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Assessment of Some Heavy Metal Levels and its Related Health Hazards in Two Staple Foods Grown in Mining Communities of Ebonyi State

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Authors' contributions

This work was carried out in collaboration among all authors. Authors UAJ, CI and UOH designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors EC and EN managed the analyses of the study. Authors ONV, OPE and OCJ managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Background: This study assessed the levels of some heavy metals in two staple foods grown within mining sites at Ishiagu and Enyigba communities of Ebonyi State. The control site was Umuezeokoha community. The present study is significantly important in respect to hazardous effect of heavy metal accumulation in staple food as there was no or scarcity of data available in Nigeria on this aspect.

Materials and Methods: The two commonly cultivated food crops namely *Manihot esculentus* (cassava) and *Telfairia occidentalis* (fluted pumpkin) were grown within <20m, 100m before mining sites. The crops were collected from the three farms at the peak of the harvesting period, processed and were analyzed for heavy metals using AAS technique.

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Results: The results revealed that heavy metals; Pb, Cu, Ni, Zn and Mn in *Manihot esculentus* tubers in all the farms within Ishiagu and Enyigba mining sites were comparable to each other and control site but Cr levels in control site was higher than others and that of WHO/FAO maximum permissible limit. Only As from A_2 in Ishiagu had the highest value and exceeded WHO/FAO maximum permissible limit. Fe from B_1, B_2 in Enyigba and that of control had the highest values when compared to others but Fe in all samples investigated exceeded WHO/FAO maximum. Also, Pb, Cu, Ni, Zn, and Mn in *Telfairia occidentalis* leaves in all the farms within mining sites were comparable to control site except As levels from A_2 in Ishiagu and from control site which was higher compare to others including WHO/FAO maximum permissible limit. Cr only from A_2 in Ishiagu, B_2 and B3 in Enyigba was highest even with WHO/FAO maximum permissible limit. Fe too from all the farms in Enyigba and control had highest values even with WHO/FAO maximum permissible limit.

Conclusion: The results showed that the investigated food crops from two mining communities and the control site were not safe for consumption.

Keywords: Heavy metals; tubers; leaves; AAS; Ishiagu; Enyigba; Mines.

1. INTRODUCTION

Rapid economic development is the prime goal of many countries that resort to assorted activities to exploit their natural endowments. Mining which is one of such activities has the potential of contributing to the development of areas endowed with mineral resources. Mining is a lucrative business in Nigeria especially Ebonyi State and the activity is on increase on daily basis for many reasons; it provides both internal and external economic benefits to state. Internally, it creates employment to the teeming unemployed youths as well as uneducated and unskilled rural populace and it is a substantial font of foreign exchange among others [1,2]. To this effect, it is of the essence to investigate the side effect or consequence on workers, neighboring communities and the environment in general.

Mining activities contribute to environmental pollution and degradation by the release of particulates and gaseous materials [2]. Manifestations of specific impacts are on the air, water, soil, earth surface, plants and animals [3, 4]. Similarly, other negative impacts includes swamp creation, deterioration of ground water, erosion of soil, noise, generation of dust, smoke and fumes; production of noxious gases and ground vibration [5,6] to mention but a few.

Metals have been extensively studied and their effects on human health regularly reviewed by international bodies such as the WHO. Heavy metals have been used by humans for thousands of years [7]. Some heavy metals have bio-importance as trace elements but the biotoxic effects of many of them in human biochemistry are of great concern. Although several adverse health effects of heavy metals have been known for a long time, exposure to heavy metals continues, and is even increasing in some parts of the world, in particular in less developed countries, though emissions have declined in most developed countries over the last 100 years [8]. Recent data indicated that adverse health effects of cadmium exposure, primarily in the form of renal tubular damage. It possibly has effect on bone and fractures, and may occur at lower exposure levels than previously anticipated [9,10]. Heavy metals are persistent in the environment, contaminate the food chains, and cause different health problems due to their toxicity. Chronic exposure to heavy metals in the environment is a real threat to living organisms [11-13].

