Evaluation of Heavy Metals Contamination in Solid Waste Compost in Maiduguri, Nigeria

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Abstract: *The need for heavy metals assessment in solid waste compost had become imperative due to its uses as an alternative to chemical fertilizer by irrigation farmers in Maiduguri. A total of 12 soil samples for the two solid waste dumpsites were collected at the depth of 30 cm using soil auger for laboratory analysis. The soil samples for dry and wet seasons were analysed for pH, Zinc, iron, copper, cadmium, chromium, lead, arsenic and manganese. The soil pH was measured using Turbo pH/mV/temp. Meter. The soil samples were digested using acid digestion method with polytetraflouroethylene (PTFE) Teflon bomb in a mixture of concentrated nitric acid (HNO_3), concentrated hydrochloric acid (HCl) and 27.5% hydrogen peroxide (H_2O_2). The digested soil samples were analysed for the heavy metals using the multi-wave plasma atomic emission spectrophotometer (MP-AES 4200). The mean pH values of the soil samples analyzed for dumpsite A and B ranged from 6.88-8.17 and all the samples falls within FAO standard limit. The mean concentrations of Zn, Fe, Cu and Pb for dumpsite A and B ranged from 404-1181 mg/Kg, 3138-11803 mg/Kg, 18-97 mg/Kg and 12.75-136 mg/Kg for dry and wet season respectively. While, the mean concentrations of As, Cd, Cr and Mn ranged from 97-131 mg/Kg, 0.5-2.95 mg/Kg, 28.45-72.85 mg/Kg and 238-665 mg/Kg for dry and wet season respectively. The mean concentration of Zn, Fe, Pb, As and Mn for the two dump sites were above FAO standard limit for soil quality in both seasons, while Cd, Cu and Cr were within the FAO standard limit. All the indices revealed that the study area was seriously affected by different heavy metals and the use of solid waste compost as organic manure may accumulate the metals to a harmful level as can be introduced into the food chain.*

Key words: *Compost, Heavy metal, Soil and Solid waste*

Strictly as per the compliance and regulations of:

1.0 INTRODUCTION

The roles of heavy metals in soils are important due to the potential environmental and health implications posed by it and have been known to play a variety of role in the environment which ranges from known human health hazard to ecological hazards due to their toxicity and bio-

accumulative behavior (Dudka and Miller, 1999). Pollutants are the causes of alterations in water quality and soil degradation around the world, which include microbes, nutrients, organic chemicals, oil, heavy metals and sediments (Sunday e*t al.*, 2013). Although some metals like Cu, Fe, Mn, Ni and Zn are essential as micronutrients for life processes in plants and microorganisms, other like Cd, Cr and Pb have no known physiological activity and have been proved detrimental beyond a certain limit (Bruins *et al.*, 2000 and Adakole and Abolude, 2012). Vegetables cultivated in soils polluted with toxic metals take up such metals and accumulate in their edible and non-edible parts in quantities high enough to cause clinical problems to animals and human beings consuming these metal-rich plants as there is no good mechanism for their elimination from the human body (Alam *et al.*, 2003, Arora et al., 2008 and Bhuiyan et al., 2011). Toxic metals are known to have serious health implications, including carcinogenesis induced tumor promotion, and hence the growing consciousness about the health risks associated with environmental chemicals has brought a major shift in global concern towards prevention of heavy metal accumulation in soil, water and vegetables (Ahmed *et al.*, 2009 & Mortula and Rahman, 2012).

The rate and characteristics of leachate production depends on a number of factors such as solid waste composition, particle size, and degree of compaction, hydrology of the sites, age of the landfill, mixture, temperature and availability of oxygen (Ogundiran and Afolabi, 2008). The volume of leachate depends principally on the area of the landfill, the meteorological and hydro-geological factors and effectiveness of capping. The volume of leachate generated is therefore expected to be high in humid regions with high rainfall, or high runoff and shallow water table (Ogundiran and Afolabi, 2008). These leachates are solutions, essentially organic or inorganic complexes of biodegradation components of solid wastes flowing from the refuse dumps, saturated with rainwater (Kassenga and Mbluligwe, 2009). Solid waste application to agricultural land is a common practice as it contains organic matter and some essential plant nutrients like nitrogen and phosphorus, which have fertilizer value. Its application enhances soil productivity and improves soil physical conditions. Prolonged exposure to heavy metals such as copper, cadmium, lead, zinc, and nickel can cause harmful health effects in humans. Previous studies revealed carcinogenic effects of several heavy metals such as chromium, cadmium, lead, mercury and arsenic (Bhata, 2002).

