PRINT ISSN 1119-8362
Electronic ISSN 2659-1502

Full-text Available Online at
https://www.ajol.info/index.php/jasem
https://www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 27 (11) 2393-2399 November 2023

Bioaccumulation and Potential Risk Assessments of Heavy Metals in Two Varieties of Edible Vegetables (*Amaranthus hybridus* and *Celosia argentea*) around Lapite Dump Site, Akinyele Local Government Area, Ibadan, Oyo State, Nigeria

[1]*SMART, MO; [2]BAMIGBOYE, TO; [1]ISOLA, JO; [3]FAWOLE, OA; [4]IBIRONKE, OH; [1]OGIDAN, OA; [1]OLAOLUWA, IR

[1]Federal College of Forestry, Jericho, Ibadan, Oyo state, Nigeria.
[2]Federal University of Agriculture, Abeokuta, Ogun state, Nigeria.
[3]Forestry Research Institute of Nigeria, Jericho, Ibadan, Oyo state, Nigeria.
[4]Ekiti State University, Ado-Ekiti, Ekiti State, Nigeria.

**Corresponding Author Email: tusmart14@gmail.com*
Co-Author Email: fadipetolulopeola@yahoo.com; shinaisola06@gmail.com; fawoleolakunle@yahoo.com; ibironke.olalekanhenry@gmail.com; ogidantosh@gmail.com; olaoluwaisaiah4@gmail.com

ABSTRACT: The objective of this paper was to evaluate the bioaccumulation and potential risk assessments of heavy metals in two varieties of edible vegetables (*Amaranthus hybridus* and *Celosia argentea*) around Lapite Dump Site of Akinyele Local Government Area, Ibadan, Oyo State, Nigeria using different standard analytical techniques. The mean concentrations of the heavy metals showed that Pb, Cd and Mn (3.05mg/kg, 0.67mg/kg, and 129.61mg/kg) are the metals with means higher than their respective permissible values (PL) for humans (0.3mg/kg, 0.2mg/kg, and 6.64mg/kg respectively). These three heavy metals are also the metals with the most significant contamination and pollution factor according to the calculated contamination factor and geo-accumulation index. The bioaccumulation factors showed that Mn and Zn are the heavy metals accumulated most in the plants with the leaves having high content of these metals more than the stems. Pollution load index calculated revealed that the dumpsite area has been deteriorated (PLI > 1) making activities around the area (including agriculture) and the habitants at high risk of health hazards. Consequently, planting and other human activities in this area should be discouraged while appropriate authorities should get involved in impact assessment of the environment to relocate the farms and habitants of the area to a more suitable and environmental friendly area.

DOI: https://dx.doi.org/10.4314/jasem.v27i11.5

Cite this paper as: SMART, M. O; BAMIGBOYE, T. O; ISOLA, J. O; FAWOLE, O. A; IBIRONKE, O. H; OGIDAN, O. A; OLAOLUWA, I. R. (2023). Bioaccumulation and Potential Risk Assessments of Heavy Metals in Two Varieties of Edible Vegetables (*Amaranthus hybridus* and *Celosia argentea*) around Lapite Dump Site, Akinyele Local Government Area, Ibadan, Oyo State, Nigeria. *J. Appl. Sci. Environ. Manage.* 27 (11) 2393-2399

Dates: Received: 12 October 2023; Revised: 2 November 2023; Accepted: 14 November 2023 Published: 30 November 2023

Keywords: heavy metals; contamination factor; pollution load index; bioaccumulation

Metals are found naturally in the earth's crust and their compositions vary among different localities, resulting in spatial variations of surrounding concentrations. Heavy metals are generally referred to as those metals which possess a specific density of more than 5 g/cm^3 and adversely affect the environment and living organisms (Järup, 2003). The transfer of heavy metals to man can occur through the ground (inhalation and ingestion of dust), food, water, air or skin (result of dermal absorption of contaminants from soil and water) (Chehregani and Malayer, 2007). Heavy metal contamination can come from natural or anthropogenic origins such as soil erosion, natural weathering of the earth's crust, mining, industrial effluents, urban runoff; sewage discharge, insect or disease control agents applied to crops, and spent oil (Jaishankar *et al.*, 2014). Crops and vegetables grown in soils contaminated with