Food security is a high-priority issue for sustainable global development both quantitatively and qualitatively. In recent decades, adverse effects of unexpected contaminants on crop quality have threatened both food security and human health. Heavy metals and metalloids (e.g., Hg, As, Pb, Cd, and Cr) can disturb human metabolomics, contributing to morbidity and even mortality [14].

The diverse and emerging issues of food security have become a global concern, particularly their inextricable association with human health [15-18]. In Ebonyi State, Farming is one of the major economic sectors and livelihood of the average Ebonyian depends either on agriculture or agriculture related business. In Ishiagu and Enyigba communities, farm lands are increasingly being used for mining. As a result, the limited available agricultural lands are now found within or very close to mine indulgences. Thus, mining activities have deprived most Farmers access to fertile lands hence agricultural activities are not that widespread in the area and are predominantly on small scale basis. *Manihot esculentus* (cassava) tubers and *Telfairia occidentalis* (fluted pumpkin) leaves are one of the major food crops grown by farmers in the municipality. These staple foods are consumed in almost every household in Southern Nigeria forming an important source of nutrients.

The primary sources of heavy metals in the soil environment and agriculture are atmospheric deposition, livestock manure, irrigation with wastewater or polluted water, metallo-pesticides or herbicides, phosphate-based fertilizers, and sewage sludge–based amendments [19-22]. Several case studies in China were carried out to describe the health risks caused by heavy metal contamination of food crops as a result of wastewater irrigation [23,24]. Mine tailings are crushed rocks that are left over after extraction is stored in special containment systems such as dams by some mining companies. These tailings contain heavy metals that find themselves in the environment when there is a leakage, flooding or when the wind blows. The heavy metals in tailing materials find themselves in soils, water bodies and plants.

Most heavy metals are distributed in the body through blood to tissues [25]. Lead is carried by red blood cells to the liver and kidney and subsequently redistributed to the teeth, bone and hair mostly as phosphate salt [26]. Arsenic is distributed in blood and accumulates in heart, lung, liver, kidney, muscle and neural tissues and also in the skin, nails and hair [8]. Lead is released into the atmosphere from industrial processes as well as from vehicle exhausts. Therefore, it may get into the soil and flow into water bodies which can be taken up by plants and hence human exposure of lead may also be through food or drinking water [27]. The plants absorb the heavy metals from contaminated soils through their roots and those that settle on the plants get into the plant organs through their leaves [28]. When these heavy metals get into the plant system they are stored in the roots, shoot and fruits. In cases where the soils and food crops are contaminated with heavy metals, it would result in accumulation of these heavy metals in humans who eat them resulting in malfunctioning of some human organs [2].

Some of the heavy metals in high doses can be harmful to the body while others such as cadmium, mercury, lead, chromium, silver, and arsenic in minute quantities have delirious effects in the body causing acute and chronic toxicities in humans [29,30]. In the human body, these heavy metals are transported and compartmentalized into body cells and tissues binding to proteins, nucleic acids destroying these macromolecules and disrupting their cellular functions. As such, heavy metal toxicity can have several consequences in the human body. It can affect the central nervous function leading to mental disorder, damage the blood constituents and may damage the lungs, liver, kidneys and other vital organs promoting several disease conditions [31,32]. Based on this, it is necessary to assess the safety of these crops for human consumption, bearing in mind the probable toxicity and persistent nature of heavy metals and the frequent consumption of them in our hinterlands and municipalities.

2. MATERIALS AND METHODS

2.1 Study Area

The present study was carried out in two mining sites located in Enyigba community in Izzi LGA and Ishiagu community in Ivo LGA while the control was at Umuezeokoha community in Ezza North LGA.

