



Physicochemical Characteristics and Heavy Metal Levels in Soil Samples obtained from Selected Anthropogenic Sites in Abeokuta, Nigeria

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ABSTRACT: This study assessed the effect of heavy metals introduced into the soils through human activities which can bio-accumulate in plants and passed to man via the food chain that can pose health risk. Topsoil samples were collected from selected anthropogenic and control sites (dumpsites, mechanical workshops, abattoirs, fuel filling stations and hospital incinerators) in Abeokuta, Nigeria at the depths 0-5cm, 5-10cm and 10-15cm. Physicochemical parameters such as pH, moisture content, bulk density, organic matter, organic carbon, particle size distribution and Mn, Zn, Pb, and Cd were analyzed in soils using standard methods. Soil pH values ranged from 5.17 - 8.28, moisture content ranged from 3.50 - 28.55 %, bulk density ranged from 0.78 - 2.29 gcm⁻³, organic matter ranged from 0.09 - 16.01 %, organic carbon ranged from 0.02 % - 8.48 %. Mean concentrations of heavy metals (mgkg⁻¹) ranged from 182.69 ± 61.95 - 697.06 ± 85.62; 122.69 ± 30.04 - 632.94 ± 508.79; 19.38 ± 6.72 - 158.50 ± 71.41; 0.25 ± 0.00 - 1.63 ± 1.38 for Mn, Zn, Pb and Cd respectively. Distribution pattern of heavy metals in petrol stations, abattoirs, mechanic workshops and hospital incinerator sites were Mn > Zn > Pb > Cd, while for dumpsites Zn > Mn > Pb > Cd. Pollution index indicated that soil qualities varied between slightly contaminated to severely polluted status. This showed that the heavy metal contamination of the soils does not call for any alarm; proactive measures must be taken to minimize accumulation of these metals. ©JASEM

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Heavy metals are released into the environment by both natural and anthropogenic sources. The main natural sources of metals in soils are chemical weathering of mineral; the anthropogenic sources are associated mainly with industrial, agricultural, mining, land disposal of waste, waste incineration, mechanic workshop and fuel filling station (Fernando *et al.*, 2012). Heavy metals contamination of topsoil has been a major concern regarding their toxicity, persistence and non-degradability in the environment. Toxicity of these compounds has been reported extensively (Momodu and Anyakora, 2010; Anyakora *et al.*, 2011). They accumulate overtime in soils, which act as a sink from which these toxicants are released to the groundwater and plants and end up through the food chain thereby causing various toxicological effects. Effects of elevated concentrations of heavy metals to soil functions, soil microbial composition and microbial growth have long been reported under both field and laboratory condition (Tyler *et al.*, 1989). Health effect of elevated levels of Zn are severe vomiting, diarrhoea, bloody urine, liver, kidney failure and anaemia (Fosmire, 1990), while excessive Pb poison causes inhibition of haemoglobin synthesis, dysfunction in the kidneys, reproductive systems and cardiovascular system (Ferner, 2001). Other effects of Pb poison are damage to gastro-intestinal system, mental retardation in children, abnormalities in fertility and pregnancy (Dara, 2000). Excess Cd have being reported to bring about renal dysfunction, anaemia,

hypertension, bone marrow disorder, cancer, kidney damage, bronchitis, liver and brain disorder (Dara, 2000), while, high concentration of manganese could results in kidney failure, liver and pancreases malfunctioning (Underwood, 1977). Human activities in urban areas largely contribute to the contamination of urban soils and this is a major health concern. Iwegbu *et al.*, (2006) reported elevated concentration of Cd, Cr, Cu, Pb, Ni, and Zn in an automobile mechanic workshop soil while Dauda and Odoh, (2012) in their study revealed the high degree of contamination of Pb, Cd and Zn in soil from fuel filling stations in Benue state. In addition, Ubwa *et al.*, 2013 reported high levels of Cd, Zn, Ni, Cr and Pb from soil around the Gboko Abattoir. The extent of human impact is now so pervasive and profound, that there is need to investigate the levels of heavy metals in soils from different anthropogenic sites. The objective of this study is to determine the physicochemical characteristics and heavy metals in surface and sub-surface soil samples from control sites and selected anthropogenic sites (dumpsites, mechanical workshops, abattoirs, fuel filling stations and hospital incinerators) in Abeokuta, Nigeria.

