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Review of Edible Plants in Dumpsites: Risks of Heavy Metals Toxicity and Implications for Public Health

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Authors' contributions

This work was carried out in collaboration between all authors. Authors NAO, SEO, GOA and SOE wrote the first draft of the manuscript. Authors NAO, SEO and GOA managed the literature searches and author SOE edited the manuscript. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Studies of dumpsites have revealed that the surrounding soils and water are contaminated with high threshold of heavy metals through anthropogenic inputs. In this review, the uptake and toxicity risks of these heavy metals by habitual edible plants at levels above threshold limit and the implications for public health have been discussed. Edible plants are plants with nutritional and medicinal potentials which can salvage numerous human and animal needs when taken. Edible plants like most other underutilized plants in dumpsites have developed mechanisms which enable them to not

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only survive but accumulate high level of toxic heavy metals due to high level of environmental metal load in the dumpsites. This ultimately could lead to high human and animal exposure to these toxic elements through food-chain/food-web or direct ingestion of soils. The toxic effects caused by excess concentrations of these heavy metals in living organisms vary considerably and present numerous clinical situations ranging from neurological disorder, cellular damage among others and death in extreme cases. This review suggest the urgent need for policy makers to regulate the use of dumpsites for arable farming and the dependence on edible plants in dumpsites to avert heavy metal poisoning in populations.

Keywords: Dumpsite soils; edible plants; heavy metals; toxicity; public health.

1. INTRODUCTION

The use of dumpsites for arable farming and the use of dumpsite compost soils for increasing the fertility of soils for the cultivation of vegetables, fruits and food crops in Nigeria and most developing countries of the world are serious issues of concern to the general public who want to know the safety of such food crops for human and animal consumption [1,2]. The sources of heavy metal to plants are their growth media (soil, air and nutrients) from where they are taken up by roots or foliage [3-5]. Some heavy metals such as Cu, Zn, Mn, and Fe have been reported to be essential to pants' growth and development. Others such as Cd, Hg, As, Cr etc have been shown not to play any functional role in plants at all concentrations [6,7]. The behaviour of heavy metals in soil-plant system is crucial to the understanding of the mobility, bioavailability and toxicity of the heavy metals in an ecosystem [3,8]. Plants growing on dumpsites can accumulate toxic metals at high concentration causing serious risk to human health when consumed [9-13].

The uptake of heavy metals by plants from soil varies due the variation of the soil physicochemical properties (pH, organic matter content, cationic exchange capacity, etc) and the plant species involved [4,5,8,9,14,15]. High load of heavy metals have been reported in crops grown in abandoned heavy metal polluted areas and dumpsites [12-14].

Heavy metals exceeding threshold limits and leading to environmental pollution are introduced into the environment from anthropogenic sources such as domestic and industrial wastes, and agricultural activities among others. Since these heavy metals are non-biodegradable, they tend to accumulate in the ecosystem and are absorbed by flora and fauna where they bio-magnify and cause varying degree of toxicities [15-18]. In Nigeria as in most African countries, population explosion has led to the generation of large quantities of waste which are usually dumped in arable farmlands without recourse to the concomitant risks they may impose in soil and surrounding surface and ground water [19,20].

Food crops and vegetables are known to be the largest sources of nutrients for the developing world due to low income and poor standard of living as a result of population explosion [1,8]. The dependence of these populations on these cheaper sources of nutrients demand greater attention since reports have shown that the habitual environment such as dumpsites where these food crops and vegetables are grown influences their overall content as they may contain toxicants such as potentially harmful elements/metals [2,5-7]. Poor legislation and the use of such dumpsites for the cultivation of edible vegetables, fruits and food crops for human and animal consumption without routine assessment of the toxicological health risk of such practice is misleading.

This paper, therefore aims to review the studies of the plant-uptake of heavy metals in dumpsites and surrounding environment and point out the risk and health implications posed to humans and animals on consumption of plants cultivated on such soils.

2. BIOAVAILABILITY AND MOBILITY OF HEAVY METALS TO PLANTS

The health risks of refuse dumpsites have been assessed in various ways using total and bio-available forms of heavy metal content of the organisms living in or within the vicinity of the dumpsites [21,22]. Although total heavy metals may not completely give the predictive insight of the health risks, the chemical species of the metals as influenced by the physicochemical properties of the waste soils critically measure the overall risk of a refuse dumpsite [4-6,21,22].

Reports have that soil-plant transfer of heavy metals constitute serious risks since organisms depend on energy recycling via food chain/web for the sustainability of the ecosystem [21-26]. We have previously reported that there is a strong correlation between the percentage mobile phase of heavy metals in dumpsites and the soil physicochemical properties [3-5]. Dumpsites soils have been reported to contain anthropogenic input of heavy metals at levels above threshold limits when compared to soils from uncontaminated area and the bioavailability of these heavy metals in most dumpsites in Nigeria is well documented [3-5,9-13,24,27]. Our earlier research experiences in most of the dumpsites in South-East, Nigeria have shown that the available metal in the sequentially extracted fractions followed the general order: residual > reducible > exchangeable > acid soluble > oxidizable for Cd, residual > oxidizable > reducible > acid soluble > exchangeable for Cu, reducible > oxidizable > acid soluble > residual > exchangeable for Mn, residual > exchangeable > reducible > oxidizable > acid soluble for Pb, residual > reducible > oxidizable > exchangeable > acid soluble for Zn, residual > exchangeable > reducible > oxidizable > acid soluble for Fe, residual > oxidizable > acid soluble > reducible > exchangeable for Ni and residual > oxidizable > acid soluble > reducible > exchangeable for Cr [3-5,8-13,27]. These reports were in line with the reports of other researchers carrying out similar studies [23,24,28-33]. Consistently, reports have shown that sequential extraction of heavy metals in dumpsites soils indicated higher percentages (%) of the non-residual fraction for most metals except Cu. Our study on numerous dumpsites soils in South-East, Nigeria (as shown Fig. 1) implicated higher percentage mobility for metals studied except Cu. These our earlier reports have shown that the overall order of the mobility and bioavailability of selected metals in most of the dumpsites studied follow this trend: Cd > Fe > Pb > Mn > Zn > Cr > Ni > Cu [3-5,8-13,34]. Similar findings on dumpsites and heavy metal polluted sites have been reported and well documented [23-26].

