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RESEARCH ARTICLE

COMPARATIVE STUDIES OF METAL (Pb, Cr, Hg, As AND Al) UPTAKE BY LEAFY VEGETABLES AND FRUIT GROWN IN GARDENS AROUND THE KING TOM REFUSE DUMP IN FREETOWN

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ABSTRACT

The King Tom refuse dump site is a repository of different kinds of wastes such as biodegradable waste, recyclable materials, electrical and electronic waste, hazardous waste, toxic waste and inert waste. Most substances in these wastes invariably contain heavy metals. The areas around the refuse dump have long been utilized for vegetable gardening by poor residents in the King Tom community. This study was aimed at assessing levels of toxic heavy metals (Pb, Cr, Hg, As and Al) in selected vegetables and fruit grown in the gardens around the King Tom dump site to ascertain bioaccumulation and possible HM toxicity. Two sampling sites were chosen for this research; gardens in the King Tom dumpsite in the west end and controlled site (Congo Water) in the East end of Freetown. Two commonly consumed leafy vegetables in Freetown, Manihot utilisimma (Cassava leaves), Ipomea batatas (Potato leaves) and fruit Solanu m melongena (Garden egg) were chosen for research. After sample preparation, the level of heavy metals in the soil and plant samples was determined spectrophotometrically, using Spectrophotometer model (Niton XL3t GOLDD+handheld X-ray fluorescence). Results indicate that metal levels in dump site soil are far higher than those in controlled site soil and that Al recorded highest level followed by Pb, Cr and As for dump site soil. Hg was not detected in both sample sites investigated. In the leafy vegetables and fruit, the metal levels were found to be in the following order; Al>Cr>Pb>As. The order of bioaccumulation of the metals in the leafy vegetables and fruit is; Pb:Solanum melongena (Garden egg)>Ipomea batatas (Potato leaves)>Manihot utilisimma (Cassava leaves); Cr:Ipomea batatas (Potato root)>Manihot utilisimma (Cassava leaves)>Solanum melongena (Garden egg);Al :Ipomea batatas (Potato root)>Ipomea batatas (Potato leaves) Manihot utilisimma (Cassava leaves)>Solanum melongena (Garden egg); As :Ipomea batatas (Potato leaves)>Ipomea batatas (Potato root)>Solanum melongena (Garden egg)for both sample sites investigated. The Product moment correlation coefficients between soil and cassava leaves (rsc), between soil and potato leaves (rsp), and between soil and garden eggs (rsg)were calculated to giversc= 0.994, rsp= 0.992 and rsg= 0.997; indicating very strong relationships between the soil and plant parts. This implies that the dumpsite soil is the most likely source of the extra metal concentrated in the plant parts.

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INTRODUCTION

The influx of people migrating from rural areas to cities in African countries, has led to an astronomical increase in size and population of cities. In sub-Saharan Africa, only 35% of the population lives in urban areas, and urban population grew by 150 % between 1970 and 1990(*www.encapafrica.org., 2009*). In Serra Leone migrants arriving in the cities from other areas of the country are mostly unskilled and have poor educational background. They mainly engage in various economic activities such as sand and stone mining, petty-trading, bike riding and urban vegetable farming for their livelihood. For those pursuing the vegetable growing option access to land and water in the cities is a major challenge. Thus Landfills and/or open refuse dumps and areas around them have become very attractive places to vegetable growers.

