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Heavy Metals in Soils, Ash and *Tridax Procumbens* in the Vicinity of the University College Hospital Incinerator in Ibadan, South-West, Nigeria

Falana H. Damilola and Olajumoke A. Morenikeji*

Abstract
Heavy metal concentrations in soils and *Tridax procumbens* in the vicinity of the University of Ibadan College Hospital incinerator and in its bottom ash were determined. The concentrations of chromium, cadmium, lead and nickel were checked in soil and plant at some distances of 10m, 20m, and 30m away from the incinerator between June and August using atomic absorption spectrophotometry. There was a control site at 7km away from the incinerator. The mean concentrations of heavy metals in soils from the incinerator site were in the order: Ni > Cr > Pb > Cd. Concentrations of Cr, Cd, Pb, and Ni were highest at 10m from the incinerator. The mean concentration of Cr (42.90 ± 8.93mg/kg), Cd (4.40 ± 3.39mg/kg) and Ni (87.40 ± 8.98mg/kg) were however significantly higher at 10m from the incinerator when compared to the corresponding concentrations at the control site ($p < 0.05$). The mean concentrations of heavy metals in plant from the incinerator site were in the order Cr > Pb > Ni > Cd. Concentrations of Cr, Pb, and Ni in plant were highest at 10m from the incinerator while Cd concentrations were highest at 30m. The mean concentration of Ni (19.41 ± 12.65mg/kg) was however significantly higher at 10m from the incinerator when compared to the corresponding concentration at the control site ($p < 0.05$). Mean concentrations of Cr and Pb were higher in the ash when compared with concentrations in soil and plant samples. Heavy metal concentrations were however within the permissible limits specified by USEPA. Potential effect of the incinerator on the soil and plant around the area is minimal and might therefore present negligible impact on the population living around the area. However, there is a need to carefully dispose of the bottom ash to avoid the hazards of fly ash.

Key words: Heavy metals, Incinerator bottom ash, Soil, *Tridax procumbens*, University College Hospital.

Introduction

Heavy metals constitute an ill-defined group of inorganic chemical hazards, and those which are most commonly found at contaminated sites are Lead (Pb), Chromium (Cr), Arsenic (As), Zinc (Zn), Cadmium (Cd), Copper (Cu), Mercury (Hg), and Nickel (Ni) [1]. Heavy metals have been known to act as biological poisons due to their bioaccumulation abilities. Their levels are highly concentrated in soil and sediments, which are readily taken up by plants during growth [2]. Not all the traces of heavy metals in plants and animals are the results of human activity. Some arise through the absorption processes of naturally occurring soil components. Purely theoretically, every 1000 kg of "normal" soil contains 200g of chromium, 80g of nickel, 16g of lead, 0.5g of mercury and 0.2g of cadmium; therefore it is not always easy to assign a definite cause for increased heavy metal content [3]. Toxic metals are daily ingested by humans either through air, food, water and soil.

Wastes generated from medical activities can be hazardous, toxic and even lethal because of their high potential for disease transmission and incineration has been used for treating or managing these wastes [4]. However incinerators do not solve the problems of toxic materials present in wastes. Toxic materials are simply converted to other forms, some of which may be more toxic than the original materials. Emissions can then re-enter the environment as contaminants in stack gases, residual ashes, and wastewater [5]. Even, the most technologically advanced incinerators emit thousands of pollutants that contaminate air, soil and water. Identified emissions include heavy metals such as lead, cadmium, arsenic, chromium, mercury, halogenated hydrocarbons, acid gases, particulate matter, and volatile organic compounds such as dioxin and furans.

Falana H. Damilola and Olajumoke A. Morenikeji*
**Department of Zoology, University of Ibadan, Ibadan, Nigeria*

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Medical wastes have been reported to contain toxic heavy metals and persistent organic pollutants [6 - 8]. Metal distribution between soil and vegetation is a key issue in assessing the effect of metals in the environment [9].

