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Full Length Research Paper

Heavy metal transfer to vegetables from contaminated farmland adjoining sub urban animal park/market, Uyo

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A natural, riparian buffer/farm adjoining a 3000 m^2 suburban animal park/market in Uyo municipality was investigated to establish the heavy metal (HM) pollution and transfer to plants/vegetables grown on the soil affected by polluted runoff and organic waste disposal from upslope animal market/park. Wet acid digestion and atomic absorption spectrometry were applied to determine HM concentrations. Data were analyzed using SPSS ver.17. Heavy metal pollution index (HPI), transfer factor (TF) and leaf/root HM ratio (LFR) were evaluated. Heavy metal concentrations in the contaminated soils were high and significantly above normal ranges ($p<0.05$; $p<0.01$). The HM concentrations varied significantly ($p<0.05$) between plots on the buffer/farm. Significant correlation ($r = 0.862$-0.968, $p< 0.01$) between HM in contaminated farm soil and cultivated plants was observed. HPI varied between 1.84 and 1.80. TF showed wide variability between farm plots and metal analytes. The HM levels in vegetable leaves were high and correlated significantly with HM in its soil ($r = 0.874$) and in roots ($r = 0.986$). HM leaf/root ratio >1.0 was obtained for 6 HMs, while Cd, Hg and V had <1.0. Regulating the content of Pb in soil can control the level of co-absorption of other HMs by plants.

Key words: Heavy metal toxicity, riparian farmland, sub-urban animal market, vegetables, heavy metal pollution index (HPI), transfer factor.

INTRODUCTION

A riparian buffer/farm exists at the downslope boundary of the suburban animal park/market, Uyo buffering it from the adjacent drainage stream. The NPS runoff draining the organic waste polluted park/market spreads through the farm buffer before emptying into the adjacent second-order stream (Dingman, 1994). Also an abattoir stands on the left wing of the facility and its wastewater is disposed directly on the farm/buffer together with the disposal of ditritus, stale browse twigs and soiled hay, silage and grass; and dust, dropping oil and settling fumes from trucks of loaded animal goods arriving and parking there. These organic wastes are drained by unregulated NPS runoff to the buffer/farm at varying velocity from the usually high intensity rainfall.

Essentially, the riparian buffer/farm mitigates the polluted overland flow, settles out sediment/nutrients on its floor, removes pollutants, infilters some into the soil (which may cause pollution at soil depth) and passes relatively less polluted water to the downslope water channel (Wikipedia, 2011; Osmond et al., 2002; Hawes and Smith, 2011). The farm is at zone three of the buffer. Zone two and the uncultivated section of zone three are grazed by the cattle guided by their nomadic handlers after which they rest at the park waiting to be sold or butchered. The traders and settlers eat the vegetables from the farm. Until now (2010), no orchestrated investigation into its pollution status and environmental impact was carried out. However, some studies have shown that

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heavy metals (HM) are leached into soils close to waste dumps or vicinity of waste producing sources and are transferred into the plants grown on such polluted soils up to toxic levels. Also, aerosol or atmospheric deposition on animal hairs and plants' leaves are known to have increased HM concentrations in their composition; some of which exceed the safe or tolerable limits of the countries' standards. Instances of HM pollution are recorded for India and China (Sharma et al., 2008; Cui et al., 2004; Kopittke et al., 2007; Song et al., 2009; Yang et al., 2009). Since the environmental baseline data and impact assessment were not investigated for soils in the animal park/market subcatchments, before now, such data was not available to compare and drive decisions to control pollution mining activities, even though consumption of fodder and vegetables by vulnerable animals and persons go on unabated. Therefore, assessment of HM status in the area is critically imperative because of municipality expansion and socio-economic significance of the market; the need to protect lives from any toxic HM pollution effect; and the need to sustain eco-friendly trans-border business environment. Therefore, the objectives of the study were: (1) to investigate heavy metal content in the soil and consumable vegetables grown on the riparian buffer/farm adjoining Uyo municipality goat/cattle market; (2) to evaluate heavy metal pollution index and toxic level transfer factor from soil to the dietary vegetables grown on it and provide valuable environmental impact information for quality management of the dynamic, economic environment involving mass waste/animal movement and human interaction.