Agricultural soil contamination with heavy metals through the repeated use of solid waste compost, chemical fertilizers and pesticides is one of the most severe ecological problems in Nigeria. Soil in the long run represents a major sink and source of heavy metal ions, which are incorporated in the food (Oguntimehin *et al.*, 2005). When crops are planted on such soils, heavy metals are extracted in their soluble forms. Subsequently, these metals were consumed indirectly by human beings and animals. This is particularly evident in most African rural communities that believed dumpsites traditionally used for putrescible wastes were fertile and could be used for agricultural purposes. Traditionally, people cultivate a variety of crops in some temporarily abandoned sections of the dumpsite. Also, farmers from nearby area often collect "soils" from the dumpsite to be used as compost on the farms. This is because of the general belief that the native fertility of soil from a waste dumpsite is high (Amusan *et al.,* 2005). However, many fall victim of heavy metal consumption due to lack of adequate information on the status of heavy metals in dumpsites. The variation of heavy metals concentration in dumpsites is largely determined by human activities and operations around each site Ajayi (2005), for instance showed that the maximum concentrations of Cu, Cd, Ni, Pb, Fe, and Mn were found in the surface soil of an automobile dumpsite, while the presence of Zn, Fe, Mn, and Pb was also reported to be found in municipal dumpsite (Ibitoye *et al.*, 2005). Farmers had begun to use solid waste compost as an alternative to fertilizer irrigation and rainy season farming in Maiduguri. Although, the application of solid waste compost has become a common practice in small-scale irrigation scheme in Maiduguri to enhance crop yield and soil conditions. Long-term application will elevate the metal concentrations in the soil and trans-located into food and fodder crops. The objective of this study

is to assess the concentration of heavy metals in soil compost of the two municipal solid waste dumpsites.

2.0 MATERIALS AND METHOD
2.1 Study Area
The study was conducted at Kumshe and Bakasi in Maiduguri which lies between latitude 11^0 $5''$ – 11^0 $55''$ N and longititude 13^0 $02''$ -13^0 $16''$ E on a vast sedimentary basin, with gentle undulating gradient of 345m above sea level. Maiduguri is estimated to have a population of about 1,197,497 in 2009 (NPC, 2006). According to Hess *et al.* (1996), the climate is semi-arid with three distinct seasons, cool-dry season (October to March), hot season (April to June) and a rainy season (July to September). The annual rainfall ranges from 560 to 600mm. The cold (dry harmattan) season runs from November to March when temperatures fall to about 20°C and a dry dusty wind blows from the Sahara desert (Jaekel, 1984). The area is fragile and highly susceptible to drought with relative humidity of 13% in dry season and 65% in rainy season. The two municipal solid waste dumpsites A & B were still in their active stage aged 18 and 23 years respectively.

2.2 Soil Sampling and Analysis
Random sampling technique was adopted to identify two open municipal solid waste dumsites labeled A and B at a distance of 7.16km apart as shown in Figure 1. Soil sampling was conducted according to soil sampling for environmental contaminants (ASTM, 2004). The soil sampling was conducted under average temperature and relative humidity of 24.4 °C and 16.4% and 32.25 °C and 59.8% for dry and wet season respectively. At each dumpsite five sampling points and a control at a distance away the dumpsites were marked and three replicates at each point were collected at the depth of 0- 30 cm using soil auger and put together to form a composite sample. The composite samples were well-mixed, making a total of 12 soil samples from the study area. The soil samples were labeled SAO, SAN, SAE, SAS, SAW & SAC and SBO, SBN, SBE, SBS, SBW & SBC for dumpsite A and B respectively. The soil samples were air-dried at room temperature for four days, and ground to fine powder and sieved with a 2 mm sieve to remove the coarse soil components and then taken to the laboratory for heavy metals analysis.