2.2 Collection and Preparation of *Manihot esculentus* (Cassava) Tubers and *Telfairia occidentalis* (fluted pumpkin) leaves

The tubers of *Manihot esculentus* were peeled with kitchen knife. The peeled tubers and leaves of *Telfairia occidentalis* were washed with clean water and cut into pieces using clean knife. The sliced tubers were sun-dried while that of the leaves of *Telfairia occidentalis* were shade dried. The dried tubers and leaves were pulverized differently into powder using pestle and mortar in Department of Soil Science, National Root Crop Research Institute, Umudike, Abia State, Nigeria.

2.3 Determination of Minerals in Crop Samples

The levels of metals; Pb, As, Cr, Cu, Ni, Zn, Fe and Mn were measured with Varian AA240 Atomic Absorption Spectrophotometer as described by APHA [33]. Two grams of the sample was mixed with 20ml of acid mixture (650 ml concentrated HNO_3, 80 ml perchloric acid, 20 ml concentrated H_2SO_4) in a digestion flask. The mixture was heated until a clear digest is obtained. The digest was diluted to 100 ml mark and aspirated into an AAS. Absorbance was read at wavelength of the metals.

2.4 Experimental Design

Three communities were selected for the research and they include: Ishiagu, Enyigba and Umuezeokoha in Ivo, Izzi and Ezza North LGA respectively. Ishiagu and Enyigba communites were selected because of deposits of some minerals in the areas and accessibility to farmlands. Three farms were used in both Ishiagu and Enyigba communites for the study. The farms were designated as A_1, A_2, A_3, B_1, B_2 and B_3. A_1 and B_1 were farms in the areas at less than 20 m away from mining sites, A_2 and B_2 were farms 100 m forward away from mining sites while A_3 and B_3 were farms 100 m backward away from mining sites and all served as experimental areas. Umuezeokoha community served as control and was designated as C. The Crops were collected from each of the three communities at the peak of harvest for each crop.

2.5 Statistical Analysis

The data generated from the analysis were subjected to one- way analyses of variance (ANOVA). Means were compared for significance using Duncan's Multiple Range test (P<0.05). Concentrations of heavy metals were expressed as mean ± SD (Standard Deviation). This analysis was estimated using Statistical Package for Social Sciences (SPSS), version 23.

3. RESULTS

Tables 1 and 2 present the mean ± SD concentrations of heavy metals in the tubers of *Manihot esculentus* and leaves of *Telfairia occidentalis* from farms within Ishiagu and Enyigba mining sites respectively.

4. DISCUSSION

Lead (Pb): The concentrations of Pb in the tuber of *Manihot esculentus* and leaves of *Telfairia occidentalis* in all the farms were comparable to each other and were all underneath the WHO maximum permissible limit (WHO-MPL) (Table 1). The report of Ajiwe et al. [34] on Pb levels in *Manihot esculentus* tubers grown at farms located south, west and east of Galena Mining in Ishiagu is in conformity with obtained results but diverged with the one obtained north. Obasi et al. [4] reported high levels of Pb in *Telfairia occidentalis* and *Amaranthus hybridus* leaves more than WHO-MPL from Ishiagu-Enyigba communities which differed with the result of this study. Oti and Nwabue [35] stated that Pb levels of *Telfaria occidentalis, talinum triangulare and Amaranthus hybridus l*eaves cultivated around Enyigba mine were below WHO-MPL which are in unity with the obtained results but diverged with that of *Vernonia amigdalina and solmun nigrum leaves.* The main concern in this work was lead because it is highly toxic even at minute concentration and can be harmful to man who consumed the contaminated crops. The existences of lead have effects on the gastrointestinal tract, kidneys, and central nervous system. Children exposed to lead are at risk for impaired development, lower IQ, shortened attention span, hyperactivity, and mental deterioration while adults usually experience decreased reaction time, loss of memory, nausea, insomnia, anorexia, and weakness of the joints when exposed to lead.

