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Analyses of Metal Cations in the Bottom Ash of Hospital Incinerator and Open Waste Burning Dumpsite in Umuahia, Abia State, Nigeria

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Abstract

This study determined the level of metal cations in incinerator bottom ash and open burning dumpsite in Medical Centre, Umuahia. Samples were collected at the depths of 0-15 cm, 15-30 cm from bottom ash, 0-15cm, 15-30cm and 30-45cm from soil within hospital open dumpsite. Metal cations were analyzed using the absorption spectrophotometer (AAS) and results subjected to principal component analysis (PCA), geo-accumulation (I_{-geo}) and Contamination/Pollution Index (C/PI) indices. Data presented using ANOVA, and mean separated with (LSD) at $P \leq 0.05$ and $p \leq 0.01$. Effect of soil depths on cation variability in ash and soil was significant at $p \leq 0.05$ and ≤ 0.01 levels respectively. Cations decreased in order of : $Zn^{2+} \geq Mn^{2+} \geq Cu^{2+} \geq Cr^{2+} \geq Pb^{2+}$ Cd^{2+}in bottom ash; $Zn^{2+} \geq Cu^{2+} \geq^{2+} Mn^{2+} \geq Cr^{2+} \geq Pb^{2+} \geq Cd^{2+}$ in open dumpsite. PCA indicate high loadings on Cu^{2+}, Pb^{2+}, Mn^{2+}, Cd^{2+} in ash while dumpsite loaded with Cd^{2+} , Cr^{2+}, Mn^{2+} and Zn^{2+}. C/PI decreased in order of: $Cu^{2+} \geq Zn^{2+} \geq Cr^{2+} \geq Mn^{2+} \geq Cd^{2+}/Pb^{2+}$ for bottom ash ; $Cu^{2+} \geq Zn^{2+} \geq Cr^{2+} \geq Mn^{2+} \geq Pb^{2+} \geq Cd^{2+}$ for open dumpsite indicating slight to very slight contamination respectively. I_{-geo} was in decreased order of: $Cd^{2+} \geq Pb^{2+} \geq Mn^{2+} \geq Cr^{2+} \geq Cu^{2+} \geq Zn^{2+}$in ash and $Cd^{2+} \geq Pb^{2+} \geq Mn^{2+} \geq Cr^{2+} \geq Zn^{2+} \geq Cu^{2+}$in dumpsite indicating uncontaminated to moderately status. Therefore, incinerator bottom ash should be properly managed through pretreatment and landfill disposal and open burning should be discouraged to avert further environmental pollution.

Keywords: Bottom ash; Open dumpsite; Multivariate analysis; Hospital wastes; metal cations

Introduction

Wastes are generated from human activities and in most cases not properly managed (Adefemi and Awokunmi, 2009; Saiani *et al*., 2014; Brunner and Rechberger, 2015). This leads to low environmental quality which accounts for 25% of all preventable ill health in the world (WHO, 2002). In developing countries of the world, medical waste incineration is the main strategy used in treating hospital wastes (Adama *et al*., 2016). Despite its advantages, the incineration of medical and municipal waste is a significant source of dioxins, furans, polychlorinated biphenyls (PCBs) and other toxic organic substances. Chlorinated compounds are formed by the presence of plastics, such as polyvinyl chloride (PVC) and disinfection products which contain chlorine (Adama *et al.*, 2016).Many developed countries have phased out the use of incineration for hospital waste management and have moved to treat hospital waste through the use of autoclave, microwave, and recycling as a way of mitigating health and environmental consequences (Igboekwe *et al.*, 2011; Anamul *et al.*, 2012; Ubuoh *et al*., 2019b). Meanwhile, developing countries are still practicing incineration and open burning leading to environmental degradation (Adama *et al.*, 2016).

Between 75% and 90% of the waste produced by health care providers is non-risk or general health care waste, and remaining the 10-25% of health care waste is regarded as hazardous and may create a variety of health risks (Racho, 2002; Auta and Morenikeji, 2013, Ubuoh *et al.*, 2014). The potential risk in healthcare waste management is a concerning issue nowadays (Racho, 2002; Lo and Liao, 2007; Shams and Purkayastha, 2011). During incineration, more toxic forms of some of these substances can be created (Beyersmann, 2002). Studies have reported heavy metals from incinerator ash leaked into drinking water resources (ATSDR, 2015; Ubuoh *et al*., 2019), thus incinerated hospital waste bottom ash has more heavy metals which if not well disposed of can pollute the environment and pose public health problems (Auta and Morenikeji, 2013; Mohajer *et al.*, 2013). Based on these environmental concerns, incinerator bottom ash and open dumpsite management have been under continuous scrutiny and control in recent times (Gidarakos *et al.*, 2009). Hospital waste incineration is known to not completely destroy the metallic components of the waste stream but rather concentrate heavy metals into the bottom ash (Anamul *et al.*, 2012, Yuanming *et al*, 2016).However, many researchers have done work on hospital waste incinerator ash outside Nigeria (Tanjim *et al.*, 2012; Adama *et al.*, 2016; Bakkali *et al*., 2013; Nkonge *et al.*, 2012; Batterman, 2004). In Abia State, there is no much attention given to hospital waste incinerator ash leading to scarce information with regards to the effects of elemental compositions in hospital incinerator bottom- ash and hospital open waste dumpsite in Medical Centre, Umuahia for effective and proper management of medical wastes.

The aim of this work was to identify metal cations and their levels in hospital incinerator bottom ash (HIBA) and hospital open dumpsite (HOD) exposed to incessant burning. The analysis output would provide valuable information for the decision making in the hospital waste management.

Materials and Methods

This study was carried out in the Federal Medical Centre; Umuahia in Abia State Nigeria (Fig. 1). The State is located on Latitude 5^{o}25'N and Longitude 7^{o}30'E. It occupies about 5,833.77sq.km with a population density of 450/km. The State has a population of about 2,833,999 (NPC,2006) with an average annual rainfall of 1900–2200 mm which is evenly distributed throughout the wet season with a temperature ranges of 21^{o}C–27^{o}C (NRCRI, 2014). Almost 90% of the total waste generated from all hospital areas is deposited at dumping sites located at an open reserve area (ABSEED, 2005).