The soil samples for dry and wet seasons were analysed for pH, Zinc (Zn) iron (Fe), copper (Cu), cadmium (Cd), chromium (Cr), lead (Pb), arsenic (As) and manganese (Mn). The soil pH was measured using Turbo pH/mV/temp. meter at 1:2 soil to water ratio for 45 minutes. The soil samples were digested using acid digestion method with polytetraflouroethylene (PTFE) Teflon bomb in a mixture of concentrated nitric acid (HNO_3), concentrated hydrochloric acid (HCl) and 27.5% hydrogen peroxide (H_2O_2) according to the USEPA method 3050B for the analysis of heavy metals and major ions (USEPA, 1998). The digested soil samples were analysed for the heavy metals using the multi-wave plasma atomic emission spectrophotometer (MP-AES 4200).

2.3 Method of Assessing soil Contaminants
In this study, Geo-accumulation index (I_{geo}), Contamination Factor (C_f), Modified degree of contamination (mC_d) and Pollution load index (PLI) were used to assess the heavy metal contamination in soils of the study area.

3.3.1 Geo-accumulation index: is widely used in the assessment of contamination by comparing the levels of heavy metals obtained to background levels originally used with bottom sediments (Atiemo et al., 2012; Muller, 1969). It is calculated using equation (i)

$$I_{geo} = \log_2\left(\frac{C_n}{1.5B_n}\right) \qquad \text{i}$$

Where, C_n = measured concentration of the elements studied

B_n = geochemical background value of the element in fossil argillaceous sediment. In this study, the concentration of the control samples is taken to represent the pre-industrial concentration as suggested by (Victor *et al.*, 2006). The following classification is given for geo-accumulation index:

<0 - unpolluted,
0-1 - unpolluted to moderately polluted,
1-2 - moderately polluted,
2-3- moderately polluted to highly polluted,
3-4- highly polluted,
4-5- highly polluted to very highly polluted
>5 - Very highly polluted

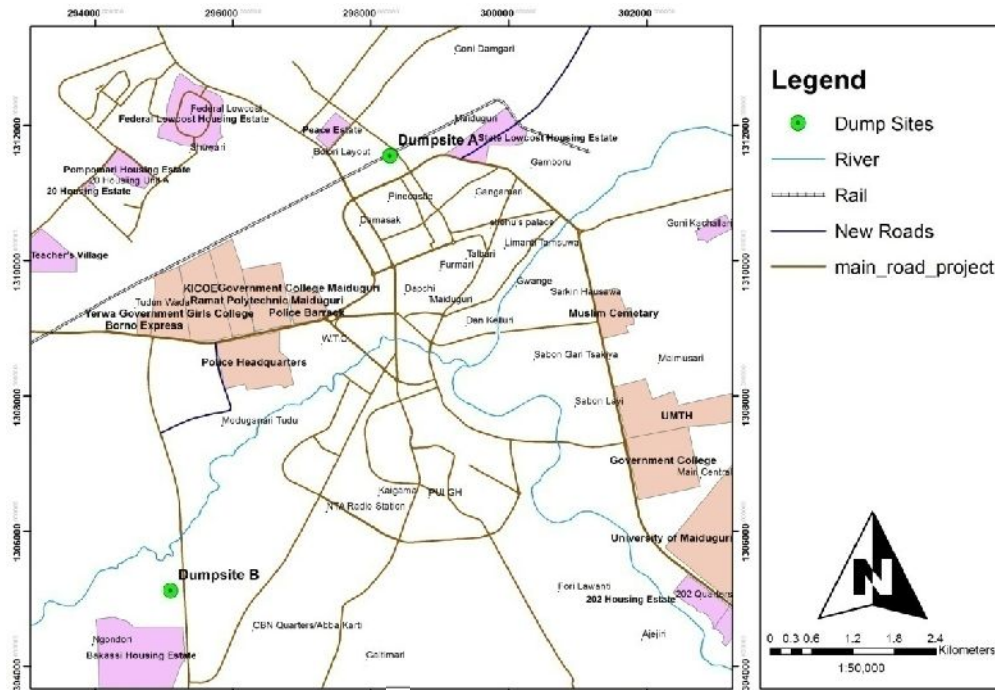**Figure 1: GIS Map of Maiduguri showing the sampling points**