**Corresponding Author Email: tusmart14@gmail.com*

potentially toxic elements have greater susceptibility to uptake these elements. Consumption of vegetable has increased in recent years due to its health benefits and uptake of heavy metals by vegetables is a major pathway for toxic elements through the soil to enter the food chain and bio-accumulates leading to health risk (Ihedioha *et al.,* 2021). Heavy metal has serious health implication especially with regards to crops grown on such soils (Steffan *et al.,* 2017). Most of these heavy metals are necessary for both plants and animal growths at uncontaminated levels. Several studies on the effects of bioaccumulation in plants through uptake of heavy metals from soils at high concentrations have been carried out and indicate great health risks, taking into consideration food chain implications. Utilization of food crops contaminated with heavy metals is a major food chain route for human exposure, especially those under continuous cultivation. The cultivation of such plants in contaminated soil represents a potential risk since the plant tissues can accumulate heavy metals **(**Mohsen and Mohsen, 2008). Heavy metals become toxic when they are not metabolized by the body and accumulate in soft tissues. Chronic ingestion of toxic metals has undesirable impacts on humans and the associated harmful impacts become perceptible only after several years of exposure (Khan *et al.*, 2008). Heavy metals are essential micro nutrients, but after certain concentration they pose public health risk. They cause liver damage, kidney damage, diabetes, and arteriosclerosis, irregular heart rhythm, lung cancer, corrosive action on the skin, etc. (Ataikiru, 2021). Long-term effect of heavy metal exposure to human and higher animals includes mental lapse, kidney failure, and central nervous system disorder (Nwaogu *et al.,* 2014). As a result of increasing anthropogenic activities, heavy metals pollution of soil, water, and atmosphere represents growing environmental problems affecting food quality and human health.

Waste dump site is final place for all types of waste, either municipal solid waste, collected and transported directly to landfills, or industrial waste or other materials from waste treatment facilities which are useless (Akintola, 2014). Dumpsite wastes are commonly burnt and ashes produced are richer in metal contents. These ashes are either dissolved in rainwater and leached into the soil contaminating the underground water, or washed away by runoff into streams and rivers, thereby contaminating the environment. Open dumpsites are used for disposal of solid wastes without environmental controls. Dumping of solid wastes in open is of serious health risk and constitutes problems on environment because they are mostly contaminated. Because there will always be waste to be disposed of, landfill forms the basis of every waste management plan. Dumping of solid wastes in open is of serious health risk and constitutes problems on environment because they are mostly contaminated. Most of the dump sites are not logically selected, planned or well managed (Odewumi, *et al.,* 2016), and most farmers tend to prefer these sites (because of the rich organic content) neglecting the hazardous state of the site. Thus, the objective of this paper was to evaluate the bioaccumulation and potential risk assessments of heavy metals in two varieties of edible vegetables (*Amaranthus hybridus* and *Celosia argentea*) around Lapite Dump Site, Akinyele Local Government Area, Ibadan, Oyo State, Nigeria.

MATERIALS AND METHODS

Area of Study: The study area, Lapite refuse dumpsite is located within Ibadan metropolis in Akinyele local government area and lies within longitudes 3^{o} $54^{I}60^{II}$ E and 3^{o} $91^{I}64^{II}$ E and latitudes 7^{o} 58^{I} 5^{II}N and 7^{o} 57^{I} 32^{II}N in southwestern Nigeria. It was opened in 1998 and still in use till date. It covers an approximate 20 hectares of land along Old Oyo Road. The study area falls within the humid and sub-humid tropical climate of southwestern Nigeria There are presence of the agricultural activities in the area; there are banana plantation, maize, vegetables and cassava farms.

Materials: Materials used in the field work study include hand trowel, hand glove, maker, paper tape, nylon, field book, sample bag, and Global Positioning System (GPS).

Collection of Vegetable Samples: Random sampling technique was employed to collect the vegetable samples. These vegetables were collected and bulked according to various plot. These vegetables were dried for days and taken to the laboratory for heavy metal constituent analysis.

Collection of Soil Samples: Soil samples was collected in each plot the vegetables were collected at a depth of 0-15cm using the hand trowel. The soil samples were air dried for 3 days and also taken to laboratory for sieving and elemental constituent analysis. Soils samples were collected randomly in order to determine the bioaccumulation rate of the metals from the soils to the vegetable plants.