MATERIALS AND METHODS

Site description

The park/market is about 3000 m^2 and the downstream riparian buffer fringe is about 500 m long along the downstream river reach. The study site is in Uyo, the capital territory of Akwa Ibom State, Nigeria; at the downstream boundary of the municipal, intensive animal (goat and cattle) park/open market. It buffers between the park and the downstream of Iba Oku Urban drainage River. The buffer/farm area is used for cultivation of vegetables for dietary use by the traders and others. Many of the goat/cattle traders domicile in shanties there.

Sampling and pre-treatment

Soil samples were collected at 0 to 20 cm soil depth from three plots in three sections of the buffer fallow/farm. At each plot, soil samples were collected from different spots using soil auger and bulked into one batch sample for each section, using a clearly labeled 10-mm diameter plastic-covered plate. The batched samples from the three buffer sections were taken at the same time to the soil laboratory of University of Uyo within four hours for physical and chemical parameter analysis. Parts of the bulked samples were transferred, in properly covered boxes, to the Engineering laboratory of Aluminum Smelter Company, Nigerian (RUSAL – ALSCON), Ikot Abasi, Akwa Ibom State, Nigeria for metal analysis. At the same, time individual vegetables (pumpkin or telfeira leaves), vines, stalks and roots were harvested from the plots at which soil samples were taken and put into polythene bags, which were taken alongside the soil samples for processing. Each soil sample was spread on old cardboard to air-dry, at room temperature; and then ground in agate mortar and sieved through 100-mesh plastic sieve. It was stored in a labeled nylon bag and kept for analysis. Each plant sample was weighed fresh; oven–dried at 80°C for 24 h, then allowed to cool before being milled with a blender and kept in an air-tight container for chemical analysis. The pH of soil sample was measured with a glass – electrode in a 1:5 soil–water suspension, using pH meter H198127 HANNA model.

Digestion of heavy metal

HM in soil, plant leaves and roots samples were treated with wet nitric acid digestion (Matusiewicz, 2011). A 1.0 g of sub sample of soil or 0.5 g of plant leaves or 0.5 g of root sub-samples was weighed into an ultra-clean digestion flask with 20 ml $HN0_3$, 5ml hydrochloric acid (H_2O_2), and HCl mixture. The sample–acid solution suspension was left at room temperature overnight and then evaporated on a hot plate at 105°C until it turned white (showing that the digestion was completed). In the case of plant leaves and roots, 0.5 g of each sub-samples was used and the sample-acid solution suspension was left at room temperature overnight, and then heated in a digestion chamber at 100°C for 1 h, then at 170°C for 6 h.

The mineral residues were allowed to cool, then diluted with 20 ml deionized (distilled) water and the solution filtered with Whatman filter paper into a volumetric flask. The mineral solution was made up to 100 ml for the soil samples, and to 50 ml for the plant and root sample each with deionized water and stored in a fridge at 4°C for HM analysis (Sharma et al., 2008) or were determined immediately using atomic absorption spectrometer (AAS) (UNICAM model) for Cu, Cr, Zn, and Pb and Cd (APHA, 1985; Matusiewicz, 2011).

Statistical analysis

Statistical analysis was performed on the data using SPSS ver. 17.0 package for descriptive statistics, ANOVA analysis of significant difference between heavy metals, and correlation and regresssional relationships.

Heavy metal index (HPI)

The total heavy metal load in the polluted soil transferred to vegetables at sampling locations were computed and compared using heavy metal pollution index (HPI) as the geometric mean of all heavy metals concentrations at the particular site, using the equation (Usero et al., 2005; Wang, 2007; Sharma et al., 2008):

$$HPI = C_{m1} \times C_{m2} \times \ldots \times C_{mn})^{1/n} \quad (1)$$

where C_{mn} is the concentration of nth heavy metal in soil or vegetable samples, and n is number of HM analytes considered in the samples.