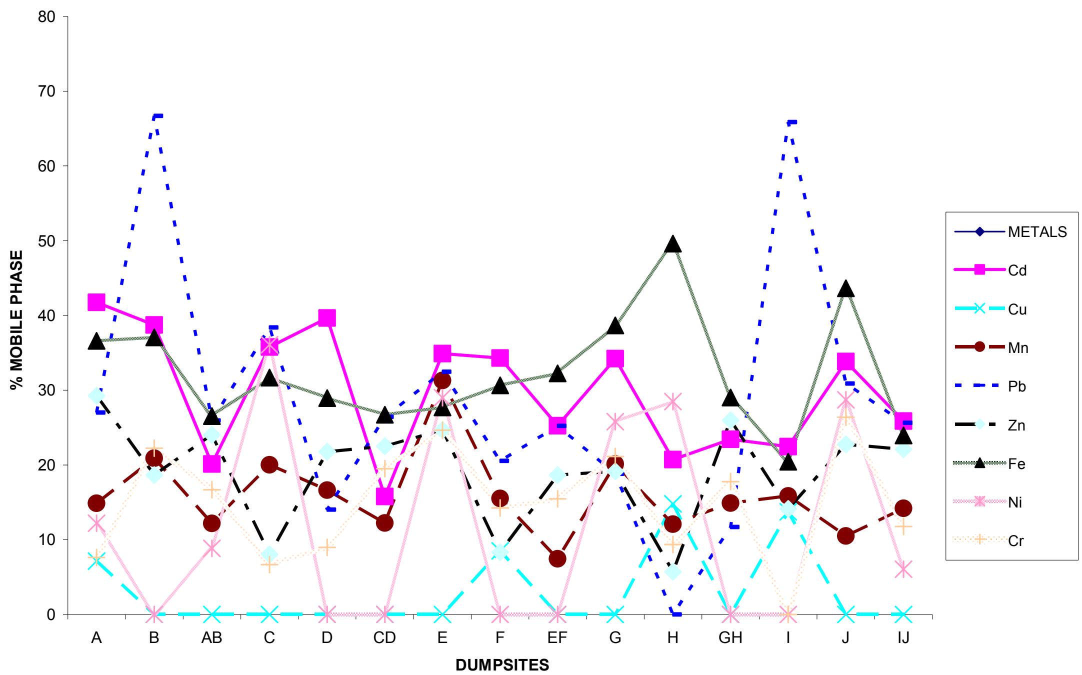

Fig. 1. Persentage (%) mobile phase of total extractable metals

Where A = Burrow pit-Aba, B = Ntiga-Isiala Ngwa, AB = Control site for Aba, C = Ubakala-Umuahia, D = Abia Tower-Umuahia, CD = Control site for Umuahia, E = Umuka-Okigwe, F = Ubahu-Okigwe, EF = Control site for Okigwe, G = Ishiagu-Enugu Junction, Ishiagu, H = Ntave-Ishiagu, GH = Control site for Ishiagu, I = Four corner-Enugu, J = Amaéchi-Enugu, IJ = Control site for Enugu.
Source: Obasi, 2012; Obasi et al., 2012a:b; Obasi et al., 2013a:b

3. HEAVY METAL UPTAKE BY PLANTS

Plants (roots, stem and leaves) grown in dumpsites and metal polluted soils have be reported to accumulate heavy metals far beyond the recommended threshold limits when compared to uncontaminated soils. The accumulation of these metals has been shown to vary greatly among plants species and uptake of these metals to the various plant parts has been demonstrated to be primarily dependent on the plant species, its inherent controls and the soil quality [3-5,8-14,35-42].

Soil-plant transfer indices of plants species such as translocation factors (TF), biological concentration factors (BCF) and biological accumulation coefficient (BAC) values greater than unity (>1) had been used to evaluate their potentials for phytoextraction, and phytostabilization [43-45]. Studies in Nigeria have shown that some edible and medicinal plants such as *Amaranthus hybridus*, *Talinum triangulare*, *Carica papaya*, *Ipomea batatas*, *Luffa aegyptica*, *Telfeleria occidentalis* among others that grows in dumpsites have Translocation Factor (TF), Biological Concentration Factor (BCF) or Biological Accumulation Coefficient (BAC) values greater than one (> 1) for metals such as Cd, Cu, Mn, Pb, Zn, Fe, Ni and Cr among others [3-5,8-13, 27,34]. For example, our findings from dumpsites in Ibii community, Afikpo North, Ebonyi State, South-East, Nigeria (Figs. 2-4) showed phytoremediation quotient greater than unity (> 1) for some metals. This suggests that these plant species have developed tolerance mechanisms to adapt to the heavy metals stress in their habitual environment and as such have potentials to accumulate these metals in their edible harvestable parts as documented by numerous researchers [8-13,35-42]. The implications are that these metals which have been accumulated by plants might be transferred through food chain and food web within the ecosystem to human and animals where they might pose serious threat to health.