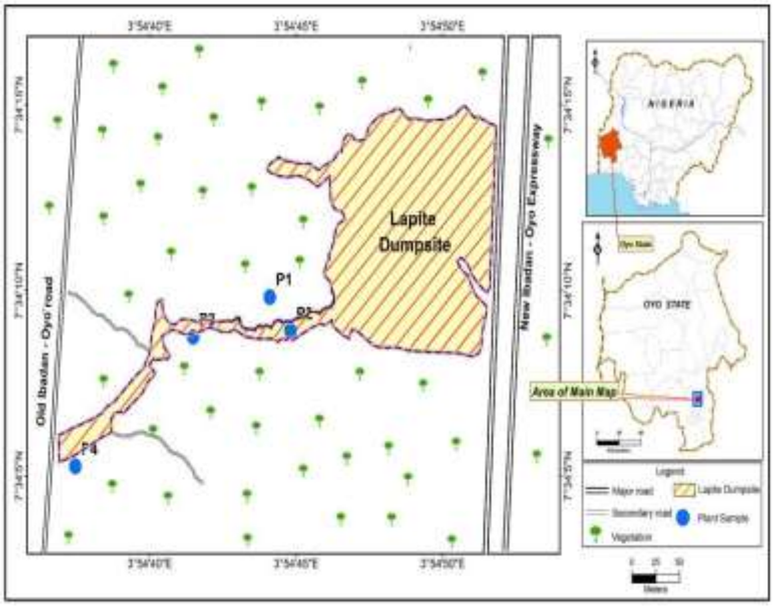

Fig 1. Map showing the Vegetable Plant Collection Points

Procedure for Heavy Metal Analysis in Plant: The shoot, root and leaf of each plant sample were oven dried and milled into a powder form. 0.5g of each sample was weighed into a beaker and 10mcs of an acid mixture of nitric acid/perchroic acid in ratio 2:1 was added under a furnace cupboard. The beaker content was placed on a hot plate (heating mantel) for digestion for a period of time ranging from 5mins to 10mins, a colour change was observed from a brownish red to colourless. The digest was then allowed to cool for 25 mins and then later mixed with distilled water. The digest was read on a bulk scientific atomic absorption spectrophotometer model 210/211 VGP to determine the concentration of all the hosted heavy metals.

Determination of Bioaccumulation Factor: The Bioaccumulation factor is the ratio of the concentration of heavy metals in plants and in soils. It is an indicator of a plant's capacity to accumulate heavy metals, (Chen *et al.*, 2016)
The BAF was calculated using equation 1;

$$BAF = \frac{\mathrm{Pi}}{\mathrm{Si}} \qquad (1)$$

Where Pi is the concentration of a heavy metal in plants (mg/kg), and Si is the concentration of the same heavy metal in the soil where the plant grows (mg/kg).

Risk Assessment Analyses: Contamination Factor (CF): The contamination factor calculation was used (Hakanson *et al.*, 1980 as used by Olatunji and Olisa 2014) to determine the level of contamination of elements in the soil and the selected vegetables around the study area and it's express as thus in euation 2;

$$\mathrm{CF} = \frac{\text{Mean concentration}}{\text{background level}} \qquad (2)$$

The contamination factor classification consists of four classes ranging from low contamination to very high contamination; low contamination (CF < 1), moderate contamination (1≤CF<3), considerable contamination (3≤CF<6), and very high contamination (CF>6).

Geo-Accumulation Index: Geo-accumulation index (Igeo) as given by Müller (1969) and used by Gupta (2014) was used to assess the pollution level of heavy metal in the plants. Formula of Igeo is shown in Equation 3 while the seven classes of Igeo is as presented in Table 2.

$$Igeo = log2\frac{Ci}{1.5Cn} \qquad (3)$$

Where Ci is the concentration of the determined elements in the plant. Cn is the background concentration of the element while 1.5 is the conversion factor. The geo-accumulation index classification consists of 7 classes namely unpolluted (0), unpolluted to moderately polluted (0-1), moderately polluted (1-2), moderately polluted to strongly polluted (2-3), strongly polluted (3-4), strongly polluted to extremely polluted (4-5), extremely polluted (5-6).

Determination of Pollution Load Index (PLI): The pollution load index (PLI) was used to measure the general quality of the study area in term of pollution. The plants in the area was generalized and the quality was measured using the contamination factor and the number of the element studied. The equation for PLI is thus express as used by Jorvik, 2017 in equation 4:

$$PLI = (CF1 * CF2 * \dots\dots\dots\dots CFn)^{1/n} \qquad (4)$$

Where n is the number of metals and CF is the contamination factors.