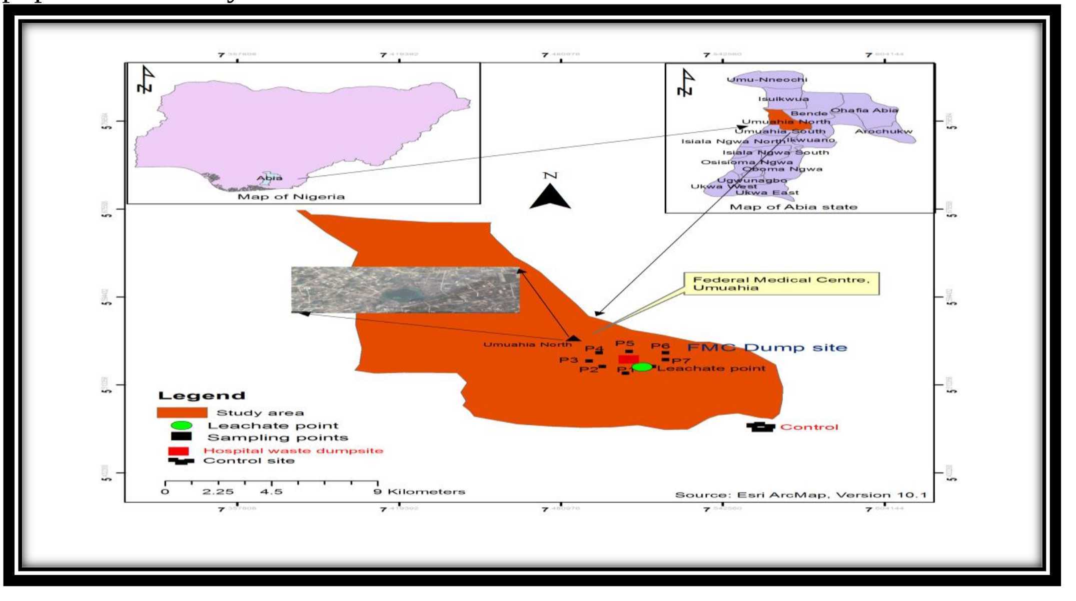

Fig.1: Map of Abia State Showing the Study Location

Samples collection and Preparation

Sampling locations were selected based on anthropogenic activities; such as hospital incinerator bottom ash (HIBA) where ash was collected from inside the incinerator and hospital open dumpsite (HOD) where soil samples were collect from Medical Centre in Umuahia. Soil sample was analyzed with two replicates and different depths: 0-15 cm, 15-30 cm from HIBA, and 0-15cm, 15-30cm and 30-45cm as control from hospital dumpsite using soil auger and transferred into cellophane bags, sealed with minimal air space and labeled with carbon free paper outside and stored in a cool place with a temperature of not more than 4^{o}C. Samples were air dried for 48 hours, and then sieved with 2 mm mesh to remove debris; gravel and other materials prior to analysis in Federal Department of Agricultural Land Resources and Climate Change Management's Laboratory, Umudike. Samples were also taken from sites according to global positioning system for accuracy. For incinerator ash-Latitude 5^{0}31'0.186 N; Longitude 7$^{o.}$29'38.088 E; for open burning-Latitude 5^{0}31'7.968 N; Longitude 7^{0}29'39.6442 E (Ubuoh *et al*, 2019).

Determination of Heavy Metals For $Zn^{2+}$and Mn^{2+}: 5g of the dried sieved soil was digested with HNO_3-HCl according to USEPA method 3050B to extract the metals. The concentrations of Zn^{2+} and Mn^{2+} were measured by Perkin-Elmer Analyst 300 atomic absorption spectrophotometer (AAS). Determination of Cu^{2+}, Cr^{2+} , Mn^{2+}, Cd^{2+} , Pb^{2+} in the soil was according to the method of Ideriah *et al*. (2007). Exactly 0.2 g of the soil sample was weighed and 6.0 ml freshly prepared aqua-regia (1:3) HNO_3: HCl respectively was added and allowed to stand overnight and placed in a digestion block for about 30mins. It was allowed to cool and then filtered into a 100 ml volumetric flask with distilled water according to the method of Olayinka *et al.* (2017). The filtrate was analyzed for selected heavy metals using Perkin-Elmer Analyst 300 atomic absorption spectrophotometer (AAS). Before the analysis, equipment was calibrated using the appropriate standards.

Multivariate Statistics

The index of geo-accumulation (I_{geo}): I_{geo} is calculated to estimate the enrichment of metal concentrations above the background level which was proposed by Muller (1969) (Table 1). I_{geo} is calculated using following equation:

$$\mathbf{I_{geo} = Log_2(\frac{C}{n}\ \ 1.5_B)n}$$

Equation 1

Where C_n = the measured concentration of heavy metal in the soil sample.

B_n = the geochemical background concentration of the heavy metal

Table 1: Showing categorization of geo-accumulation (I_{-geo})

I_{-geo} value	I_{-geo} class	Designation of soil quality
>5	6	Extremely contaminated
4-5	5	Strongly to extremely contaminated
3-4	4	Strongly contaminated
2-3	3	Moderately to Strongly contaminated
1-2	2	Moderately contaminated
0-1	1	Uncontaminated to Moderately contaminated
0	0	Uncontaminated

Muller, 1996

Contamination/Pollution Index (C/PI) of the Metals

The Contamination/Pollution Index (C/PI) of the metal cations in hospital bottom ash and the soil from open dumpsite were calculated using the scheme formulated by Lacatusu (2000).

$$\frac{\mathbf{C}}{\mathbf{PI}} = \frac{\textbf{Concentration of metals in the soil}}{\textbf{Target values from reference table}}$$

Equation 2

The target values were obtained by using standard formulated by the Department of Petroleum Resources of Nigeria (DPR), cluster abundant values for maximum allowable concentration of heavy metals in soil in mg/hg^{-1}(Cd:0.8, Cr:100, Cu: 36, Pb:85, Zn:140, Mn: 439, Fe 57. Contamination /Pollution index values greater than 1, defines pollution range, but when it is less than 1, it defines contamination range (Lacatusu, 2000). The significance of contamination /pollution index is shown in Table 2.

Table 2: Showing the significance of intervals of contamination/pollution index (C/PI)

C/PI	Significance	ACRONYM
<0.1	Very slight contamination	VSLC
0.10 – 0.25	Slight contamination	SLC
0.26 – 0.5	Moderate contamination	MC
0.51 – 0.75	Severe contamination	SC
0.76 – 1.00	Very severe contamination	VSC
1.1 – 2.0	Slight pollution	SLP
2.1 – 4.0	Moderate pollution	MP
4.1 – 8.0	Severe pollution	SP
8.1 – 16.0	Very severe pollution	VSP
>16.0	Excessive pollution	EP

Lacatusu (2000).