Heavy metal transfer factor (TF)

The TF from contaminated soil to vegetables was calculated as follows (Cui et al., 2004):

Table 1. Mean metal concentrations of heavy metal pollution in soil and plant of the riparian buffer farm/fallow.

Heavy metal	Soil				Plant			
	RS	AB	DS	F-value	RS	AB	DS	F-value
Pb	2423.4	2039.49	2340.75	62.43**	85.8	79.43	82.73	8.90**
Zn	1258.8	308.5	755.81	20.88**	31.45	25.73	61.15	4.58**
Cu	583.86	296.81	315.92	5.79**	60.12	75.98	12.78	27.30**
Ni	1.56	1.1	1.42	1.53	0.01	19.75	0.09	256.80**
Mn	246.16	216.83	299.48	9.17**	19.89	16.93	14.74	2.23**
Cd	642.51	0.08	1.11	52.35**	39.44	16	0.04	8.09**
Hg	1.08	1.29	1.2	13.40**	0.31	0.1	0.16	109.38**
Cr	0.53	0.45	0.4	5.31**	0.1	0.02	0.04	89.71**
V	79.09	67.54	0.13	40.63**	8.23	8.15	0.02	315.64**
HPI	1.84	1.84	1.80					

** Significant at p <0.01.

Table 2. Concentrations of heavy metal in leaf and root samples.

Heavy metal	Conc. in leaf (mgkg^{-1})	Conc. in roots	Ratio (L/R)	t-value
Pb	1276.57	1096.17	1.16	38.35**
Zn	3377.38	2374.52	1.42	0.97
Cu	642.06	341.69	1.88	46.55**
Ni	6.18	4.89	1.26	5.80*
Mn	782.47	736.26	1.06	7.86*
Cd	0.06	0.33	0.18	1.96
Hg	0.24	0.31	0.77	-0.67
Cr	0.37	0.28	1.32	1.91
V	0.05	0.11	0.45	-7.18*

*Significant at p<0.05; ** significant at p <0.01; L/R = HM in leaves/ HM in root.

TF = Metal concentration in plant tissue (fresh weight basis)/metal concentration in soil (dry weight basis) from where plants was grown (2)

RESULTS AND DISCUSSION

Concentration and distribution of heavy metals in soils at buffer farm/fallow

Three waste sites adjoining or adjacent the riparian buffer fallow/farm drained directly into the buffer zone farm and soil. These were the goat and cattle roasting site (RS), the abattoir (AB) and the park/market dumpsite (DS). The sampling plots on the farm were identified after them as RS, AB and DS. Table 1 shows the summary of the concentrations of heavy metals in waste polluted soils and in plants at those plots in the riparian buffer as affected by the waste pollution from the municipality animal park/market. Heavy metals are needed by plants in trace amount for their nutritive values, especially the vegetables (FAO, 1986; Gopalan et al., 1998; Roy and Chakrabarti, 2003). However, their concentrations in the waste -polluted soils were Quite high (Table 1). The mean concentrations of Pb varied between the plots and farm sections as 2423.39±1110.2 mg/kg at RS, 2039.49±140.67 mg/kg at AB and 2340.75±114, 95 mg/kg at DS. The concentration distribution followed the sequence: RS > DS > AB. Zn increased in the order: RS > DS > AB with mean values of 1258.80±63.22, 755.81±137.54 and 308.50±286.2 mg/kg, respectively. Comparing the values of Pb and Zn with the critical values of 0.5 and 1.0 mg/kg reported for Pb and Zn by Tricys (2002), the entire waste polluted soil contained very high concentrations of Pb and Zn, which might be toxic to plants since plants require these elements in very small quantity (FAO, 1986). These sequences are summarized into Distribution order matrix in Table 2.