Land fills and/or open refuse dumps have been common municipal solid waste (MSW) disposal practices all over the world (*Nagendran et. al., 2006*) and Sierra Leone is yet to properly design and operate sanitary land fills in and around urban towns. Refuse dumps in cities in Sierra Leone usually hold all kinds of solid wastes including: biodegradablewaste, recyclable materials, inert waste, electrical and electronic waste, hazardous waste and toxic waste. This mixture of solid wastes in refuse dumps is a reservoir of hazardous substances that can increase the health risks emanating from the leachate and gases (Erses *et al.,* 2005). MSW can bleed toxic materials and pathogenic organisms into dumps and landfill leachate contaminating ground or surface water, depending on the drainage system and the composition of the underlying soils (www.encapafrica.org., 2009). Land fill leachate is one of the main sources of groundwater and surface water pollution which may percolate through soil reaching water aquifers (Bashir *et al.,* 2009). Heavy metals are naturally presentin the earth's crust, but become concentrated as a result of various human caused activities (Brath waite and Rabone, 1985). Heavy metals can bind to vital cellular components in the human body such as structural proteins, enzymes, and nucleic acids, and interfere with, and in some cases inhibit their normal functioning (Emsley, 2011). Symptoms and effects of heavy metal toxicity can vary according to the metal or metal compound, and the dose involved. Generally, long-term exposure to toxic heavy metals can have carcinogenic, central and peripheral nervous system and circulatory effects (Gilbert and Weiss, 2006). Ingestion of plant- and animal-based foods is the largest sources of toxic heavy metals in humans (Dueck D., 2000). Absorption through direct skin contact with soil is another potential source of toxic heavy metals contamination (Duffus, 2002). Heavy metals can bioaccumulate in organisms since they are difficult to metabolize (Dyer, 2009 and Adepoju-Bello and Alabi, 2005). Heavy metal pollution is a serious and widely environmental problem due to their persistent and non-biodegradable nature(Yuan C. G, *et al.,* 2004).A brief survey of some toxicity symptoms of the metals in this study is as follows.

Aluminium (Al): Is not a heavy metal (specific gravity of 2.55 -2.80). Studies suggested that aluminium might have a possible connection with developing Alzheimer's and Parkinson's disease also causes senility and presenile dementia (Bakare-Odunola, 2005). Excess levels of aluminum mobilize calcium and heavy metals to move from bones to the central neural tissue.

Mercury (Hg): Is a toxic substance which has no known function in human biochemistry or physiology and does not occur naturally in living organisms. Toxicity of mercury results in acute poisoning ;(fever, diarrhea, vomiting) and chronic poisoning; (inflammation of gums and mouth, nonspecific kidney disorder, neurotic disorder, metallic taste) (Gilbert S .G, and Weiss B., 2006).

Chromium (Cr): Metal and Chromium (III) compounds are not considered a health hazard; whereas chromium (VI) compounds are toxic to human health and carcinogenic (Pearce J. M, 2007). Low level exposure can irritate the skin and cause ulceration. Long term exposure can cause kidney and liver damage, and damage to circulatory and nerve tissue (ATSDR, 2000)

Arsenic (As): Is a highly toxic metalloid element and it is thought that it may affect the chromosomes of humans and their health. The inorganic form of arsenic found in contaminated meats, weed killers and insecticides can be very toxic (Pizzaro *et al.,* 2003).

Lead (Pb): Is the most prevalent toxic heavy metal contaminant (Chowdhury and Chandra, 1987). In humans exposure to lead can result in a wide range of biological effects depending on the level and duration of exposure. High levels of exposure may result in toxic biochemical effects in humans which in turn cause problems in the synthesis of haemoglobin, effects on the kidneys andcause chronic damage to the nervous system. (Gomez–Ariza, *et al.,* 2000). All the above metals are very likely to be present in MSW as the solid metal or compounds. Dumpsite soils may accumulate heavy metals resulting in soil contamination. Increased heavy metal uptake by crops, in polluted soilsmay lead to deleterious effects on food quality and safety. Vegetables are known to represent a rich source of vitamins, minerals, and fibers for human diet, and also have beneficial antioxidative effects. However, vegetables and fruit grown in contaminated soilmay have the potential to accumulate relatively high amounts of heavy metals (Sharma et al. 2006; Marshall *et al.,* 2007; Sharma *et al.,* 2009). This work will attempt to assess levels of heavy metals (Pb, Cr, Hg, As and Al) in selected vegetables and fruits grown in areas around the King Tom dumpsite in Freetown; to ascertain bioaccumulation and possible HM toxicity.