Principal Component Analysis (PCA)

Principal component analysis (PCA) was performed to establish possible factors that contribute towards the metal cation concentrations and source apportionment. All data set was subjected to factor analysis (FA). The number of significant principal components (PC) was selected on the basis of Varimax orthogonal rotation with Kaiser Normalization with eigenvalue ≥ 1. (Ruiz et *al*, 1998; Hu *et al*, 2011; Ubuoh and Ekpo, 2017):

$$Z_{ji=}a_{fi}\dot{f}_{i} + a_{f2}\ f2i + a_{f3}f_{3i} + \ldots + a\ f_{m}a_{f}f_{mi} + e_{fi}$$

Equation 3

Where:

z = measured variable,
a = factor loading,
f = factor score,
e = residual term accounting for errors or other sources of variation,
i = sample number and
m = total number of factors.

Statistical Analysis. For all the metal cations in bottom ash and the soils tested, comparisons of means were analyzed statistically using analysis of variance (ANOVA). The post-hoc test was also carried out to determine the significant at $p\leq 0.05$ using Least Squared Difference (LSD). The relationships between cations at different depths of incinerator bottom ash and open dumpsites were subjected to multivariate analysis. Pearson correlation analysis was used to assess the correlation between the metals in the soil. All statistical analyses were performed using SPSS version 22.0 and Microsoft Excel 2013.

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Results and Discussion

From Table 3, the mean values of Cu^{2+}, Zn^{2+}, Mn^{2+}, Cd^{2+}, and Pb^{2+} recorded no significant different at $p\geq 0.05$ between the two bottom ash depths. However, means of Cr^{2+} had significant difference between 0-15cm and 15-30cm depths at $p\leq 0.05$. Cations abundance in bottom ash were in decreased order of $Zn^{2+} \geq Mn^{2+} \geq Cu^{2+} \geq Cr^{2+} \geq Pb^{2+} \geq Cd^{2+}$, with corresponding values of 17.5 mg/l, 6.4 mg/l, 3.0 mg/l, 2.9 mg/l, 0.116 mg/l, 0.0007mg/l respectively . Accordingly, Adama *et al (*2016) detected highest concentration of Zn among the sampled metals in the hospital waste incinerator bottom ash in Ghana. The finding was similar to researches carried out in Morocco and Kenya (Nkonge *et al.,* 2012; Bakkali *et* *al.,* 2013). The heavy metals found in the bottom ash are usually associated with the waste feed stock (thermometers, blood pressure cuffs, laboratory chemicals, plastics, syringes, etc.) or construction material of the incinerator (Sturz *et al.,* 1998). The high levels of Zn may be due to the clay used to make the bricks from which incinerators were built and the fact that many of the medical items are made of metal alloys such as Zn and Ti (Sturz *et al.,* 1998; Zhao *et al*., 2010). The decreasing Pb in bottom ash was suspected to be due to fewer components of incinerated sharp objects which consisted of needles and plastic syringes. This result is in tandem with the finding of Zhao *et al.* (2009) who observed low concentration of Pb^{2+} in hospital incinerator bottom ash. The result is at variant with the finding of Hickman (1987) who reported that Pb and Cd are the two most often found metals in medical waste which mostly come from plastics. Nkonge *et al.,* (2012) also found high concentrations of Cr, Cd and Pb from ash residues from incinerated ash which is against the result of the recent study that reported less concentration in hospital incinerator bottom ash in Umuahia. In general, the levels of metal cations in the bottom ash revealed a wide variation in concentrations due to the hospital wastes contents. Accordingly, a wide variation in the concentration of metals was due to diversity in the initial waste compositions, design of incinerator and, operating conditions (Sabiha *et al.,* 2008).

The cation like Zn^{2+} being dominant factor present in the incinerator bottom ash , if it reacts with oxygen and/or water can generate hydrogen gas and the different stoichiometrical equations of the reactions are given below (Pera *et al.* 1997; Saikia *et al.,* 2015; Garcia *et al.,* 2016; Aneeta *et al.,* 2018):

$$\mathbf{Al + 2OH- + H_2O \rightarrow [AlO\,(OH)_2] - + H_2 \uparrow pH > 7} \quad \ldots \quad \textbf{Equation 5}$$

$$\mathbf{Al + 2OH- + 6H_2O \rightarrow 2[Al\,(OH)_4\,] - aq + 3H_2} \quad \ldots \quad \textbf{Equation 6}$$

$$\mathbf{Zn + 2OH- \rightarrow ZnO\,2^{2-} - + H_2} \quad \ldots \quad \textbf{Equation 7}$$

$$\mathbf{2Al + Ca\,(OH)_2 + 2H_2O \rightarrow Ca\,(AlO_2) + 3H_2} \quad \ldots \quad \textbf{Equation 8}$$

It is also reported that, a widespread use of hydrogen could, of course, have unknown environmental effects due to increased anthropogenic emissions of molecular hydrogen in the atmosphere (Tromp *et al.,* 2003). The H_2 gas production in storage facilities of ashes is problematic (Mizutani *et al*, 1999; Ilyas et *al*, 2010; Hiraki *et al*, 2005). Emissions of hydrogen result to increased burdens of eight methane and ozone and hence to an increase in global radioactive forcing. Hydrogen is accordingly an indirect relatively active trace gas with a global warming potential (Derwent *et al.*, 2001; US D.O.E, 2003).

Table 3: Metal Cations in Incinerator Bottom Ash in Federal Medical Centre, Umuahia

Ash Depths	Incinerator bottom ash sample					
	Cu^{2+} (Mg/l)	Zn^{2+}(Mg/l)	Mn^{2+}(Mg/l)	Cr^{2+},(Mg/l)	Cd^{2+}(Mg/l)	Pb^{2+}(Mg/l)
R_1-0.15cm	1.9900± 0.02[a]	11.520±0.05[a]	4.300± 5.43[a]	2.400 ±0.28[a]	0.0007 ±0.00[a]	0.0790± 0.10[a]
R_2-15-30cm	2.0110 ± 0.003[a]	11.900±1.20[a]	4.100± 0.50[a]	1.090 ±0.11[b]	0.0006 ±0.00[a]	0.073 ±0.01[a]
Mean	3.0	17.5	6.4	2.9	0.0007	0.116
SEM	0.0090	0.6010	2.7300	0.1510	0.0001	0.4960
F-LSD$_{0.05}$	0.0545	3.6590	1.6590	0.9210	0.0004	0.3016

Means with the same letter (s) in superscripts along the column are not significantly different at ($p< 0.05$).