PLI qualification is based on geometric mean of perfection (PLI<1), presence of baseline level of pollutant (PLI=1) and deterioration of the size or site (PLI>1).

RESULTS AND DISCUSSIONS

Heavy Metal Concentration: The summary of heavy metals concentration on vegetables and soil samples are as presented in Tables 1 and 2. In the summary table for heavy metals concentration of the vegetables (Table 1), the mean concentration of Pb, Cd and Mn (3.05mg/kg, 0.67mg/kg, and 129.61mg/kg) in the vegetable samples are above their respective permissible values (PL) for humans (0.3mg/kg, 0.2mg/kg, and 6.64mg/kg respectively) indicating a high concentration of these metals in the vegetables. The mean concentrations of Ni and Zn (2.27 and 61.55 mg/kg) are below their respective permissible limit (67.9 and 99.4 mg/kg) indicating a normalcy of these two metals in the vegetables of the study area. The high concentration of Pb in the dumpsite may be due to high disposal of lead batteries and paints, PVC pipes, and agricultural activities. The high concentrations of Cd in the vegetables samples from the dumpsite may be due to disposals of batteries, plastics and synthetic rubber materials in the dumpsite while the high concentration of Mn may also be due to disposal of batteries, soil erosion and water ways release, and automobile workshop refuse dumped in the area. The mean concentration of Cd (0.67 mg/kg) is lesser when compared with the mean concentration (7.24mg/kg) of Zhou *et al.*, 2016 who did a research on the “Accumulation of Heavy Metals in Vegetable Species Planted in Contaminated Soils and the Health Risk Assessment” in China. The mean concentration of Pb (3.05 mg/kg) is higher when compared with the vegetables of Jimeta and Nguore areas of Adamawa (0.3mg/kg) according to Sakiyo *et al.*, 2020 who worked on “Concentration of Heavy Metals in Vegetables Cultivated around Dumpsites in Jimeta and Ngurore Areas, Adamawa State, Nigeria”.

Table 1. Heavy Metal Concentration (mg/kg) in Vegetable Samples

S/N	Vegetable ID	Pb (mg/kg)	Cd (mg/kg)	Ni (mg/kg)	Mn (mg/kg)	Zn (mg/kg)
	LAH_1	3.37	0.00	0.87	26.00	45.55
	SAH_1	1.63	1.75	1.12	9.50	62.80
	LAH_2	4.14	1.35	3.13	51.70	55.85
	SAH_2	2.22	2.25	1.87	11.55	72.10
	LCA_1	3.11	0.00	5.56	382.25	96.80
	SCA_1	3.12	0.00	1.50	373.40	35.25
	LCA_2	4.25	0.00	3.0	143.95	81.30
	SCA_2	2.60	0.00	1.11	38.55	42.75
	PL	0.3	0.2	67.9	6.64	99.4
	MEAN/SD	3.054±1.0	0.67±0.95	2.27±1.58	129.61±158.98	61.55±20.97

Key: PL= W.H.O Permissible Limit (FAO/WHO, 2011.); LAH_1= Leaves of Amaranthus hybridus from Upslope 1; SAH_1= Stems of Amaranthus hybridus from Upslope 1; LAH_2= Leaves of Amaranthus hybridus from Upslope 2; SAH_2= Stems of Amaranthus hybridus from Upslope 2; LCA_1 = Leaves of Celosia argentea from Midslope ; SCA_1= Stems of Celosia argentea from Midslope; LCA_2 = Leaves of Celosia argentea from Downslope; SCA_2= Stems of Celosia argentea from Downslope

Table 2. Heavy Metal Concentration (mg/kg) in Soil Samples

S/N	Soil ID	Pb (mg/kg)	Cd (mg/kg)	Ni (mg/kg)	Mn (mg/kg)	Zn (mg/kg)
	SH_1	19.55	0.00	8.30	7.30	21.05
	SH_2	83.95	2.30	18.85	19.00	48.05
	SA_1	201.50	1.65	49.7	12.95	43.95
	SA_2	178.56	3.11	23.43	15.50	42.11

*Key**:** SH_1: Soils collected from Amaranthus hybridus plot of Upper slope 1; SH_2: Soils collected from Amaranthus hybridus plot of Upper slope 2; SA_1: Soils collected from Celosia argentea plot of Midslope; SA_2: Soils collected from Celosia argentea plot of Downslope*

