IJIRR

International Journal of Information Research and Review
Vol. 06, Issue, 05, pp.6292-6298, May, 2019

REVIEW ARTICLE

HEAVY METAL UPTAKE BY CUCUMBER (*CUCUMIS SATIVUS*) GROWN ON SOLID WASTE CONTAMINATED SOIL IN NEKEDE, IMO STATE

***Akhionbare, S.M.O., Enwerem, M.L., Umunnakwe, J.E. and Anyanwu, J.C.**

Department of Environmental Technology, Federal University of Technology, Owerri

ARTICLE INFO

Article History:
Received 28th February, 2019
Received in revised form
15th March, 2019
Accepted 20th April, 2019
Published online 30th May, 2019

Keywords:
Bioaccumulation,
Concentration,
Contaminated soil,
Transfer factor.

ABSTRACT

The research was carried out to assess the level of some trace metals in cucumber planted on contaminated soil in Nekede, Owerri. The mean concentrations of Pb, As, Ni, Hg and Fe in the fruits of the cucumber plant from the topsoil were 0.256, 78.82, 98.84, 3.49, and 96.63mg/kg, respectively while the values for the subsoil were 1.24, 49.77, 96.32, 2.58 and 162.66 mg/kg respectively. The mean concentration of Pb, As, Ni, Hg and Fe in the leaf of the cucumber plant from the topsoil were 1.24, 49.77, 96.32, 2.58, 162.66 mg/kg respectively while the mean concentration for the subsoil were 9.51, 0.00, 97.31, 0.00, 2.59 and 95.44mg/kg respectively. The mean values of Pb, As, Ni, Hg and Fe in the leaf for the control (topsoil) were 6.37, 2.22, 1.91, 2.99, 43.68 mg/kg respectively while the mean values for the control (subsoil) were 11.00, 1.34, 5.53, 3.01, 61.74 mg/kg respectively. The result indicated clear differences in heavy metal (Pb, As, Ni, Hg, and Fe) bioaccumulation among the various parts of the cucumber plant from the topsoil and subsoil. Except for Hg and Fe, the heavy metal concentrations in all the investigated cucumber fruits and leaves exceeded regulatory limits set by the World Health Organization, the Food and Agriculture Organization and other international standards. Soil–plant transfer factors indicated low accumulation of the heavy metals into the fruits and leaves of the cucumber, except for Ni in both the fruit and leaf. The pH values of the top soil samples ranged from 4.60 to 6.20. The range of As, Hg, Fe, Cr, Co, Zn, Cu, Cd, Ni and Pb for the topsoil samples were 0.114 - 1.441, 0.368 – 0.448, 8.483 – 9.826, 2.567 – 13.776, 0.00 – 0.131, 10.885 – 14.479, 0.375 – 18.915, 0.008 – 0.031, 0.00 – 0.00, 0.897 – 4.363 and 4.60 – 6.20 mg/kg respectively. The pH values of samples from the subsoil ranged from 4.40 to 4.80 with a mean value of 4.6. The range of As, Hg, Fe, Cr, Co, Zn, Cu, Cd, Ni and Pb for samples collected from the subsoil were 0.642 – 1.902, 0.322 – 0.897, 9.572 – 18.125, 0.00 – 10.430, 0.00 – 0.082, 10.849 -20.270, 0.199 – 22.340, 0.012 – 0.402, 0.00 -0.254 and 1.189 – 36.073mg/kg respectively. The result of the one-way analysis of variance revealed that there was no statistically significant difference ($p > 0.05$) in the mean level of heavy metals in the fruits and leaves of cucumber from the top soil and subsoil obtained from both the polluted and control sites. The Tukey post hoc test revealed that there was no statistically significant difference ($p > 0.05$) between the heavy metal accumulation in the cucumber of the topsoil and subsoil from the polluted and control sites. The BAFs of all the heavy metals were less than 1.0, except for Fe and Ni. Additionally, the BAFs of Fe, Ni and As were higher than the BAFs of Pb and Hg. The study recommended the articulation of strategies by the government to enforce proper management and disposal of solid waste through strict and dedicated implementation of waste management policies.

INTRODUCTION

Heavy metals are significant environmental pollutants, and their toxicity is a problem of increasing significance for ecological, evolutionary, nutritional and environmental reasons. The term ‘heavy metal’ refers to any metallic element that has a relatively high density and is toxic or poisonous even at low concentration (Lenntech Water Treatment and Air Purification, 2004).

***Corresponding author:** **Akhionbare, S.M.O.,**
Department of Environmental Technology, Federal University of Technology, Owerri