4. HEAVY METALS AND PUBLIC HEALTH

At low and optimal concentrations, heavy metals are essential to the maintenance of various biochemical and physiological functions in living organisms. However, they exceed certain threshold limits, the constitute nuisance to flora and fauna. The toxicity of heavy metals arises from the fact that some of their chemical properties make them to avert control mechanisms such as homeostasis, transport, compartmentalization and binding of required cell

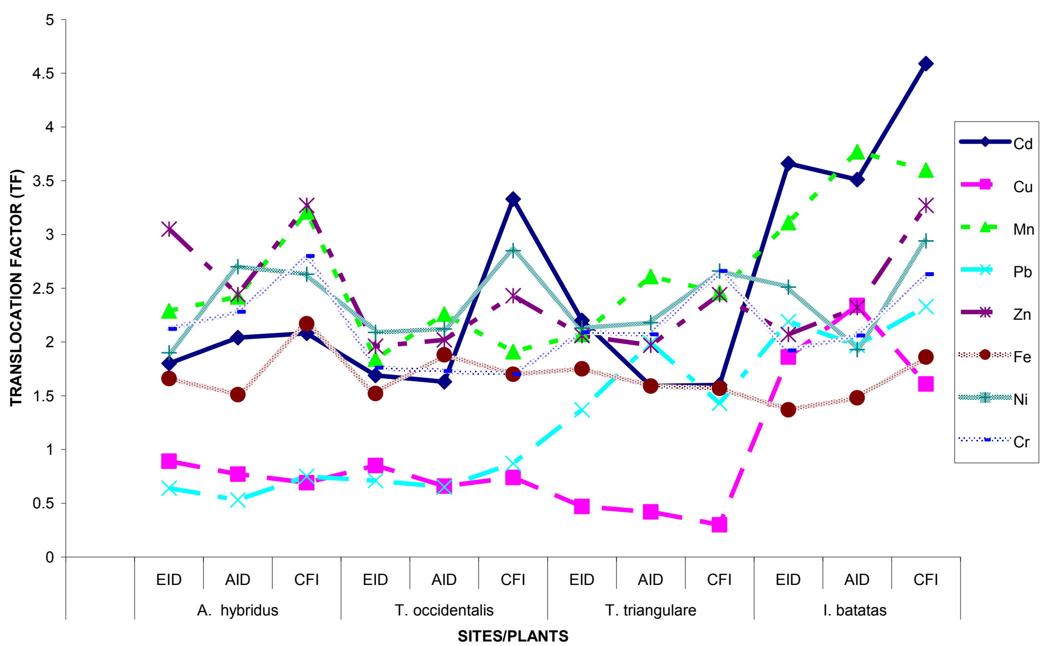

Fig. 2. Translocation factor (TF) of plants for all the metals in the studied sites
EID= Eluuogo Ibii dumpsite, AID = Agboogo Ibii dumpsite, CFI = Control Farmland Ibii
Source: Obasi et al., 2015a

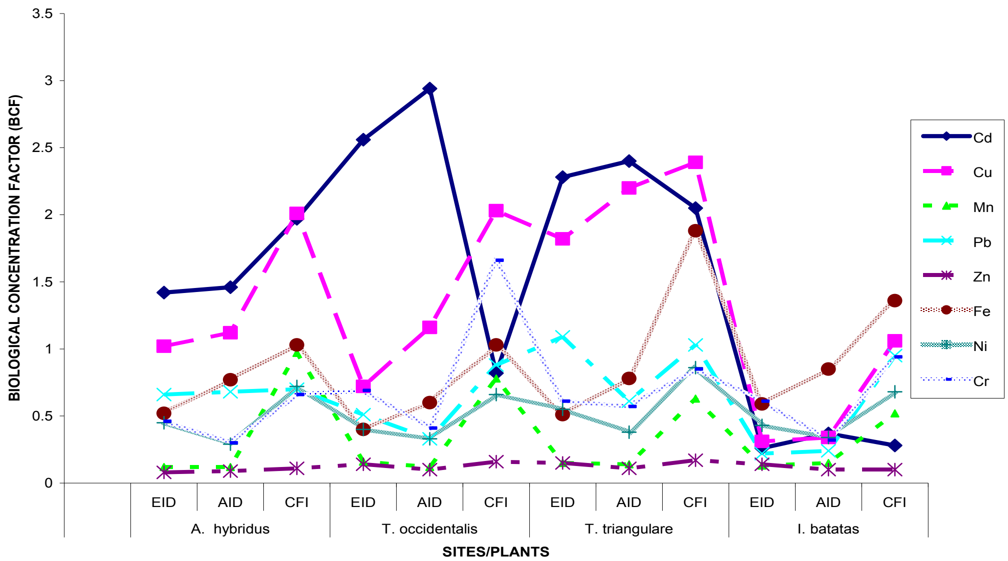

Fig. 3. Biological concentration factor (BCF) of plants for all the metals in the studied sites
EID= Eluuogo Ibii dumpsite, AID = Agboogo Ibii dumpsite, CFI = Control Farmland Ibii
Source: Obasi et al., 2015a

