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Article

Assessment of Heavy Metals Levels and Leaching Potentials in Dumpsites Soils in Wukari, North-Eastern Nigeria

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Abstract: In this study, we report on the analytical assessment of heavy metals contents of soils collected from different dumpsites in Wukari and environs. The levels of Cu, Cd, Pb, Fe and Zn metals were determined and the data obtained was subjected to pollution evaluation methods such as contamination factor (CF) and pollution load index (PLI). The contamination factors (CFs) revealed a moderate to extreme contamination of the dumpsites and a decreasing trend in the heavy metals concentrations was observed in soils collected at about 100 metres from the respective dumpsites which indicated some leaching of the metals from the dumpsites to adjacent environment. The pollution load index (PLI) showed that some of the dumpsites are severely polluted as the PLI of the metals from each sample site exceeded the PLI of the background (control) sample (0.2). Spearman's rank correlation analysis showed clear correlations ($p<0.001$) amongst the metals suggesting a common source.

Keywords: Heavy metals, Soil pollution, dumpsites, Wukari

1. Introduction

Heavy metals pollution represents a serious problem for human health and for life in general. The emergence of heavy metals in the environment is a consequence of man's several anthropogenic activities. These metals pose serious deleterious burdens on fauna and flora of lakes and streams when they leach and are carried by surface run-offs from contaminated soils in areas where they are highly concentrated such as dumpsites and landfills (Akinwummi et al, 2010). The introduction of electronic wastes into our environment has contributed greatly to the increase in levels of heavy metals in soil and vegetation grown in dumpsites (Osinbanjo, 2009). The soil and plants on these dumpsites constitute a serious threat to the health of people living around such areas (Adefemi and Awokunmi, 2009).

Locations and places with accumulated solid wastes are called refuse dumps but a designated place for dumping of refuse is known as dumpsite. Despite the best attempts at waste avoidance, reduction, reuse and recovery (recycling, compositing and energy recovery), landfill and waste disposal sites are still principal focus for ultimate disposal of residual wastes and incineration residues world-wide (CCME, 1991). The placement and compaction of municipal wastes in landfills facilitates the development of facultative anaerobic conditions that promote biological decomposition of dumpsites and land filled wastes. Hence, leachates of diverse compositions are produced (Aralp, 2001; Campbell, 2003). The extent of soil pollution by heavy metals and base metal ions (some of which are soil micronutrients) is very alarming. It has been observed that the larger the urban area, the lower the quality of the environment (Amusan et al, 2005). In Nigeria, it is generally believed that individuals, government and environmental agencies pay little or no attention to the environmental impact of waste disposal and management, even when it is a statutory responsibility of the parties concerned.

Recent studies have also revealed that e-waste dumpsites can transfer significant levels of toxic and persistent metals into the soil environment and eventually these metals are taken up by plants parts and transfer same into the food chain (Greenpeace, 2009). Consequently, higher soil heavy metals concentration can result in higher levels of uptake by plants (John et al, 1972). These heavy metals and toxins when released pollute the soil and environment causing health hazards to humans within such vicinities. Vegetables grown in such soils absorb heavy metals and toxins and pose serious health risks to human and animals. The toxins ultimately find their way into the food chain. Studies have shown that the heavy metals pollution of soils and water courses can impair important biochemical processes such as eutrophication, posing a threat to water bodies' mobility. They can also migrate to ground water, with the effects of mobilizing factors like rainfall and wind strength, thereby changing the usable properties of the water bodies.

In this study, we probe the quality of soils around dumpsites in Wukari and environs so as to ascertain the levels of heavy metals in the dumpsites scattered across various locations in Wuakri, Taraba state. Heavy metals analyzed were; Cu, Cd, Pb, Zn and Fe. Additionally, soil quality indicator parameters such as pH, cation exchange capacity (CEC), total organic carbon (TOC) and total organic matter (TOM) were carried out. Analysis of the soil at various distance from the dumpsites were also carried out to assess the leaching potentials of these heavy metals and their effects on adjacent environments. The results obtained showed high level of contamination judged from the high concentration of these metals at the various dumpsites sampled. A decreasing trend in the levels of these metals were however observed in soils sampled from given distance from the dumpsites, which points to the fact that metals leachates were swept by some natural factors such as rain and wind to adjacent environment.

This study constitutes a significant component of our research enquiries into the environmental pollution assessment studies that has been on-going for years with findings reported in the literature (Achadu et al 2013; Achadu et al, 2015a; Achadu et al, 2015b).