‘Heavy metals’ is a general collective term, which applies to the group of metals and metalloids with atomic density greater than 5 g/cm^3 (Akhionbare *et. al.*, 2013) or 5 times or more, greater than water (Hawkes,1997). Once introduced into the environment through the air, drinking water, food, or countless varieties of man-made chemicals and products, heavy metals are taken into the body via inhalation, ingestion and skin absorption. If heavy metals enter and accumulate in body tissues faster than the body’s detoxification pathways can dispose of, then a gradual build-up of these toxins occurs. High concentration exposure is not a necessity to produce a state of toxicity in the body, as heavy metal accumulation occurs in body tissues gradually and, over time, can reach toxic levels, much beyond the permissible limits (Suruchi *et al.*, 2012). Heavy metals contamination of vegetables cannot be underestimated as these food stuffs are important components of human diet. However, intake of heavy metal-contaminated vegetables may pose a risk to the human health. Heavy metal contamination of the food items is one of the most important aspects of food quality assurance. International and national regulations on food quality have lowered the maximum permissible levels of toxic metals in food items due to an increased awareness of the risk these metals pose to food chain contamination (Radwan and Salama, 2006). Heavy metals can be readily taken up by vegetable roots, and can be accumulated at in the edible parts of vegetables. Human activities such as industrial production, mining, agriculture and transportation release a high amount of heavy metals to the biosphere. The primary sources of metal pollution are the burning of fossil fuels, smelting of metal like ores, municipal wastes, fertilizers, pesticides and sewage (Rai, 2009). Heavy metals as one of the major contaminants of food supply may be considered the most important problem to our environment. In general, they are not biodegradable, have long biological half-lives and have the potential for accumulation in the different body organs leading to unwanted side effects. Lead and cadmium are among the most abundant heavy metals and are particularly toxic.

Soil is one of the important environmental components and plays a role as a medium for plant growth where it can recycle the nutrient and resources needed by plant. Heavy metals may be added and present in the soil due to agricultural activities such as addition of fertilizers and pesticides, soil amendments, organic fertilizers and in waste materials recycled to the soil. Soils are therefore the major sinks for heavy metals released into the environment by the aforementioned anthropogenic activities and unlike organic contaminants which are oxidized to carbon (IV) oxide by microbial action, most metals do not undergo microbial or chemical degradation, and their total concentration in soils persists for a long time after their introduction (Wuana and Okieimen, 2011). Accumulation of heavy metal in the environment becomes a health hazard because of their persistence, bioaccumulation and toxicity to plants, animals and human beings. Vegetables can be exposed to the heavy metals contamination when cultivated in polluted agricultural soils. Heavy metals that are attached with soil water and soil particles will be absorbed by plant roots and accumulated in vegetables (Aweng *et. al*., 2011). Soil to plant transfer is one of the key processes of human exposure to heavy metals through the food chain. Heavy metals uptake via the roots from contaminated soils and direct deposition of contaminants from the atmosphere onto plant surfaces can both lead to plant contamination with heavy metal (Zhuang *et al*., 2009).

The level of heavy metal in soils and the forms in which they exist are influenced by pedogenetic processes (Herawati *et al.,* 2000). Vast portions of farmlands have been contaminated by metals as a result of the activities of mining, smelting, fossil fuel burning, phosphate fertilizers and sewage sludge (Navarro *et al.,* 2008). Soil-to-crop transfer of heavy metals is the major pathway of human exposure to heavy metals. Food crops grown in metal-contaminated soil can uptake and accumulate metals in quantities high enough to affect food quality and safety (Muchuweti *et al.*, 2006). Uptake and transfer of heavy metals through food crops are affected by the level of metals in soils, soil properties, pH, age of food crop, food crop types and species (Xu *et al*., 2015; Yang *et al.,* 2015). It becomes imperative to evaluate heavy metal uptake by cucumber (*Cucumis sativus*) grown on contaminated soil. It is necessary to assess the levels of trace elements concentration in different varieties of fruits and vegetables (Nirmal et *al*., 2007). Contamination of foods by heavy metals has become a challenge for producers and consumers. The main sources of heavy metals to vegetable crops are their growth media (soil, air, nutrient solutions) from which these heavy metals are taken up by the roots or foliage (Lokeshwari and Chandrappa, 2006). The toxic and detrimental impacts of heavy metals become apparent only when long-term consumption of contaminated vegetables occurs. Regular monitoring of heavy metals in vegetables and other food items should be performed in order to prevent excessive build up of these heavy metals in the human food chain (Khanna and Khanna, 2011). Vegetables can take up and accumulate heavy metals in quantities high enough to cause clinical problems to humans (Alam *et al.,* 2003). Daily metal intake estimate does not take into account the possible metabolic ejection of the metals but can easily tell the possible ingestion rate of a particular metal. Dietary intake of food results in long-term low level body accumulation of heavy metals and the detrimental impact becomes apparent only after several years of exposure (Oluyemi *et al.,* 2008; Orisakwe *et al*., 2012). Leafy vegetables grown on heavy metal contaminated soils accumulate higher amounts of metals than those grown in uncontaminated soils because of the fact that they absorb these metals through their roots (Al-Jassir *et al*., 2005; Sharma *et al*., 2006; Sharma *et al*., 2007; Marshall *et al.,* 2007). Heavy metals are persistent in the environment and are subject to bioaccumulation in food-chains. They are easily accumulated in the edible parts of leafy vegetables, as compared to grain or fruit crops (Mapanda *et al*., 2005).