Significant variations occurred in the content of Zn at the three sections, with RS having the highest concentration and AB the least. Hence, application of these fresh wastes on agricultural soil may cause significant variation in the contents of Pb and Zn in the soil. Similarly, concentration of Cu followed the trend RS> DS > AB with values of 583.86±294.57, 315.92±109.62 and 296.81±23.71 mg/kg, respectively. There may be Cu toxicity in soils polluted by any of these wastes because the entire mean values are significantly higher than the critical values of 0. 2 mg/kg for crop production (EPA, 2006). For concentration of Ni, the distribution followed the order RS > DS> AB with mean values of 1.56±2.45 1.41±2.12 and 1.09±1.70 mg/kg.

These values were not greater than 4.5 mg/kg (EPA, 2006) as critical values for crop production; therefore, the entire waste-polluted soil samples had low Ni content. The highest concentration of Manganese (Mn) was obtained in DS followed by RS and AB with mean values of 299.48±34.10, 246.16±41.18 and 216.83±46.03 mg/kg. A significant difference in Mn content of soil was observed at the three waste locations ($p< 0.05$), and were attributed to variations in the components of the wastes. Concentration of Cd decreased from RS to DS, then AB with mean values of 642.52±153.72, 1.11±0.54 and 0.08±6.03 mg/kg, respectively. A significant difference ($p<0.05$) was observed in mean Cd in the soil at the three wastes locations. The outstanding values of Cd in RS (Table 1) may be due to the quantity and composition of wastes, which may contain more decomposable materials from the ashes of roasted animals, as to affect soil composition markedly (Table 2). This high value is alarming when compared with the normal range of 0.05 to 0.20 mg/kg (EPA, 2006). Therefore, there may be Cd toxicity in soils amended with RS while that of other wastes may not have serious toxicity problem. Similarly, concentration of Hg increased in the order: RS > AB > DS with mean values of 0.53±0.14, 0.45±0.20 and 0.40±0.13 mg/kg, respectively. The distribution had significant difference ($p<0.05$) with location (hence type of organic waste). Concentration of Cr also varied marginally with location (hence type of organic wastes on soil) with AB having the highest (1.29±0.28 mg/kg) followed by DS (1.20±0.23 mg/kg) and RS (10.08 ±0.38 mg/kg). The difference was significant. The distribution of V decreased from RS to AB to DS, with mean values of 79. 09±16.07, 67.34±18.48 and 0.13±0.00 mg/kg, respectively. There was significant difference ($p>0.05$) in V content of waste polluted soil at the three locations. Comparing the means of Cr, Hg and V with normal ranges of 0.1 to 0.5, 0.01 to 0.1 and 0.1 to 10 mg/kg (EPA, 2006), soil amended with any of the waste samples can cause toxicity in relation to these three heavy metals.

Significant variation in Mn, Cd, Cr, Hg and V with depth was observed. Concentration of Mn decreased slightly with depth, while that of Hg and Ni did not follow any definite trend with depth. This may suggest the susceptibility of these metals to leaching action of the infiltrating rainfall-runoff through the riparian buffer/farm, occasioning root imbibition of their element in soil water into the plant as seen in heavy metal concentrations in plants (Table 1).

HM distribution variability matrix

Table 3 shows the distribution order matrix, summarizing the order of spatial variability of mean HM concentration, hence, variation of HM effect in the plots/sections of the buffer/farm soil, as influenced by the organic wastes from the municipality animal park/market, Uyo.

Farm plots near roasting site (RS) had the highest HM pollution in contaminated soil; the farm plots adjacent abattoir (AB) was relatively less polluted by HM in soil, while plots near dumpsite (DS), receiving mostly solid wastes, had the least HM concentration, perhaps, the solid wastes had time to decompose and leach into soil. RS had the highest, perhaps due to the ash residue effect.