2. Materials and Methods

2.1. Study Area

Wukari is the study area and the headquarters of Wukari local government area of Taraba state, North-eastern region of Nigeria. It is occupied by the Jukun people with an area of about 4,308km^2 and an estimated population of about 214,546, (National Population Census, 2006).

2.2. Sampling and Sample Locations

Familiarization trips were embarked upon before sampling so as to have a proper overview and firsthand knowledge of the areas, the location/topography of the dump sites as well as the suitable time and method of sampling to adopt were also taken into consideration.

Sampling locations were selected based on the population distribution and density of Wukari and the prevalence of dumpsites. Various dumpsites were visited and a total of forty one (41) samples including control samples taken from relatively distant locations were collected within Wukari at the following locations namely; Holy Spirit (HS); Yam market (YM), Old BB (BB) and Mission quarters (MQ), respectively. Composite and discrete sampling techniques were employed in the sampling. Soil samples were collected randomly at depths within 15-20cm from the soil surface, depending on the topography of the point. Discrete samples were randomly collected, then bulked together. A representative sample was then drawn from this bulked volume. This same procedure was also used to collect samples from about 100 metres from the respective dumpsites to assess the metal leachates from the main dumpsites.

2.3. Sample Preparation Procedure

Samples were dried for 72 hours then sieved with aluminum sieve mesh followed by oven drying at 110ºC for 1 hour and cooled in a desiccator. Samples were then put in polythene bags, labeled accordingly and kept for analysis.

2.4. Physicochemical Parameters Determination

2.4.1. Soil pH

Soil pH was determined following standard procedures using a soil-water ratio of 1: 2.5 (w/v). Briefly: 1g of soil sample was weighed in a 50ml beaker followed by the addition of 25ml of distilled water. The content was shaken well for about 30 minutes and the pH meter electrode which had already been calibrated with the standard buffer solutions was inserted into the prepared sample. The pH was then read directly from the read out scale of the pH meter. Cation exchange capacity (CEC), Total organic carbon (TOC) and total organic matter (TOM) were determined according to the USDA procedure (USEPA, 1996).

2.4.2. Heavy metals determination

5g of each soil sample was weighed into a 150ml conical flask after which 20ml of aqua regia (1:3 of HNO_3:HCI) was added. The mixture was gently swirled to ensure proper mixing. It was then digested on a hot plate at 80^{o}C in a fume cupboard for about 3hours (until the brown fumes disappeared and white fumes appeared and a quarter of the original volume left). The mixture was then cooled and filtered into a 100ml cleaned standard flask and made up to the mark with de-ionized water. The procedure was repeated for all soil samples. The concentrations of heavy metals were determined by Atomic Absorption Spectrometer (Perkin Elmer AA Analyst (USA)). Blanks were also prepared using the same procedures of digestion of the samples. Copper, Cadmium, Zinc, Iron and Lead standards of various concentrations were prepared and used for the calibration of the AAS instrument before the runs.

2.5. Assessment of Metal Contamination

As described previously (Achadu, 2015a), heavy metal enrichment and degree of contamination in soils and analytical data were subjected to pollution calculation methods expressed in equations 1-2 (Sutherland, 2010), with the aim of deriving realistic estimates for the amount of contamination that has impacted soils at the various dumpsites.

2.5.1. Contamination factor (CF)

The level of contamination of soil by metal is expressed in terms of a contamination factor (CF) calculated as:

$$\mathrm{CF}=\frac{C_{m(sample)}}{C_{m(background)}} \quad (1)$$

where the contamination factor CF < 1 refers to low contamination; 1 ≤ CF < 3 means moderate contamination; 3 ≤ CF ≤ 6 indicates considerable contamination and CF > 6 indicates very high contamination.

2.5.2. Pollution load index (PLI)

Each site was evaluated for the extent of metal pollution by employing the method based on the pollution load index (PLI) developed by Thomilson et al. (1980), as follows:

$$PLI=(\boldsymbol{CF_1} \times \boldsymbol{CF_2} \times \boldsymbol{CF_3} \times \ldots .\boldsymbol{CF_n})^{\boldsymbol{1/n}} \quad (2)$$

where n is the number of metals studied (5 in this study) and CF is the contamination factor calculated as described in Equation 1. The PLI provides simple but comparative means for assessing a site quality, where a value of PLI < 1 denotes perfection; PLI = 1 represents that only baseline levels of pollutants are present and PLI > 1 would indicate deterioration of site quality (Thomilson et al., 1980).