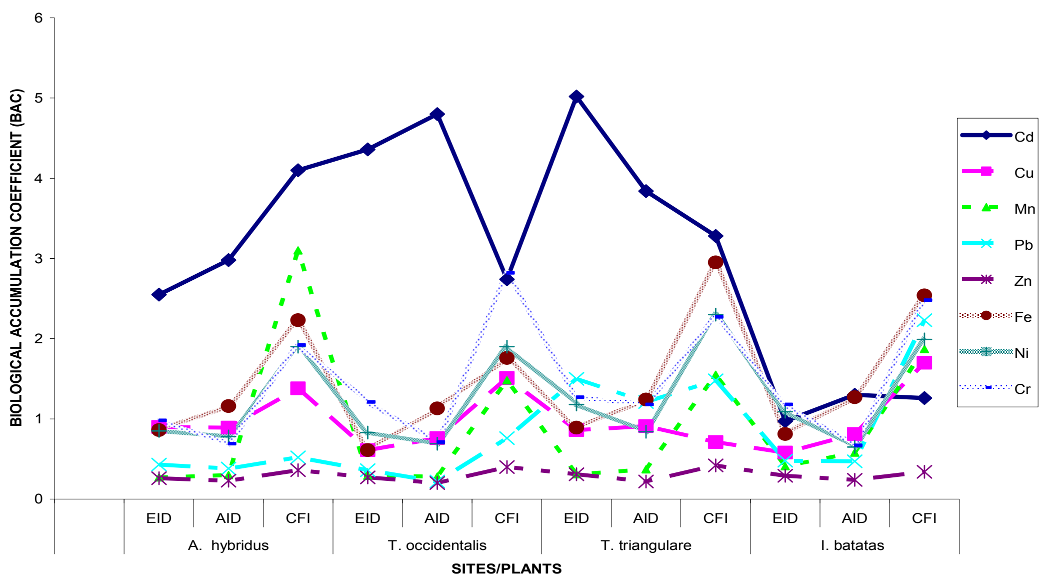

Fig. 4. Biological accumulation coefficient (BAC) of plants for all the metals in the studied sites
EID= Eluuogo Ibii dumpsite, AID = Agboogo Ibii dumpsite, CFI = Control Farmland Ibii
Source: Obasi et al., 2015a

constituents devised by living organisms for their protections. Thus, these chemical properties enable heavy metals to form coordinated molecular binding with protein and numerous biological molecules and as such replace or substitute the correct molecule from their natural binding sites leading to several toxicities causing malfunctioning of cells. The effects of toxicity of heavy metals span across varying degrees of pathological conditions ranging from mutation to DNA damage at the molecular level to carcinogenicity, teratogenicity and metabolic disorders among others [46]. Several factors such as absorbed dose, route of exposure, duration of exposure (acute or chronic) and oxidative states determine to a large extent the toxic effects of different heavy metals. The toxicities of heavy metals cover a wide facet because they are non-biodegradable and tend to recycle along the ecosystem [47,48]. Reports have shown that edible plants parts contain arsenic, cadmium, chromium, copper, lead, nickel, iron, manganese and zinc among others in varying amounts depending on the environment where the plants grew. These metals when absorbed from their habitual soil environment are transferred to other organisms in the ecosystem where the biomagnify and cause risks for human health and the environment [49-51].

The toxicity of heavy metals to humans and animals arise from various mechanisms involving binding to important proteins causing cellular damage and generation of reactive species.

Heavy metals have been reported to form intermediate compounds of high toxicities [49]. For example, inorganic arsenic compounds have been shown to be methylated by bacteria, algae, fungi and humans to give intermediate products (monomethylarsonic acid (MMA) and dimethylarsinic acid (DMA)) which highly toxic product that cause arsenic-induced carcinogenesis [52]. Similarly, lead metal toxicity have been shown to be due to its ability to replace other bivalent cations like Ca^{2+}, Mg^{2+}, Fe^{2+} and monovalent cations like Na^{+} in various biological and metabolic processes. This ionic mechanisms causing lead toxicity manifest in various biological processes such as cell adhesion, intra- and inter-cellular signaling, protein folding, maturation, apoptosis, ionic transportation, enzyme regulation, and release of neurotransmitters [49]. For example Flora et al. [46] have demonstrated that lead can substitute calcium even in picomolar concentration and as such affect protein kinase C, which regulates neural excitation and memory storage.

Mecury toxicity is wide spread and has been reported to be potential neurotoxins [53]. Cadmium on the other hand has been shown to be hapatotoxic and nephrotoxic via its association with cystein-rich protein such as metallothionein. Also, reports have indicated that when cadmium bind with cystein, glutamate, histidine or aspartate ligands, they cause iron deficiency [54]. The replacement of zinc by cadmium due to same oxidation states in metallothionein, inhibit it from acting as a free radical scavenger within the cell [49,53].