MATERIALS AND METHODS

Description of study area: Abeokuta is the capital of Ogun State, southwestern Nigeria. It is situated between latitudes 7° 6'N to 7° 13'N and longitudes 3°16'E to 3° 25'E on the east bank of the Ogun River, around a group of rocky outcroppings that rise above

the surrounding wooded savanna (Hoiberg, 2010). The city is situated 81 km south-west of Ibadan and 106 km north of Lagos with population of 593,100 by World Population Reviewed (WPR, 2015). Abeokuta is within the rain forest zone of Nigeria; and enjoys a tropical climate with distinct wet and dry seasons with dry period of about 130 days (Orebiyi *et al.* 2008). It has a high population density of more than 500 persons per hectare. The population have continue to grow making the city to sprawl toward surrounding villages and smaller towns such as Ajebo, Osiele, Odeda, Imala, Aro to mention a few.

Samples collection and Preparation: Sampling locations were selected based on anthropogenic activities; such as dumpsites, abattoirs, mechanic workshops, petrol stations, hospital incinerator sites and soil samples collected from the same sources in Abeokuta city and also from two control sites (uncultivated forest and lawn) in Federal University of Agriculture Abeokuta.

Samples were collected at different depths (0-5 cm, 5-10 cm, 10-15 cm) using soil auger and transferred into cellophane bags, tightly sealed with minimal air space and labelled with carbon free paper outside and stored in a cool place to prevent breaking down of organic matter. Samples were air dried for 48 hours, and then sieved with 2 mm mesh to remove debris, gravel and other materials prior to analysis.

Soil Analysis: Determination of pH (H₂O): The pH of soil samples was determined according to Bamgbose *et al.* (2000). 10 grams of the air dried sample were weighed into 100 ml beaker and 20 ml of distilled water was added. The mixture was allowed to stand for 30minutes with occasional stirring with glass rod. The electrode of calibrated pH meter (Horiba pH meter D-51) was inserted into the partially settled suspension and the pH of the soil was measured.

Determination of Bulk Density: Bulk density was determined according to the method of Hunt and Gilkes, (1992) adopted by McKenzie *et al.* (2004). Samples were collected by coring, where a thin-walled metal cylinder of known volume (V) was pushed into the soil at right angles to ground surface. The cylinder was then dug out and the soil core was gently pushed out of the cylinder using a plunger, into a cellophane bag and transported to the laboratory where it was oven-dried at 105°C and weighed as (M).

$$\text{Bulk density} = \frac{\text{mass of the sample (M)(g)}}{\text{Volume of the tin (V)(cm}^3\text{)}}$$

Moisture Content: The moisture content of the soil is an indication of the amount of water present in the soil. It was determined according to the method described by Anderson and Ingram (1989). 1g of a representative sample of the soil was placed in a clean dry crucible of known mass. The mass of the container and soil were determined (W₂) using an analytical balance (OHAUS Advance AR 3130 Model). The crucible was placed in an oven maintained at 110± 5°C for 4 hours to obtain a constant weight (W₁). The measurement was done in duplicate. % Moisture was calculated as follows:

% Moisture = (W₂ – W₁)/Sample weight; Where W₂ = weight of crucible + weight of sample before oven drying; W₁ = weight of crucible + weight of sample after oven drying.

Particle size Analysis: Particle size analysis was determined according to the method of Bouyoucos (1962). 50 g of the soil sample was soaked overnight with 50 ml of cagon solution. The mixture was then transferred into a 1000 ml measuring cylinder and was made up to mark. The mixture was shaken and left for 40 secs. before dipping the hydrometer into it to determine the sandy content while the clay and silt was determined after 3 hours interval (for the mixture to settle down) through the same process. The temperatures were then recorded simultaneously. % sand, % clay and % silt were calculated as follows where H₁ and H₂ are hydrometer readings at 40 secs and 3 hours respectively at corresponding temperature readings T₁ and T₂:

$$\% \text{ sand} = 100 - [H_1 + 0.2 (T_1 - 68) - 2.0]^2$$

$$\% \text{ clay} = [H_2 + 0.2 (T_2 - 68) - 2.0]^2$$

$$\% \text{ slit} = 100 - (\% \text{ sand} + \% \text{ clay})$$

Determination of Organic Carbon: The organic carbon content of soils was determined by the Walkey- Black and digestion method as described by Anderson and Ingram (1989). About 1 g of soil sample was placed into a block digester tube (sample weight) and added 5 ml of potassium dichromate solution and 7.5 ml of concentrated H₂SO₄. The tube was placed in a pre- heated block at 145-155 °C for 30 minutes, then removed and allowed to cool. The digest was quantitatively transferred into a 100 ml conical flask and then added 0.3 ml of O-phenanthrene- ferrous complex (ferroin) indicator solution, then stirred and mixed properly using magnetic stirrer. The digest was titrated with ferrous ammonium sulphate solution with end point

indicating a change from greenish to brown colouration. The organic carbon content expressed in percentage as follows was based on 77% recovery factor

$$\% \text{ Organic C} = \frac{N(T - B)}{W} \times 0.390$$

Where N = Normality of KMnO_4 ; T = Volume of KMnO_4 used in titration of soil; B = Volume of KMnO_4 used in titration of blank; and W = Weight of soil in gram

Determination of trace elements (Zn and Mn): 5 g of the dried sieved soil was digested with HNO_3 -HCl according to USEPA method 3050B to extract the metals. The concentrations of Zn and Mn were measured by Perkin-Elmer Analyst 300 atomic absorption spectrophotometer (AAS).