2.6. Data Analysis

In order to study the characteristics of the dumpsite soils, the concentrations of heavy metals contents in the surface soils were subjected to correlation analysis to determine association as well as the differences in the concentrations between different sampled locations. Descriptive statistical analysis was also employed for the data obtained. Mean and standard deviations were determined.

3. Results and Discussion

The results of the concentration levels of Cu, Cd, Fe, Pb and Zn determined from soil samples from the various dumpsites are shown in Table 1 and Fig. 1. Physicochemical parameters such pH of the soils from the different sampled sites is presented in Table 2 along with parameters such as CEC, TOM and TOC. Data reported here including results of these heavy metals concentration evaluation from samples collected at about 100 metres from the main dumpsites was used to examine the extent of contamination spread and effect of leaching. Concentrations of individual heavy metal elements and their background data are given in the Table 1.

All heavy metals tested in the soils extracted from the dumpsite possess significant differences from those obtained in the control, but not the case in all locations. High volumes of these metals in the dumpsites are connected to increased anthropogenic activities and lack of eco-friendly culture (Tanee and Eshalomi-Mario, 2015). Pile of wastes containing divergent materials from degradable to non-degradable and electronic wastes are a major source of heavy metals (Osinbanjo, 2009). Hence, excessively high levels (metals) indicate some level of contamination from point and non-point sources.

Table 1. Heavy metals concentrations in soils collected from the various dumpsites

D. site	Distance form dumpsite (metres, m)	Heavy metal concentration ((µg/g) Mean±SD				
		Cu	Cd	Fe	Pb	Zn
HS	0	2.69±0.32	0.01±0.001	3.84±1.44	1.14±0.13	7.58±0.48
	100	0.89±0.08	ND	1.52±0.51	0.88±0.11	1.49±0.51
YM	0	4.19±1.1	ND	15.36±4.2	3.02±0.71	15.622±1.82
	100	1.74±0.18	ND	9.1±1.15	1.26±0.34	7.94±1.01
BB	0	3.15±0.33	ND	5.51±0.97	1.39±0.42	10.43±0.94
	100	1.05±0.05	ND	2.75±0.74	0.37±0.41	5.86±0..57
MQ	0	0.58±0.29	ND	0.95±0.15	0.15±0.05	2.83±0.55
	100	ND	ND	0.79±0.19	0.07±0.03	1.07±0.47
HS[a]	Control	0.98	ND	0.51	0.09	1.09
YM[a]	-	1.2	ND	5.07	0.54	3.45
MQ[a]	-	ND	ND	0.23	0.01	0.21
BB[a]	-	0.25	ND	1.70	0.20	1.22

a- Control results

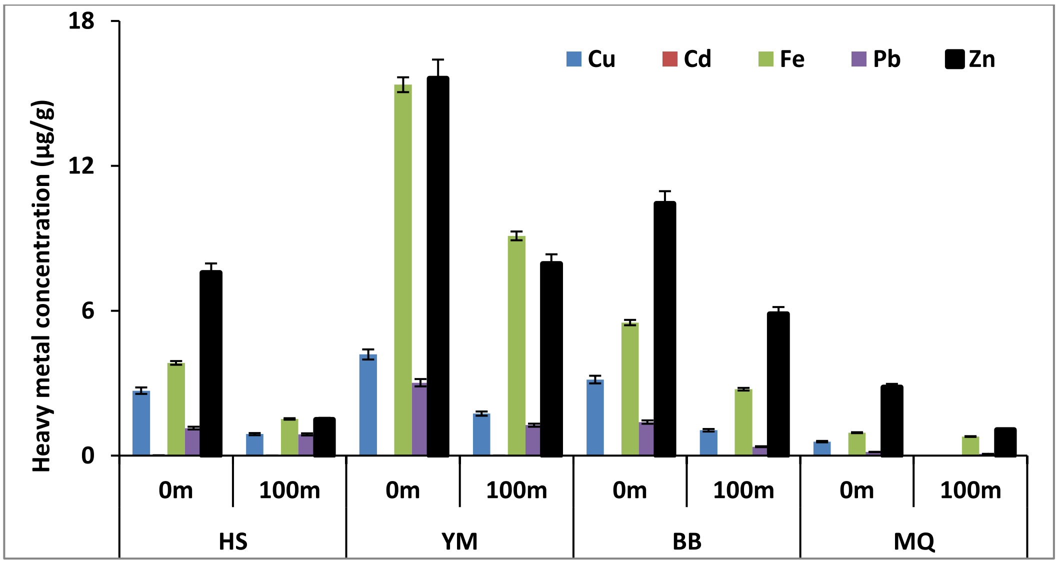

Fig. 1. Heavy metals concentrations (mean and standard deviation) of soils collected from dumpsites and 100 metres distance

