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Assessment of Soil pH and Heavy Metal Concentrations in Agricultural Land Impacted with Medical Waste Incinerator (MWI) Flue Ash (FA) in Abia State, Nigeria

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ABSTRACT: This study focused on the effect of heavy metals being introduced into soils through medical waste incinerator flue ash by collecting soil samples at different depths and distances to determine soil pH, Cu, Zn, Cr, Cd, Pb and Mn contents using standard methods and multivariate tools for data summary. Mean soil pH values ranged: 5.2 – 6.2 > 4.8 of control due to flue ash as a liming agent and farming practices respectively, with low pH that encourages mobility and absorption of heavy metals in ecosystems. Heavy metals in incinerator site(mgkg^{-1}) ranged:2.00105 ± 0.00-2.09050 ±0.00; 4.0011±0.00-12.3250±0.00; 6.0405±0.01-8.0150±0.01; 4.0150±0.00-7.0805±0.07; 0.2100±0.01-1.0950±0.01; 0.00±0.00-0.001100±0.00; 0.0305±0.01-0.1150±0.00 for Cu, Zn , Mn, Cr, Cd and Pb respectively, with control 0.55 ± 0.01-1.25 ± 0.01;1.25 ± 0.01-1.45 ± 0.01; 13.15 ± 0.07-14.15 ± 0.07; 0.02 ± 0.01; 0.00 ± 0.01-0.03 ± 0.01; .54 ±0.01-.54 ± 0.01 for Cu, Zn , Mn, Cr, Cd and Pb respectively .Metals were in order of: Cd≤ Cu ≤Pb≤ Cr≤Mn≤ Zn(LSD0.05). Result revealed that Cr, Cd and Pb were below the limits for agricultural soil by FAO, and were higher at 50-100m and decrease farther from incinerator. Negative correlation exists between Cr and Zn; Zn and Cu due to farming practices, Mn, Cd recorded positive correlation due to incinerator flue ash. Factor 1 loaded Cu positively, Cr, Pb, Mn, and Zn negatively loaded. Factor 2, exception of Cr, Cd, Pb, and Mn loaded negatively due to flue gas and lithogenic respectively, C/PI indicated soil being slightly, moderately to severely contaminated respectively. I_{geo} indicated uncontaminated to moderately contaminated, showing that heavy metal contaminations of soils is minor.

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Incineration of waste remains a disputed waste management disposal option in many countries of the world (Damgaard *et al*., 2010).Although incineration is a largely diffuse and effective way of treating solid waste, health effects associated with stack emissions remain a major public concern (Sofia and Lopes, 2017), and some toxics present in waste or formed during the process, may escape pollution control devices and be released to the atmosphere. Ultimately, these chemical scan cross environmental boundaries reaching different media: soil, water, biota, and vegetation (Gidarakos *et al.,* 2009). As a result of the trans-boundary, human health can be directly or indirectly affected through different pathways including soil (USEPA, 1998a). Accordingly, incineration of medical waste also converts the waste into essentially non-combustible solid residue or ash (Gidarakos *et al.,* 2009), and other outputs such as flue gas and heat (Samwel *et al*, 2012). Thus, the flue gases must be cleaned of gaseous and particulate pollutants before they are dispersed into the atmosphere (Samwel *et al*., 2012).Health-care waste has more heavy metals than municipal solid waste (Zhao *et al.,* 2010). When health-care wastes are incinerated mercury (Hg) residue is left in the bottom ash while the rest is released as gaseous emission typically called fly ash (FA) , which is the by-product produced due to the combustion process (Valentim *et al.*, 2009). The component of fly ash varies significantly, which depends on the makeup of waste burned. But all the fly ash includes some amount of silicon dioxide (SiO_2) both amorphous and crystalline and calcium oxide (CaO) (Santosh, 2009). Flueash which is entrained in the flue gas, also contains trace amount of toxic metals (U, Th, Cr, Pb, Hg, Cd etc), which may have negative effect on human health and plants due to low soil pH (Dhadse *et al.*, 2009), which influenced the mobility and absorption of heavy metals in the soil (Violate *et al.,* 2008). Such metal in fly ash can move through the air and deposited as dust or by precipitation that fall to the soil as contaminant and can seriously affect soil's ability to perform some of its key functions in the ecosystem (Ubuoh *et al.,* 2014). Authors like Adama *et al.* (2016), Josephat *et al.* (2016) only worked on the characterization of incinerator bottom ash without looking at the effects of incinerator flue gas on soil for