Arsenic (As): Arsenic was detected in all the investigated crops and only *Telfairia occidentalis* from control site had value that exceeded WHO-MPL (Tables 2). The As concentrations of *Telfaria occidentalis and Amaranthus hybridus* grown within Enyigba mine was beneath WHO-MPL and the report is in peace with the outcome of this study while that of Talinum *triangulare* were above and differed with the results [35]. Alan et al. [36] reported high levels of arsenic in different vegetables grown in Bangladesh which is in peace with the results obtained. The concentration of As was high enough to cause problems to human that consume these metal rich vegetables. Consumption of the contaminated vegetables will surely result to health penalties which include kidney and liver damage, gastrointestinal effect, peripheral neuropathy, Skin lesion, Lung cancer and death.

Chromium (Cr): Levels of Cr was higher than WHO-MPL in the *Manihot esculentus* from Umuezeokoha and *Telfairia occidentalis* in farm 2 and 3 from Enyigba mine while others were below WHO-MPL. The result of this study is in accordance with report of Ajiwe et al. [34] on Pb levels in cassava tubers grown in farms within Galena Mining in Ishiagu. Only Cr levels in *Amaranthus hybridus* from Enyigba was below. *The report of* Oti and Nwabue [35] on Cr levels *of Telfaria occidentalis, Talinum triangulare*

Table 1. Concentrations of heavy metals in cassava tubers (*Manihot esculentus*) in Ishiagu and Enyigba

		Heavy metal concentrations (mg/kg)							
Locations	**Farms**	**Pb**	**As**	**Cr**	**Cu**	**Ni**	**Zn**	**Fe**	**Mn**
Ishiagu	A1	0.03±0.003	0.01±0.004	0.03±0.00	0.03±0.003	0.01±0.004	3.07±0.08	2.00±0.03	1.48±0.12
	A2	0.06±0.02	4.55±0.55	0.03±0.01	0.02±0.01	0.01±0.01	4.05±2.05	3.54±0.76	1.18±0.38
	A3	0.02±0.01	0.04±0.05	0.02±0.02	0.01±0.003	0.013±0.003	3.33±0.25	2.30±0.25	2.64±0.32
Enyigba	B1	0.02±0.01	0.01±0.004	0.01±0.003	0.01±0.003	0.04±0.002	3.52±0.45	4.51±0.56	1.06±0.15
	B2	0.04±0.01	0.02±0.01	0.02±0.01	0.03±0.004	0.02±0.01	3.58±0.50	4.48±0.57	0.47±0.36
	B3	0.01±0.02	0.01±0.01	0.03±0.01	0.03±0.01	0.03±0.01	1.81±0.20	2.15±0.13	1.72±0.45
Umuezekoha	C	0.07±0.02	0.01±0.01	0.28±0.02	0.02±0.01	0.01±0.001	5.27±0.81	5.61±1.17	4.84±3.68
MPL (WHO/ FAO)	STD	0.30	0.10	0.05	0.05	67.00	100.00	0.80	500.00

Results Presented as Mean ± Standard Deviation (n=3)
MPL = Maximum Permissible Limit
WHO= World Health Organization
FAO = Food and Agriculture Organization

Table 2. Concentrations of heavy metals in fluted pumpkin leaves (*Telfairia occidentalis*) in Ishiagu and Enyigba

		Heavy metal concentrations (mg/kg)							
Locations	**Farms**	**Pb**	**As**	**Cr**	**Cu**	**Ni**	**Zn**	**Fe**	**Mn**
Ishiagu	A1	0.03±0.01	0.04±0.05	0.02±0.01	0.03±0.01	0.01±0.01	5.37±0.48	3.02±0.98	1.09±0.29
	A2	0.13±0.18	0.07±0.06	0.15±0.15	0.02±0.02	0.01±0.01	2.92±1.22	3.53±0.35	1.15±0.24
	A3	0.08±0.11	0.01±0.02	0.03±0.02	0.04±0.01	0.01±0.003	6.02±1.19	2.20±1.75	1.30±0.70
Enyigba	B1	0.04±0.07	0.05±0.05	0.02±0.02	0.05±0.02	0.02±0.01	5.34±0.98	18.25±7.76	1.35±0.3
	B2	0.05±0.01	0.01±0.01	0.22±0.02	0.05±0.01	0.02±0.01	4.56±0.52	18.17±3.57	1.02±0.26
	B3	0.02±0.01	0.02±0.04	0.28±0.01	0.04±0.01	0.01±0.001	5.47±0.44	20.40±2.28	0.86±0.04
Umuezekoha	C	0.04±0.02	0.04±0.02	0.43±0.05	0.03±0.03	0.04±0.02	0.01±0.003	6.10±1.30	23.65±11.86
MPL (WHO/ FAO)	STD	0.30	0.10	0.05	73.00	67.00	100.00	0.80	500.00