Table 4: Pearson Correlation Matrix of Metal Cations in the Incinerator Bottom Ash in Medical Centre, Umuahia

Variables	Cu^{2+}	Zn^{2+}	Mn^{2+}	Cr^{2+}	Cd^{2+}	Pb^{2+}
Cu^{2+}	1					
Zn^{2+}	0.32	1				
	0.68					
Mn^{2+}	-0.858*	-0.134	1			
	0.142	0.866**				
Cr^{2+}	-0.69	-0.224	0.237	1		
	0.31	0.776	0.763			
Cd^{2+}	-0.133	-0.953*	0.091	-0.081	1	
	0.867	0.047	0.909**	0.9198**		
Pb^{2+}	-0.867	-0.113	0.999**	0.26	0.063	
	0.133	0.887	0.001	0.74	0.937**	1

**** Correlation is significant at 0.01 levels (2-tailed).**

*** Correlation is significant at 0.05 levels (2-tailed).**

From the result in Table 4 , there is negative correlation existing between Mn^{2+} and Cu^{2+} at the surface of the incinerator bottom ash (r^2:-0.86), Mn^{2+} positive with Zn^{2+} (r^2:0.87), and Cd^{2+} negatively correlated with Zn^{2+} (r^2 :0.95), and Cd^{2+} positively correlated between Mn^{2+} and Cr^{2+} (r^2:0.91, r^2:0.92), Pb^{2+} positively correlated with Mn^{2+} (r^2:0.10) and Cd^{2+} (r^2:0.94) respectively. The results show correlations between cation compositions at $p \leq 0.01$ and $p \leq 0.05$ levels at the topsoil and subsoil respectively.

Table 5: Varimax Rotated Matrix of Metal Cations in incinerator bottom- ash in Federal Medical Centre, Umuahia

S/N	Variables	Component (PC_1)	Component (PC_2)
1	Cd^{2+}	-0.165	0.692
2	Cr^{2+}	-0.310	-0.084
3	Cu^{2+}	0.549	0.099
4	Pb^{2+}	-0.508	-0.200
5	Mn^{2+}	-0.508	-0.181
6	Zn^{2+}	0.243	-0.657
	Eigen values	**3.168**	**1.854**
	Percentage variation (%)	**52.79**	**30.91**
	Cumulative (%)	**52.79**	**83.69**

From Table 5, two components were considered in the factor analysis in bottom ash .The first component explains 52.79% of the total variance with loading on Cu^{2+}, Pb^{2+} and Mn^{2+} respectively. The second component explains 30.91% of the total variance with loading on Cd^{2+}, Zn^{2+} with the two components constituting 83.80%. The positive loaded metal cations are suspected to have originated from hospital wastes in incinerator. The negative loaded metal cations are suspected to have originated from geogenic sources. Several of these cations are carcinogens or can cause neurological, hematopoietic effects in humans (Denison and Ruston, 2013).

Table 6: Metal Cations in Hospital Open Waste Burning in Medical Centre, Umuahia

Soil Depths	Soil Sample: Hospital Open Waste Burning					
	Cu^{2+} Mg/l	Zn^{2+} Mg/l	Mn^{2+} Mg/l	Cr^{2+} Mg/l	Cd^{2+} Mg/l	Pb^{2+} Mg/l
R_1	2.015 ± 0.01^{b}	7.0150 ± 0.01^{b}	1.4050 ± 0.01^{a}	1.085 ± 0.01^{c}	0.001 ± 0.00^{b}	0.021 ± 0.00^{a}
R_2	2.0002 ± 0.00^{ab}	9.0021 ± 0.00^{c}	3.0700 ± 0.00^{c}	0.905 ± 0.00^{a}	0.00031 ± 0.00^{a}	0.051 ± 0.00^{b}
R_3	1.997 ± 0.00^{a}	6.0805 ± 0.00^{a}	2.5050 ± 0.01^{b}	1.050 ± 0.07^{b}	0.00105 ± 0.00^{c}	0.0505 ± 0.01^{c}
Mean	4.7	7.4	2.3	1.5	0.0008	0.04
SEM	0.0034	0.0041	0.0041	0.2920	0.00004	0.0029
F-$LSD_{0.05}$	**0.0152^{NS}**	**0.0131^{***}**	**0.0184^{***}**	**0.1312***	**0.0013*** **	**0.0131*** **

Means with the same letter (s) in superscripts along the column are not significantly different d ($p< 0.05$).

Results in Table 6 indicated that, the mean values of metal cations in soil sampled from open waste burning site such as Zn^{2+}, Mn^{2+}, Cr^{2+}, Cd^{2+} and Pb^{2+} were significantly different from each other, while Cu^{2+} was insignificant at various soil depths at $p \leq 0.05$ respectively. There were significant differences between depths R_1 and R_3 for the mean value of Cu^{2+} while insignificant difference existed at R_1 and R_2 at $p \leq 0.05$ respectively. The effects of depth on metal cations availability on soil was highly significant at ($p \leq 0.01$) for Zn^{2+}, Mn^{2+}, Cd^{2+} and Pb^{2+} respectively. Above all, the levels of metal cations in the hospital open waste burning site were in decreased abundance order of $Zn^{2+} \geq Cu^{2+} \geq^{2+} Mn^{2+} \geq Cr^{2+} \geq Pb^{2+} \geq Cd^{2+}$ having corresponding values of 7.4mg/l, 4.7mg/l, 2.3mg/l, 1.5 mg/l, 0.04mg/l, 0.001 mg/l with Zn^{2+} dominating that may precipitate as hydroxide that can increase environmental pollution and disturbance of ecological balance, through biological adsorption and chemical ion-exchange. The result is in tandem with the findings of Alba *et al.* (1997) in Spain, Zhao *et al.* (2009) in China who reported that Zn recorded the highest concentration among other heavy metals in hospital wastes.