Concentration of heavy metals in plant samples

Variations were observed in heavy metal contents of plant samples obtained from the three locations (Table 1). The highest concentration of Pb was obtained at RS with 85.80±2.93 mg/kg, followed by DS with 82.73±2.05 mg/kg, while AB had the least (79.43±0.094 mg/kg). Total concentration of Zn decreased from DS to RS to AB with respective mean values of 61.15±29.79, 31.45±7.62 and 25.72±0.67 mg/kg in that order. Concentration of Cu varied in the order AB>RS> DS with mean values of 75.98±21.62, 60.12±29 and 12.78±0.95 mg/kg. Mean Ni was generally low except in plants obtained from AB (Table 1). Their means were 0.01±0.001 mg/kg (RS), 0.09±0.09 mg/kg (DS) and 19.75±2.46 mg/kg (AB). There were significant differences ($p>0.05$) in Pb, Zn, Cu and Ni contents in leaves obtained from plants at these three locations. Furthermore, the highest Mn was obtained at RS (19.89±1.34 mg/kg) followed by AB (16.93± 0.7 mg/kg), while DS had the least (14.74±5.78 mg/kg). Cd varied in the order RS> AB> DS with mean values of 39.44±15, 16.00±1848 and 0.04±0.02 mg/kg. Concentration of Cr was generally low too, with 0.31±0.02 mg/kg in RS, 0.10±0.02 mg/kg in AB and 0.16±0.037 mg/kg in DS; RS had the highest mean value of 0.01, 0.04±0.01 and 0.02±0.01 mg/kg while the highest V was obtained in RS (8.23±0.57 mg/kg) followed by AB (8.15 ±0.72 mg/kg) with DS having the least (0.02±0.01 mg/kg). There were significant differences in all heavy metal concentrations among plants samples obtained from the three locations in the riparian buffer farm/fallow. Heavy metal content of the plant samples is a reflection of their concentrations in the wastes polluted soil sample (Table 2). RS had the highest heavy metals followed by DS, while AB had the

Table 3. Sequence of HM mean concentration spatial variation in buffer/farm sections at Uyo municipality animal market/park.

Matrix of mean order distribution in soil			
HM	**RS**	**AB**	**DS**
Pb	1	3	2
Zn	1	3	2
Cu	1	3	2
Cd	1	3	2
Mn	2	3	1
V	1	2	3
Ni	1	3	2
Hg	3	1	2
Cr	1	2	3
Total	12	23	19
Ratio	1	2	1.5
RDP	22	43	35

Matrix: 1 = highest, 2 = low, 3 = lowest. Ratio = relative sum of the order indices; 1 = relatively highest, 2 = relatively half of 1, 1.5 = middle way. RDP = relative distribution % = sum of section order matrix/sum of all sections order matrix.

least and this was the same pattern among plants (Tables 1 and 4). The order of variation and the level of HM in plant correlated perfectly with those of the soil. Comparing the mean concentrations of heavy metals in three groups of plants with the normal range of 0.05 to 0.25 mg/kg for Pb, 0.025 to 0.15 mg/kg for Zn, 0.05 to 02 mg/kg for Cu, 0.0001 to 0.001 mg/kg for Vi, 0.02 to 0.5 mg/kg for Mn, 0.08 to 0.02 mg/kg for Cd, 0.1 to 0.5 mg/kg, for Cr, 0.001 to 0.01 mg/kg for H, and 0.01 to 1.01 mg/kg for V reported by Jontos (2004), shows that plant grown in the waste points had excess concentration of heavy metals. This indicates that such plants could be harmful to animals and even humans who consume them (USEPA, 2007). However, for their remediation effect, they could be used in controlling excess heavy metals in the soil.

Concentration of heavy metals in leaves and roots plants

Leaves and roots are the apexes of the living plant system with the root imbibing assimilable nutrients and water from the soil for food and growth (health) and yield of the plant.