The ionic specie of Cr(vi) and biological reductants such as thiols and ascorbate have been shown to produce reactive oxygen species (superoxide ion, hydrogen peroxide, and hydroxyl radical). This highly reactive ionic Cr specie like most other heavy metals ionic species cause oxidative stress in the cell and as such cause damage to DNA and proteins [55]. In the same way, free iron has been reported to cause lipid peroxidation, which may cause severe damage in mitochondria, microsomes and other cellular organelles [56]. The attack of heavy metals on a cell and the balance between reactive oxygen species (ROS) production and their subsequent defense by antioxidants is shown in Fig. 5 [49]. Iron toxicity on cells manifests as iron mediated tissue damage which arises from cellular oxidization and reduction mechanisms that affects intracellular organelles such as mitochondria and lysosomes. Also, excess intake of iron has been associated with the release of a wide range of free radicals. These free radicals have been shown to attack DNA, leading to cellular damage such as mutation and malignant transformations which in turn cause an diverse diseases [57].

The toxic effects of heavy metal cannot be over emphasized. The effects range from lowering energy levels to causing damage to the functionality of vital organs such as the brain, lungs, kidney, liver, blood composition among others. Long-term exposure to heavy metals and their compounds have been reported to cause gradual and progressive physical, muscular, and neurological degenerative processes. These processes initiate diseases such as multiple sclerosis, Parkinson's disease, Alzheimer's disease and muscular dystrophy and ultimately cancer on a repeated long-term exposure [58]. Concentration and duration induced effects of heavy metals varies. For example, lower and shorter levels of arsenic exposure has been shown to manifest clinically in nausea and vomiting, reduced production of erythrocytes and leukocytes, abnormal heart beat, etc. while long-term exposure have been implicated in the formation of skin lesions, internal cancers, neurological problems, pulmonary disease, peripheral vascular disease, hypertension and cardiovascular disease and diabetes mellitus [59]. Mazumder [60] reported that chronic arsenicosis results in many irreversible changes in vital organs with no effective treatment and high mortality rate.

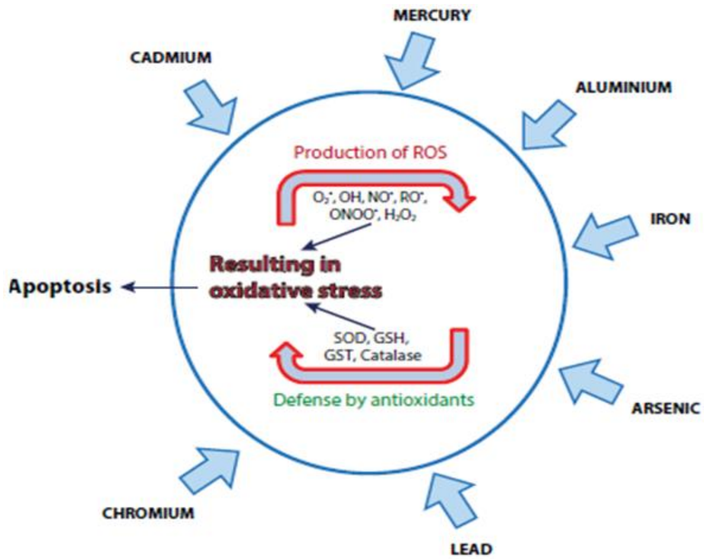

Fig. 5. The Effects of heavy metals on a cell and the balance between ROS production and the subsequent defense presented by antioxidants
Source: Jaishankar et al., 2014

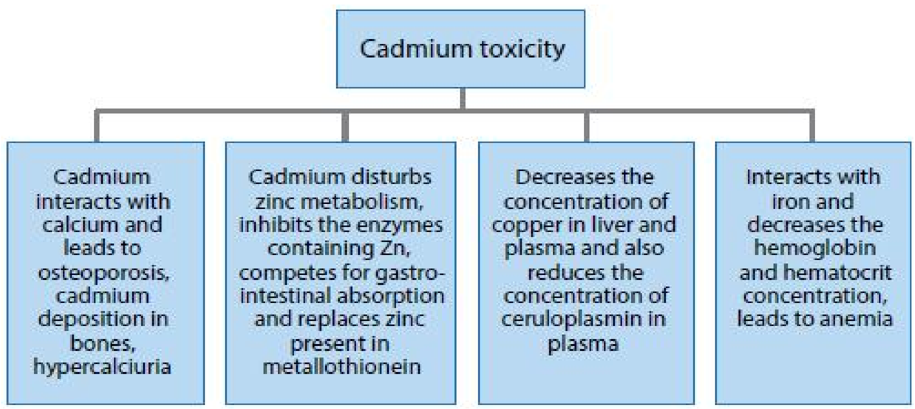

Fig. 6. Values of cadmium toxicity
Source: Flora et al., 2008

Exposure frequency and concentration of heavy metals affect their toxicities. For example, acute exposure haevy metals have been implicated in loss of appetite, headache, hypertension, abdominal pain, renal dysfunction, fatigue, sleeplessness, arthritis, hallucinations and vertigo. Chronic exposure of these metals on the other hand have been associated with mental retardation, birth defects, psychosis, autism, allergies, dyslexia, weight loss, hyperactivity, paralysis, muscular weakness, brain damage, kidney damage and may even cause death [61]. Reports have shown that exposure to higher amounts of chromium compounds in humans causes inhibition of erythrocyte glutathione reductase, which interfers with methemoglobin in hemoglobin formation [62,63]. Other effects of chromate compounds include induction of DNA damage in different ways, for example: formation of DNA adducts, chromosomal aberrations, sister chromatid exchanges, alterations in replication and transcription of DNA leading to various forms of mutation with clinical manifestations in cancer and abnormal cells formation [64,65]. Excess iron uptake is a serious problem as it increases the risk of cancer while reports have shown that cadmium interacts with essential nutrients through which it causes its toxicity effects as summarized in Fig. 6 [46].