Table 2. Physicochemical parameters (CEC, pH, TOM and TOC) of on-site samples and 100 metres distance

D.site	Distance form dumpsite (metres, m)	Physicochemical parameters Mean±SD			
		pH	**CEC (%)**	**TOM (%)**	**TOC (%)**
HS	**0**	6.28±0.42	48.28±2.60	3.04±0.13	3.77±0.38
	100	7.02±0.13	53.09±2.49	3.12±0.24	4.15±0.25
YM	**0**	5.65±0.44	12.82±0.57	1.23±0.26	0.86±0.18
	100	6.6±0.30	14.94±0.68	1.66±0.05	1.13±0.06
BB	**0**	6.28±0.21	46.65±7.65	2.70±0.41	3.0±0.41
	100	6.91±0.09	52.74±3.41	2.58±0.48	3.41±0.35
MQ	**0**	7.2±0.22	13.8±1.38	1.91±0.12	3.18±0.25
	100	7.2±0.13	1.98±0.23	1.98±0.23	3.11±0.31
HS[a]	**Control**	7.00	22.50	2.88	1.23
YM[a]	**-**	6.80	15.50	1.98	2.34
MQ[a]	**-**	7.50	12.20	2.55	0.94
BB[a]	**-**	6.90	18.90	1.67	2.89

a-Control results

The levels of the heavy metals determined were expectedly observed to be generally lower in soils samples collected at 100 metres distance in all dumpsites, with Cd ranging from 0.01-not detectable (ND). These results show that heavy metals leached from the soil in the dumpsite, migrating to adjacent areas. Amongst the tested heavy metals, high level of Fe and zinc were found as well as copper. Fe ranged between 0.15-3.02 µg/g with the highest mean concentration recorded at YM dumpsites, the same trend was observed for Zn and Cu metals with highest concentrations recorded at YM dumpsites (Table 1 and Fig. 2). The pH of the soils in all dumpsites soils was in the range of 5.65 to 7.20 with YM dumpsite recording the lowest (5.65) and dumpsites MQ has the highest mean pH value of 7.20. This result also indicates that samples collected from YM dumpsite are more acidic as compared to those from other study sites which are within the range of 6.2-7.20. As previously reported, acidity or alkalinity levels of soils affect their physicochemical properties and bioavailability of metals. The slightly acidic pH recorded in YM dumpsite is in line with higher levels of metals found in that site and indicate some level of contamination of the site. However, other parameters such as the cation exchange capacity (CEC) were used to further probe the quality of the soils in the sampled sites. CEC ranged from 12.82 to 48.28 Cmol/kg, with YM and HS having the lowest and highest CEC values, respectively. As discussed above, YM possesses the lowest CEC value and since CEC is a measure of the buffering capacity of soils and high CEC values may indicate the tendency of leaching in soils to be slowed down, YM dumpsite may easily leach heavy metals away from its site. Average levels of total organic matter and carbons ranged from 1.23-3.12 and 0.86-4.51, respectively. These values range have been reported before in the literature for dumpsite soils (Tanee and Eshalomi-Mario, 2015; Amos et al, 2014). However, the values of TOM and TOC are relatively low in YM compared to other sample site (Table 2 and Fig 2). Health effects and environmental impacts of heavy metals have been reviewed extensively in the literature and hence was not fully discussed (Fergusson, 1990; Goyer, 2001; Chang et al, 1996; Tchounwou et al, 2012).