2.3.2 Contamination Factor (C_f): the assessment of soil contamination was also carried out using the contamination factor and is the single element index. It can be used to differentiate between the metals originating from anthropogenic activities and those from natural processes and to assess the degree of anthropogenic influence (Fagbote and Olanipekun, 2010). High contamination factor values suggest strong anthropogenic influence.

$$C_f = \frac{C_o^i}{C_{n2}^i} \qquad\qquad ii$$

Where, C_o^i = mean content of metals from sample sites
C_n^i = control samples concentration of individual metals.
Five contamination categories of contamination factor are recognized **(**Hakanson, 1980 and Dasaram *et al.*, 2011)
C_f<1 Low contamination factor
1 < C_f <3 Moderate contamination factor
3< C_f < 6 Considerable contamination factor
6< C_f Very high contamination factor

2.3.3 Degree of contamination (C_d): is the sum of contamination factors for all elements examined represents the C_d of the environment. The calculated degree of contamination is therefore defined as the sum of the C_f for the pollutant species specified by Hakanson (1980).

$$C_d = \sum_{i=1}^{n} C_f \qquad\qquad iii$$

The C_d is aimed at providing a measure of the degree of overall contamination in surface layers in a particular sampling site. In this present study we applied a modification of the factor as applied by Krzysztof *et al.* (2004) that used the concentration of elements in the earth's crust as a reference value, similar to the other factors.

Modified Degree of Contamination: Abrahim (2008) presented a modified and generalized form of the Hakanson (1980) equation for the calculation of the overall degree of contamination at a given sampling site as follows:

(a) The modified formula is generalized by defining the degree of contamination as the sum of all the contamination factors for a given set of estuarine pollutants divided by the number of analyzed pollutants;

(b) The mean concentration of a pollutant element is based on the analysis of at least three samples

(c) The baseline concentrations are determined from standard earth materials

The modified equation for a generalized approach to calculating the degree of contamination is given in equation iv.

$$mC_d = \frac{\sum_{i=1}^{i=n} C_f}{n} \qquad\qquad iv$$

Where, n = number of analyzed elements

C_f = contamination factor.

Using this generalized formula to calculate the modified degree of contamination allows the incorporation of many metals as the study may analyse with no upper limit. Seven different categories of modified degree of contamination for soil by Abrahim and Parker (2008)

$mC_d < 1.5$ Nil to very low degree of contamination
$1.5 \leq mC_d < 2$ Low degree of contamination
$2 \leq mC_d < 4$ Moderate degree of contamination
$4 \leq mC_d < 8$ High degree of contamination
$8 \leq mC_d < 16$ Very high degree of contamination
$16 \leq mC_d < 32$ Extremely high degree of contamination
$mC_d \geq 32$ Ultra high degree of contamination

2.3.4 Pollution load index: was proposed by Tomlinson *et al.* (1980) for detecting pollution which permits a comparison of pollution levels between sites and at different times. The pollution load index was obtained as a concentration factor of each heavy metal with respect to the background value in the soil. According to Angula (1996), the pollution load index is able to give an estimate of the metal contamination status and the necessary action that should be taken. In this study, the mean concentrations of the metals studied reported were used as the background for those heavy metals as suggested by Turekian, and Wedepohl (1961).

$$PLI = \sqrt[n]{C_{f1} \times C_{f2} \times C_{f3} \times \dots \dots \times C_{fn}} \qquad\qquad v$$

Where, *n* = number of metals studied

C_f = contamination factor calculated as described in Equation ii.

Pollution load index value of ≥100 indicates an immediate intervention to ameliorate pollution. Pollution load index value of ≥50 indicates a more detailed study is needed to monitor the site, whilst a value of <50 indicates that drastic rectification measures are not needed.