MATERIALS AND METHODS

Study Area: Two sampling sites were chosen for this research; the King Tom dumpsite in the west end and control led site (Congo Water) in the East end of Freetown. The locations of these areasare given in the table below using the global positioning system (GPS).

Table1. Geographical information system (GIS) for sampling sites

Sampling Sites	GIS Coordinates		Altitude (m)
	North	West	
King Tom (dumpsite)	08° 28.846'	13°12.548'	035
Congo Water (Controlled site)	08°27.535'	13°10.382'	034

Sample collection and preparation: The figures below (1a, b and c) show images of the plant samples collected from both sampling areas (dumpsite and controlled site). The leafy vegetables and fruit harvested were washed with distilled water to remove soil particles and other debris. The Ipomea batatas (potato leaves) plant was further separated into root and shoot (stem and leaves). The samples were sun-dried for two weeks and then pulverized to fine powder (125µm). The powdered samples were then placed in polythene containers prior to metal analysis. Soil samples from the gardens in the dumpsite and controlled site were obtained at different depths; top layer (0 – 10cm) and bottom layer (10 – 20cm) from the different locations. The soil samples were air-dried for two weeks, ground and homogenized in an agate mortar and sieved to 125µm particle size. They were placed in polythene containers and stored at room temperature prior to laboratory analysis.

Chemical analysis

Determination of heavy metal concentration in samples: The loose powder method was used for sample preparation (Honma, 2005). 3g of each powdered sample was placed into a sample cell of 30mm ID opening and 5mm depth and covered with transparent plastic film as shown in figure 2 below. The concentration of heavy metals was determined in both soil and plant samples spectrometrically, using Spectrometer model (Niton XL3t GOLDD+handheld X-rayfluorescence), figure 3. The elements were quantified and the results expressed in parts per million (ppm) of dry matter. The Niton XL3t GOLDD+hand held X-rayfluorescence (Thermo Fisher) instrument uses an Ag-anode X-ray tube with a voltage of 50 kV and is equipped with a Si-drift detector (SEDD). An accurate energy and efficiency calibration of the spectrometer was made using a certified reference material (NIST Montana Soil 2710a from IAEA, Vienna, Austria). The spectrum acquisition time is 300 sec for each sample and the dead time was around 50%.

Figure 1a: *Ipomea batatas* (Potato leaves)

Figure 1b. *Solanum melongena* (Garden egg)

Figure 1c. *Manihot utilisimma* (Cassava leaves)

Figure 2. Cells containing samples

Figure 3. the XRF Spectrophotometer model (Edxrf niton XL3t 900)

Determination of pH and organic matter content of soil samples: The pH was determined by dissolving 1g of the powdered soil in 100ml distilled/deionized water and shaken until homogeneity was achieved. A glass electrode pH meter (Labtek India) was used to measure the pH of the soil sample in a 1:10 soil to water solution (Shulka, 2009). For organic matter content, the soil samples were first heated in amuffle furnace at 105°C for 24hours to remove moisture and then at250°C for at least 16 hours for complete combustion (Reddy *et al.,* 2009). The soil organic matter content (%OM) is calculated from the relation:

$$\%OM = \frac{\text{Pre - ignition weight (g) - Post - ignition weight (g)} \times 100}{\text{Pre - ignition weight (g)}}$$

RESULTS

pH and organic matter: Results obtained from pH and organic matter determination are given below in table 2

Mean concentration of metals (PPM) in soil samples and plant parts: The following table 3 indicates mean concentration of metals (ppm) in soil samples. Tables 4 and 5 provide mean metal concentration (ppm) in vegetables and fruit grown in both dumpsite and controlled site.