5. CONCLUSION

In this review, the effects of heavy metals accumulation by edible plants grown on dumpsites soils on public health were discussed. It was shown that plants grown on dumpsites accumulate heavy metals at levels beyond the threshold limit partly due to the high levels of heavy metals in the dumpsite soils and the ability of these plants to develop tolerance mechanisms in this habitual environment. These heavy metals can be transferred through feeding relationship (food chain and food web) to humans and animals where they exert numerous toxicities in humans and as such calls for public health concern. There is need for policy makers and environmentalist to put forward and enforce legislations guiding the management and disposal of domestic and industrial solid wastes and cultivation of food crops and vegetables in farmland within the vicinity of dumpsites. National and international co-operation is vital for framing appropriate tactics to prevent heavy metal toxicity arising from the use of dumpsites for arable farming and the use of dumpsites habitual plants for nutritional and medicinal purposes.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Khan S, Farooq R, Shahbaz S. Health risk assessment of heavy metals for population via consumption of vegetables. World Applied Science Journal. 2009;6(12):1602-1606.
2. Khan S, Cao QYZ, Huang YZ, Zhu YG. Health risks of heavy metals in contaminated soils and food crops irrigated with waste water in Beijing, China. Environment Pollution. 2008;125(3):686-692.
3. Obasi NA. Biochemical studies on soil and air quality assessment of dumpsites on the Enugu-Port Harcourt Expressway, South-East, Nigeria (Ph.D Thesis). Nigeria: Abia State University Uturu (ABSU); 2012.
4. Obasi NA, Akubugwo EI, Ugbogu OC, Chinyere G. Heavy metals bioavailability and phyto-accumulation potentials on selectd plants on Burrow-pit Dumpsite in Aba and Ntigha Dumpsite in Isiala Ngwa of Abia State, Nigeria. Nigeria Journal of Biochemistry and Olecular Biology. 2012a;27(1):27-45.
5. Obasi NA, Akubugwo EI, Ugbogu OC, Glory Otuchristian. Assessment of physicochemical properties and heavy metals bioavailability in dumpsites along Enugu- Port Harcourt expressways, south-east, Nigeria. Asian Journal of Applied Sciences. 2012b;5(6):342-356.
6. Shanker AK, Cervantes C, Loza Tavera H, Avadainayagam S. Chromium toxicity in plants. Environment International. 2005;31: 739-753.
7. Sharma P, Dubey RS. Lead toxicity in plants. Brazilian Journal of Plant Physiology. 2005;17(1):1-26.
8. Sardar K, Ali S, Hameed S, Afzal S, Fatima S, Shakoor MB, Bharwana SA, Tauqeer HM. Heavy metals contamination and what are the impacts on living organisms. Greener Journal of Environmental Management and Public Safety. 2013;2(4):172-179.
9. Obasi NA, Obasi SE, Igbolekwu RI, Nkama OJ, Eluu SO. Health risk assessment of the quality of plants cultivated around Eluogo and Agboogo Ibii Aged Dumpsites in Ibii, Afikpo North L.G.A. of Ebonyi State, Nigeria. American Journal of Environmental Engineering and Science. 2015a;2(6):100-108.
10. Obasi NA, Obasi SE, Akubugwo EI, Elom SO, Alisa CO. Health risk assessment of selected wild valuable plants species grown around Amaozara and Amaechara dumpsites soils in Amasiri, Afikpo North L.G.A. of Ebonyi State, Nigeria. Proceedings of the 3rd International Conference on Chemical, Agricultural and Medical Sciences (CAMS-2015), Singapore. C1215029 (Dec 10-11); 2015b.
11. Obasi NA, Elom SO, Edeogu CO, Alisa CO, Obasi SE. Soil environmental metals speciation and associated health risks in selected edible leafy plants on Amaechi and Fourcorner dumpsites in Enugu of Enugu State, Nigeria. International Journal