Results Presented as Mean ± Standard Deviation (n=3)
MPL = Maximum Permissible Limit
WHO= World Health Organization
FAO = Food and Agriculture Organization

Vernonia amigdalina and *Solmun nigrum* leaves from Enyigba agreed with the outcome of the study in farm B_2 and B_3. Consumption of the affected vegetables will certainly lead to health consequences which include kidney and liver damage, skin rashes, stomach upset and ulcer, respiratory problems and lung cancer and alteration of genetic materials.

Cupper (Cu): Concentrations of Cu in crops from all the farms investigated were underneath WHO-MPL (Table 1and 2) which suggest that none of the crops was contaminated by Cu. The outcome of the study is in tranquility with the report of Oti [37] on cupper levels of *Manihot esculentus*, *Colocosia and Xanthosama, Dioscorea rotundata and Ipomoea batatas* tubers grown in a lead-zinc derelict mine. Also, the report of Obasi et al. [4] on levels of Cu from Ishiagu-Enyigba in *Telfairia occidentalis* and *Amaranthus hybridus* leaves has the same opinion with outcome of this work.

Nickel (Ni): Nickel concentrations in all the studied crops were below WHO-MPL (Table 1 and 2). This suggests that all the studied crops were free of Ni contamination and therefore are safe for human consumption. The outcome of the study is in tranquility with the report of Oti [37] on cupper levels of *Manihot esculentus*, *Colocosia and Xanthosama, Dioscorea rotundata and Ipomoea batatas* tubers grown in a lead-zinc derelict mine. Nickel at this level is not a known toxic metal to human health. Excess and deficiency of Ni in crops are disadvantageous to human health [38,39]. Deficiency of nickel have been linked with hyperglycemia, hypertension, depression, sinus congestion, fatigue, reproductive failures and growth problems in humans, while excess intake of Ni leads to hypoglycemia, asthma, nausea, headache and epidemiological symptoms like cancer of nasal cavity and lungs. The prescribed safety limit of Nickel is 3 to 7 mg/day in human.

Zinc (Zn): Concentrations of Zn in all the studied crops were below WHO-MPL (Table 1 and 2). The Zn levels of *Telfaria occidentalis, Talinum triangulare, Amaranthus hybridus* (Amaranth or pigweed); *Vernonia amygdalina* and *Solmun Nigrum* cultivated around Enyigba mining site are in agreement with the result obtained [38]. Among all the studied metals, Zn is the least toxic and it is an essential element in the human diet as it is required to maintain the apt functions of the immune system, normal brain activity and is fundamental in the growth and development of the foetus [40]. Zinc deficiency in the diet may be more detrimental to human health than excess zinc in the diet [41,42]. Zinc shortage causes birth defect and anaemia, stomach cramps and vomiting and skin irritation etc. Although, the average daily intake of zinc is 7-16.3 mg Zn/day, the recommended dietary allowance for it is 15 mg Zn/day for men and 12 mg Zn/day for women [43].