Table 7: Pearson Correlation Matrix of Metal Cations in the Hospital Open Waste Burning Site in Medical Centre, Umuahia

Variable	Cu^{2+}	Zn^{2+}	Mn^{2+}	Cr^{2+}	C d^{2+}	Pb^{2+}
Cu^{2+}	1					
	0.032					
Zn^{2+}	0.063	1				
	0.905**					
Mn^{2+}	-0.744	0.519	1			
	0.09	0.292				
Cr^{2+}	0.443	-.821*	-0.81	1		
	0.378	0.045	0.051			
Cd^{2+}	0.188	-.963*	-0.717	0.935**	1	
	0.721	0.002	0.109	0.006		
Pb^{2+}	-0.686	-0.708	0.236	0.267	0.503	1
	0.132	0.115	0.652	0.609	0.309	

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

Compositional relations in hospital open dumpsite is indicated in (Table 7), showing correlations between cationic compositions at $p \leq 0.01$ and $p \leq 0.05$ levels at the top and subsoil's respectively. From the result , there is positive correlation between Cu^{2+} and Zn^{2+}, Zn^{2+} correlated negatively with Cr^{2+} and Cd^{2+}, Cr^{2+} correlated Cd^{2+}·, Mn^{2+} and Pb^{2} defines no relationship with any of the cations. The presence of toxic cations such as Cu^{2+} and Zn^{2+} at high concentrations in ashes was probably the result of their use as alloys for medical equipment (needles, dissecting equipment's) (Athanasius *et al.*,2008). Ultimately, 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 the open dumping of incinerator ash. The negative correlation between cations may be the changes in their chemical forms (speciation) and bioavailability (Wuana and Okieimen, 2011).

Table 8: Principal Component Analysis of elemental composition hospital open dumpsite in Medical Centre, Umuahia

Variable	Component (PC_1)	Component (PC_2)
Cadmium (Cd^{2+})	0.51679*	-0.1058
Chromium (Cr^{2+})	0.50886*	0.07237
Copper (Cu^{2+})	0.17926	0.61705*
Lead (Pb^{2+})	0.19277	-0.62192*
Manganese (Mn^{2+})	-0.42216*	-0.37454*
Zinc (Zn^{2+})	-0.4759*	0.27525
Eigen values	**3.646**	**2.191**
Variation (%)	**60.77**	**36.52**
Cumulative (%)	**60.77**	**97.29**

From Table 8, two components were considered in the factor analysis. The first component explains 60.77% of the total variance with loading on Cd^{2+}, Cr^{2+}, Mn^{2}, and Zn^{2+}. The second component explains 36.52% of the total variance with loading on Cu^{2+}, Pb^{2+}, and Mn^{2+} constituting 97.29% variation of metal cations in hospital waste dumpsite. The strong correlations observed in Cd^{2+}, Cr^{2+}, Zn^{2+} in PC_1 indicate that each of the paired elements has common contamination sources which in this case may be linked to the hospital dumpsite. Ultimately, the percentage load of cations was higher in HOD with 97.29% than 83.7% in HIBA in the study area due to reduction in waste volume and reactivity in hospital incinerator than hospital open dumpsite burning. The result conforms to the finding of Zakaria *et al.* (2005) who observed that incineration processes can easily destroy organic compounds and some metals found in hospital wastes. This also conforms to the earlier finding by Pickens (2007) who indicated that the use of De Montfort incinerator for healthcare waste treatment is better than open waste burning. The result of the study did not form with the finding of Amfo-Out *et al.* (2015) who reported that concentrations of the heavy metals from the incinerated ash were higher than the counterpart from the open-pit in Ghana

Table 9: Contamination/Pollution Index (CPI) of Metal Cations in Hospital Incinerator Bottom Ash (HIBA) and Hospital Open Dumpsite (HOD) in Umuahia

Soil Depth	Cu^{2+}	Zn^{2+}	Mn^{2+}	Cr^{2+}	Cd^{2+}	Pb^{2+}
			Hospital Incinerator Bottom ash			
0 – 15	0.106	0.103	0.001	0.022	0.001	0.000
15 – 30	0.106	0.101	0.004	0.012	0.001	0.001
0 – 15	0.105	0.102	0.011	0.026	0.001	0.002
15 – 30	0.106	0.109	0.005	0.010	0.001	0.001
Mean	**0.106**	**0.104**	**0.005**	**0.040**	**0.001**	**0.001**
Significance	SC	SC	VSC	VSC	VSC	VSC
			Hospital Open Dumpsite			
0 – 15	0.106	0.100	0.002	0.011	0.001	0.000
15 – 30	0.106	0.104	0.004	0.009	0.000	0.001
30 – 45	0.105	0.043	0.003	0.010	0.001	0.006
Mean	**0.106**	**0.102**	**0.003**	**0.023**	**0.001**	**0.002**
Significance	*SC	SC	VSC	VSC	VSC	VSC

***SC:** slight contamination; VSC: Very slight contamination;

Pollution index for incinerator bottom ash (HIBA) and hospital open dumpsite for metal cations at different depths are presented in Table 9. From the result of the pollution indices at 0-15cm, 15-30cm, 30-45cm soil depths for Cu^{2+}, Zn^{2+}, Mn^{2+}, Cr^{2+}, Cd^{2+} and Pb^{2+} with the mean values ranged between 0.001-0.106 where Cd^{2+} and Pb^{2+} recorded the lowest mean pollution indices and Cu^{2+} recorded the highest mean index indicating very slight contamination and slight contamination HIBA respectively. The contamination index of heavy metals in hospital open dumpsite also follow the same trend of HIBA where Cu^{2+} recorded the highest mean index (0.106) with Cd^{2+} being the lowest mean index (0.001) indicating slight contamination and very slight contamination respectively.