Plants of the family Asteraceae such as *Chromolaena odorata*, *Tridax procumbens, Synedella nodiflora*, and *Vernonia cinerea* have been reported to be heavy metal tolerant (survive and thrive) and bioaccumulators [10-11]. *Tridax procumbens* is traditionally used in the treatment of fever, typhoid fever, cough, asthma, epilepsy and diarrhoea [12]. This study aims to determine the concentrations of some heavy metals in the bottom ash, soil and *Tridax procumbens* found around the University College Hospital incinerating site.

Materials and Methods

Study Site

The sampling site was the incinerator at the University College Hospital (U.C.H) Ibadan, Oyo state, Nigeria. The sampling site lies between longitude 7° 24′ North and latitude 3° 54′ East (Fig. 1). Biomedical wastes generated in the hospital are trucked to the site to be burnt at the incinerator. Ashes generated are collected and packed in metal and plastic drums for onward disposal at Apete dumpsite in Ibadan. The control site was a location (Wadie Martin road, University of Ibadan campus) 7km away from the incinerator site, where no incineration of wastes takes place.

Collection of Samples

The soil and plant samples were collected at the U.C.H incinerator site over a period of three months from June to August, 2012. The samples were collected at some distances of 10m, 20m and 30m away from the incinerator (three samples each for soil and plant). The soil samples were collected at a depth of about 15cm using a hand trowel. The choice of plant species collected was based on its importance and presence in relation to other plant species found at the site. Plant samples were collected within an area of 2m by 2m. Identification and authentication of plant (UIH-22338) was done at the Herbarium in the Department of Botany, University of Ibadan. All the samples were collected in polythene bags and labelled accordingly. Soil and plant samples were dried in an oven at a temperature of 80°C, ground into finer sample using a mortar and pestle and then sieved. Ash samples were collected at the incinerator base.

Analysis of Samples

The heavy metals determined were: Cadmium (Cd), Chromium (Cr), Lead (Pb), and Nickel (Ni). Samples (0.5g each) were weighed into 150 ml conical flask, 10 and 20ml of acid mixture of $HCLO_4$:HNO_3 respectively at ratio 1:2 was added [13]. The conical flask was placed on a digester hot plate in a fume cupboard and the mixture was heated until it turned colourless. Heating was done at 150°C for about thirty minutes and then allowed to cool. The digest was filtered into a 25ml volumetric flask and made to mark with distilled water. Heavy metals concentrations in the digest were made to mark with distilled water and heavy metal concentrations (mg/kg) measured using atomic absorption spectrophotometer (Buck scientific AAS 210/211 VGP).

The soil pH was determined by weighing 10g of soil into a beaker followed by addition of 10ml distilled water (ratio 1:1). The mixture was stirred using a stirring rod and the pH of the soil was measured using a pH meter.