Comparing the concentrations of the heavy metals in leaves and root samples, the result showed that Pb in leaves was 1276.57 mg/kg, but 1096.17 mg/kg in roots, showing a significant difference ($p<0.01$). Mean of Zn was 3377.38 mg/kg in leaves and 2374.52 mg/kg in roots; 642.06 mg/kg of Cu obtained in leaves showed a significant difference ($p<0.01$) from 341.69 mg/kg obtained in roots. Similar differences were observed between leaves and root contents of Ni, Mn, Cd, Hg, Cr and V (Table 2), with those of Ni, Mn and V being significant at $p<0.05$. This implies that concentrations of heavy metals differ significantly ($p<0.05$, $p<0.01$) between leaves and roots (Table 2). The ratio of HM in leaves to HM in roots (L/R) were greater than 1.0 (actually 1.06 to 1.88) for Pb, Zn, Cu, Ni and Mn, but less than 1 (actually 0.18 to 0.77) for Cd, Hg, Cr and V. The high and significant content in consumable vegetable leaves at such accessible agricultural buffer/farm does not present eco-friendly economy to the fallow/farm under the present polluted waste drainage. This should be restored for the sake of settlers and traders there. Some settlement chamber, or cutoff drain or bio-filter should be installed for toxic metal pollution from direct access to the vegetable farm.

Interaction among elements in plant samples

Table 4 shows the correlation coefficient for elements within plant samples obtained from three waste locations. Pb interacted significantly with Cu, Ni, Mn and V with r = 0.993, 0.975, 0.973 and 0.978, respectively. Zn had significant relationship with Hg only (r = 0.988), while Cu correlated significantly with Ni, Mn and V with r = 0.963, 0.968 and 0.955, respectively. Also, there was significant relationship between Ni and Mn (r = 0.928) as well as with V (r = 0.991). Furthermore, Mn correlated significantly with V only (r = 0.928), while others did not have any significant relationship ($p < 0.05$). This means that increases in heavy metal concentration related directly with increases in Pb, Cu, N, Mn and V in plants. Pb had the greatest influence on other heavy metal content in plants, as increases in Pb content in plants can increase almost half of other heavy metal's content in those plants. This may result in heavy metal toxicity. Therefore, regulating the concentration of Pb in the soil may influence the concentration of other heavy metals absorbed by plants.

Interaction between heavy metals in soil and plants

It is believed that elemental content of any plant including heavy metals depends on the distribution of such elements in soils on which the plants are grown. Correlation coefficients between heavy metals in soils and in plants grown on them show very significant relationship ($p<0.01$) for selected heavy metals (Tables 4 and 5). Significant correlation ($p<0.05$) existed between heavy metals in soils and Pb, Zn, Cu, and Cd (5 out of 9 HM observed) in plants; other HM – Ni, Mn, Cr, Hg and V- in plant had no significant relationship with HM in soil.

Table 4. Correlation co-efficient r, between heavy metal in soil and plants.

Plant/soil	Pb	Zn	Cu	Ni	Mn	Cd	Cr	Hg	V
Pb	0.911*	0.968**	0.539	0.144	0. 413	0.951**	-0.424	0.200	0.304
Zn	0.718	0.688	0.469	0.320	0.606	0.427	-0.632	-0.545	-0.424
Cu	0.877*	0.938**	0.555	0.142	0.376	0.961**	-0.355	0.311	0.399
Ni	0.862*	0.958**	0.520*	0.041	0.321	0.980**	-0.301	0.206	0.344
Mn	0.905*	0.917*	0.584*	0.237	0.516	0.913*	-0.485	0.213	0.210
Cd	0.769	0.704	0.462	0.403	0.526	0.594	-600	0.188	0.184
Cr	0.088	0.292	-0.230	-0.587	-0.512	-0.568	0.404	-0.609	0.753
Hg	-0.635	-0.577	-0.422	-0.353	-0.623	-0.289	0.653	-0.663	0.546
V	0.881*	0.974**	0.453	0.020	0.332	0.952**	-0.377	0.098	0.258

Table 5. Correlation coefficients among heavy metal in plants sample.