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agricultural purposes. Accordingly, strong accumulation of heavy metals in agricultural soils has been reported by Xia *et al*. (2014), but there has been little research on the heavy metal distribution due to incinerator flue ash on agricultural land. Public concern about environmental pollution has focused attention on the disposal of urban and industrial waste hence this study intends to investigate the soil pH and heavy metal concentrations in agricultural land impacted with medical waste incinerator flue ash in Abia State, in view of interpreting the suitability of its soil for crop production.

MATERIALS AND METHODS

Study Area: This study was carried out in Medical Centre (MC) in Abia State, Nigeria. The state is located on Latitude 5^{0}25N and Longitude 7^{0}30E. The state covers an area of about 5,243.7 sq.km with a population of 2,833,999 (NPC, 2006). It has an average annual rainfall that ranges between 1900 - 2200mm, almost evenly distributed throughout the wet season while temperature ranges between 21-27^{0}C (NRCRI, 2014).

Soil Sampling Technique: Soil was sampled at four different sampling points away from the incinerator. Three of the sampling points were within 200m from the incinerator (interval between sampling points were 50m apart) at the windward direction, whereas the fourth point was 1,000m in the demonstration farm, Michael Okpara University, Umudike (MOUAU) as control. Soil samples were collected at the depths: 0-15cm, 15- 30cm using a Dutch soil auger and a spatula. The soil samples were dried at 105^{0} C for 24 hours and then ground to a particle diameter of <0.25mm in an agate mortar (Shams and purkayastha , 2011) , and were stored in labeled polythene bags and were taken to the laboratory for analysis of soil pH and heavy metals respectively.

Determination of soil pH and Heavy metals: The pH of soil was measured with the help of pH meter after filtered solution was measured (Shamsand purkayastha; 2011). For heavy metal determination in soil sampled**,** 1gram of each of the sieved soil samples was digested using the nitric/perchloric acid digestion procedure. Presence of important heavy metals including copper (Cu), zinc (Zn), chromium (Cr), cadmium (Cd), lead(Pb) and manganese (Mn) were determined using Atomic absorption Spectrophotometer (AAS) (UnicamSolaar32 model) following the standard procedures as given in APHA (1995). All analyses were done in duplicates.

Multivariate Analytical Techniques: Multivariate statistics were employed to elicit quantitative information about the origin and relationship of potentially toxic elements in soils sampled (Borùvka *et al.,* 2005).

*The index of geo accumulation (I_{-geo}):*The degree contamination of heavy metals in soils was assessed with the geo-accumulation index (I_{-geo}) introduced by Muller (1969), taking into account the upper limit of background concentration. The method was employed in pollution assessment of heavy metals in urban soils, urban road dust and agricultural soils from China (Wei and Yang 2010). The geo-accumulation index is computed using the equation:

$$I_{-geo} = \log 2({Cn}/{1.5}\, B)2 \qquad (1)$$

Where Cn is the measured content of the element in soil, and B_n is the background value in soil. According to Muller (1969), the I_{-geo} for each metal is calculated and classified as: uncontaminated ($I_{-geo} \leq 0$); slightly contaminated ($0 < I_{-geo} \leq 1$); moderately contaminated ($1 < I_{-geo} \leq 2$); moderately to heavily contaminated ($2 < I_{-geo} \leq 3$); heavily contaminated ($3 < I_{-geo} \leq 4$); heavily to extremely contaminated ($4 < I_{-geo} \leq 5$); extremely contaminated ($I_{-geo} > 5$).