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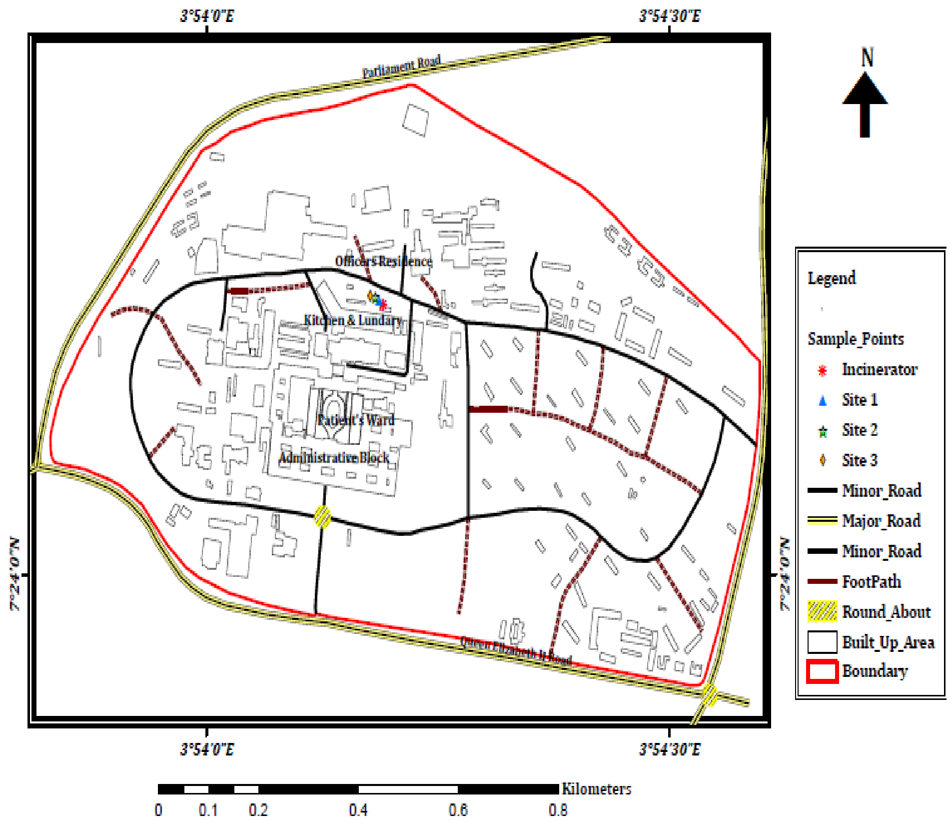

Fig. 1: Map of University College Hospital showing the Sampling points.

Data Analysis

Descriptive statistics (mean and standard deviation), ANOVA with Duncan's multiple range test and Pearson correlation were carried out using SPSS version 16.0. The magnification coefficient which is the concentration of heavy metals in the plant divided by the concentration in the soil sample was calculated to show the rate of uptake of the heavy metal by the plants. The level of significance was set at $p < 0.05$.

Results

Heavy Metals in Soil Samples

Metal concentration in the soil from the incinerator site ranged from 7.85mg/kg to 49.05mg/kg for Cr, from ND to 8.15mg/kg for Cd, from ND to 101.50mg/kg for Pb, from 13.40mg/kg to 95.90mg/kg for Ni while for the control soil, metal concentration ranged from 10.00mg/kg to 23.10mg/kg for Cr, from ND to 1.00mg/kg for Cd, from ND to 0.50mg/kg for Pb, from 21.40mg/kg to 31.40mg/kg for Ni. At a distance of 10m from the incinerator, concentrations of Cr, Cd, Pb, and Ni were higher compared with other distances. The concentrations of Cr, Cd and Ni were however significantly higher at the distance of 10m from the incinerator when compared to the metal concentrations at the control site (Table 1). The trends of heavy metals across the month are shown in Figure 2. Soil pH values ranged from 6.3 to 8.4 in the incinerator site while it ranged from 6.0 to 7.4 in the control site.

Table 1: Concentrations of Heavy Metals in Soil from the Incinerator and Control Site during Study Period

Heavy metals	Distance (m)	Range (mg/kg)	Mean	S.D
Cr	10	32.65 - 49.05	42.90^{b}	8.93
	20	7.85 - 21.4	13.08^{a}	7.28
	30	11.6 - 30.8	18.66^{a}	10.55
	Control	10 - 23.1	18.36^{a}	7.26
Cd	10	1.55 - 8.15	4.40^{b}	3.39
	20	ND – 1	0.33^{a}	0.57
	30	ND - 0.5	0.16^{a}	0.28
	Control	ND – 1	0.33^{a}	0.57
Pb	10	ND - 101.5	33.83^{a}	5.86
	20	ND - 0.5	0.16^{a}	0.28
	30	23 - 43.5	31.66^{a}	10.61
	Control	ND - 0.5	0.16^{a}	0.28
Ni	10	78 - 95.9	87.40^{b}	8.98
	20	13.4 – 52	27.90^{a}	21.01
	30	17.65 - 29.95	22.75^{a}	6.41
	Control	21.4 - 31.4	27.91^{a}	5.64