of Life Sciences Biotechnology and Pharma Research. 2014;3(4):152-165.
12. Obasi NA, Akubugwo EI, Kalu KM, Ugbogu OC. Speciation of heavy metals and phyto-accumulation potentials of selected plants on major dumpsites in Umuahia, Abia State, Nigeria. International Journal of Current Biochemistry Research. 2013a; 1(4):16-28.
13. Obasi NA, Akubugwo EI, Kalu KM, Ugbogu AE, Okorie UC. Toxicological assessment of various metals on selected edible leafy plants of Umuka and Ubahu Dumpsites in Okigwe of Imo State, Nigeria. Journal of Experimental Biology and Agricultural Sciences. 2013b;1(6):441-453.
14. Okoronkwo NE, Ano AO, Odoemenam S. Environment, health and risk assessment with the use of an abandoned municipal waste dump site for food crop production. Paper accepted for presentation by division of Agric and food chem. at the 230th American. Chem. society Aug. 28 – Sept. 1; 2005a.
15. Krissanakriangkrai O, Suparpacboon W, Juwa S, Chacwong S, Swaddiwudhipong W. Bioavailable cadmium in water, sediment and fish, in a highly contaminated area of Thai-Myammy border. Thammasat International Journal of Science and Technology. 2009;14:60-68.
16. Ozturk M, Ozozen G, Minareci O, Minareci E. Determination of heavy metals in fish, water and sediments of Avsar dam Lake in Turkey. Iranian Journal of Environmental, Health Science and Engineering. 2009;6:73-80.
17. Benjamin M, Mwashot M. Levels of caesium and lead in water, sediment and selected fish species in Mombasa Kenya Western Indian. Oceanic Journal of Marine Science. 2003;2:25-34.
18. Ikem A, Egiebog NO, Nyavor K. Trace elements in water, fish and sediment from Tuskegee Lake, Southeastern USA. Water, Air Soil Pollution. 2003;149:51-75.
19. Abul S. Environmental and health impact of solid waste disposal at Mangwaneni dumpsite in Manzini: Swaziland. Journal of Sustainable Development in Africa. 2010;12(7):64-73.
20. Nubi OA, Osibanjo O, Nubi AT. Impact assessment of dumpsite leachate on the qualities of surface water and sediment of River Eku, Ona-ara Local Government, Oyo State, Nigeria. Science World Journal. 2009;3(3):17-20.
21. Kabata-Pendias A. Soil-plant transfer of trace elements: An environment issue. Geoderma. 2004;122:143-149.
22. Cataldo DA, Wildung RE. Soil and plant factors influencing the accumulation of heavy metals by plants. Environmental Health Perspectives. 1978;27:149-159.
23. Ikhouria EU, Urunmatsoma SOP, Okieimen FE. Preliminary investigation of chemical fraction and heavy metal accumulation in plant maize (*Zea mays*) grown on chromated copper arsenate (CCA) contaminated soil amended with poultry droppings. African Journal of Biotechnology. 2010;9(18):2675-2682.
24. Uba S, Uzairu A, Harrison GFS, Balarabe ML, Okunola OJ. Assessement of heavy metals bioavailability in dumpsites of Zaira metropolis, Nigeria. African Journal of Biotechnology. 2008;7(2):122-130.
25. Iwegbue CMA, Emuh FN, Isirimah NO, Egun AC. Fractionation, characterization and speciation of heavy metals in composts and compost-amended soils. African Journal of Biotechnology. 2007;6(2):067–078.
26. Gupta AK, Sinha S. Chemical fractionation and heavy metal accumulation in the plant of *Sesamum indicum* (L.) Var. T55 grown on soil amended with tannery sludge: Selection of single extractants. Chemosphere. 2006;64: 161-173.
27. Akubugwo EI, Obasi A, Chinyere GC, Eze E, Nwokeoji O, Ugbogu EA. Phytoaccumulation effects of *Amaranthus hybridus* L. grown on buwaya refuse dumpsites in Chikun, Nigeria on metals. Journal of Biodiversity and Environmental Sciences. 2012;2(5):10-17.
28. Alvarez EA, Mochon MC, Sanchez JCJ, Rodriguez MT. Heavy metal extractable forms in sludge from waste-water treatment plants. Chemosphers. 2002;47: 765-775.
29. Tokalioglu S, Kantal S, Elci L. Determination of heavy metals and their speciation in lake sediments by flame atomic absorption spectrophotometer after a four stage sequential extraction procedure. Analytical Chemistry Acta. 2000;413:33-40.
30. Liu WH, Zhao JZ, Ouyang ZY, Söderlund L, Liu GH. Impacts of sewage irrigation on heavy metal distribution and contamination