Iron (Fe): The concentrations of Fe in all the investigated crops were above WHO-MPL (Table 1 and 2). The acute toxicity of Fe ingested from normal dietary sources in man has not been reported because amount of Fe absorbed in typical subjects is subject to mucosal regulation so that excessive iron is not stored in the body. However, effects of toxic doses of iron in animal studies are characterized by initial depression, coma, convulsion, respiratory failure and cardiac arrest. Thus, subjects with impaired ability to regulate iron absorption will be at risk from excessive exposure to iron. Excess iron intake may result in siderosis in liver, pancreas, adrenals, thyroid, pituitary and heart depending on the chemical form [44]. Fe is an essential element in the human diet.

Manganese (Mn): Levels of Mn was lower than WHO-MPL in all the investigated food crops (Table 1 and 2). The report of Oti [37] is in agreement with the obtained results of this study. Manganese ions function as cofactors for a number of enzymes in higher organisms, where they are essential in detoxification of superoxide free radicals. Manganese is also a required essential trace nutrient for all known living organisms. In larger amounts, it can cause a poisoning syndrome in man, with neurological damage which is sometimes irreversible [45]. Human body [46] contains about 10 mg of manganese, which is stored mainly in the liver and kidneys. In the human brain, the manganese is bound to manganese metalloproteins most notably glutamine synthetase in astrocytes [47].

5. CONCLUSION

The results of the study revealed that crops from all the studied areas contained lead but were below WHO-MPL. *Manihot esculentus* tubers and *Telfairia occidentalis* leaves had accumulated high levels of As in A_2 from Ishiagu and control site respectively. Cr from control site, A_2 and A_3 from Ishiagu were above WHO-MPL. These food crops are in high demand in

Abakaliki and other areas within the locality because they are part of daily staple food. Continuous consumption of these crops will inevitably result to health consequences. There is a need for regular evaluation of trace metals in these crops by Federal and State protection agencies. The studied plants could be used for environmental monitoring based on metal loads.

CONCENT AND ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Yeboah JY. Environmental and health impact of mining on surrounding Communities: A Case Study of anglogold ashanti in Obuasi. A Master of Arts Thesis, The Department of Geography and Rural Development, Faculty of Social Sciences, College of Art and Social Sciences, Kwame Nkrumah University of Science and Technology. 2008;17-21.
2. Obasi NA, Obasi SE, Elom SO, Kalu KM, Aloke C, Igwenyi IO, Isienyi CC, Attamah JC. Health risk assessment of heavy metals in Ameri lead-Zinc mining community via consumption of Cassava (*Manihot esculenta* Cruz) in Ikwo L.G.A., Ebonyi State, Nigeria. American-Eurasian J. Sustainable Agric. 2017;11(6):22-30.
3. Okeke CN. Geology and Mineral Resource. Blessing or Curse? Journal of International Law. 2008;42(1):193-210.
4. Obasi NA, Obasi SE, Nweze E, Amadi SO, Aloke C, Aloh GO. Heavy metal pollution and human health risk assessment of Farmlands around Enyigba lead-zinc mining site, Ebonyi State, Nigeria. Proceedings of the 4th World Congress on Civil, Structural, and Environmental Engineering (CSEE'19). 2019;ICEPTP 135.
5. Roberts JR. Metal toxicity in children. In Training Manual on Pediatric Environmental Health: Putting It into Practice 1999 Jun. Emeryville, CA: Children's Environmental Health Network; 1999.
6. Edit A, Nganje AJ, Ekwere AS, Ukpong AJ. Groundwater chemistry and quality of Nigeria: A Status Review. African Journal of Engineering Science and Technology. 2011;**5**(13):1152-1169.
7. Mahurpawar M. Effects of heavy metals on human health. Int. J. Res. Granthaalayah, 2015;530:1-7.
8. Järup L. Hazards of heavy metal contamination. British Medical Bulletin. 2003;68(1):167-182.
9. Lindh U, Hudecek R, Danersund A, Eriksson S, Lindvall A. Removal of dental amalgam and other metal alloys supported by antioxidant therapy alleviates symptoms and improves quality of life in patients with amalgam-associated ill health. Neuroendocrinol Lett. 2002;23:459–82
10. Guallar E, Sanz-Gallardo MI, van't Veer P, Bode P, Aro A, Gomez-Aracena J, Kark JD, Riemersma RA, Martin-Moreno JM, Kok FJ; Heavy Metals and Myocardial Infarction Study Group. Mercury, fish oils, and the risk of myocardial infarction. N Engl J Med.2002;347:1747–54.
11. Wieczorek-Dąbrowska, M., A. Tomza-Marciniak, B. Pilarczyk, and A. Balicka-Ramisz, "Roe and red deer as bioindicators of heavy metals contamination in north-western Poland," Chemistry and Ecology. 2013;29(2):100–110.
12. Ali H, Khan E, Ilahi I. Environmental chemistry and ecotoxicology of hazardous heavy metals: environmental persistence, toxicity, and bioaccumulation. Journal of Chemistry; 2019.
13. Orisakwe OE, Nduka JK, Amadi CN, Dike DO, Bede O. Heavy metals health risk assessment for population via consumption of food crops and fruits in Owerri, South Eastern, Nigeria. Chemistry Central Journal. 2012;6(1):77.
14. Rai PK, Lee SS, Zhang M, Tsang YF, Kim KH. (2019). Heavy metals in food crops: Health risks, fate, mechanisms, and management. Environment International. 2019;125:365-385.
15. Clarke BO. Review of 'emerging' organic contaminants in biosolids and assessment of international research priorities for the agricultural use of biosolids, Environ. Int. 2011;37:226-247
16. Säumel I, Kotsyuk M, Hölscher C, Lenkereit F, Weber I, Kowarik. How healthy is urban horticulture in high traffic areas? Trace metal concentrations in