Table 10: Pollution /geo-accumulation index of heavy metals in Hospital incinerator bottom ash and Hospital Open Dumpsite

Depths	Cu^{2+}	Zn^{2+}	Mn^{2+}	Cr^{2+}	Cd^{2+}	Pb^{2+}	I_{geo}Class	*Remark
			Hospital Incinerator Bottom ash					
A.0 – 15	-4.75	-4.18	-11.29	-6.09	-10.97	-13.29	1	*UC to MP
15 – 30	-4.75	-4.04	-8.38	-10.32	-11.29	-10.97	1	UC to MP
B.0 – 15	-4.76	-4.19	-7.29	-5.84	-10.97	-9.70	1	UC to MP
15 – 30	-4.75	-4.25	-8.16	-7.20	-10.70	-10.70	1	UC to MP
Mean	**-4.76**	**-4.22**	**-7.724**	**-6.52**	**-10.84**	**-10.20**	**1**	UC to MP
			Hospital Open Dumpsite					
0 – 15	-4.75	-4.90	-9.83	-6.38	-10.29	-12.29	1	UC to MP
15 – 30	-4.75	-4.54	-8.97	-7.38	-11.70	-11.29	1	UC to MP
30 – 45	-4.76	-5.11	-8.97	-7.36	-10.29	-8.00	1	UC to MP
Mean	**-4.75**	**-4.85**	**-9.25**	**-7.04**	**-10.76**	**-10.53**	**1**	UC to MP

* UC to MP: uncontaminated to Moderately Polluted

Using the geo-accumulation and pollution indices, our study of hospital incinerator bottom ash and soil from open dumpsite were uncontaminated to moderately contaminated with metal cations such as Cu^{2+}, Zn^{2+}, Mn^{2+}, Cr^{2+}, Cd^{2+}, and Pb^{2+} in hospital incinerator bottom ash and hospital open dumpsite respectively , with Cu^{2+} dominating and Pb^{2+} being the lowest (Table 10).The results is in consonant with the finding of Adama *et al.* (2016) who reported moderate contamination/pollution from incinerator site in Ghana. The result is in tandem with the findings of Zhao *et al.* (2009), Zhao *et al.* (2010), Kougemitrou *et al.* (2011), Saleh (2016) who observed that bottom ash produced by hospital incinerators contained high levels of heavy metals such as Zn , Pb, Cr, Cu, Mn and Cd, that can create a significant risk to the environment. Therefore, the produced bottom ash from the two incinerators may be classified as hazardous wastes, and care should be taken during dumping (Gautam et *al*., 2010; Nurmesniemi *et al.*, 2012).

Conclusion

The study revealed varied heavy metals concentrations in the bottom ashes from the hospital incinerator bottom ash and hospital open dumpsite waste. From the study, metal cations were found in decreasing abundance order of $Zn^{2+} \geq Mn^{2+} \geq Cr^{2+} \geq Pb^{2+} \geq Cu^{2+} \geq Cd^{2+}$ in incinerator bottom ash; $Zn^{2+} \geq Cu^{2+} \geq^{2+} Mn^{2+} \geq Cr^{2+} \geq Pb^{2+} \geq Cd^{2+}$ in open dumpsite through burning, with Zn^{2+} dominating respectively. Result of Principal Component Analysis recorded high loading on Cu^{2+}, Pb^{2+}, Mn^{2+}, Cd^{2+} in bottom ash that constituted 83.7% less than 97.29% in open dumpsite with loading on Cd^{2+}, Cr^{2+}, Mn^{2+} and Zn^{2+}. Cations with positive loadings: Cu^{2+}, Zn^{2+} in PC_1, Cd^{2+} in PC_2 of incinerator bottom ash and Cd^{2+}, Cd^{2+} (PC_1), Cu^{2+} (PC_2) of open burning originated from bottom ash and open burning respectively. Results of contamination index of metal cations indicate slight contaminated and very slight contaminated in bottom ash and open dumpsite respectively. The result of pollution index indicated uncontaminated to moderately pollution in bottom ash and open burning respectively. Therefore, incinerator bottom ash should be properly managed through pretreatment and engineering landfill disposal and open burning should be discouraged to avert human health and environmental consequences from improper medical wastes management.

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References

Abia State Economic Empowerment and Development Strategy (ABSEEDS) (2005). Abia State Economic Empowerment and Development Strategy, Publication: Umuahia: Abia State of Nigeria. *Physical Description*. Pp.126.

Adama, M. R. Esena, B. Fosu-Mensah, and Yirenya-Tawiah, D. (2016). Heavy Metal Contamination of Soils around a Hospital Waste Incinerator Bottom Ash Dumps Site. Hindawi Publishing Corporation.

Journal of Environmental and Public Health Volume 2016, Article ID 8926453, 6 pages.

Adefemi, O. S., and Awokunmi, E. E. (2009). The impact of municipal solid waste disposal inAdo-Ekiti metropolis, Ekiti State, Nigeria. *Afri. J. Environ. Sci. Technol.*, *3*(8), 186-189.

Agency for Toxic Substances and Diseases Registry (ATSDR) (2015). *Agency for Toxic Substances and Diseases Registry,* Toxicological Profiles, Toxic Substances Portal.

Alba, N., Gasso, S., Lacorte, T., and Baldasano, H. (1997). "Characterization of Municipal Solid Waste Incineration Residues from Facilities with Different Air Pollution Control System." *Waste Management* 47: 1170-1179.

Al-Meshan, M., Nasrallah, H., and Ahmed, A. (2001).Comparative Study of Heavy Metals in Bottom Ash from Hospital Incinerators in the State of Kuwait." *Kuwait Journal of Science* 28 (2): 347-857.

Amfo-Otu,R., Kyerewa, S. G., Ofori, E. A and Sadick, A (2015). Comparative study of heavy metals in bottom ash from incinerators and open pit from healthcare facilities in Ghana. *Oct. Jour. Env. Res.* Vol. 3(1): 050-056.

Anamul, H.M.D; Rahman, J. and Tanvir, M. (2012). Zn and Ni of bottom ash as a potential diffuse pollutant and their application as fine Aggregate". *Journal of Civil Engineering Research,* Vol.2 (6), pp. 64-72.

Aneeta, M. J., Ruben, S., Philip, V. H., Stijn, M and Nele, D. B. (2018). The Use of Municipal Solid Waste Incineration Ash in Various Building Materials: A Belgian Point of View. *Review. MPI* Materials 2018, 11, 14.

Athanasios, V., Nikiforos, I., Konstantinos, F., Athanasios, V. , Nikiforos, I. and Konstantinos, F. (2008). Metal leachability, heavy metals, polycyclic aromatic hydrocarbons and polychlorinated biphenyls in fly and bottom ashes of a medical waste incineration facility. Los Angeles, London, New Delhi and Singapore .

Auta, T. and Morenikeji, O. A. (2013). Heavy metal concentrations around a hospital incinerator and a municipal dumpsite in Ibadan City, South-West Nigeria," *Journal of Applied Sciences and Environmental Management,* Vol. 17(3):pp. 419–422.