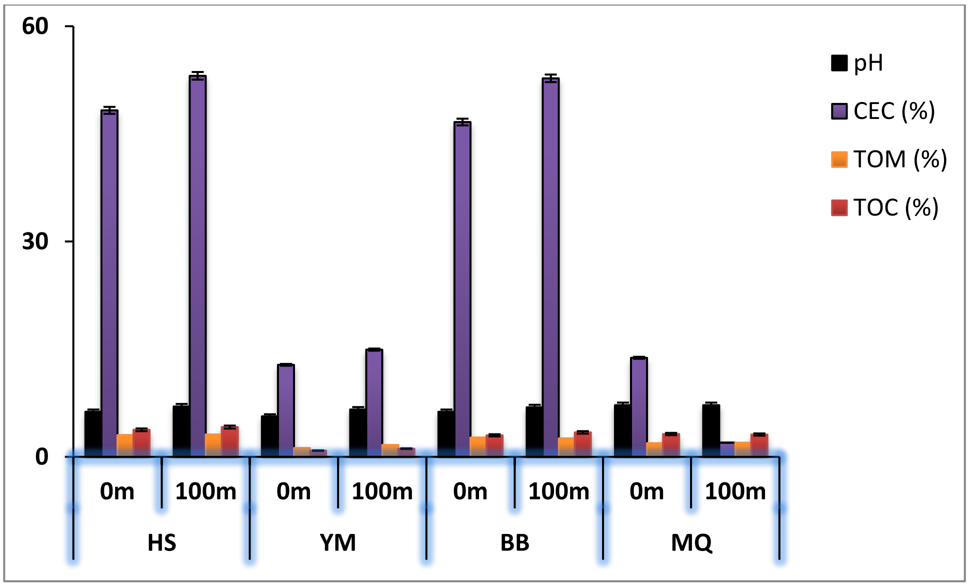

Fig. 2. Physicochemical parameters (mean and standard deviation) results of soils collected from dumpsites and 100 metres distance

3.1. Contamination Factor (CF)

Contamination factors (CFs) are used to assess the intensity or the extent of metals contamination of sites. CFs recorded for various metals in various dumpsites are presented in Table 3 and Fig 3. Using the contamination factor categories previously described, all sampled sites did not quite suffer contamination by Cd, though it was difficult to ascertain the CF for Cd due to the fact that it was not detected in virtually all dumpsites. CFs for all metals was relatively higher in YM as compared to the other sample sites. As shown in table 3, other sites that suffered contamination using the CFs convention is BB where the CFs for Pb (6.95) and Zn (8.55) exceed the arbitrary value (6) considered to indicate a high level contamination.

Table 3. Contamination factors estimated for the respective heavy metals

	Cu	Cd	Fe	Pb	Zn
HS	2.74	-	3.03	5.59	5.95
YM	12.6	-	7.53	12.67	13.48
BB	3.49	-	3.81	6.95	8.55
MQ	-	-	4.13	15	4.83

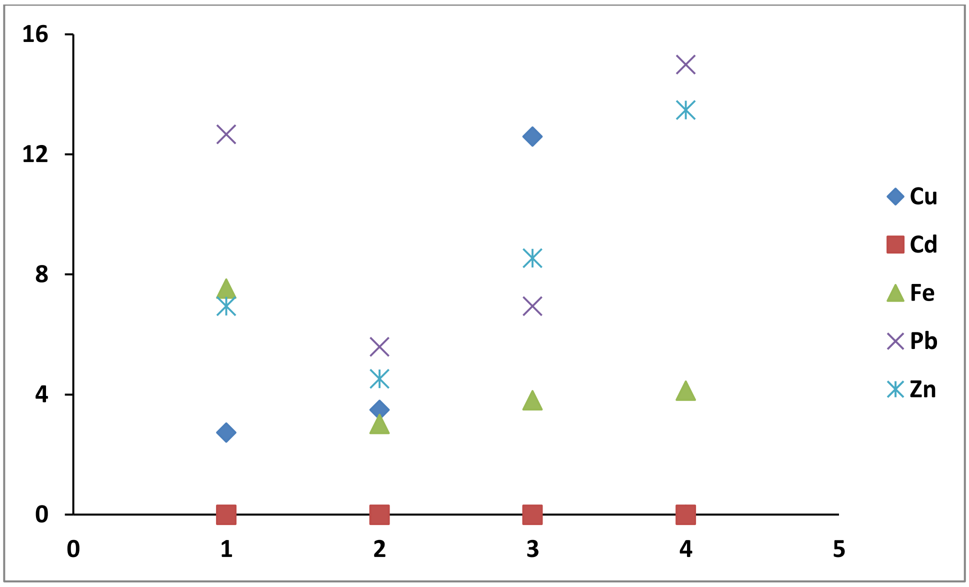

Fig. 3. Contamination factor for heavy metals estimated in the dumpsites soil samples