Bioaccumulation Factor of Heavy Metals on Vegetables: This was calculated to know the rate of accumulation by which heavy metals are accumulated in each sample which will indicate the metals that are absorbed or taken up and deposited or stored faster than being metabolized. This also tells us the mobility rate of each heavy metal from soils to the plant. The Bioaccumulation factor (BAF) of the selected vegetables is as presented in table above. In the calculated BAF above, it is observed that manganese and zinc are the heavy metals that are accumulated the most of the heavy metals studied throughout the plant samples. This indicates that manganese and zinc are the metals with the highest mobility rate from the soils to the vegetables of the study area and also the two metals are metals taken up and stored faster than they are metabolized in the leaves and stems of the vegetable plants.

Table 3. Determination of Bioaccumulation Factor

S/N	Plant Samples	Pb	Cd	Ni	Mn	Zn
				mg/kg		
	LAH$_1$	0.17	0.00	0.10	3.56	2.16
	SAH$_1$	0.08	-	0.13	1.30	1.98
	LAH$_2$	0.05	0.59	0.17	2.72	1.16
	SAH$_2$	0.03	0.98	0.10	0.61	1.05
	LCA$_1$	0.02	-	0.11	29.52	2.20
	SCA$_1$	0.02	-	0.03	28.83	0.80
	LCA$_2$	0.02	-	0.13	9.29	1.93
	SCA$_2$	0.01	-	0.05	2.49	1.02

Key: LAH$_1$= Leaves of Amaranthus hybridus from Upslope 1; SAH$_1$= Stems of Amaranthus hybridus from Upslope 1; LAH$_2$= Leaves of Amaranthus hybridus from Upslope 2; SAH$_2$= Stems of Amaranthus hybridus from Upslope 2; LCA$_1$ = Leaves of Celosia argentea from Midslope; SCA$_1$= Stems of Celosia argentea from Midslope; LCA$_2$ = Leaves of Celosia argentea from Downslope; SCA$_2$= Stems of Celosia argentea from Downslope.

The other heavy metals (Pb, Cd, and Ni) have low BAFs indicating that their mobility rate from the soils to the plant is low and they are being mobilized faster than they are taken up and stored. In the *Amaranthus hybridus* plant, the leaves of the plant taken at the first point and second point of the upper slope (LAH$_1$ and LAH$_2$) have higher bioaccumulation factor of Mn (3.56 mg/kg and 2.72 mg/kg) and Zn (2.16 and 1.16 mg/kg) than the stems of the plant of the first and second point of the upper slope (SAH$_1$ and SAH$_2$) of the *Amaranthus hybridus* plant (1.30mg/kg and 0.61 mg/kg; 1.98 and 1.05mg/kg). This indicates that the leaves of the *Amaranthus hybridus* have organs that take up and store Mn and Zn faster than the organs in the stems while there are faster metabolic reaction of these two heavy metals in the stem than the leaves. In the *Celosia argentea* plants also, it is also observed that the leaves of the plant taken at the middle slope and the down slope (LCA$_1$ and LCA$_2$) have higher bioaccumulation factor of Mn (29.52 and 9.29 mg/kg) and Zn (2.20 mg/kg and 1.93 mg/kg respectively) than the stems of the plant of the middle and down slope (SCA$_2$ and SCA$_2$) of the *Celosia argentea* plant (28.83 mg/kg and 2.49 mg/kg; 0.80 and 1.02mg/kg). This indicates that the leaves of the *Celosia argentea* have organs that take up and store Mn and Zn faster than the organs in the stems while there are faster metabolic reaction of these two heavy metals in the stem than the leaves. This observation above also applies with the heavy metals with low BAFs (Pb, Cd and Ni), that is they all have leaf factors greater than the stems in the *Amaranthus hybridus* and *Celosia argentea* plants. Consequently it can be concluded that the leaves of vegetables plants of the study area take up and store heavy metals from the soils of the study area than the stems, while the stems have higher metabolic reaction rate than the leaves of the vegetables.