MATERIALS AND METHODS

Study Area: The study was conducted at Nekede Mechanic Village and on a virgin farmland located at Obinze as (the control), in Owerri, the capital city of Imo State. Owerri lies between latitude $4^0$45'N and $5^0$50'N, longitude $6^0$35'E and $7^0$30'E, and covers an area of approximately 5,529.17km^2. The climate of Imo State is humid semi-hot equatorial type. The state experiences heavy rainfall of 2000-2400 mm per year (Onweremadu & Peter, 2016). The high annual rainfall encourages large volumes of runoff. Variations occur in rainfall amount from year to year usually between 1,990mm and 2,200mm (Anyadike, 1992). Relative humidity oscillates between 75% and 90% between the Dry and Rainy seasons. The mean annual temperature is above 20^0C with the hottest months being January to March. Owerri has a tropical climate. It has significant rainfall in most months, with a short dry season. The climate here is classified as Am by the Koppen-Geiger system. The average annual temperature in Nekede is 26.4^0C. Precipitation here averages 2200 mm. The least amount of rainfall occurs in January. The average in this month is 17mm. In June, the precipitation reaches its peak, with an average of 363 mm. the temperatures are highest on average in March, at around 27.9 ^{0}C. At 25.0 ^{0}C on average, August is the coldest month of the year. The variation in the precipitation between the driest and wettest months is 346 mm. The variation in annual temperatures is around 2.9 ^{0}C. Nekede has an average annual relative humidity of 75 per cent which is highest during the rainy season, when it rises to about 90 per cent.

Sample collection and analysis: The samples used for the this study were collected randomly from three (3) different dump sites at Nekede mechanic village, labeled 1, 2 and 3 while the 4^{th} (control samples) was collected from a virgin farmland at Obinze. Using properly labeled sterile polythene bags, top and sub soil samples of these four different experimental sites were collected within the rooting depth of (0-15cm) and (15-30cm) respectively with the aid of soil auger for heavy metals analysis. All the samples were then taken to laboratory, oven dried at 60°C before wet digestion using Aqua-regia mixture (70% high purity HNO_3 and HCl ratio 3:1). Cucumber seeds were planted on each of the top and sub soil of the experimental sites (dump sites 1, 2 and 3, and the control (site 4). The cucumbers were irrigated and grown for a period of two (2) months to bear fruits. Each of the experimental samples were collected in properly labeled sterile polythene bags, oven dried at 60^0C in the laboratory before wet digestion using aqua-regia for heavy metals determination in each of the samples. Aqua-regia mixture (70% high purity HNO_3 and HCl ratio 3:1) and 5 mL 30% H_2O_2 were added to an empty 100 mL beaker and heated at 80°C till the solution became cleared (Rodrigues-Flores and Rodriguez-Castellon, 1982). The resulting solution was cooled and filtered. The filtrate was made up to 50 mL with de-ionised water and kept at room temperature for further analysis of heavy metals. For the heavy metal analysis of dry vegetable, 1 g sample was taken into a 100 mL acid washed beaker, 25 mL aqua-regia and 5 mL 30% H_2O_2 were added (Rodrigues-Flores and Rodriguez-Castellon, 1982). The mixture was digested at 80°C until a clear solution was obtained. After cooling, the digested samples were filtered and diluted to 50 mL with de-ionised water. Determination of the heavy metals such as Cu, Cr, Hg, Zn, Fe, Ag, Pb, Cd and Ni in the filtrate of vegetables and blanks was achieved by atomic absorption, spectrophotometer (model: Buck 200A). The instrument was calibrated using manually prepared standard solution of respective heavy metals. An analytical grade of a nitrate salt of Pb and granules of Cu and Zn were used in the preparations of solutions used in the spiking of samples for Pb, Cu and Zn.

RESULTS

Table 4.1 shows variation in the levels of heavy metals from soil samples collected from the waste dump sites. The pH values of the top soil samples ranged from 4.60 to 6.20 with a mean value of 5.367. The range of As, Hg, Fe, Cr, Co, Zn, Cu, Cd, Ni and Pb for the topsoil samples were 0.114 - 1.441mg/kg, 0.368 – 0.448 mg/kg, 8.483 – 9.826 mg/kg, 2.567 – 13.776 mg/kg, 0.00 – 0.131 mg/kg, 10.885 – 14.479 mg/kg, 0.375 18.915 mg/kg, 0.008 – 0.031 mg/kg, 0.00 -0.00 mg/kg, 0.897 – 4.363 mg/kg and 4.60 -6.20 mg/kg respectively, with mean values of 0.919, 0.416, 9.364, 7.596, 0.044, 13.271, 6.557, 0.017, 0.00 and 2.215 respectively. The values for the control were 1.282, 0.447, 10.226, 6.307, 0.00, 7.297, 18.400, 0.030, 0.00 and 4.140mg/kg respectively. The pH value of the topsoil from the control was 5.8. The pH values of samples from the subsoil ranged from 4.40 to 4.80 with a mean value of 4.6. The range of As, Hg, Fe, Cr, Co, Zn, Cu, Cd, Ni and Pb for samples collected from the subsoil were 0.642 – 1.902,