*Contamination /Pollution Index (C/PI):*The contamination /pollution index was derived by employing the contamination/pollution index as defined by Lacutusu (2000), and Department of Petroleum Resources of Nigeria (DPR, 2002) for maximum allowed concentrations of heavy metals in soil and was used as follows: Cd 0.8 mg kg^{-1}, Cr100 mg kg^{-1} , Cu 36 mg kg^{-1}, Pb 85 mg kg^{-1} , Zn 140 mg kg^{-1} and Mn 850 % derived from crustal abundance expressed as:

$$\frac{C}{PI} = \frac{\text{Concentration of metal in soil}}{\text{Target value from reference table}} \qquad (2)$$

Table 1: Showing the significance of intervals of Contamination/Pollution Index (C/PI)

C/PI	Significance
<0.1	Very slight contamination
0.10 – 0.25	Slight contamination
0.26 – 0.5	Moderate contamination
0.51 – 0.75	Severe contamination
0.76 – 1.00	Very severe contamination
1.1 – 2.0	Slight pollution
2.1 – 4.0	Moderate pollution
4.1 – 8.0	Severe pollution
8.1 – 16.0	Very severe pollution
>16.0	Excessive pollution

Adapted from Lacutusu (2000).

PLI value close to one, indicates heavy metal loads near the background level, while values above one, indicate soil pollution (Liu *et al*., 2005).Therefore, soils with PLI value of more than 1 are polluted, whereas values less than 1 indicate no pollution

(Harikumar *et al.,* 2009). The significance of C/PI is indicated in Table 1.

*Statistical Analysis***:** Results obtained from all samples were subjected to descriptive (mean, standard deviation and ranges) and inferential (ANOVA) statistics and P<0.05 was considered to indicate statistical significance. Mean values were separated using Duncan's Multiple Range Test. To help in the identification of different soil parameters, Principal Component (PC) analysis was performed to establish possible factors that contribute towards the concentrations and source apportionment of soil characteristics. The number of significant principal components was selected on the basis of varimax orthogonal rotation with Kaiser Normalization at Eigen values greater than 1 (Anyadike, 2009). The statistical analysis was performed using SPSS version 20. Geographical Positioning System (GPS) was used for soil sampling accuracy (Table 2).

Table 2: Soil Sampling Points in Incinerator Flue Gas Site soil at Graded Distances and coordinates

S/N	Soil sample	Distances	Coordinator
1	Soil samples (1)	50-100 meters	Lat 5^0 31'0.354N, Long 7.29^0 38.292E
2	Soil samples (2)	100-150meters	Lat $5^0$30'59.484N, Long $7^0$29'38.736E
3	Soil samples (3)	150-200meters	Lat.$5^0$30'58.542N, Long $7^0$29'38.94E
4	Soil samples (4)	Control	Lat.$5^0$30'52.278N, Longitude $7^{0'}$30'0.378 E

RESULTS AND DISCUSSION

The results in Table3-4 showed the mean, maximum, minimum values, standard deviation and variance of the effect of the flue ash on soil pH and heavy metals at graded distance. Table 5 shows correlation analysis of heavy metals. Table 6-7 indicate Eigen vector values for PC and contamination/Pollution Index of heavy metals in soil sample at graded distances respectively, and Table 8 shows contamination/geo-accumulation index of heavy metals in the soil at various distances. From the result in Table 3, soil pH (in H_2O) ranged between 5.150±0.00 - 5.900±0.07 indicating slightly acidic and control with 4.81 ± 0.01indicating highly acidic at the depth of 0-15cm respectively. Soil pH at 15-30cm ranged between 5.250±0.00 -6.400±0.07 less acidic than control site with 4.51 ± 0.01. The overall average soil pH based on distance was in acidic order of 4.8< 5.2 > 5.7 > 6.2 signifying (D_5, $D_{2,}$ $_{D4}$, D_1). The effect of depth and distance was highly significant ($p \leq 0.01$) on the pH levels of the sampled soil.