Means with superscript ‘b’ are significantly higher at $p < 0.05$.
ND = Not Detected

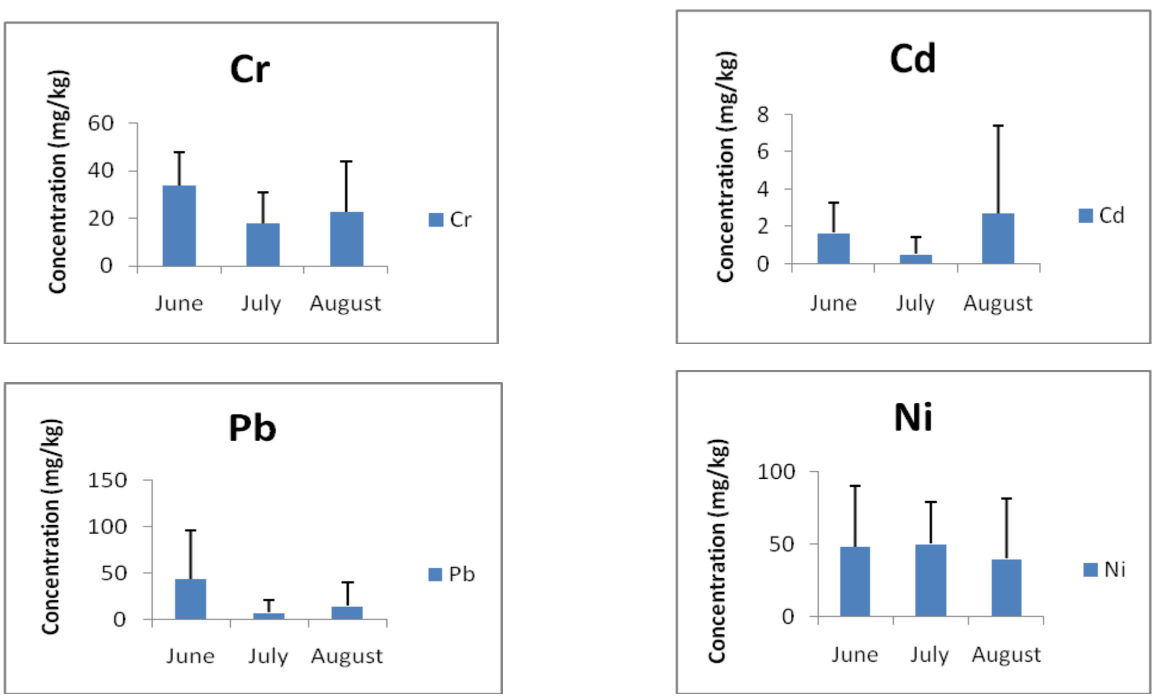

Fig. 2: Monthly trend showing metal concentrations in soil samples. Bars indicate standard deviation.

Heavy Metals in Plant Samples

Cr concentration in plants from the incinerator site ranged from ND to 267.65mg/kg, Cd ranged from ND to 2.00mg/kg, Pb ranged from ND to 129.00mg/kg, Ni ranged from ND to 33.80mg/kg, while in the control plant, Cr concentration ranged from ND to 10.40mg/kg, Cd ranged from ND to 0.50mg/kg, Pb ranged from ND to

10.00mg/kg, Ni ranged from ND to 0.05mg/kg. At 10m from the incinerator, concentrations of Cr, Pb, and Ni were higher compared to other distances while Cd showed higher concentration at the distance of 30m. The concentration of Ni was however significantly higher at the distance of 10m from the incinerator when compared to the concentration at the control site (Table 2). The trends of metal across the month are shown in Figure 3. Magnification coefficients for the heavy metals Cr, Cd, Pb and Ni were 1.37, 0.28, 0.66, 0.16 respectively. Heavy metals reduced in concentration through the months except Cd which later increased in August. Positive correlation was observed in heavy metal concentration between soil and plants except for Cadmium. These relations were however only significant for Nickel ($r = 0.783$) at $p<0.05$ (Table 5).