Plant/soil	Pb	Zn	Cu	Ni	Mn	Cd	Cr	Hg	V
Pb	1								
Zn	0.513	1							
Cu	0.993	0.422	1						
Ni	0.975	0.578	0.963	1					
Mn	0.973	0.484	0.968	0.928**	1				
Cd	0.771	0.140	0.788	0.612	0.792	1			
Cr	0.470	-0.400	0.530	0.454	0.405	0.400	1		
Hg	-0.388	-0.988	0.290	-0.450	-374	-0.052	0.524	1	
V	0.978	0.609	0.955**	0.991	0.928	0.641	0.444	-0.487	1

Pb in plant correlated significantly ($p<0.05$) with the following HM in soil: Pb, Cu, Ni, Mn, and V at r = 0.91, 0.88, 0.96, 0.91, and 0.88, respectively. Zn in plant varied significantly ($p<0.05$) with Pb, Cu, Ni, Mn, and V at r = 0.97, 0.94, 0.96, 0.92, and 0.97, respectively; Cu correlated significantly ($p<0.05$) with Ni and Mn in soil although at merely good level, that is, about 50% increase of Cu in plant is associated with 50% increase of Ni and Mn in soil. Cd in plant correlated very significantly ($p<0.01$) with Pb, Cu, Ni, Mn and V in soil at $r \geq 0.95$ with metals in soil at which the plant grew (Table 4).

All HM in plants had only fair and not significant correlations with Zn (r = 0.72 to 0.32), Cr and Hg; rather they had negative correlation with all metals in soil, showing a reciprocal relationship with Cr and Hg. All metals in soil had only a fair but not significant relationship with Ni, Mn, Cr, Hg and V. Thus, waste–polluted soil at the riparian farm may not produce significant increase in Cu, Ni, Mn, Cr, Hg and V in plants. Pb, Zn, Cu, Ni, Mn and V in soils equally had significant effect of increasing selected HM (Pb, Zn, Cd) in plants at different coefficient. It was noted that changes in soil factors, which were not influenced by soil HM were made up by soil pH effect (Douglass, 2010).

Interaction amongst heavy metals in plant

Table 5 shows the correlation coefficients for heavy metals within the plant samples obtained from three waste contaminated soil plots. Interaction between heavy metals in plants was very significant mainly for those metals, which also had significant correlation with heavy metals in soil (Tables 4 and 5). Very significant ($p<0.01$) intra-plant relationship of heavy metals were observed between Pb with Cu, Ni, Mn and V at r = 0.99, 0.975, 0.973 and 0.978, respectively; between Zn with Hg only (r = 0.988), between Cu with Ni, Mn and V at r = 0.963, 0.968 and 0.955 respectively; between Ni with Mn and V at r = 0.0928 and 0.991 respectively; and in Mn with V only at r = 0.928. Others had low or insignificant correlation with any heavy metal within plants (r = 0.77-0.40); while Hg had reciprocal interactions with Cd (r = -0.05). Cd also had insignificant interactions (r = 0.14) with Zn. Pb had the greatest influence on other heavy metals in plants as increase in Pb can increase half (4 out of 8) of other heavy metals in plant. This may result in heavy metal toxicity. On the other hand, under the polluted soil environment, regulating the concentration of Pb in the soil may influence the necessary changes in the concentrations

Table 6. Heavy metal transfer factors from polluted soil to vegetable at buffer/farm adjoining animal farm park/market.