2.4 Data Analysis

The heavy metals of the soil samples were analysed using descriptive statistics to produce a table, which contain the minimum, maximum, mean and standard deviation and correlation coefficient (Microsoft excel, 2016). A correlation coefficient near 1 or -1 indicates a strong relationship between two variables, while r closer to zero suggests no relationship between the variables (Ha and Ha, 2011). A positive value of r indicates a direct relationship between the variables while a negative value of r indicates an inverse relationship (Salvendy, 2012). Parameters showing *r* > 0.7 are considered to be strongly correlated, whereas if the r-value is between 0.5 and 0.7, the two parameters have a moderate correlation (Venkatramanan, 2013).

3.0 RESULTS AND DISCUSSION

3.1 Heavy metals characteristics of the soil samples

The mean pH values of the soil samples analyzed for dumpsite A and B ranged from 6.88-8.17 and standard deviation of 0.042 and 0.43 for dry and wet season respectively. The pH values of dumpsite A were slightly acidic, while for dumpsite B was slightly alkaline. The pH values for the two dumpsites in wet season was alkaline, the increased in pH during the wet season was due to increase in leacahate from the solid waste and all the samples falls within FAO standard limit of 6.5-8.5. The lower values of standard deviation reveal slight variations in pH distributions within the dump sites as presented in table 1and 2. The mean concentrations of Zn, Fe, Cu and Pb for dumpsite A and B ranged from 404-1181 mg/Kg, 3138-11803 mg/Kg, 18-97 mg/Kg and 12.75-136 mg/Kg for dry and wet season respectively. While, the mean concentrations of As, Cd, Cr and Mn ranged from 97-131 mg/Kg, 0.5-2.95 mg/Kg, 28.45-72.85 mg/Kg and 238-665 mg/Kg for dry and wet season respectively as presented in Table 1and 2. The mean trend of heavy metals concentration in the dry season for dumpsite A was; Fe > Zn > Mn > As > Cr > Pb > Cu > Cd, while, Zn > Fe > Mn > As > Cr > Cu > Pb > Cd in the wet season seasons as presented in table 1. The mean trend for dumpsite B in the dry season was; Fe > Zn > Mn > As > Cr > Cu > Pb > Cd, while, Fe > Zn > Mn > Cu > As > Pb > Cr > Cd in the wet season as shown in Table 2. The trend of site B was similar to site A for Fe, Zn, Mn, and Cd. The mean concentration of Zn, Fe, Pb, As and Mn for the two dump sites were above FAO standard limit for soil quality in both seasons, while Cd, Cu and Cr were within the FAO standard limit as presented in Table 1 & 2. The mean concentration of Fe, Zn, Mn and As were higher in both dump sites despite their distance apart, this might be ascribed to the geological formation of the study area. The concentrations of the analyzed heavy metals were higher during the wet season, when the rainfall was comparatively high to decompose the biodegradable materials in the dump sites to form a leachate. The higher standard deviation values of the heavy metals reveal higher variations in metals distributions within the dump sites, which depend on the composition of the solid waste.

Table 1: Mean and standard deviation of heavy metals concentration of dumpsite A

		Min	Max	Mn/SDEV	Min	Max	Mn/SDEV	FAO
Ph	-	6.8	6.89	6.84±0.042	7.22	8.3	7.97±0.43	6.5-8.5
Zn	mg/Kg	91.25	2777	682±1172	2.5	3159	7811±1341	100
Fe	mg/Kg	1550	6118	3538±1699	1847	13029	7616±4598	425
Cu	mg/Kg	7	51.25	18.85±18.3	6.5	93	33±34.48	73
Pb	mg/Kg	12.75	23.25	19.7±4.25	3.25	25	12.75±11	0.3

As	mg/Kg	116	151	131±13.05	66.25	167	128±39.13	20
Cd	mg/Kg	0.25	0.75	0.5±0.25	0.25	2.75	1.4±0.98	5
Cr	mg/Kg	24.75	32.25	28.45±2.83	11.5	69.75	44±25.76	100
Mn	mg/Kg	217	281	238±25.54	62	2012	614±798	100

