cycle caused by human production is much more extended than the natural lead cycle and has caused lead pollution to be an issue of worldwide concern (Oforka et *al*., 2012). Lead, in vegetables, accumulates in the body of humans who consume the product and depending on the concentration may have an adverse effect on major body organs and systems (Patrick, 2006a). The adverse effect of Pb is dose and exposure duration dependent, in other words, more than the required threshold for food could be dangerous (Rowland and McKinstry, 2006).

Cadmium (Cd) is another toxic heavy metal of great environmental concern. Cd levels in the environment vary widely and emissions to the environment are normally transported incessantly between the three main environmental compartments: air, water, and soil. Cd uptake by vegetables may be mainly from soil and water. Cd in vegetables can eventually enter the body of humans who consume these products. Some effects associated with cadmium are kidney and liver damage, anemia and hypertension (Givianrad *et al.,* 2009). In the late 1960s, environmental cadmium contamination was established as the cause of an epidemic of bone disease (itai-itai disease) in Japan. Since that time, increasing scientific interest has been devoted to cadmium as an environmental contaminant. Awareness is now been disseminated in some countries concerning the small margin of safety between existing intake levels and levels that may cause adverse health effect to the population (Ngumbu, 2014).

The current study sought to investigate the levels of Cd and Pb in edible vegetables sold in major markets in Monrovia, Liberia.

II. METHODS AND MATERIAL

Collection of Samples and Study Region

A total of thirty-six vegetable samples, belonging to six plant species, were randomly purchased from major markets in Monrovia from February to August 2016. The vegetable species considered were *Abelmoschus esculentus (L.) Moench* (okra), *Solanum melongena L.* (eggplant), *Brassica oleracea var (L.) capitata* (cabbage), *Solanum lycopersicum* (tomatoes), *Cucumis sativus Linn* (cucumber), and *Capsicum annuun L* (green pepper).

Sampling and Pretreatment of Vegetable Samples

When purchased, the samples were put in polyethylene bags and transferred immediately to the laboratory. At the laboratory, samples were washed separately with tap water to remove contaminants resulting from the soil or handling. The edible parts (Table 1) were further washed with deionized water, cut into small pieces, and then dried overnight in an oven at 40 ^{0}C. The dried samples were crushed and ground to a powder using a clean mortar and pestle. The ground samples were put in well-labeled polyethylene bags and kept at 4 ^{0}C awaiting further processing (Mapanda *et al*., 2005).

Table 1: Names of vegetables, number of samples considered and edible parts used for analysis of Cd and Pb

English name	Scientific name	Sample size (n)	Part used
Okra	Abelmoschus esculentus (L.) Moench	6	fruit
Eggplants	Solanum melongena L.	6	fruit
Cabbage	Brassica oleracea var L. capitata	6	leaf
Tomatoes	Solanum lycopersicum	6	fruit
Cucumber	Cucumis sativus Linn	6	fruit
Green Pepper	Capsicum annuun L	6	fruit

Extractions and Preparations of Vegetable Samples

Extraction of metals from the samples was done by aqua regia following a method described by Taghipour and Mosaferi, (2013) with minor modifications. About 1.0 ± 0.01 g of the powdered samples were put into labeled digestion tubes to which aqua regia in ratio 3: 1 (12mL of conc. HCl + 4 mL of conc. HNO_3) was added. The contents were then mixed by swirling and then covered with digestion tube glass covers and allowed to stand for at least 12 hours in a fume cupboard. The digestion tubes containing the sample solutions were placed on a digestion block under a fume hood and heated at 95 ^{0}C for 30 minutes. The samples were then cooled and filtered using a Whatman 47 mm filter paper. The filtrates were topped to 100 mL in volumetric flasks using 0.1 M HNO_3. Prior to analysis, standard solutions (Merck NJ, USA) were used to calibrate the instrument and calibration curves were prepared.

Analysis of Vegetable Samples

For analytical quality control, reagent blanks and sample replicates were randomly inserted in the analysis process to assess contamination and precision. Recovery studies were conducted to demonstrate the efficiency of the overall procedure. Recovery of the metals was determined by spiking one sample with increasing amounts of metal standard solution. The spiked samples were then digested (as all other samples) and analyzed for heavy metal contents. Certified reference material (CRM), GBW 10043 was also included in triplicate. The recovery rates for the metals ranged from 97% to 102%. All samples were analyzed in triplicates for the presence of heavy metals using flame atomic absorption spectroscopy (FAAS) at appropriate wavelengths (Table 2).

Table 2: Optimal instrumental parameters for FAAS determination of Cd and Pb

PARAMETER	METAL	
	Pb	Cd
Wavelength (nm)	283.8	228.8
Lamp current (%)	75	75
Spectral width slit (nm)	0.7	0.7
Flame	Acetylene-Air	Acetylene-Air
Acetylene Flow rate (L/min)	0.8-1.0	0.8-1.0
Temperature (^oC)	2300	2300
Time of Measurement (sec)	4.0	4.0
Background correction	On	On

Data Analysis

In order to analyze the data, SPSS, Inc, Chicago, IL software version 16.0 was used and the results were expressed as mean, standard deviation, and range of concentrations. To compare the average concentration of heavy metals in the vegetable samples, parametric tests of one-way analysis of variance (ANOVA) by confidence level of 95% and a significance level of 0.01 was considered.