Table 4.1. Levels of pH and heavy metals in Soil

Sample	As	Hg	Fe	Cr	Co	Zn	Cu	Cd	Ni	Pb	pH
S1, mg/kg	1.311	0.614	18.125	10.430	0.082	20.270	22.340	0.402	0.00	36.0730	4.80
S2, mg/kg	0.642	0.322	9.775	0.00	0.012	10.990	0.199	0.012	0.254	1.237	4.40
S3 ,mg/kg	1.902	0.897	9.572	0.00	0.00	10.849	0.233	0.013	0.00	1.189	4.60
Mean (mg/kg)	1.285	0.611	12.491	3.477	0.0313	14.036	7.591	0.142	0.085	12.833	4.6
T1, mg/kg N05^{0}31.114' 007^{0}02.703'	0.114	0.448	8.483	13.776	0.131	14.479	0.375	0.011	0.00	1.385	5.30
T2, mg/kg N05^{0}27.844' E007^{0}01.948'	1.201	0.433	9.826	6.436	0.00	10.885	18.915	0.008	0.000	4.363	4.60
T3, mg/kg N05^{0}27.528' E007^{0}01.969'	1.441	0.368	9.783	2.576	0.00	14.450	0.380	0.031	0.00	0.897	6.20
Mean (mg/kg)	0.919	0.416	9.364	7.596	0.044	13.271	6.557	0.017	0.00	2.215	5.367
CS, mg/kg	1.361	0.428	11.703	21.176	0.071	0.550	0.520	0.013	0.00	0.615	6.70
CT, mg/kg N05^{0}23.35' E006^{0}59.176'	1.282	0.447	10.226	6.307	0.00	7.297	18.400	0.030	0.00	4.140	5.8

T1 - Top Soil sample collected @ depth 0-15cm at polluted waste dump site point 1
T2 - Top Soil sample collected @ depth 0-15cm at polluted waste dump site point 2
T3 - Top Soil sample collected @ depth 0-15cm at polluted waste dump site point 3
S1 - Sub- Soil sample collected @ depth 15-30cm at polluted waste dump site point 1
S2 - Sub- Soil sample collected @ depth 15-30cm at polluted waste dump site point 2
S3 - Sub- Soil sample collected @ depth 15-30cm at polluted waste dump site point 3
CT - Control Top Soil collected @ depth 0-15cm
CS - Control Sub-soil collected @ depth 15-30cm

Table 4.2 Mean Result of heavy metal analysis of Cucumber fruit and leaf

S/N	PARAMETERS	SOIL 1				CONTROL SOIL				International Standards
		TOP SOIL		SUBSOIL		TOP SOIL		SUBSOIL		
		FRUIT	LEAF	FRUIT	LEAF	FRUIT	LEAF	FRUIT	LEAF	
1	Lead , µg/g Pb	0.256	1.24	ND	9.51	9.82	6.37	8.40	11.00	0.2[a] 0.3[b]
2	Arsenic , µg/g As	78.82	49.77	54.99	ND	0.86	2.22	2.32	1.34	0.2[c]
3	Nickel , µg/g Ni	98.84	96.32	101.63	97.31	1.78	1.91	9.14	5.53	1.5[d]
4	Mercury, µg/g Hg	3.49	2.58	6.19	2.59	2.20	2.99	2.54	3.01	10[e]
5	Iron , µg/g Fe	96.63	162.66	139.97	95.44	14.02	43.68	78.41	61.74	425[b]

[g]China food hygiene standard, 1994, [b]WHO (Codex Alimentarius Commission, Joint FAO/WHO, 2001 and codex alimentarius commission, 1994); [c]WHO (codex alimentarius commission, 1991); . [a]WHO/FAO (Codex Alimentarius Commission. Joint FAO/WHO, 2007) and indian standard awashthi; [d]WHO/FAO (FAO/ WHO,codex general standard for contamination and toxin in foods, 1996)

0.322 – 0.897, 9.572 – 18.125, 0.00 – 10.430, 0.00 – 0.082, 10.849 -20.270, 0.199 – 22.340, 0.012 – 0.402, 0.00 -0.254 and 1.189 – 36.073mg/kg respectively, with mean values of 1.285, 0.611, 12.491, 3.477, 0.0313, 14.036, 7.591, 0.142, 0.085 and 12.833 mg/kg respectively. The values for samples collected from control subsoil were 1.361, 0.428, 11.703, 21.176, 0.071, 0.550, 0.520, 0.013, 0.00 and 0.615 mg/kg for As, Hg, Fe, Cr, Co, Zn, Cu, Cd, Ni and Pb respectively. The mean pH for the control subsoil was 6.70. The concentrations of the heavy metals in the fruits and leafs of the cucumber are presented in Table 4.2. As can be seen, clear differences were found in the concentrations of the heavy metals. The mean concentrations of Pb, As, Ni, Hg and Fe in the fruits for the top soil were 0.256 mg/kg, 78.82 mg/kg, 98.84mg/kg, 3.49 mg/kg, and 96.63mg/kg, respectively while the values for the subsoil were 1.24mg/kg, 49.77mg/kg, 96.32 mg/kg, 2.58 mg/kg and 162.66 mg/kg respectively. For the Control, the mean concentration of the heavy metals (Pb, As, Ni, Hg and Fe) in the fruits for the top soil were 9.82mg/kg, 0.86mg/kg, 1.78mg/kg, 2.20mg/kg and 14.02mg/kg respectively while the values for the subsoil were 8.40mg/kg, 2.32mg/kg, 9.14mg/kg, 2.54mg/kg and 78.41mg/kg respectively. The mean concentration of Pb, As, Ni, Hg and Fe in the leaf of the cucumber plant from the topsoil were 1.24, 49.77, 96.32, 2.58, 162.66 mg/kg respectively while the mean concentration for the subsoil were 9.51, 0.00, 97.31, 0.00, 2.59 and 95.44mg/kg respectively.