vegetable crops from plantings within inner city neighbourhoods in Berlin, Germany, Environ. Pollut. 2012;165:124-132.

17. Toth G, Hermann T, Da Silva MR, Montanarella L. Heavy metals in agricultural soils of the European Union with implications for food safety, Environ. Int. 2016;88:299-330.
18. Rai PK. Phytoremediation of Emerging Contaminants in Wetlands, CRC Press, Taylor & Francis, Boca Raton, Florida, USA. 2018;248.
19. Gall JE, Boyd RS, Rajakaruna N. Transfer of heavy metals through terrestrial food webs: A review. Environ. Monit. Assess. 2015;187:201.
20. Woldetsadik D, Drechsel P, Keraita B, Itanna F, Gebrekidan H. Heavy metal accumulation and health risk assessment in wastewater-irrigated urban vegetable farming sites of Addis Ababa, Ethiopia, International Journal of Food Contamination. 2017;4:9.
21. El-Kady AA, Abdel-Wahhab MA. Occurrence of trace metals in foodstuffs and their health impact. Trends Food Sci. Technol. 2018;75:36-45.
22. Elgallal M, Fletcher L, Evans B. Assessment of potential risks associated with chemicals in wastewater used for irrigation in arid and semiarid zones: a review. Agric. Water Manag. 2016; 177:419-431.
23. Wang F, Wang Z, Zhu C. Heteroexpression of the wheat phytochelatin synthase gene (TaPCS1) in rice enhances cadmium sensitivity. Acta Biochim. Biophys. Sin. 2012;44:886-893.
24. Chang CY, Yu HY, Chen JJ, Li FB, Zhang HH. Accumulation of heavy metals in leaf vegetables from agricultural soils and associated potential health risks in the Pearl River Delta, South China, Environ. Monit. Assess. 2014;1547-1560.
25. Florea A-M, Busselberg D. Occurrence, use and potential toxic effects of metals and metal compounds. Biometals. 2006; 19:419-427.
26. Ming-Ho Y. Environmental Toxicology: Biological and Health Effects of Pollutants, Chap.12. 2nd ed. Boca Raton, USA: CRC Press LLC; 2005.
ISBN 1-56670-670-2
27. Wani AL, Ara A, Usmani JA. Lead toxicity: A review. Interdisciplinary Toxicology. 2015;8(2):55-64.
28. Smical AI, Hotea V, Oros V, Juhasz J, Pop E. Studies on transfer and bioaccumulation of heavy metals from soil into lettuce. Environmental Engineering and Management Journal. 2009;7(5):609-615.
29. Engwa GA, Ferdinand PU, Nwalo FN, Unachukwu MN. Mechanism and Health Effects of Heavy Metal Toxicity in Humans. In Poisoning in the Modern World-New Tricks for an Old Dog? IntechOpen; 2019.
30. WHO/FAO/IAEA. Trace Elements in Human Nutrition and Health. Switzerland: Geneva: World Health Organization; 1996.
31. Monisha J, Tenzin T, Naresh A, Blessy BM, Krishnamurthy NB. Toxicity, mechanism and health effects of some heavy metals. Interdisciplinary Toxicology. 2014;7(2):60-72