III. RESULTS AND DISCUSSION

All the vegetables analyzed in this study are consumed by humans. All the analyzed vegetable samples contained detectable concentrations of Cd and Pb (Table 3). Mean concentrations (and range) of total Cd and Pb in edible portions of vegetables were 0.092 (0.042-0.131) and 0.150 (0.093-0.180) mg kg^{-1}, respectively. The average concentrations of heavy metals in all vegetable samples were in the order of Pb > Cd (Figure 1).

Abelmoschus esculentus (L.) Moench (okra) recorded the highest mean concentration of Cd while Solanum lycopersicum (tomatoes) had the lowest mean Cd level. The highest mean Pb concentration was recorded in Brassica oleracea var L. capitata (cabbage) while Cucumis sativus Linn (cucumber) recorded the lowest mean Pb level. These results appeared to be in agreement with earlier assertions by Chen et al., 2014 that leafy vegetables tended to demonstrate higher concentrations of Cd and Pb than fruiting and legume vegetables.

The detectable levels of Pb and Cd recorded in this study could be attributed to the concentrations of the metals in the soil where the vegetables were cultivated. Household dump sites generally tend to contain organic wastes and are considered fertile spots for the cultivation of vegetables. The drawback, however, is that these wastes are often unsorted and at times contain used batteries and other electronic waste materials that are sources of Cd and Pb. This results in an increase of metal levels in the soil and subsequent increase in plant uptake potential. This is in agreement with reports from previous studies (Al Jassir et al., 2005; Akinola and Ekiyoyo, 2006) that heavy metal levels are generally high in effluent irrigated gardens.

Table 3 : Results of Cd and Pb levels (mg kg-1) in vegetable samples analyzed

		Cd (mg kg^{-1})		Pb (mg kg^{-1})	
Scientific name	**n**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**
Abelmoschus esculentus (L.) Moench.	6	0.131± 0.013	0.072-0.195	0.171± 0.020	0.132-0.195
Solanum melongena L.	6	0.081± 0.020	0.055-0.187	0.161± 0.011	0.141-0.187
Brassica oleracea var L. capitata	6	0.100± 0.004	0.051-0.162	0.180 ± 0.013	0.112-0.195
Solanum lycopersicum	6	0.042± 0.002	0.040-0.051	0.121± 0.003	0.091-0.144
Cucumis sativus Linn	6	0.103± 0.023	0.072-0.177	0.093 ± 0.004	0.071-0.150
Capsicum annuun L	6	0.092± 0.012	0.077-0.106	0.173± 0.012	0.120-0.192
FAO/WHO maximum permissible limits		**0.20**		**0.30**	

n = sample size; SD= standard deviation

In general, the Cd and Pb levels reported in this study are either in agreement or lower, by an order of magnitude, than concentrations of similar heavy metals reported in vegetables from other regions of the world. For example, in 2013 Akan et al determined heavy metal levels in freshly harvested vegetable samples from four agricultural locations in Biu Local Government Area, Borno State, Nigeria. The Cd and Pb levels (mg kg-1) reported in their study were in the range 0.34-5.44 and 0.25-4.56 respectively; below which our values fall. Cd and Pb concentrations (mg kg-1) in vegetables collected from Maun market in Botswana was in the range 0.31-0.80 and 0.88-4.73 respectively (Bati et al 2017), below which our values fall. Mean Cd and Pb levels in the current study were also in agreement or lower than values reported in vegetable samples from parts of Brazil, Nigeria and China (Guerra et al 2012; Doherty et al 2012; Chen et al 2014).

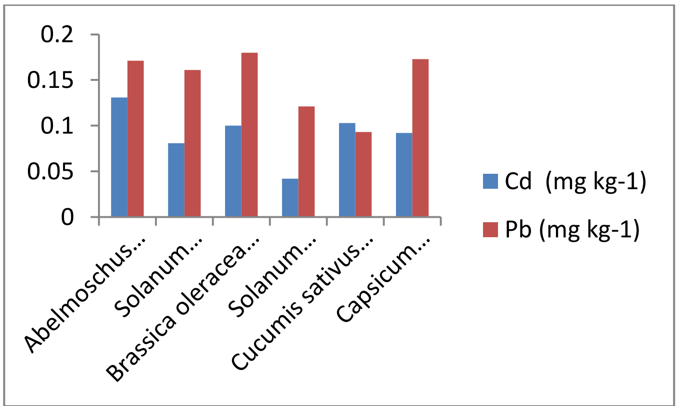

Figure 1: Comparison of Cd and Pb levels in vegetable samples analyzed

IV. CONCLUSION

This study showed that the Cd and Pb levels in the vegetables analyzed were generally below the safe limits of 0.20 mg kg-1(Cd) and 0.30 mg kg-1(Pb) set up by FAO/WHO; suggesting that, at the moment, the vegetable samples analyzed are safe for human consumption considering Cd and Pb levels. It is, however, expedient to continuously monitor heavy metal levels in common foodstuffs consumed by the population. Future research should, therefore, pay considerable attention to the potential health risk of heavy metals via other exposure pathways and other regions of Liberia.

V. ACKNOWLEDGEMENT

Special thanks go to Dr. Emmett A. Dennis, President of the University of Liberia and Dr. Ophelia Inez Weeks, Vice President for Academic Affairs, the University of Liberia for their zillions backing and inspirations for the capacity building process of young academic researchers in the midst of the numerous challenges.

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