The mean values of the heavy metals (Pb, As, Ni, Hg and Fe) in the leaf for the control (topsoil) were 6.37, 2.22, 1.91, 2.99, 43.68 mg/kg respectively while the mean values for the control (subsoil) were 11.00, 1.34, 5.53, 3.01, 61.74 mg/kg respectively. These results indicated that clear differences in heavy metal (Pb, As, Ni, Hg, and Fe) bioaccumulation existed among the various parts of the cucumber plant from the topsoil and subsoil. There was no significant difference ($P > 0.05$) in the levels of these heavy metals in cucumber planted in the topsoil and the subsoil. Except for Hg and Fe, the heavy metal concentrations in all the investigated cucumber fruits and leaves exceeded regulatory limits set by the World Health Organization, the Food and Agriculture Organization and other international standards (Table 4.2). Soil–plant transfer factors indicated low accumulation of the heavy metals into the fruits and leaves of the cucumber, except for Ni in both the fruit and leaf. The result of correlation analysis of heavy metals in soil (Table 4.3) showed that the soil parameters exhibited both positive and negative correlations of diverse magnitudes. The result revealed that Fe concentrations were highly significant positively ($p < 0.05$) correlated with Cd ($r = 0.95667$) and Pb ($r = 0.9471$); the Co concentrations correlated significantly positively ($p < 0.05$) with Hg ($r = 0.91039$); Cu correlated significantly positively ($p < 0.05$) with Hg ($r = 0.91618$), Cr ($r = 0.91965$) and Co ($r = 0.82006$); the Cd concentrations

Table 4.3 Correlation matrix of pH and heavy metals in soil

	As	Hg	Fe	Cr	Co	Zn	Cu	Cd	Ni	Pb	pH
As		0.14013	0.54366	0.5705	0.11829	0.67152	0.69228	0.75174	0.34993	0.7806	0.74948
Hg	0.57005		0.61598	0.64283	0.91039*	0.67005	0.91618*	0.54852	0.35181	0.55095	0.40535
Fe	0.25411	0.21099		0.50922	0.49348	0.32528	0.13377	0.00019689	0.7148	0.0003555	0.88239
Cr	-0.23789	-0.19541	0.27535		0.037227	0.38529	0.91965*	0.73655	0.3011	0.74318	0.12879
Co	-0.59682	-0.047864	0.28524	0.73637		0.63669	0.82006*	0.41871	0.63738	0.45101	0.71005
Zn	-0.17897	0.17981	0.40067	-0.35703	0.19895		0.48117	0.089357*	0.96961*	0.093833	0.18707
Cu	0.16721	0.044765	0.57759	0.042908	-0.096566	0.29305		0.12475	0.47571	0.066619	0.56857
Cd	0.134	0.25115	0.95667*	0.14242	0.33403	0.63705	0.58864		0.71053	1.6175E-06	0.62854
Ni	-0.38233	-0.38095	-0.15455	-0.4193	-0.19856	-0.016213	-0.29655	-0.15694		0.69374	0.29046
Pb	0.11811	0.24968	0.9471*	0.13874	0.31255	0.63038	0.67436	0.99133*	-0.16638		0.52263
pH	0.13525	-0.34313	-0.06289	0.58364	0.15721	-0.51944	-0.23905	-0.20367	-0.42772	-0.26702	

*The correlation is significant at $p < 0.05$

Table 4.4 Correlation matrix of heavy metals accumulated in cucumber fruits and leaves

	Pb	As	Ni	Hg	Fe
Pb		0.056306	0.025706	0.1523	0.98485*
As	0.86817*		0.0011439	0.052824	0.44759
Ni	0.92228*	0.99031*		0.046073	0.58794
Hg	0.74057	0.87374*	0.88487*		0.54404
Fe	0.0119	0.44949	0.3297	0.36649	

correlated significantly positively ($p < 0.05$) with Zn (r = 0.089357) and Pb (r = 0.99133); and significantly positive correlation ($p < 0.05$) was established between Ni and Zn (r = 0.96961). pH correlated highly positively with As (0.74948) and Fe (0.88239). This could explain the bioavailability of these metals in soil and their relatively high transfer factors in the cucumber fruits and leaves. Furthermore, the Pb concentrations in edible parts were found to be highly significant positively ($p < 0.05$) correlated with the concentrations of Fe (r = 0.98485); the As concentrations were highly significant positively ($p < 0.05$) correlated with the concentrations of Pb (r = 0.86817); the Ni concentrations were highly significant positively ($p < 0.05$) correlated with the Pb (r = 0.92228) and As (r = 0.99031); Hg concentrations were highly significant positively (p < 0.05) correlated with As (r = 0.87374) and Ni (r = 0.88487). It appears that the absorption, transport, and accumulation of Pb, Ni, Hg in edible parts might have a relationship with those of As. A one-way ANOVA and Tukey post hoc test were used to evaluate the differences among vegetable parts. The result of the one-way analysis of variance revealed that there was no statistically significant difference in the mean level of heavy metals in the fruits and leaves of cucumber from the top soil and subsoil obtained from both the polluted and control sites. The Tukey post hoc test revealed that there was no statistically significant difference between the heavy metal accumulation in the cucumber of the topsoil and subsoil from the polluted and control sites (Appendix A).