in Beijing, China. Environment International. 2005;31:805–812.
31. Ma LQ, Rao GN. Chemical fractionation of cadmium, copper, nickel, and Zinc in contaminated soil. Journal of Environmental Quality. 1997;26:259-264.
32. Raskin I, Nanda-Kumar PBA, Dushenkov S, Salt DE. Bioconcentration of heavy metals by plants. Current Opinion Biotechnology. 1994;5:285-290.
33. Kuo S, Heilman PE, Baker AS. Distribution and forms of Cu, Zn, Cd, Fe and Mn in soils near a copper smelter. Soil Sci. 1983;135:101-109.
34. Obasi NA, Obasi SE, Aloh GO, Nnachi EO. Health risk assessment of selected dumpsites in Amata-Akpoha community using cultivated edible plants. Research Journal of Environmental Toxicology. 2017;11(2):62-71.
35. Ebong GA, Akpan MM, Mkpenie VN. Heavy metal contents of municipal and rural dumpsite soils and rate of accumulation by Carica papaya and *Talinum triangulare* in Uyo, Nigeria. E-Journal of Chemistry. 2008;5(2):281-290.
36. Ebong GA, Etuk HS, Johnson AS. Heavy metals accumulation by *Talinum triangulare* grown on waste dumpsites in Uyo metropolis, Akwa Ibom State, Nigeria. Journal of Applied Sciences. 2007;7(10): 1404-1409.
37. Chunilall V, Kindness A, Johnalagada SB. Heavy metal uptake by two edible Amaranthus herbs grown on soils contaminated with lead, mercury, cadmium, and nickel. Journal of Environmental Science and Health. 2005;40:375-385.
38. Okoronkwo NE, Ano AO, Igwe JC, Onwuchekwa EC, Nnorom I. Levels of toxic elements in soils of abandoned waste dump site. Paper accepted bv division of chemical toxicology for at the 230th American chemical society Aug. 28 – Sept. 1; 2005b.
39. Chiroma TM, Hymore FK, Ebawele RO. Heavy metal contamination of vegetables and soils irrigated with sewage water in Yola. NJERD. 2003;2(3):17-21.
40. Amusan AA, Ige DV, Olawale R. Characteristics of soils and crops uptake of metals in municipal waste dumpsites in Nigeria. Journal of Human Ecology. 2005;17:167-171.
41. Ihenyen A. A comparative study of Pb, Cu and Zn in roadsides sediments in Metropolitan Lagos and Benin, Nig. Environ. Int. 1991;18(1):103–105.
42. Ndiokwere CL. A study of heavy metal pollution from motor vehicle emission and its effect on road side vegetation and crop in Nigeria. Environ. Pollut. Series. 1984;8(7):35–42.
43. Cui S, Zhou Q, Chao L. Potential hyper-accumulation of Pb, Zn, Cu and Cd in endurant plants distributed in an old semetery, northeast, China. Environmental Geology. 2007;51:1043-1045.
44. Li MS, Luo YP, Su ZY. Heavy metals concentrations in soils and plant accumulation in a restored manganese mine land in Guangxi, South China. Environmental Pollution. 2007;147:168-175.
45. Yoon J, Cao X, Zhou Q, Ma LQ. Accumulation of Pb, Cu and Zn in native plants growing on a contaminated Florida Site. Science of the Total Environment. 2006;368:456-464.
46. Flora SJS, Mittal M, Mehta A. Heavy metal induced oxidative stress and its possible reversal by chelation therapy. Indian J Med Res. 2008;128:501–523.
47. Jaishankar M, Mathew BB, Shah MS, Gowda KRS. Biosorption of few heavy metal ions using agricultural wastes. Journal of Environment Pollution and Human Health. 2013;2(1):1–6.
48. Nagajyoti PC, Lee KD, Sreekanth TVM. Heavy metals, occurrence and toxicity for plants: A review. Environ Chem Lett. 2010;8(3):199–216.
49. Jaishankar M, Tseten T, Anbalagan N, Mathew BB, Beeregowda KN. Toxicity, mechanism and health effects of some heavy metals. Interdiscip Toxicol. 2014;7(2):60–72.
50. Morais S, Costa FG, Pereira ML. Heavy metals and human health. In: Environmental health – emerging issues and practice. Oosthuizen, J. (ed)., InTech., UK. 2012;227–246.
51. Lambert M, Leven BA, Green RM. New methods of cleaning up heavy metal in soils and water. Environmental science and technology briefs for citizens. Kansas State University, Manhattan, KS; 2000.
52. Singh N, Kumar D, Sahu A. Arsenic in the environment: Effects on human health and possible prevention. J Environ Biol. 2007;28(2 Suppl):359–365.
53. Patrick L. Toxic metals and antioxidants: Part II. The role of antioxidants in arsenic

and cadmium toxicity. Altern Med Rev. 2003;8(2):106–128.
54. Castagnetto JM, Hennessy SW, Roberts VA, Getzoff ED, Tainer JA, Pique ME. MDB: The metalloprotein database and browser at the Scripps Research Institute. Nucleic Acids Res. 2002;30(1):379–382.
55. Stohs SJ, Bagchi D. Oxidative mechanisms in the toxicity of metal ions. Free Radic Biol Med. 1995;18(2):321–336.
56. Albretsen J. The toxicity of iron, an essential element. Veterinary Medicine. 2006;4(1):82–90.
57. Grazuleviciene R, Nadisauskiene R, Buinauskiene J, Grazulevicius T. Effects of elevated levels of manganese and iron in drinking water on birth outcomes. Polish J of Environ Stud. 2009;18(5):819–825.
58. Jarup L. Hazards of heavy metals contamination. British Medical Bulletin. 2003;68:167-182.
59. Smith AH, Lingas EO, Rahman M. Contamination of drinking-water by arsenic in Bangladesh: A public health emergency. Bull World Health Organ. 2000;78(9): 1093–1103.
60. Mazumder G. Chronic arsenic toxicity & human health. Indian J Med Res. 2008;128(4):436–447.
61. Martin S, Griswold W. Human health effects of heavy metals. Environmental Science and Technology Briefs for Citizens. 2009;15:1-6.
62. Koutras GA, Schneider AS, Hattori M, Valentine WN. Studies on chromate erythrocytes. Mechanisms of chromate inhibition of glutathione reductase. Br J Haematol. 1965;11(3):360–369.
63. Schlatter C, Kissling U. Acute fatal bichromate poisoning. Beitrage zur Gerichtlichen Medizin. 1973;30:382–388.
64. O'Brien T, Xu J, Patierno SR. Effects of glutathione on chromium-induced DNA crosslinking and DNA polymerase arrest. In: Molecular Mechanisms of Metal Toxicity and Carcinogenesis. Springer, US. 2001;173–182.
65. Matsumoto ST, Mantovani MS, Malaguttii MIA, Dias AL, Fonseca IC, Marin-Morales MA. Genotoxicity and mutagenicity of water contaminated with tannery effluents, as evaluated by the micronucleus test and comet assay using the fish *Oreochromis niloticus* and chromosome aberrations in onion root-tips. Genet Mol Biol. 2006;29(1): 148–158.

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