The variation in soil acidity in the study site is suspected to be due to flue ashes added to the soil as liming agent while the control recorded very low pH suspected to be caused by farming practice. From Table 4, mean level (mg/kg^{-1}) of Cu in topsoil ranged between 2.00105±0.00- 2.09050±0.00 higher than control with 0.55 ± 0.01 and in subsoil Cu :2.00305±0.00-2.09100±0.00 higher than control with 1.25 ± 0.01 , Zn in topsoil : 4.0011±0.00 - 12.3250±0.00 far greater than control with 1.25 ± 0.01 and subsoil : 6.0150±0.00-8.0150±0.01 higher than control with 1.45 ± 0.01, Mn in topsoil :4.4500±0.01-7.0805±0.07 quite less than the control with 14.15 ± 0.07 in subsoil: Mn in subsoil:2.0605±0.07-6.0705±0.01 l less than control with 13.15 ± 0.07, Cr in topsoil : 0.2100±0.01 and 1.0950±0.01 slightly higher than control (0.02 ± 0.01 , and subsoil: 0.6050±0.01-1.7150±0.01 higher than control with 0.02 ± 0.01, Cd in the topsoil :0.000300±0.00-0.000305±0.00 higher than control - 0.00020 ± 0.01 and at topsoil :0.001050±0.00-0.000505±0.00 far higher than control with 0.00 ± 0.01 and Pb in topsoil :0.0805±0.00-0.1050±0.00 less than 1.63 ± 0.01 obtained from control., and the subsoil : 0.0305±0.01-0.1150±0.00 lower than control with 1.54 ± 0.01 respectively. The $LSD_{0.05}$ inter of heavy metals in soil affected by incinerator flue gas were in order of**:** 0.0002(Cd)< 0.0019 (Cu) <0.0100(Pb)< 0.0212(Cr)< 0.07135 (Mn)< 5.0208 (Zn)

From the correlation analysis in Table 5, Cr and Zn; Zn and Cu, had high significant negative relationship suggesting these heavy metals as a result of farming practices such as irrigation with sewage water, excessive fertilization, application of animal manure, and pesticide application while Mn and Cd had a high significant positive correlation in soil sampled . Factor 1 was positively loaded with Cu suspected to come from flue gas while negatively loaded with Cr, Pb, Mn, and Zn with percentage variation of 43.60, which is suspected to be predominantly lithogenic. Factor 2 was negatively loaded with Cd, Pb, Mn and positively loaded with Cr with percentage variation of 38.24.

Table 3: Mean ± SD of the Effect of Incinerator Flue Gas on Soil pH at Graded Distances in Medical Centre, Abia State

Parameter	Depth	*D_1	*D_3	D_3	$LSD_{0.05}$inter.	Control (D_4)
pH (H_2O)	0-15cm (R_1)	5.900±0.00	5.150±0.00	5.900±0.07		4.81 ± 0.01
	15-30cm (R_2)	6.400±0.07	5.250±0.00	5.450±0.07	0.1153***	4.51 ± 0.01
Average pH	-	6.15±0.035	5.2±0.00	5.7±0.07		4.81±0.01

*= *D_1:50-100m; D_2: 100-150m; D_3: 150-200m,* (D_4): *Control-1000m*

Table 4: Mean ± SD of the effect of Incinerator Flue Gas on Heavy Metal concentrations in Soil at Graded Distances in Medical Centre, Abia State