DISCUSSION

The levels of pH and heavy metal characteristics of the soils tested are shown in Table 1. The As, Cr, Co and pH values were higher in the topsoil than in the subsoil from the polluted sites, while the Hg, Fe, Zn, Cu, Cd, Ni and Pb concentrations of the topsoil were significantly lower than their values for the subsoil (Table 4.1). Hg, Zn, Cu, Cd, and Pb values of the topsoil from the control site were higher than their subsoil values. However, the values of As, Fe, Cr, Co and pH for the topsoil were quite lower than their subsoil values from the control (Table 4.1). The results indicated that both the topsoil and subsoil were generally acidic. The lower pH can be attributed to human activities going on in the study area. This is in line with the findings of Song *et al.* (2012) and Yang *et al.* (2015) who reported that lower pH in soils has been attributed to intensive farming practices. The differences observed between the heavy metal values from polluted and control sites were significant (P < 0.05). This shows that there is local difference in the heavy metal characteristics of these soils. Table 4.2 shows the mean result of heavy metal analysis in cucumber leaves and fruits. The result revealed higher accumulation of Pb in the fruits and leaves of topsoil from the control site compared to the waste dumpsite. Pb was not detected in the fruits of cucumber planted in the subsoil from the dumpsite but showed high accumulation in the fruits of cucumber planted in the control site. Bioaccumulation of Pb in the leaf of cucumber from the control subsoil was also higher than that of the dumpsite. Bioaccumulation of Arsenic (As) by the fruit and leaf of cucumber planted in the topsoil from the waste dump was significantly higher (p<0.05) than their values obtained from the control site. Arsenic value was also higher in the fruit of cucumber harvested from the waste dump compared to the fruit harvested from the control. However, it was not detected in the leaf of cucumber harvested from the dumpsite but was detected in the leaf of cucumber harvested from the control. The bioaccumulation of Ni was significantly higher (p< 0.05) in both the fruits and leaves of cucumber harvested from the topsoil and subsoil from the dumpsite when compared to the values from the control site. There was higher accumulation of Hg in the fruit of cucumber harvested from the topsoil of the dumpsite compared to the fruit harvested from the control. However, the level of Hg in the leaf of cucumber from the control was greater than the level in the leaf from the dumpsite. The same trend can be observed for the subsoil, with greater accumulation of Hg in the fruit of cucumber from the waste dump than in the fruit of cucumber from the control site while the leaf of the cucumber from the dump site had lower bioaccumulation than the leaf from the control. There were higher bioaccumulation of Fe in the fruit and leaf of cucumber planted in both the topsoil and subsoil of the dumpsite compared to the bioaccumulation of the metal in the fruit and leaf of cucumber planted in both the topsoil and subsoil of the control site. The result revealed that the fruit generally accumulated more Pb, As, Ni and Hg than the leave, whereas iron accumulation was greater in the leaves than the fruits. The high bioaccumulation of these metals in leaves and fruits of cucumber may be as a result of the acidity of the soil. However, Kabata-Pendias and Pendias (1992) have reported that increase in soil pH in some cases does not lead to decrease in heavy metal availability. According to Eriksson (1989), for instance, a high Cd accumulation and toxicity in a high pH soil has been reported. Some of the heavy metals had very high accumulation compared to others. From the results, the accumulation ability of the heavy metals were Fe > Ni > As > Hg > Pb for the waste dumpsite and Fe > Pb > Ni > Hg > As for the control site. The result suggested that Fe had greater accumulation ability in the fruits and leaves of cucumber than Pb, Ni, As and Hg.

The high accumulation of Fe in the aerial parts of the cucumber could be because it is essential for the plant's growth and absorbed by the root and translocated to the aerial parts of the plant more rapidly while Pb and Hg being toxic, were not required for vegetable growth and therefore had limited uptake and storage in aerial parts of the cucumber plant. The high accumulation of some heavy metals in the vegetal parts of the cucumber can also be attributed to the fact that the leaves and fruits were easily exposed to contaminated soil because of their dwarfish nature with the fruits and leaves always on the ground. However, the low accumulation of most of these toxic metals, especially in the control site, suggests that cucumber is suitable for being planted in soil contaminated with these metals. However the high accumulation for some metals in the waste dump sites suggest that they are unsuitable for being planted on contaminated soil. This however, is in conflict with the findings of Herawati *et al.*(2000), who reported that lower concentrations of Pb, Cd, Zn and As were found in bitter gourd, towel gourd, cucumber, and pumpkin and were classified as "low accumulators. They also suggested that the low accumulators were suitable for being planted on contaminated soil, while the high accumulators were unsuitable. In this study, significant difference was found in the concentrations of heavy metals in the fruits and leaves of the cucumber. The result revealed that the leaf of the cucumber planted in the polluted sites accumulated more Pb and Fe than the fruit whereas the fruit accumulated more As, Ni, Hg than the leaf. The ability for heavy metal accumulation by the cucumber fruits was higher than for the leaves. Different parts of plants have different accumulation ability for different heavy metals. For instance, Jarup (2003) and Lalor *et al.*(1998)