Heavy Metals in Ash

Mean concentration of each metal in ash from the incinerator base is as follows: 117.40 ± 35.78mg/kg for Cr, 1.61 ± 1.46mg/kg for Cd, 56.50 ± 6.11mg/kg for Pb, 13.46 ± 6.87mg/kg for Ni.

Comparison of Mean Concentration of Heavy Metals in Soil, Plant and Ash

Mean concentrations of Cr and Pb were higher in the ash when compared with concentrations in soil and plant samples. However, concentration of Ni was highest in the soil while Cd concentration was slightly higher in soil than in the ash sample. The plant had the lowest concentrations of the heavy metals except for Cr whose concentration was higher than in the soil sample (Table 4).

Table 2: Concentrations of Heavy Metals in Plant from the Incinerator and Control Site during Study Period

Heavy metals	Distance (m)	Range (mg/kg)	Mean	S.D
Cr	10	ND - 267.65	95.31[a]	149.52
	20	ND - 8.9	2.96[a]	5.13
	30	ND - 13.25	4.41[a]	7.64
	Control	ND - 10.4	3.46[a]	6.00
Cd	10	ND – 1.0	0.33[a]	0.57
	20	ND - 0.5	0.16[a]	0.28
	30	ND – 2.0	0.88[a]	1.02
	Control	ND - 0.5	0.16[a]	0.28
Pb	10	ND – 129	43.01[a]	74.47
	20	ND – 1.0	0.33[a]	0.57
	30	ND - 0.5	0.16[a]	0.28
	Control	ND – 10	3.33[a]	5.77
Ni	10	10.25 - 33.8	19.41[b]	12.65
	20	ND - 0.1	0.033[a]	0.057
	30	ND - 11.75	3.91[a]	6.78
	Control	ND - 0.05	0.016[a]	0.028

Means with superscript ‘b’ are significantly higher at $p < 0.05$.
ND = Not Detected