Contamination Factor of Heavy Metals: The calculated contamination factor (CF) is shown below. This was used to determine the degree of contamination each metal has on the vegetables around the study area. The various calculated CFs for each element are as follows using the permissible limits as background values; Pb-10.17, Cd-3.35, Ni-0.33, Mn-19.52, Zn-0.62. The CF table showed that Pb, Cd and Mn are the metals showing significant contamination factors, with Pb and Mn having highly contaminated (CF>6) the vegetable in the study area (10.17 and 19.52 respectively) while Cd has considerably contaminated the vegetables (3.35). This is consequent with the mean concentration table which showed greater mean values than their respective permissible limits. The CF of Pb and Cd are lower when compared with the highest CF values of Pb and Cd (36 and 70) of Ogbaran and Uguru 2021. The contamination factor of Ni and Zn are low (CF<1), and this indicates that Ni and Zn have not contaminated the vegetables of the study area. The CF of Ni is also lower when compared with the highest value of CF value (50) of Ogbaran and Uguru 2021.

Geo-accumulation Index (Pollution Factor) Analysis: The Geo accumulation index was used to assess the level of pollution of these heavy metals in each vegetable samples collected around the study area.

Table 4: Geo-accumulation Index of Heavy Metals on Vegetables

Metals	Pb	Cd	Ni	Mn	Zn
LAH$_1$	0.87	-	-2.07	0.42	-0.51
SAH$_1$	0.56	0.76	-1.96	-0.02	-0.38
LAH$_2$	0.96	0.65	-1.51	0.72	-0.43
SAH$_2$	0.69	0.87	-1.74	0.06	-0.32
LCA$_1$	0.84	-	-1.26	1.58	-0.19
SCA$_1$	0.84	-	-1.83	1.57	-0.63
LCA$_2$	0.98	-	-1.53	1.16	-0.26
SCA$_2$	0.76	-	-1.96	0.59	-0.54

Key: LAH$_1$= Leaves of Amaranthus hybridus from Upslope 1; SAH$_1$= Stems of Amaranthus hybridus from Upslope 1; LAH$_2$= Leaves of Amaranthus hybridus from Upslope 2; SAH$_2$= Stems of Amaranthus hybridus from Upslope 2; LCA$_1$ = Leaves of Celosia argentea from Midslope; SCA$_1$= Stems of Celosia argentea from Midslope; LCA$_2$ = Leaves of Celosia argentea from Downslope; SCA$_2$= Stems of Celosia argentea from Downslope.

The calculated geo-accumulation index showed that the leaves and stems collected from the study area are all moderately polluted with Pb (Igeo=0-1) while the stems and leaves of the *Amaranthus hybridus* collected at the upper slope are the vegetable plants showing moderate pollution by cadmium. Ni and Zn are unpolluted in both the *Amaranthus hybridus* and *Celosia argentea* of the study area (Igeo≤0) while the stem of the *Amaranthus hybridus* collected at the first upslope point can also be said to be unpolluted with manganese. The leaves of the vegetables collected at the two points of the upslope, together with the stems collected at the second point of the upslope and the stems of *Celosia argentea* of the down slope showed that they are also unpolluted with Mn but tending towards moderate pollution by Mn. The leaves and stems of *Celosia argentea* collected at the midslope are all moderately polluted by Mn (Igeo=1-2) while the leaves of the *Celosia argentea* of the downslope are also moderately polluted with manganese. This geo-accumulation index analysis had shown that the same metals that have contaminated (Pb, Mn, and Cd) the two vegetables have also polluted either or both of them with Mn showing the most significant pollution degree among the three. Cadmium is not polluted in the vegetables of the midslope and the downslope despite having some factors of contamination.

Pollution Load Index: The Pollution Load Index for the soil samples was calculated to determine the overall pollution load of the area covered. Even though some of the heavy metals have not contaminated or polluted all the vegetable plants of the study area, the geometric mean calculated (2.67) showed that the whole dumpsite area has been deteriorated (PLI>1). This indicates that the vegetable plants and other plants and soils of the study area are not fit for use or consumption.

Conclusion: The bioaccumulation factor revealed that Mn and Zn are the metals with higher BAFs when compared with other heavy metals studied. Contamination factor and the geo-accumulation index showed that Pb, Cd and Mn are the metals that have significantly affect the vegetables while the pollution load index showed that the dumpsite area has been deteriorated. Consequently, planting and living around this dumpsite should be discouraged; Environmental Impact Assessment (EIA) should be done to relocate these farmlands and habitats to a more environmental friendly area.

REFERENCES

Akintola, OO (2014). Geotechnical and Hydrogeological assessment of Lapite waste dumpsite in Ibadan, Southwestern Nigeria. Unpublished PhD Thesis, University of Ibadan, 307.