Metal	Soil Depth	$^*D_1$	$^*D_2$	$^*D_3$	$LSD_{0.05}$ inter.	Control
Cu	R_1	2.00105±0.00	2.09050±0.00	2.02050±0.00		0.55 ± 0.01
	R_2	2.00305±0.00	2.09100±0.00	2.08050±0.00	0.0019***	1.25 ± 0.01
Zn	R_1	8.0150±0.03	4.0011±0.00	12.3250±0.00		1.25 ± 0.01
	R_2	8.0150±0.01	6.0405±0.01	6.0150±0.00	5.0208***	1.45 ± 0.01
Mn	R_1	5.0550±0.00	4.4500±0.01	7.0805±0.07		14.15 ± 0.07
	R_2	4.0150±0.00	6.0705±0.01	2.0605±0.07	0.07135***	13.15 ± 0.07
Cr	R_1	1.0950±0.01	0.2100±0.01	0.6050±0.01		0.02 ± 0.01
	R_2	1.7150±0.01	0.8050±0.01	0.6050±0.01	0.0212***	0.02 ± 0.01
Cd	R_1	0.000305±0.0	0.001100±0.00	0.000300±0.0		0.03 ± 0.01
	R_2	0.000505±0.0	0.001050±0.00	0.000000±0.0	0.0002**	0.00 ± 0.01
Pb	R_1	0.0905±0.01	0.0805±0.00	0.1050±0.00		1.63 ± 0.01
	R_2	0.0705±0.00	0.1150±0.00	0.0305±0.01	0.0100***	1.54 ± 0.01

*= *D_1:50-100m; D_2: 100-150m; D_3: 150-200m*

Table 5: Correlation Analysis of Heavy Metals of Soil in the Medical Incinerator Flue Gas Site

Variable	Copper	Zinc	Manganese	Chromium	Cadmium	Lead
Copper	1					
Zinc	-0.703*	1				
	0.011					
Manganese	-0.232	0.573	1			
	0.469	0.051				
Chromium	-0.709**	0.279	-0.075	1		
	0.01	0.38	0.817			
Cadmium	0.483	-0.505	0.35	-0.24	1	
	0.111	0.094	0.264	0.453		
Lead	-0.125	0.335	0.945**	-0.017	0.552	1
	0.7	0.288	0	0.958	0.063	

*** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).*

Table6: Eigen Vector Values for Principle Component of the effect of Hospital Incinerator Flue Gas on Heavy Metal concentrations

Variable	Factor 1	Factor 2
Cadmium (Cd)	0.17476	-0.54934*
Chromium (Cr)	-0.32795*	0.30285*
Copper (Cu)	0.52225*	-0.27343
Lead(Pb)	-0.3334*	-0.54331*
Manganese (Mn)	-0.41327*	-0.48055*
Zinc(Zn)	-0.55427*	0.07508
Eigen values	2.616	2.294
Percentage variation	43.60	38.24
Cumulative	43.60	81.84

* *($P \leq 0.05$)*

Contamination/Pollution Index(C/PI) **:** The pollution load values from incinerator flue gas within 50-200cm varied between mean of Cu (0.057-0.058) signifying severe contaminated , Zn (0.036-0.057) moderate to severe contaminated, Mn (0.006), Cr (0.005-0.014), Cd (0.001) and Pb (0.001) which is slightly contaminated respectively, which may cause severe, moderate and slight contaminated to soil if incinerator flue gas continued respectively (Table 7).

Contamination/Geo-Accumulation (**I_{geo}**)**:** The values of I_{geo} are shown in Table 8. Using the geo-accumulation indices, our study of soils within 50-200m from the incinerator where flue gas, mean Cu ranged between -4.6915 to -9.4389, Zn -4.7141 to -9.2228, Mn-4.8235 to -8.3841, Cr -6.7764 to -7.9658, Cd -10.2877 to -11.7027 and Pb-10.4103 to -11.2877 which were found in the class 0 uncontaminated remark indicating uncontaminated to moderately contaminated soil.