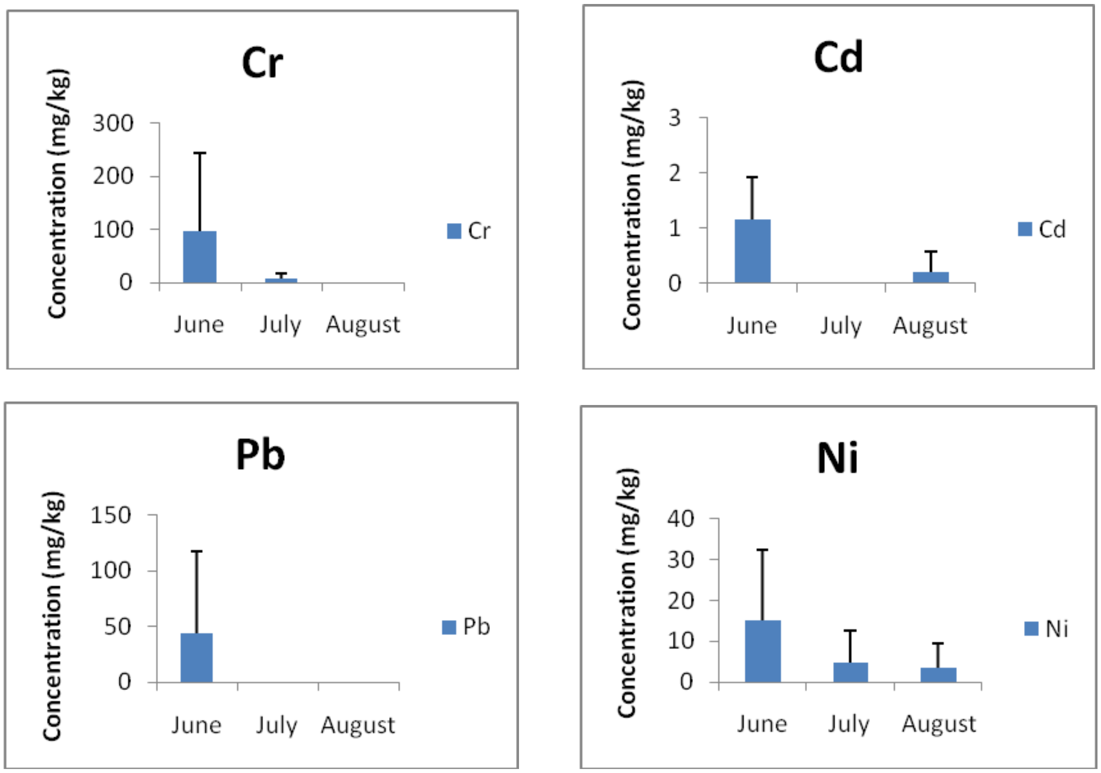

Fig. 3: Monthly trend showing metal concentrations in plant samples. Bars indicate standard deviation.

Table 3: Acceptable Limits of Metal Concentrations in USEPA [14] and British Geological Survey [15] compared with sampled Soils in the Study

	Incinerator site (mg/kg)	U.S.E.P.A (mg/kg)	B.G.S (mg/kg)
Cr	24.88	230	100 – 150
Cd	1.63	70	1 – 1.2
Pb	21.88	400	70
Ni	46.01	1600	50 – 60

Table 4: Mean Concentration of Heavy Metals in Soil, Plant and Ash during Study Period

	Soil mg/kg	Plant mg/kg	Ash mg/kg
Cr	24.88 ± 15.79	34.23 ± 87.80	117.40 ± 35.78
Cd	1.63 ± 2.69	0.46 ± 0.68	1.61 ± 1.46
Pb	21.88 ± 33.95	14.50 ± 42.93	56.50 ± 6.11
Ni	46.01 ± 33.30	7.76 ± 11.39	13.46 ± 6.87

Table 5: Correlation between Heavy Metals in Soil and Plant Samples

Metals	**r value**
Cr	0.600
Cd	-0.120
Pb	0.879
Ni	0.783*

* Correlation is significant at the 0.05 level.

Discussion

Heavy Metals in Soil Samples

Concentrations of some of the investigated metals in soil were found to decrease with increasing distance from the incinerator. The mean concentration of heavy metals in soil from the incinerator site was in the order Ni > Cr > Pb > Cd. It was expected that the concentrations of heavy metals in soil from the incinerator site should be significantly greater than in soil from the control site. At the distance of 10m, all the heavy metals investigated were higher in concentrations compared to the metal concentrations at other distances and control site. However, it was only at 10m away from the incinerator that there were significant differences in chromium, cadmium and nickel concentrations in soil from the incinerator site when compared to soil from the control site. At 20m and 30m away from the incinerator, there was no significant difference between heavy metals in soil from the incinerator and control site. Chromium, cadmium and lead concentrations in soil from the incinerator site decreased from the month of June to July, and later increased in August. Nickel concentration increased from June to July then decreased in August. Metal concentrations in soils were within acceptable concentrations in comparison with USEPA and British Geological Survey which implies that there was no marked heavy metal contamination in soil from the incinerator site and that decrease in the concentrations of heavy metals through the months might have been due to leaching in the soil caused by rainfall. The pH of soil ranged between 6.30 and 8.40 while the mean soil pH was 7.23. The pH is the most important factor influencing metal uptake. In particular, a decrease in soil pH from 7 to 4 causes an increase in the uptake of Cd and Ni. However, when considering usual acidity levels in agricultural soils, a pH decrease had no observed effect on Pb and Cr uptake [16]. At pH of 2 to 3, more heavy metals can be absorbed by plants and indeed absorption of lead can increase with increasing pH from 3 to 8.5 [17, 18, 19]. The leachability of Chromium (VI) increases as soil pH increases and arsenic mobility increases while in acidic soils, nickel becomes more mobile and often leaches down to the adjacent groundwater [1].