3.2. Pollution Load Index (PLI)

To effectively ascertain and distinguish the very limits of pollution as regards the combined effects of the metals in the dumpsites, pollution load index (PLI) described in Equation 2 was used. Figure 4 shows results of the PLI for the five (5) metals studied at these dumpsites. Based on the results presented (Figure 4), the overall degree of contamination by the metals is of the order YM>BB>HS>MQ. These are estimated values and discussed below. All the dumpsites showed strong signs of pollution or deterioration of soil quality, as the background (control) sample's PLI was calculated to be 0.2 and a baseline value of $\leq$ 1.0 indicates well (good) to moderate soil quality. Relatively high PLI values at YM, BB and to some degree in HS suggest input from anthropogenic sources attributed to increased human activities and/or long time dumping of refuse. These dumpsites are situated the middle or around settlements where there are high human activities, hence susceptible to heavy metals contamination.

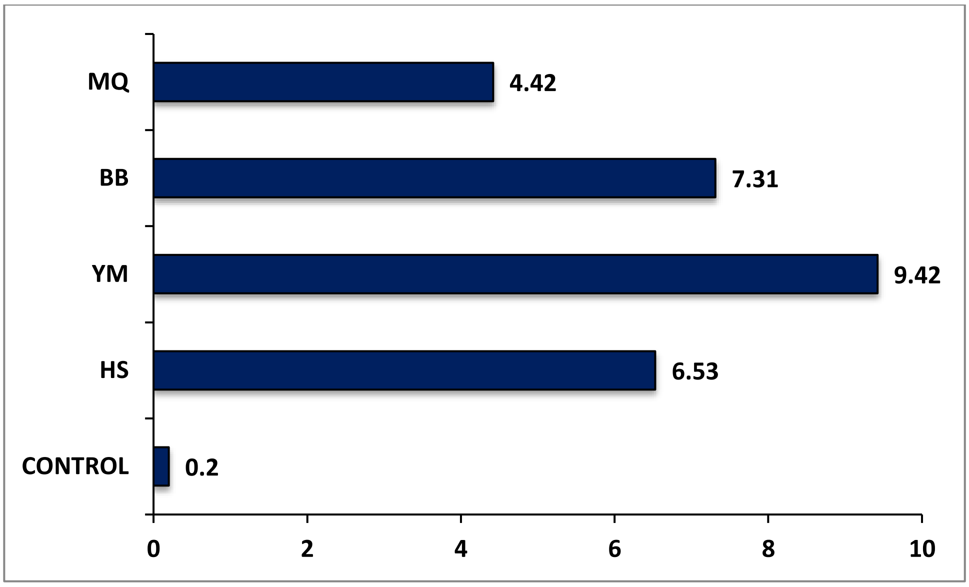

Fig. 4. Pollution index of heavy metals assessed in dumpsite soils

3.3. Statistical Analysis

Inter-elemental associations were also evaluated employing Spearman's rank correlation coefficient, ρ and the results are presented in Table 4. Results indicated that some elemental pairs, for example Pb/Zn (r = 0.935, P < 0.001), Zn/Cu (r = 0.981, P < 0.0001), and Cd/Pb (r = 0.908, P< 0.0001) and Cd/Cu (r= 0.858, P<0.001) have very strong correlations with each other except for the later. Strong correlations signify that each paired elements have common contamination sources.

Table 4. Spearman's rank correlation for the heavy metals in soils from the dumpsites

	Cu	**Cd**	**Fe**	**Pb**	**Zn**
Cu	1.00				
Cd	0.858	1.00			
Fe	0.921	0.890	1.00		
Pb	0.901	0.905	0.807	1.00	
Zn	0.981	0.721	0.889	0.935	1.00

4. Conclusions

The levels of Cu, Cd, Fe, Pb and Zn in soils collected from various dumpsites were analyzed onsite and within 100 metres distance from the site. Concentrations of the respective metals were found to be higher in the on-site soils samples compared to those from within 100 metres distance. Pollution assessment methods revealed that the sites suffered some deterioration in soil quality and highest for samples collected at Yam market (YM). We ascribe this to be due to the high density of human activities and population in that area. This study elucidate the need for proper attention regarding waste disposal as high levels of contamination with heavy metals could lead to the leaching of these metals to adjacent farmlands and potable water sources, which would eventually find their way into the food chain.

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