Table 2: Mean and standard deviation of heavy metals concentration of dumpsite B

		Min	Max	Mn/STDEV	Min	Max	Mn/STDEV	FAO
Ph	-	7.13	7.87	7.29±0.16	7.87	8.01	7.91±0.123	6.5-8.5
Zn	mg/Kg	40	1412	404±568	527	1988	1161±590	100
Fe	mg/Kg	2880	4015	3138±813	4894	13732	11803±4997	425
Cu	mg/Kg	2.75	53.5	18±20.87	35.25	156	97±46	73
Pb	mg/Kg	3	28.75	13.15±10	25	482	136±195	0.3
As	mg/Kg	110	137	126±10.7	22	149	97±58	20
Cd	mg/Kg	0.5	0.75	0.69±0.13	1.75	3.5	2.95±0.72	5
Cr	mg/Kg	22.9	143	51.83±52	47.5	107	72.85±22	100
Mn	mg/Kg	89.25	727	249±269	246	1425	665±451	100

3.2 Geo-accumulation Index

Geo-accumulation index of the soil samples analysed for the two sites in dry and wet seasons were presented in Table 3. The index of Fe, Cd, Cr and Mn ranged from -1 to 1.97, which indicates the soil samples were unpolluted to moderately polluted for the two sites in both seasons as categorized by Victor et al. (2006). Zn for site A was very highly polluted in dry season and moderate to highly polluted in wet season, while for site B, Zn was moderately polluted in dry season and highly to very highly polluted in wet season. This high index of Zn was attributed leachate from the solid waste and geological formation of the study area. The index of soil samples for Cu ranged from 0.61 to 3.93 in both seasons for two sites, which indicate slightly polluted to highly polluted. This was due to the increased in leachate from the solid waste during the rainy season. Pb and As were unpolluted for the two sites in dry season, while in wet season the values ranged from 0.25 to 3.71, which indicate slightly polluted to highly polluted. This shows that the solid waste contain materials with Pb and As composition. The overall geo-accumulation index shows that the soils were contaminated with Zn, Cu, Pb and As, which need immediate remediation measures, while Fe, Cd, Cr and Mn were moderate.

Table 3: Geo-accumulation index of the soil samples

	SAD	SAW	SBD	SBW
Zn	5.24	2.63	1.39	4.73
Fe	0.36	-0.79	-0.76	-0.04
Cu	2.19	0.61	1.76	3.93
Pb	-1.32	3.71	-0.52	2.98
As	-0.12	1.21	-0.86	0.25
Cd	-1	-0.11	0.88	1.97
Cr	-0.36	-0.71	0.33	0.33
Mn	0.25	0.20	-0.79	0.99

SA – Site A, SB – Site B

3.3 Contamination Factor
The overall contamination factor of the soil samples for two sites in both seasons were presented in Table 4. The contamination factor of the soil samples for two sites were classified as slightly to moderately contaminated with Fe, Cd, Cr and Mn for both seasons as classified by Hakanson (1980) and Dasaram et al. (2011). The contamination factor of the soil samples for Zn was considerably to highly contaminate for the two sites in both seasons. The soil samples were highly contaminated in wet season and moderately contaminated in dry season with Cu for site A, while for site B it is considerably contaminated for the two seasons. The contamination factor of the soil samples for Pb and As for the two sites ranged from 0.6 – 19.62 and 0.25 – 3.48 respectively, which indicate slightly to highly contaminated.

3.4 Modified Degree of Contamination and Pollution Load Index
The modified degree of contamination of the soil samples ranged from 2.22 – 11.04 for the two sites in both seasons, which revealed that the soils were moderately to highly contaminated with heavy metals as presented in Table 4. The contamination was high in dry season for site A, because of dilution and other run-off during the wet season; metals from the upper layer of the soil were flushed out to some extent through the canal into the adjoining vast flood zone as compared to the dry season. While for site B the contamination was high in wet season, this might attributed to leachate increase due to the rainwater within the dumpsite. This modified method can therefore provide an integrated assessment of the overall enrichment and contamination impact of heavy metals in the soil.

The pollution load index values ranged from 312-1170 for both sites, which indicated immediate intervention to ameliorate pollution since the pollution load index values were above100 as categorize by Turekian and Wedepohl (1961). The pollution load index values were higher in wet seasons for both sites, this might attributed to leachate increase from solid waste due to the rainwater within the dumpsites.