Bakkali, M. E.L , Meriem, B., Said , G., Hassan, J., Mohammed, B. , Amin, L. and Mohammed, E (2013). "Characterization of bottom ash from two hospital waste incinerators in Rabat,Morocco," *Waste Management & Research*, Vol. 31 (12), pp.1228–1236.

Batterman, S. (2004). *Findings on Assessment of Small scale Incinerators for Health-Care* Waste, Water, Sanitation and Health Protection of the Human Environment, World Health Organization, Geneva, Switzerland.

Bayersman, (2002). Effects of Carcinogenic Metal on Gene Expression" *Toxicology Letters,* Vol. 127, No. 1- 3, Pp. 63 – 68.

Brunner, P. H.; Rechberger, H. (2015) Waste to energy – key element for sustainable waste management. *Waste Management*, Vol.37, p.3-12, 2015.

Denison, R, and Ruston, J. (2013). Environmental Defense Fund. Part Two: Health and Environmental Risks of MSW Incineration and Their Control. In Denison R, Ruston J (eds.). Recycling and Incineration: Evaluating The Choices. Washington, US: Island Press; 2013 [cited 2017 Mar 21]. Available from ProQuest ebrary Web.

Derwent, R.G., Collins, W.J., Johnson, C.E., and Stevenson, D.S. (2001). Transient behaviour of tropospheric ozone precursors in a global 3-D CTM and their indirect greenhouse effects, *Climatic Change*, 49, 463-487.

Dresselhaus, M; Crabtree, G.; Buchanan, M.; Mallouk, T.; Mets, L.; Taylor, K. (2014). Basic Research Needs for the Hydrogen Economy. Report of the Basic Energy Sciences Workshop on Hydrogen Production, Storage and Use, May 13-15, 2003, report, February 1, 2004; United States.

Garcia-Lodeiro, I.; Carcelen-Taboada, V.; Fernández-Jiménez, A.; and Palomo, A. (2016) . Manufacture of hybrid cements with fly ash and bottom ash from a municipal solid waste incinerator. *Constr. Build. Mater*. 105, 218–226.

Gautam, V., Thapar, R., and Sharma, M (2010)."Biomedical waste Management: Incineration vs. Environmental Safety." *Indian Journal of Medical Microbiology* 28 (3): 131-192.

Gidarakos, E., Pentrantonaki, M., Anastasiadou, K. and

Schramm, K.W. (2009). Characterization and Hazard Evaluation of Bottom Ash Produced from Incinerated Hospital Waste, *Journal of Hazardous Materials*, Vol. 172, No, 2-3, Pp. 935 -942.

Hickman (1987). Cadmium and Lead in Bio-Medical Waste Incinerators," *Master of Science Thesis*, University of California, Davis.

Hiraki T., Takeuchi M., Hisa, M. and Akiyama, T. (2005). Hydrogen Production from waste aluminum at different temperatures with LCA. *Materials Transactions*, 46(5), pp. 1052-1057.

Hu, K. L. Zhang, F. R Lu, Y. Z Wang, R. and Xu, Y (2011). Spatial distribution of concentrations of soil heavy metals in Daxing county, Beijing," *Acta Scientiate Circumstantiae*, Vol. 24 (3), pp. 463–469.

Ideriah , T. J. K., Omuaru, V. O.T. and Osaisai, C. B (2007). Concentrations of Heavy Metals in Leachates and Water around Solid Waste Dumpsites in Port Harcourt, Nigeria. *Curr. Top. Toxicol*., 4:45-50.

Igboekwe, M.U. and Adindu, R. (2011). Groundwater Recharge through Infiltration Process. A case study of Umudike, Southeastern Nigeria. *Journal of Water Resource and Protection* **3**(5): 66-78.

Ilyas, A. , Badshah, M. , Praagh, M.V. and Persson, K.M. (2010) . Evaluation of gas production from MWI bottom ash. *Conference: Third International Symposium on Energy from Biomass and Waste*. November 2010.

Lacatusu, R., (2000). Appraising level of soil contamination and pollution with heavy metals. In: Heinike, H.J., Eckselman, W., Thomasson, A.J., Jones, R.J.A., Montanarella, L., Buckley, B. (Eds.), Land Information Systems for Planning the Sustainable Use of Land Resources, European Soil Bureau Research Report. No. 4. Office of Official Publication of the European Community's Luxembourg, pp. 393–402.

Lo, H., and Liao, Y. (2007). "The Metal Leaching and Acid-neutralizing Capacity of Msw. Incinerator Ash Co-disposed with Msw. in Landfill Sites." *Journal of Hazardous Materials* 142: 512-519.

Mizutani S., Sakai S. and Takatsuki, H. (1999). Investigation of hydrogen generation from municipal solid waste incineration fly ash. *Journal of Material Cycles and Waste Management* 2(1):16-23.

Mohajer, R.; Salehi, H.; Mohammadi, M.; Emami, H. and Azarm, T. (2013). The Status of lead and cadmium in soils of high prevalenct gastrointestinal cancer region of Isfahan", *Journal of Research in Medical Sciences*, Vol.18 (3), pp. 210-214.

Mu¨ller, G (1969). Index of geoaccumulation in sediments of the Rhine River. Geoj 2:108–118 municipal solid waste incineration fly ash. *J. Mater. Cycles Waste Manag*., 2, pp. 16-23.

National Population Commission (NPC) (2006) . *National Population Commission Census Data*, Abia State, Nigeria.

National Root Crop Research Institute, (NRCRI),(2014). *Meteorological Data*. Nigeria Tribune Newspaper, 18, 2010.pp.17-19

Nkonge, N.A., Magambo K.J., Oloo M., Kithinji J. and Ndwiga, T. (2012). Groundwater Pollution Risk from Incinerated Health-Care Waste Bottom-Ash at a National Teaching and Referral Hospital in Kenya. *Greener Journal of Medical Sciences*, **2**(6):157-162.

Nurmesniemi, R., Poykio, K., Manskinen, O. D., and Makela, M. (2012). "Comparison of the Forest Fertilizer of Fly Ash Fractions from the MW Power Plant of a Fluting Board Mill Incinerating Peat and Forest Residues." *The 27th International Conference on Solid Waste Technology and Management*, March 11-14, Ph. Pa., USA, 706-716.