reported that Cd uptake and accumulation in leafy vegetables are greater than in non-leafy vegetables. Generally, Fe which is an important nutrient for humans is considered a much lower health risk to humans than Pb, As, Ni and Hg (Hu *et al.*, 2013). Due to higher accumulation in the fruits, humans are exposed to greater health risks when they consume the fruits of cucumber harvested from dumpsites. This is in agreement with the findings of Iyaka and Kakuku (2012) and the report of the European Union (2002) on heavy metals in wastes. Significant differences were found in the BAFs of heavy metals in the edible parts of the cucumber plant. The BAFs of the heavy metals in the fruits and leaves of the cucumber planted in the polluted sites (topsoil)were generally higher than for the ones planted in the control sites (topsoil) except for Pb (in fruit and leaf), and Hg (in leaf) which had lower bioaccumulation factors. Significant differences ($p < 0.05$) were found in the BAFs of As, Ni, and Fe in the fruits and leaves of the cucumber planted in the waste dumpsite. The BAFs of all the heavy metals were less than 1.0, except for Fe and Ni. Additionally, the BAFs of Fe, Ni and As were higher than the BAFs of Pb and Hg . This means that the ability of Fe, Ni, and As accumulation in the edible parts of cucumber was much greater than that for Pb and Hg. The results also indicated that the ability for accumulation in the fruits of cucumber was higher than that for the leaves except for Fe and Pb that had higher accumulation in the leaves.

Conclusion

Vegetables can incorporate heavy metals in their parts when planted in polluted soils. Heavy metals that are attached to soil-water and soil particles will be absorbed by plant roots and could accumulate in the roots, leaves and fruits. Heavy metals uptake via the roots from contaminated soils and direct deposition of contaminants from the atmosphere onto plant surfaces can lead to plant contamination with heavy metals. This is a serious problem that can have significant implications for human health. The study revealed that the soil from the dumpsites in Nekede is contaminated with heavy metals as compared to the control site. These heavy metals were found to be accumulated in the cucumbers planted in the dumpsites. Though some of the heavy metals recorded low concentrations, they are bound to build up in soils to undesirable level if the area is continuously used as dumpsites. Except for Hg and Fe, the heavy metal concentrations in all the investigated cucumber fruits and leaves exceeded regulatory limits set by the World Health Organization, the Food and Agriculture Organization and other international standards. This should be of concern because the cucumber plant presents a toxicological risk for direct consumption by humans and other animals. This is because soil to plant transfer is one of the key processes of human exposure to heavy metals through the food chain. Since the cucumber fruits and leaves were found to be accumulators of some of the heavy metals studied, the plant can act as bioindicators, biomonitors and remediates of these heavy metals. Further study should include other crops widely grown in the area.

Recommendations

Based on the findings of this research, the following recommendations are made:

- there is need to carry out a well detailed speciation study at different soil layers in order to determine the forms in which the heavy metals are present in the soil, this is in view of their hazardous effects on the biophysical environment
- government should articulate strategies to enforce proper management and disposal of solid waste through strict and dedicated implementation of waste management policies
- the use of geo-synthetic clay liners as barriers should be adopted to prevent the contamination of soil by leachates from waste dumps
- there is need for enlightenment campaign and changes in human behavior through education and capacity building to better improve quality and preserve soil quality in Nekede
- there is also need for baseline monitoring of soil quality in the study area.

REFERENCES

Akhionbare, S.M.O., Akhionbare, W.N. and Nwachukwu, J.I. 2013. "Metals in Environmental Pollution." The Environment: Issues, Cases and Sustainability. Springfield Publishers Ltd. Owerri, pp. 250-273.

Alam, M. G., Snow, E. T. & Tanaka, A. 2003. Arsenic and heavy metal contamination of vegetables grown in samta village, Bangladesh. *Science Total Environment*, 308 (1-3), 83-96.

Al-Jassir, M. S., Shaker, A. & Khaliq, M. A. 2005. Deposition of heavy metals on green leafy vegetables sold on roadsides of Riyadh city, Saudi Arabia. *Bulletin of Environmental Contamination and Toxicology*, 75, 1020-1027

Aweng, E. R. Karimah, M. and Suhaimi, O. 2011. "Heavy metals concentration of irrigation water, soils and fruit vegetables in Kota Bharu Area, Kelantan, Malaysia," *Journal of Applied Sciences in Environmental Sanitation*, 6 (4) 463-470.

Bae, D., Gennings, C., Raymond, S. H. T. and Campain, I. A. 2000. Toxicological interaction among As, Cd and Pb in human Kerotanocytes. *Toxicological Sci*., 63, 132 -142.

Bagdatlioglu, N., Nergiz, C ,and Ergonul P G (2010). Heavy metal level in leafy vegetables and some selected fruits, *J. Verbr. Lebensm.*, 5: 421-428.

Balshaw, S., Edwards, J., Daughtry, B. & Ross, K. 2007. Mercury in seafood: Mechanisms of accumulation and consequences for consumer health. *Reviews on Environmental Health*, 22(2): 91-113.

Herawati, N., Suzuki, S., Hayashi, K., Rivai, I.F., Koyama, H. 2000. Cadmium, Copper, and zinc levels in rice and soil of Japan, Indonesia, and China by soil type. Bull Environ Contam Toxicol 64:33–39CrossRefGoogle Scholar

Khanna, S. & Khanna, P. 2011. Assessment of Heavy Metal Contamination in Different Vegetables Grown in and Around Urban Areas. *Research Journal of Environmental Toxicology*, 5: 162-179.