Table 4: Contamination Factor of the soil samples

	SAD	SAW	SBD	SBW
Zn	56.83	9.3	3.92	4.73
Fe	1.93	0.87	0.88	0.88
Cu	6.86	2.29	5.54	5.54
Pb	0.6	19.62	1.05	2.98
As	1.38	3.48	0.83	0.25
Cd	0.5	1.4	2.75	1.97
Cr	1.17	0.92	1.88	0.33
Mn	1.79	1.73	0.89	0.99
mCd	8.88	4.95	2.22	11.04
PLI	692	7395	312	1170

D – dry season, W – wet season

3.5 Correlations Matrix of the heavy metals
Pearson correlation analysis was performed between heavy metals at $p \leq 0.05$ level of significance of multi-element correlation for soil samples as presented in Table 6. The trends of inter-metallic correlation coefficient that shows strong correlation between the heavy metals of the soil samples for sites A were: Mn-Zn, Cr-Fe, Cu-Zn, Cr-Pb, Cd-Cu and Pb-Fe, and moderately correlated were: Mn-Cu, Cd-Pb, Pb-Cu, Mn-Cr, Cr-Cd, Cr-Fe, Mn-Pb and Mn-Fe. Negative correlation exist between As-Zn, As-Fe, Cr-As and Mn-As.For site B the correlation trends that show strong correlation were: Mn-Cu, Cr-Fe, Cu-Zn, Mn-Zn, Mn-Cr and As-Fe, while moderate correlations were: Cd-Zn, Mn-Fe, Cd-Cu, Cr-

Cu, Cr-As and Cu-Fe. Negative correlation exist between As-Pb, Cd-As and Mn-Pb. These values indicate high degree of positive correlations and significant linear relation between various pairs of metals, reflecting their simultaneous release and identical source from the sites, transport and accumulation in soil. The strong and moderate correlations indicate that they may have originated from common sources, and these metals may have been derived from anthropogenic sources, especially municipal solid waste. As shows either inverse (negative correlation) or no correlation with other metals, this indicates As has no common source with other metals.

Table 6: Correlation matrix of heavy metals of the soil samples for site A and B

	Zn	Fe	Cu	Pb	As	Cd	Cr	Mn
Site A								
Zn	1.000							
Fe	0.430	1.000						
Cu	0.770	0.471	1.000					
Pb	0.491	0.739	0.602	1.000				
As	-0.208	-0.125	0.252	0.339	1.000			
Cd	0.483	0.563	0.750	0.699	0.483	1.000		
Cr	0.465	0.969	0.491	0.760	-0.100	0.566	1.000	
Mn	0.972	0.531	0.700	0.550	-0.270	0.473	0.567	1.000
Site B								
Zn	1.000							
Fe	0.372	1.000						
Cu	0.771	0.536	1.000					
Pb	0.094	0.004	0.044	1.000				
As	0.231	0.715	0.391	-0.254	1.000			
Cd	0.692	0.251	0.635	0.258	-0.014	1.000		
Cr	0.469	0.797	0.607	0.059	0.572	0.270	1.000	
Mn	0.743	0.675	0.799	-0.036	0.514	0.336	0.722	1.000

Conclusion

The study revealed that the heavy metals concentrations were higher for both sites during the wet season, when the rainwater was comparatively high to decompose the biodegradable materials in the dump sites to form a leachate. The mean concentration of Fe, Zn, Mn and As were higher in both sites despite their distance apart, this might be ascribed to the geological formation of the study area. The higher standard deviation values of the heavy metals reveal higher variations in metals distributions within the dump sites, which largely depend on the composition of the solid waste. The overall geo-accumulation index shows that the soils were contaminated with Zn, Cu, Pb and As, which need immediate remediation measures. The pollution load index values for both sites, indicated immediate intervention to ameliorate pollution and the values were higher in wet seasons for both sites. The trend of Pearson correlation at 5% significant level of the heavy metals show either strong or moderate correlations with each other except As, which shows either inverse (negative correlation) or no correlation with all the metals. All the indices revealed that the study area was seriously affected by different heavy metals and the use of solid waste compost as organic manure may accumulate the metals to a harmful level as can be introduced into the food chain. Awareness on adverse effect of toxic metals should be encouraged and regular monitoring of toxic metals in the agricultural soil is needed to check the environmental soil quality.

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