Table7: Contamination/Pollution Index of Heavy Metals in Soil sample at Graded Distances at Incinerator Flue Gas Site

Distant	Soil	Cu	Zn	Mn	Cr	Cd	Pb
	0 – 15	0.056	0.057	0.006	0.011	0.000	0.001
50 – 100m	15 – 30	0.058	0.057	0.005	0.017	0.001	0.000
	Mean	0.057	0.057	0.006	0.014	0.001	0.001
		SC	SC	SLC	SLC	SLC	SLC
	0 – 15	0.058	0.029	0.005	0.002	0.001	0.001
	15 – 30	0.058	0.043	0.007	0.008	0.001	0.001
	Mean	0.058	0.036	0.006	0.005	0.001	0.001
100- 150m		SC	MC	SLC	SLC	SLC	SLC
	0 – 15	0.058	0.029	0.005	0.002	0.001	0.001
150-200m	15 – 30	0.058	0.043	0.007	0.008	0.001	0.001
	Mean	0.058	0.036	0.006	0.005	0.001	0.001
		SC	MC	SLC	SLC	SLC	SLC

SC = severely contaminated; SLT = slightly contaminated; MC= moderately contaminated

Soil pH is an important index of ecological condition of terrestrial environment (Yaseen *et al.*, 2015). It is also reported that the pH of soils increases the mobility of Pb, Cd, Cr, Cu, Hg, Ni, and Zn in case of acidity while in alkaline condition the reverse phenomenon takes place (Gunjan and Neupane, 2015). The result of the study reveals that soil pH in the study location was slightly acidic with control location being highly acidic (Fig.1). The reason remains that the falling ash is a soil liming agent leading soil being slightly acidic. The result is consistent with the findings of Santosh (2009); Jason *et al.* (2016) who observed that storage of fly ash along with lime made the soil within paper industry alkaline due to increased pH to neutralize soil acidity at the surface. The result against the finding of Yaseen *et al.* (2015) who observed that the pH of soil was acidic near the kiln and neutral farther away.

Table 8: Contamination/geo-accumulation Index of Heavy Metals in the soil at Graded Distances at Incinerator Flue Gas Site

Distant	Depths	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	Cr (mg/kg)	Cd (mg/kg)	Pb (mg/kg)	Lgeo Class	Remark
50 – 100m	0 – 15	-4.7408	-4.0905	-7.4804	-7.9658	-11.7027	-10.2877	1	UC to MC
	15 – 30	-4.6981	-5.1278	-9.2877	-7.9658	-	-12.2877	1	UC to MC
Mean	Mean	-9.4389	-9.2228	-8.3841	-7.9658	-11.7027	-11.2877	1	UC to MC
100-150m	0 – 15	-4.7524	-4.7141	-4.6584	-7.0979	-11.7027	-10.4804	1	UC to MC
	15 – 30	-4.7524	-4.7141	-4.9885	-6.4548	-11.2877	-10.9658	1	UC to MC
Mean	Mean	-4.7524	-4.7141	-4.8235	-6.7764	-11.4952	-10.7231	1	UC to MC
								1	
150-200m	0 – 15	-4.6915	-5.7103	-8.1584	-9.5873	-10.2877	-10.7027	1	UC to MC
	15 – 30	-4.6915	-5.1178	-7.7027	-7.5573	10.2877	-10.1178	1	UC to MC
Mean	Mean	-4.6915	-5.4141	-7.9306	-8.55723	-10.2877	-10.4103	1	UC to MC

UC = uncontaminated; MC= moderately contaminated

Lower pH favors availability, mobility and redistribution of the metals in the various fractions due to increased solubility of the ions in acidic environment (Gunjan and Neupane, 2015; Jason *et al.,* 2016; Olayinka *et al*, 2017). The result further shows that the effect of soil depths and distances were highly significant ($p \leq 0.01$) on the level of soil pH in the sampled soil.The result of the effect of incinerator flue gas on heavy metals in soil varied between incinerator site and control at different distances. This was observed by Wenchao *et al*.; (2018) who explained that concentration of heavy metals in soil showed marginally significant differences in distances ($p>0.1$), and the maximum concentrations of these heavy metals were close to municipal solid waste incinerator (MSWI) within 500 m and 1000 m distances (Afzali *et al*., 2014). Gunjan and Neupane (2015) also reported that the average metal concentration showed a diverse variation with respect to direction and distance. The correlation result showed that Cr and Zn; Zn and Cu recorded negative relationship suspected to come from farming practices. Sailu (2014) observed that agricultural practices such as application of fertilizers and pesticides are known to increase the concentration of heavy metals in the soil while Mn and Cd recorded positive correlation suspected to come from incinerator flue gas. The strong correlations observed indicate that each of the paired elements in the soil has common contamination sources which in this case may be linked to incinerator flue smoke in the study. Olayinka*et al*., (2017) observed that higher concentration of cadmium at incinerator flue gas may be due to the wastes that contained Poly vinyl chloride (PVC), nickel-cadmium batteries.