HM		Site ID	Transfer factors	HM	Site Id	Transfer factor
		RS	0.035±0.026	Cd	RS	0.061±0.101
Pb		AB	0.039±0.007		AB	200.00±600.00
		DS	0.35±0.018		DS	0.036±0.037
		RS	0.025±0.121		RS	0.287±0.053
Zn		AB	0.084±0.002	Cr	AB	0.078±0.071
		DS	0.081±0.217		DS	0.133±0. 130
Cu	RS	RS	0.103±0.009		RS	0.189±0. 071
	AB	AB	0.256±0.091	Hg	AB	0.044±0. 050
	DS	DS	0.040±0.009		DS	0.100±0.077
Ni	RS	RS	0.064±0.00		RS	0.104±0. 035
	AB	AB	17.955±1.439	V	AB	0.124±0. 039
	DS	DS	0.063±0.042		DS	0.154±0.000
Mn	RS	RS	0.081±0.032			
	AB	AB	0.078±0.016			
	DS	DS	0.49±0.169			

of other heavy metals absorbed by plants in the riparian buffer/farm adjoining the suburban animal park/market, Uyo. Also, the positive interaction in most of the relationships indicates that the absorption of one heavy metal in plant influences the co-absorption of other heavy metals in the same plant. Hence, a relationship for regulation and control of plant's heavy metal concentrations devoid of toxicity in the waste polluted market area can be constructed with Pb as the main control factor.

Transfer factors (TF) from soils to vegetables

The HM transfer factors from soils adjacent different pollution plots (RS, AB, DS) to vegetables for the nine heavy metals varied greatly with soil and metal for the common vegetables used in the investigation. Plot AB had the highest overall TF for all heavy metals, especially for Pb, Zn, Cu, Ni, Cd, followed by RS with the highest TF for Mn, Cr, and Hg, while DS had the highest TF for Vanadium (V) (Table 6).

Using Equation (2) for computation, TF for metals also varied widely at each plot just as the metal concentration varied widely at each plots and between sections. The TF of 200 for Cd at plot AB was the highest followed by 17.955 for Ni at the same plot. The next was 0.287 for Cr on RS, 0.25 for Cu on AB, 0.189 for Hg on RS and 0.156 for V on DS (Table 6). Pb had the most uniform TF ranging between 0.035 and 0.039 for all plots. Also, TF was uniform for V while Cd, Cu and Cr had the highest TF variation at soil plots in the riparian buffer/farm.

Heavy metal pollution index (HPI).

The geometric mean of total metal load from farm soil to plants grown on it using Equation (1), gave HPI of 1.84 for AB and RS plots and 1.80 for DS plot. However, HPI rose to 2.98, 2.94 and 3.62 for the three plots, respectively, when only HM of large numerical magnitudes were considered including Pb, Zn, Cu, Mn and Cd. These also had high correlation between their levels in soil and plant (Table 5). Therefore, vegetables at the riparian buffer/farm received maximum heavy metals concentration from the 5 HMs in the soil.

Conclusion

This study has opened up key information on the environmental problem of the animal park and market at Uyo sub-urban and should continue to be studied regularly for proper environmental management of the animal market environment.

Heavy metals in the soil at the riparian buffer/farm adjoining sub-urban animal park/market, Uyo and in the plants grown on it were measured, analyzed and evaluated using wet acid digestion and AAS spectrometry. Nine heavy metals were observed. HM had high concentrations in both wastes- contaminated farm soil and plants grown on it. The HM varied significantly ($p<0.05$; $p<0.01$) in plots adjacent waste dump. Metal concentration with CV of up to 60% of the metals had magnitudes above the critical value, indicating that potential toxicity may occur should the fresh waste be incorporated as soil amendment in the form they were. Both heavy metal pollution index (HP) and transfer factor (TF) showed transfer of high concentrations of HM in the wetland into dietary vegetable at toxic levels. The sequence of variability and order of increase in HMs in plants correlated perfectly with those in the contaminated soil. Pb produced the strongest co-absorption of the other HMs in plants, hence, it can be used as the main control factor to regulate and control plants' HM concentration devoid of toxicity from polluted market/park waste.

Remediation of Pb, Mn, Cd and V in the soil is recommended. Alternatively, if aforementioned will be expensive, it should be retained for cultivation of grazing grasses and nut trees only, while litters should have a specific dumpsite on the buffer.

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