Olayinka, O. O; Akande, O. O. Bamgbose, K. and Adetunji, M. T (2017).Physicochemical Characteristics and Heavy Metal Levels in Soil Samples obtained from Selected Anthropogenic Sites in Abeokuta, Nigeria. *J. Appl. Sci. Environ. Manage.* Vol. 21 (5) 883-891

Pera, J.; Courtaz, J.; Ambroise, J. and Chababbet, M. (1997). Use of Incinerator Bottom Ash in Concrete. Cem. *Concr. Res.* , 27, 1–5.

Picken, D. J. (2007). De Montfort medical waste incinerators. (Accessed 15th January, 2015 at http://www.mwincinerator.info/en/101_welc ome.html

Racho, P (2002). A study of heavy metals in bottom ash from medical waste incinerator in Nakhonratchasima Municipality. *A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master in Environmental Engineering*

Suranaree University of Technology.

Ruiz, F . Gonz´alez-Regalado, M. L Borrego, J. Morales, J. A. Pend´on J. G., and. Mu˜noz, J. M. (1998). Stratigraphic sequence, elemental concentrations and heavy metal pollution in Holocene sediments from the Tinto-Odiel Estuary, southwestern Spain," *Environmental Geology*, Vol. 34:(4), pp. 270–278.

Sabiha, -J., Tufail , M and Sofia, K. (2008). Heavy metal pollution from medical waste incineration at Islamabad and Rawalpindi, Pakistan. *Microchemical Journal* 90 ,77–81.

Saiani, C. C. S.; Dourado, J.; and Toneto Jr, R. T.(2014). Resíduos sólidos no Brasil: oportunidades e desafios da lei federal nº 12.305 (lei de resíduos sólidos). Barueri – SP, Brazil: *Minha Editora*, 2014.

Saikia, N.; Mertens, G.; van Balen, K.; Elsen, J. V., Gerven, T. and Vandecasteele, C. (2015) Pre-treatment of municipal solid waste incineration (MSWI) bottom ash for utilisation in cement mortar. *Constr. Build. Mater*. 96, 76–85.

Saleh , A. (2016).Heavy Metal Determination in the Bottom Solid Waste Ash Produced from Sabah and Shuaiba Hospital Incinerators in Kuwait . *Journal of Environmental Science and Engineering* B 5. 215-223 .

Shams, M.T. and Purkayastha, T. (2011).Heavy metal assessment of incinerated medical waste. *B.Sc Engineering Project. Department of Civil and Environmental Engineering, Shahjalal* University of Science and Technology, Sylhet, Bangladesh.

Sturz, A., Itoh, M and Smith, S. (1998). "Mineralogy and chemical composition of clay minerals, TAG hydrothermal mound," in *Proceedings of the Ocean Drilling Program, Scientific Results*, P. M. Herzig, S. E. Humphris, D. J. Miller, and R. A. Zierenberg, Eds., p. 158, Texas A&M University, College Station, Tex, USA,

Tanjim, M.S.; Sourav, R.; Kabir, M. and Purkayastha, T. (2012). *Assessment of Heavy Metal Contamination in Incinerated medical Waste.* Department of Civil and Environmental Engineering, Shahjalal University of Science and Technology, Sylhet. *ARPN Journal of Science and Technology* Vol. **2**(10): 2225-7217.

Tromp, T. K., Shia, R. L., Allen, M., Eiler, J. M. and Yung, Y. L. (2003). Potential environmental impact of a hydrogen economy on the stratosphere. *Science* 300(5626): 1740-1742**.**

Ubuoh , E. A, Ezenwa, L. E. Ndukwu, M. C. and Emeka-Chris, C.C.(2019). Assessment of cation chemistry of groundwater near hospital wastes dumpsites in Umuahia Nigeria using multivariate and analytical index approach. *Environmental Technology & Innovation* Elsevier ,15 100371.

Ubuoh E.A. , Nwawuike N. and. Obeta, M.C. (2014): Environmental Risk Assessment of Heavy Metal Concentrations in Road Runoff with Absorption Atomic Spectrophotometer , Imo State, Nigeria.*Journal of Environment and Earth Science (USA*).www.iiste.or Vol. 4(5): ISSN 2225 -0948 .

Ubuoh, E. A. and Ekpo , F. E. (2017). Characterization by Principal Component Analysis (PCA) of the Chemistry of Atmospheric Precipitation in oil and non-oil producing Communities of Akwa Ibom State, Nigeria. CARD *International Journal of Environmental Studies and Safety Research (IJESSR*) , Vol. 2 (1), : 2536-7285.

Ubuoh, E.A., Umezuruike, S.O. Nworuh, B.O and Emeka, C. C. (2019b).Assessment of Soil pH and Heavy Metal Concentrations in Agricultural Land Impacted with Medical Waste Incinerator (MWI) Flue Ash (FA) in Abia State, Nigeria. *J. Appl. Sci. Environ. Manage.* Vol. 23 (2) :275–282.

US D.O.E. (2003). Basic Research Needs for the Hydrogen Economy. http://www.sc.doe.gov/bes/hydrogen.pdf. reterieved on 2010-07-27

World Health Organization (WHO) (2002). Water, *Sanitation and Hygiene*. World Health Organization, Geneva.

Wuana, R. A. and Okieimen, F. E. (2011) "Heavy metals in contaminated soils: a review of sources, chemistry, risks and best available strategies for remediation," *ISRN Ecology*, vol. 2011,Article ID 402647, 20 pages.

Yuanming, S., Baoling, L., En-Hua, A.M. Yiquan, L., and Zhitao, C. (2016).Gas Generation from Incinerator Bottom Ash: Potential Aerating Agent for Lightweight Concrete Production. Mater. Civ.

Eng., 2016, 28(7): 04016030.

Zakaria, M., Labib, O., Mohammed, M., El-Shall, W., and Hussein, A. (2005). Assessment of Combustion Products of Medical Waste Incinerators in Alexandria." *The Journal of the Egyptian Public Health Association* 80 (3-4): 407-431.

Zhao, L., Zhang, F., Mengjun, L., Zhen, G. L., and Wu, D. (2010).Typical Pollutants in Bottom Ashes from a Typical Medical Waste Incinerator." *Journal of Hazardous Materials* 15 (173): 181-185.

Zhao, L., Zhang, F., Wang, W., and Zhu, J. (2009). "Chemical Properties of Heavy Metals in Typical Hospital Waste Incinerator Ashes in China." *Waste Management Journal* 29 (3): 114-115.