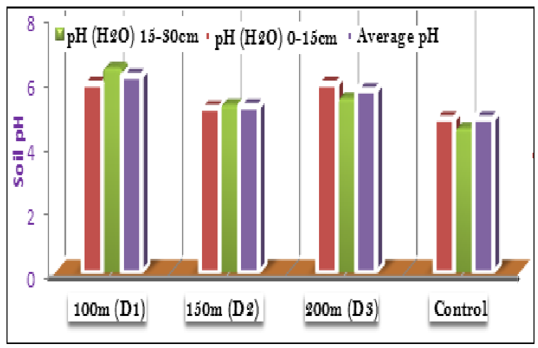

Fig 1: Variation of Soil pH in the Study and Control Locations in part of Abia State

The result of Cr obtained is lower than the critical permissible level which is 50 mg/kg-[1] for soil recommended for agriculture by MAFF (1992). Result of Zn correlation in soils obtained in the control is far below 548.56 - 642.94 obtained from hospital incinerator soil by Olayinka *et al.* (2017). These values are far lower than the natural limits of 0.01-3.0 mg/kg in soil as given by MAFF (1992) , and lower than the tolerable soil contamination standard (SCS) and sediment quality guideline (SQG) levels of concentration (Xu-Chen *et al.*, 2007).Positively loading in Factor 1 may be associated with flue gas while negatively loaded with Cr, Pb, Mn, and Zn may be associated with lithogenic. The result is consistent with the finding of Mmolawa *et al*.,2011) who reported that Mn and Zn are lithogenic in Botswana soil whereas Cu originate from various anthropogenic sources and is commonly associated with atmospheric emission (Steinnes *et al,* 2000). This factor is inorganic with the Eigen value of 2.6616 and account for 43.60 % of the total variance. Factor 2 was negatively loaded with Cd, Cu, Pb and Mn while Cr was positively loaded with the Eigen value of 2.94 accounting for 38.24 % of the total variance. Result further indicated that Cu was positively loaded due flue gas while negatively loaded Cr, Pb, Mn, and Zn were suspected to be due to the background values as lithogenic content, where environmental legislation has not yet established intervention limits for all environmental matrices (Albanese *et al.,* 2007). The pollution load values from incinerator flue gas. Cu indicates severe contamination, Zn moderate to severe contamination, Mn, Cr, Cd and Pb slightly contamination respectively. This is in line with the findings of Chen *et al*. (1994) who observed the existence of slight contamination by heavy metals in Taiyuan topsoil. Using the geo-accumulation index, mean Cu, Zn, Cr, Cd, and Pb were found in the class 0 uncontaminated remarks indicating uncontaminated to moderately contaminated soil. This is at variance with the finding of Hosik (2009) who observed the values of geo-accumulated risk (I_{-geo}) to be moderately to strongly contaminated in soils.

Conclusion: The average metal concentrations showed a diverse variation with respect to soil depths and distances. The control site was highly acidic due to sharp farm practices while the study site was slightly acidic due to flue ash as liming agent that encouraged mobility and absorption of heavy metals in the soil. Heavy metals such as Cr, Cd and Pb were below the limits for agricultural soil by FAO. Negative correlation exists between Cr and Zn; Zn and Cu due to farming practices, while Mn and Cd had positive correlation due to flue ash. C/PI shows slight, moderate and severe contaminations. I_{-geo} indicates uncontaminated to moderate contaminated due to medical waste incinerator flue gas.

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