Variation in heavy metal concentration may also be due to potential changes in the emission of metals from anthropogenic activities and heterogeneity of the samples [20]. There was no major or extensive contamination of cadmium and lead measured in soils in the vicinity of an incinerator in comparison to observed background concentrations [21]. Concentrations of heavy metals investigated near a municipal solid waste incinerator were lower than concentration used as baseline levels [20]. Metal concentrations in the vicinity of a hazardous waste incinerator were not significantly higher than acceptable limits [22].

Heavy Metals in Plant Samples

The mean concentrations of heavy metals in plant from the incinerator site was in the order Cr > Pb > Ni > Cd. In the plant, all the heavy metal concentrations showed no significant difference with the varying distances from the incinerator except nickel which was significantly higher in the plant that was at 10m away from the incinerator as compared to the control site. At distances of 20m and 30m from the incinerator, there was no significant difference between the concentrations of heavy metals in plant from the incinerator and from the control site. Monthly trends showed that chromium concentration decreased from June to August, cadmium concentration decreased from June to July then increased in August while lead and nickel concentrations decreased through the months in the plants. Concentrations of heavy metals in plants were generally lower than the concentration in the soil. Low concentrations of heavy metals in the plant may be due to the fact that the heavy metals may have been bio-accumulated in other part of the plant other than the leaf. Roots of plants have been reported to have a greater concentration of heavy metals than other plant parts such as the shoot and the foliage [22]. This is because the root is the site of nutrient uptake and storage [18]. Sikora et al. [23] reported that there were no "safe" regulatory limits on soil metal concentrations for vegetable gardens; however at a lead concentration of 0 to 100mg/kg, Hamel et al. [24] reported that there was no need to be concerned about lead exposure while a concentration of 400mg/kg and above required abatement measures. Several factors such as sampling season, homogeneity of samples and other potential pollutant sources could be responsible for uptake of heavy metals from soil by plants [25].

Plants of the family Asteraceae have been reported to be heavy metal accumulators although they may be slow growing producing low biomass, thereby using longer period (years to decades) to clean up contaminated sites [1]. This might have also affected the concentration of heavy metal that the plant is able to take up.

Heavy Metals in Soil and Plant Samples

The mean levels of heavy metals in the soil are generally higher than that of the plant samples. Positive correlations between soil and plants have been reported by Onder et al. [26] and Addo et al. [25]. Negative correlation of cadmium in soil and plant might point to the fact that the plant could assimilate elements through other organs other than the roots or have high affinity for assimilation of some elements directly from atmospheric deposition [25].

Heavy Metals in Ash

Wastes such as gloves, drips, pads, syringes, cotton wool, disposables (cups and plates), broken glass, bandages, canned drinks, nylon, cardboard and papers which are incinerated contain metals such as lead, cadmium, manganese, chromium, zinc and copper and thus, become concentrated in bottom ash after incineration. However, the concentrations of heavy metals present in ash investigated in this study were lower than the concentrations for bottom ash reported by Alba et al. [27]. Ash is usually permanently stored in landfills or monofills [26] or used in the construction of roads. Erosion over time could result in the release of persistent toxic substances back to the environment and, therefore poses potential danger to humans [5].

Bottom ash from the incinerator in the present study is usually transported in drums and sacks to a dumpsite for disposal in another part of Ibadan city. In the course of transportation, ash may become fly ash and could also fall off along the road path. Soil and plant in this present study were relatively uncontaminated. This may be due to the fact that the work was carried out in the rainy season and over a period of three months (June, July, August). It is therefore recommended that sampling should be carried out over longer period and in both the dry and rainy season. From the study, the potential effect of the incinerator on the soil and plant around the area is minimal and would therefore present negligible impact on the population living around the area. There is however a need to carefully dispose of the bottom ash to avoid the hazards of fly ash.

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