Table 2. Mean pH and Organic matter of soil samples

Sampling site	pH	Soil Organic matter Content (%)
Dumpsite	7.22	67.3%
Controlled site	6.23	32.7%

Table 3. Mean metals concentration (PPM) in soil samples

Soil sample	Metal concentration (ppm)				
	Al	As	Cr	Hg	Pb
Dumpsite	23946.6	5.2583	1496.123	<LOD	3026.64
Controlled site	38419.7	2.01	658.21	<LOD	106.04

Note: <LOD= below level of detection

Table 4. Mean metal concentration (PPM) in vegetables grown in dumpsite

Plantsample	Metal concentration (ppm)				
	Al	As	Cr	Hg	Pb
Cassava leaves	758.50	<LOD	45.70	<LOD	4.55
Potato (stem & leaves)	1253.78	9.315	<LOD	<LOD	8.59
Potato (root)	1996.90	4.59	51.41	<LOD	17.19
Garden egg	508.53	6.24	29.45	<LOD	14.58

Table 5. Mean metal concentration (PPM) in vegetables grown in controlled site

Plant sample	Metal concentration (ppm)				
	Al	As	Cr	Hg	Pb
Cassava leaves	794.29	<LOD	<LOD	<LOD	1.02
Potato (stem & leaves)	1698.31	<LOD	<LOD	<LOD	1.10
Potato (root)	1348.33	<LOD	22.12	<LOD	2.36
Garden egg	1253.69	<LOD	18.07	11.60	2.03

Table 6. WHO acceptable limits of trace metal concentration in soil (PPM)

Metal	Concentration in soil (ppm)
Al	6 – 3500
As	0.009 – 1.5
Cr	0.002 – 0.2
Hg	0.001 – 0.04
Pb	0.3 - 10

DISCUSSION

pH and Organic matter: As shown in table 2, the pH values indicate that soil from the dumpsite is slightly alkaline while that from the controlled site is moderately acidic. To a large extent the soil alkalinity could be attributed to the continuous incineration of solid wastes in the dumpsite; which also has the potential to increase the level of soil organic matter content.

Metal concentration in soils at the sampled sites: The concentration of metals in both types of soil was generally found to be highest for Al followed by Pb, Cr and as (table 3). Results in table 3 also indicate that with the exception of Al, the dumpsite soil generally contains more metals than the controlled site soil. The unusually high level of Al in the controlled site soil may be attributed to possible commercial activities involving Al metal works or some form of Al works in the areain the past. The high levels of metal in the dumpsite soil samples could possibly be due to the effect of different types of metal-bearing substances/materialsin the municipal wastes deposited at the dumpsite. The high level of Al in dumpsite soil could be attributed to the large quantities of Al-containing substances that may be present in the MSW deposited on a daily basis at the site. For the metals Pb, Cr and As their possible sources could be; discarded Pb batteries and other Pb-containing items; As-bearing waste like charcoal, pesticides, herbicides; Cr-containing scrapped metals including motor vehicle spear parts, bicycles etc in the MSW deposit. Generally Hg was not detected in both sites meaning the contribution of Hg-containing compounds in MSW such as cosmetics, fluorescent lamps etc.; is too small and Hg is also volatile.