Ataikiru, H (2021). Waste Liability and Asset" For National Sustainability. Inaugural Lecture Series,No .5 of the College of Education, Warri.

Chehregani, A; Malayer, B (2007). Removal of Heavy Metals by Native Accumulator Plants. *Int. J. Agric. Biotech.* 9(3):462–465.

Chen, H; Yuan, X; Li, T; Hu, S; Ji, J; Wang, C (2016). Characteristics of heavy metal transfer and their influencing factors in different soilcrop systems of the industrialization region, China. *Ecotoxicol Environ Saf* 126:193–201.

Gupta, S; Jena, V; Matić, N; Kapralova, V; Solanki, J (2014). Assessment of geo-accumulation index of heavy metal and source of contamination by multivariate factor analysis. *Int. J of Hazardous Mat*. 2. 18-22.

Hakanson, L (1980). An ecological risk index for aquatic pollution control a sedimentological approaches. *Wat. Research*. 14: 975-101.

Ihedioha, JN; Abugu, HO; Ujam, OT; Ekere, NR (2021). Ecological and human health risk evaluation of potential toxic metals in paddy soil, rice plants, and rice grains (Oryza sativa) of Omor Rice Field, Nigeria. *Environ. Monitor. Assess.* 193(9):1-17.

Jaishankar, M; Tseten, T; Anbalagan, N; Mathew, BB; Beeregowda KN (2014). Toxicity, mechanism and health effects of some heavy metals. *Interdisc. Toxicol.* 7 (2): 60-72.

Jarup, L (2003). Hazards of heavy metal contamination. *British Med. Bull*. 68(1):167–182.

Jorvik, E (2017). Upper crustal of trace element: A revision and uptake. *Chem. Geology* 253 (3) 1205-22.

Khan, S; Cao, Q; Zheng, YM; Huang, YZ; Zhu, YG; (2008). Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. *Environ Pollut* 152(3):686–92.

Mohsen, B; Mohsen, S (2008). Investigation of metal accumulation in some vegetables irrigated with wastewater in Shahre Rey- Iran and Toxicological implications. *American-European J of Agric. and Envt Sci*, 4(1): 86 – 92.

Muller, G; (1969). Index of Geo-accumulation in Sediments of Rhine River, *Geo J.* 2 (3) 108-118.

Nwaogu, LA; Ujowundu, CO; Iheme, CI; Ezejiofor, TN; Belonwu, DC (2014). Effect of sublethal concentration of heavy metal contamination on soil physicochemical properties, catalase and dehydrogenase activities. *Int J of Biochem Res and Rev*, 4(2): 141-149.

Odewumi, TO; Okeniyi, AG; Agbede, OA (2016). Assessment of Solid Waste Management Practices in Ibadan Metropolis. *J. Sci. Eng. Res.* 3(4): 375 – 382.

Ogbaran, AN; Uguru, H (2021). Assessment of Groundwater and Vegetable Quality around an Active Dumpsite using Pollution Index. *Civil Eng. Res. J*. 11.

Olatunji, AS; Olisa O (2014). Geochemical Study of Soil, Road Dust and Stream Sediment around Ijebu-Ode, Southwestern, Nigeria. *J. Environ. Anal. Toxicol.* 4: 229.

Sakiyo, DC; Chessed, G; Eli, J; Usongo, YJ (2020). Concentration of Heavy Metals in Vegetables Cultivated around Dumpsites in Jimeta and Ngurore Areas, Adamawa State, *Nigeria. J. Appl. Sci. Environ. Manage*. Vol. 24 (6) 1035-1040

Steffan, JJ; Brevik, EC; Burgess, LC; Cerda, A (2017): The effect of soil on human health: an overview. *European J. Soil Sci.* 159-171.

World Health Organization, Food and Agriculture Organization of the United Nations & Joint FAO/WHO Expert Committee on Food Additives (2011); Evaluation of certain food additives and contaminants: seventy-fourth [74th] report of the Joint FAO/WHO Expert Committee on Food Additives. World Health Organization.

Zhou, H; Yang, WT; Zhou, X; Liu, L; Gu, JF; Wang, WL; Zou, JL; Tian, T; Peng, PQ; Liao, BH; (2016) Accumulation of Heavy Metals in Vegetable Species Planted in Contaminated Soils and the Health Risk Assessment. *Int. J Environ. Res. Public. Health*. Mar 4; 13(3):289.