Lenntech Water Treatment and Air Purification (2004). Water Treatment, Rotterdamseweg, Netherlands. www.excelwater.com/thp/filters/Water-Purification.htm. 12/05/2014

Lokeshwari, H. & Chandrappa, G.T. 2006. Impact of heavy metal contamination of Bellandur Lake on soil and cultivated vegetation. *Current science,* 91: 622-627.

Mapanda, F., Mangwayana, E. N., Nyamangara, J. and Giller, K. E. (2005). The effect of long term irrigation using wastewater on heavy metal contents of soils under vegetables in Harare, Zimbabwe, *Agric., Ecosystems Environ.,* 107,151-165.

Marshall, F.M., Holden, J., Ghose, C., Chisala, B., Kapungwe, E., Volk, J., Agrawal, M., Agrawal, R., Sharma, R.K. & Singh, R.P. 2007. Contaminated Irrigation Water and Food Safety for the Urban and Peri-urban Poor. *Appropriate Measures for Monitoring and Control from Field Research in India and Zambia.* University of Sussex.

Muchuweti M., Birkett, J.W., Chinyanga, E. 2006. Heavy metal content of vegetables irrigated with mixtures of wastewater and sewage sludge in Zimbabwe: implication for human health. *Agric Ecosyst Environ.* 112:41–48.

Muchuweti, M., Birkett, J. W., Chinyanga, E., Zvauya, R., Scrimshaw, M. D. and Lester, J. N. (2006). Heavy metal content of vegetables irrigated with mixtures off wastewater and sewage sludge in Zimbabwe: Implications for human health. *Agric Ecosys Environ,* 112: 41 – 48.

Navarro, M., Pérez-Sirvent, C., Martínez-Sánchez, M., Vidal, J., Tovar, P., Bech, J. 2008. Abandoned mine sites as a source of contamination by heavy metals: a case study in a semi-arid zone. J Geochem Explor 96:183–193CrossRefGoogle Scholar

Nirmal, K. J. I., Soni, H. and Kumar, R. N. 2007. Characterization of heavy metals in vegetables using Inductive Coupled Plasma Analyser (ICPA), *J. Appl. Sci. Environ. Manage*., 11(3), 75-79.

Oluyemi, E.A., Feuyit, G., Oyekunle, J.A.O. & Ogunfowokan, O.A. 2008. Seasonal variations in heavy metal concentrations in soil and some selected crops at a landfill in Nigeria. *African Journal of Environmental Science and Technology,* 2, 89-96.

Orisakwe, O.E., Kanayochukwu, N.J., Nwadiuto, A.C., Daniel, D. & Onyinyechi, O. 2012. Evaluation of Potential Dietary Toxicity of Heavy Metals of Vegetables. *Journal of Environment Analytical Toxicology*, 2, 136.

Radwan, M.A. & Salama, A.K. 2006. Market basket survey for some heavy metals in Egyptian fruits and vegetables. *Food and Chemical Toxicology*, 44(8): 1273-1278.

Rai, P.K. 2008. Heavy metal pollution in aquatic ecosystems and its phytoremediation using wetland plants: An eco-sustainable approach. *International Journal Phytoremediation* 10(2):133–160.

Sharma, R.K., Agrawal, M. & Marshall, F.M. 2006. Heavy metal contamination in vegetables grown in wastewater irrigated areas of Varanasi, India. *Bulletin of Environmental Contamination.*

Sharma, R.K., Agrawal, M. & Marshall, F.M. 2007. Heavy metals contamination of soil and vegetables in suburban areas of Varanasi, India. *Ecotoxicology and Environmental Safety*, 66: 258-266.

Suruchi and Khanna P. 2011. Assessment of heavy metal contamination in different vegetables grown in and around urban areas. *Research Journal of Environmental Toxicology* 5:162–179.

Wuana, R. A. and Okieimen, F. E. 2011. "Heavy metals in contaminated soils: A review of sources, chemistry, risks and best available strategies for remediation," International Scholarly Research Network, p. 20.

Xu, D., Zhou, P., Zhan, J., Gao, Y., Dou, C. and Sun, Q. 2013. Assessment of Trace metal bio availability in garden soils and health risks via consumption of vegetables in the vicinity of Tong ling mining area, China, *Ecotoxicol. Environ. Saf*., 90:103-111.

Yang, L.Q., Huang, B., Mao, M.C., Yao, L.P., Hickethier, M., Hu, W.Y. 2015. Trace metal accumulation in soil and their phytoavailability as affected by greenhouse types in north China. Environ Sci Pollut Res 22:6679–6686CrossRefGoogle Scholar

Zhuang P., Zou, B., Li, N.Y. and Li, Z.A. 2009. Heavy metal contamination in soils and food crops around Dabaoshan mine in Guangdong, China: Implication for human health. Environ. Geochem. Health, 31: 707-715.

Zhuang, P., McBride, M.B., Xia, H., Li, N., Li, Z. 2009. Health risk from heavy metals via consumption of food crops in the vicinity of Dabaoshan mine, South China. Sci Total Environ 407:1551–1561CrossRefGoogle Scholar

****