Metal concentration in leafy vegetables and fruit: In the case of the leafy vegetables and fruit, the metal levels were found to be in the following order; Al>Cr>Pb>As, (tables 4 and 5). Ipomea batatas (Potato leaves) accumulated more metals followed by Solanum melongena **(**Garden egg**)** fruit and Manihot utilisimma (Cassava leaves). The order of metal bioaccumulation in the plant parts is Ipomea batatas (Potato leaves)>Solanum melongena **(**Garden egg**)**>Manihot utilisimma (Cassava leaves), (tables 4 and 5). Potato root absorbed the highest levels of the metals, Al>Cr>Pb than all the other plant parts, (tables 4 and 5). The order of bioaccumulation of the metals in the leafy vegetables and fruit is; Pb: Solanum melongena **(**Garden egg**)**>Ipomea batatas (Potato leaves)>Manihot utilisimma (Cassava leaves); Cr:Ipomea batatas (Potato root)>Manihot utilisimma (Cassava leaves)>Solanum melongena **(**Garden egg);Al :Ipomea batatas (Potato root)>Ipomea batatas (Potato leaves) Manihot utilisimma (Cassava leaves)>Solanum melongena **(**Garden egg**)**; As: Ipomea batatas (Potato leaves)>Ipomea batatas (Potato root)>Solanum melongena **(**Garden egg**)**for both sample sites investigated (Tables 4 and 5). The calculated Pearson Product moment correlation coefficients between soil and cassava leaves ($\mathbf{r_{sc}}$), between soil and potato leaves ($\mathbf{r_{sp}}$), and between soil and garden eggs ($\mathbf{r_{sg}}$) from data in tables 3 and 4,gaver_{sc}= 0.994, r_{sp}= 0.992 and r_{sg}= 0.997. The secorrelation coefficients indicate that a very strong relationship exist between soil and plant parts implying that the soil is the most likely source of the extra metal concentrated in the plant parts.

Conclusion

Leafy vegetables and fruit can take up heavy metals by their roots, or even via their stems and leaves, and accumulate them. This study concluded that:

- Large quantities of heavy metals are generated from MSW in the dumpsites which eventually leach into the rest of the environment.
- Among the three crops investigated, Ipomea batatas (potato leaves and potato root) accumulated the highest amount of heavy metals followed by Solanum melongena (garden egg) fruit and Manihot utilisimma (Cassava leaves).
- Al metal showed the highest concentration in both soil and plant parts and Hg was not detected.

Recommendations

- Other food sources, such as rice, other vegetables, fruits, corn etc. grown in the areas around the King Tom dumpsite must be investigated in order to assess the health risks that may be linked to intake of trace metal. Moreover, constant monitoring of heavy metals in all food commodities grown in the area must be done in order to evaluate potential health risks.
- Where possible agricultural farm lands to be provided for Gardeners as an alternative to the dumpsite for gardening purposes.
- To sensitize local Gardeners about the health hazards associated with practicing agricultural activities in polluted soils such as the King Tom dumpsite.

REFERENCES

Adepoju-Bello, A. A and Alabi, O. M. 2005. Heavy metals: A review. *The Nig. J Pharm.,* 37: 41-45.

ATSDR, 2000. Agency for Toxic Substances and Disease Registry, Atlanta, Toxicological Profile for Chromium. GA: U.S. Department of Health and Human Service, Public Health Service. 1600 Clifton Road N.E, E-29 Atlanta, Georgia. 30333(6-9) 95 - 134.

Bakare-Odunola, M. T. 2005. Determination of some metallic impurities present in soft Drinks Marketed in Nigeria. *The Nig. J Pharm.,* 4: 51-54.

Bashir, M. J. K, Isa, M. H, Kutty, S. R. M, Awang, Z. B, Abdul Aziz, H, Mohajeri, S, *et al.,* 2009. Landfill leachate treatment by electrochemical oxidation. Waste Manage; 29:2534–41.

Brathwaite, R. L, Rabone, S. D. C. 1985. "Heavy Metal Sulphide Deposits and Geochemical Surveys for Heavy Metals in New Zealand". *Journal of the Royal Society* of New Zealand15 (4): 363–370. doi:10.1080/03036758.1985. 10421713.

Chowdhury, B. A. and Chandra, R. K. 1987. "Biological and health implications of toxic heavy metal and essential trace element interactions". *Prog Food Nutr Sci.,* 11 (1): 55–113. PMID 3303135.

Dueck, D. 2000. Strabo of Amasia: A Greek Man of Letters in Augustan Rome. Routledge. ISBN 0415216729.