32. Valko M, Morris H, MTD C. Metals, toxicity and oxidative stress. Current Medicinal Chemistry. 2005;12:1161-1208.
33. American Public Health Association. Determination of metal in ambient particulate matter using AAS. American Public Health Association (APHA) and American Water Works Association and Water Pollution Control Federation, Washington DC.1999;3-27.
34. Ajiwe VIE, Chukwujindu KC, Chukwujindu CN. Heavy metals concentration in cassava tubers and leaves from Galena mining area inIshiagu, IVO L.G.A of Ebonyi State Nigeria. IOSR Journal of Applied Chemistry (IOSR-JAC}. 2018; 11(3):54-58.
35. Oti WJO, Nwabue FI. Heavy metals effect due to contamination of vegetables from Enyigba Lead Mine in Ebonyi State, Nigeria. Environment and Pollution. 2013; 2(1);19-25.
36. Alam MG, Snow ET, Tanaka A. Arsenic and heavy metal contamination of vegetables grown in Santa village, Bangladesh. Science of the Total Environment. 2003;308:83-96.
37. Oti W. J. O. Heavy Metal Accumulation in Tubers Grown in a Lead-zinc Derelict Mine and their Significance to Health and Phytoremediation. American Chemical Science Journal. 2015*;* 8(3): 1-9.
38. Joseph WG. Plants for Toxicity Assessment. (ASTM) Committee E-47 on Biological Effects and Environmental Fate. Joy Press. 1991;112-133.
39. MacNicol RD, Beckett PHT. Critical tissue concentrations of potentially toxic

elements. Plant Soil. 1985;85:107-129.
40. Prasad AS. Zinc deficiency. British Medical Journal. 2003;326(7386):409-511.
41. Nair M, Balachandran KK, Sankarnarayan VN, Joseph T. Heavy Metals in Fishes from Coastal Waters of Cochin, South West Coast of India. Indian Journal of Marine Science. 1997;26:98-100.
42. Hambidge KM, Krebs NF. Zinc deficiency: A special challenge. Journal of Nutrition. 2007;137(4):1101.
43. Agency for Toxic Substances and Disease Registry [ATSDR]. Toxicological Profile for Lead. Agency for Toxic Substances and Disease Registry, US Department of Health and Human Services, Public Health Service.1999;205:93-0606
44. Codex Alimentarius Commission. Joint FAO/WHO food standards programme codex committee on contaminants in foods fifth session: Working document for information and use in discussions related to contaminants and toxins in the GSCTFF The Hague, The Netherlands. 2011;11-88.
45. Law N, Caudle M, Pecoraro V. Manganese redox enzymes and modelsystems: Properties, structures and reactivity. International Journal of Chemistry.1998; 46:305-315.
46. Emsley J. Manganese. Nature's building blocks: An A-Z Guide to the Elements. Oxford, UK: Oxford University Press. 2001; 249–253.
47. Takeda A. Manganese action in brain function. Brain Research Reviews. 2003; 4(1):79.

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