Duffus, J. H., 2002. "Heavy Metals"—A Meaningless Term?". *Pure and Applied Chemistry,* 74 (5): 793–807. doi:10.13 51/pac200274050793.

Dyer, P., 2009. "The 1900 Arsenic Poisoning Epidemic". Brewery History (130): 65–85.

Edn. New Jersey: Prentice-Hallb139-159.

Emsley, J. 2011. Nature's Building Blocks. Oxford University Press. ISBN 9780199605637.

Erses, A. S, Fazal, M. A, Onaya, T. T. and Craig, W. H. 2005. Determination of solid waste sorption capacity for selected heavy metals in landfills. J Hazard Mater;B121:223–32.form tannery waste water. *Electron. J. Environ. Agric. Food Chem*., 2: 543–548.

Gilbert, S. G and Weiss, B. 2006. "A Rationale for Lowering the Blood Lead Action Level from 10 to 2 μg/dL". Neurotoxicology27 (5): 693–701. doi:10.1016/j.neuro.200 6.06.008. PMC 2212280. PMID 16889836.

Gomez–Ariza, J. L., Giraldez, I., Sanchez-Rodas, D. and Moralesm, E. 2000. MetalSequential Extraction Procedure optimized for heavy metal polluted and iron- oxide rich sediments. *Anal Chim Acta.,* 414: 151-164.

Honma, H. 2005. The aging process. Proceedings of the National Academy of Sciences .USA, 78 (11), 7124-7128

Nagendran, R., Selvam, A., Joseph, K. and Chiemchaisri, C. 2006. Phytoremediation and rehabilitation of municipal solid waste landfills and dumpsites: a brief review. Waste Manage; 26:1357–69.

Marshall, F. M., Holden, J., Ghose, C., Chisala, B., Kapungwe, E., Volk J., Agrawal, M., Agrawal, R., Sharma, R. K. and Singh, R. P. 2007. Contaminated irrigation water and food safety for the urban and peri-urban poor: appropriate measures for monitoring and control from field research in India and Zambia. Incpetion Report DFID Enkar R8160, SPRU, University of Sussex

Pearce, J. M. 2007. "Burton's Line in Lead Poisoning". *Eur Neurol.,* 57 (2): 118–9. doi:10.1159/000098100. PMID 17179719.

Pizzaro, I., Gomez, M., Camara, C. and Palacios, M. A. 2003. Arsenic speciation in Environmental and biological samples –Extraction and stability studies. Anal Chim Acta 495: 85-98.

Reddy, K.R., Hettiarachci, H., Gangathulasi, J., Bogner, J.E. and Lagier, T. 2009. Geotechnical properties of synthetic municipal solid waste. *Int. J. Geotechn. Eng.,* 3: 429–438.

Sharma, R. K., Agrawal, M. and Marshall, F. M. 2006. Heavy metals contamination in vegetables grown in waste water irrigated areas of Varanasi, India. *Bull. Environ. Contamin. Toxicol.,* 77: 311–318.

Sharma, R. K., Agrawal, M. and Marshall, F. M. 2009. Heavy metals in vegetables collected from production and market sites of a tropical urban area of India. Food Chem. Toxicol. 47: 58-91.

Shukla, P.K. 2009. Nutrient dynamics of teak plantations and their impact on soil productivity – a case study from India. XIII World Forestry Congress, Buenos Aires, Argentina, 18-23

Thomas Graham House, Science Park, Milton Road, Cambridge CB4 OWF, UK. Pp 234

www.encapafrica.org (1990) Environmental Guidelines for Small-Scale Activities in Africa (EGSSAA)

Yuan, C. G., Shi, J. B., He, B., Liu, J. F., Liang, L. N., *et al.,* 2004. Speciation of heavy metals in marine sediments from the East China Sea by ICP-MS with sequential extraction. *Environ Int.,* 30: 769-783.

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