Determination of soil Pb and Cd: Ni and Cd in the soil were determined according to the method of Ideriah *et al.*, 2007. Exactly 0.2 g of the soil sample was weighed and 6ml 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. The filtrate was analyzed for selected heavy metals using Perkin-Elmer Analyst 300 atomic absorption spectrophotometer (AAS).

Contamination/Pollution Index (C/P) of the Metals: The Contamination/Pollution Index (C/P) of the metals in the soils was calculated using the scheme formulated by Lacatusu, 2000.

$$\frac{C}{P} = \frac{\text{Concentration of the Metals in the Soil}}{\text{Target Value}}$$

The target value was obtained by using the standard formulated by the Department of Petroleum Resources of Nigeria (DPR)/cluster abundant values for maximum allowed concentrations of heavy metals in soil in mg kg^{-1} (Pb: 85, Mn: 437, Zn: 146, Cd: 0.8). Contamination/Pollution Index value greater than 1, defines pollution range, but when it is less than 1, it defines contamination range (Lacatusu, 2000) 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. Means were separated using Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Physicochemical Characteristics of Soil samples

Mean soil pH in dumpsites was 7.13 ± 0.94 , 7.38 ± 0.72 and 7.24 ± 0.83 for 0-5 cm, 5-10 cm and 10-15 cm depth respectively (Table 2), while in the abattoir it was 6.65 ± 0.98 , 6.87 ± 0.47 and 6.74 ± 0.74 for 0-5 cm, 5-10 cm and 10-15 cm depth respectively (Table 3). Soils taken from the fuel filling station had pH of 7.01 ± 0.49 , 6.95 ± 0.35 , and 6.98 ± 0.49 at depths of 0-5 cm, 5-10 cm and 10-15 cm (Table 4). Soil samples from selected mechanic workshop showed mean pH values of 6.70 ± 0.97 , 6.58 ± 1.35 and 6.48 ± 1.43 respectively (Table 5). Average pH values of the soil sample at hospital incinerator sites at depths 0-5 cm, 5-10 cm and 10-15 cm were 6.69 ± 0.21 , 6.59 ± 0.33 and 6.59 ± 0.24 respectively (Table 6). Soil pH values observed in this study were slightly acidic and neutral as indicated by Benton, (2002). Mean pH values obtained for mechanic workshops, dumpsites, hospital incinerators, and petrol stations at all depths were classified as slightly acidic and neutral which agreed with Dauda and Odoh (2012). The highest mean pH value was observed at abattoir sites at depth 0-5 cm while lowest at 10-15 cm depth, the range value was slightly acidic. The pH values in this study were lower than those values reported by Osakwe (2014), Farombi *et al.* (2013) and Jintao *et al.* (2011). Average pH values for all sites were lower than control sites (Table 7). Low pH from these anthropogenic sites could be as a result of the decomposition of organic matter that releases carbon (iv) oxide which reacts with water to form carbonic acid which eventually reduces soil pH. This low pH enhances solubility and mobility of heavy metals (Akan *et al.*, 2013) and the presence of humic acid which is the major acid in soil organic matter. Heavy metal mobility decreases with increasing soil pH, hence most of the sites with low pH had relatively high concentration of selected heavy metals. Generally, soil moisture content varied between 6.84% - 21.89%. In the dumpsite soil, average moisture were $16.11 \pm 1.49\%$ in 0-5cm depth, $17.89 \pm 7.27\%$ in 5-10 cm depth, and $18.38 \pm 7.34\%$ in 10-15 cm depth. Soil moisture content in the abattoirs varied with depth having $21.89 \pm 7.65\%$, $17.61 \pm 4.07\%$, and $19.50 \pm 6.62\%$ at 0-5 cm, 5-10 cm and 10-15 cm respectively. The percentage soil moisture content in mechanic workshop was $10.19 \pm 4.65\%$, $11.18 \pm 7.06\%$ and $7.90 \pm 4.39\%$ at depths 0-5 cm, 5-10 cm and 10-15 cm respectively. Soil moisture contents were found to vary with depths, which was similar to report of Wakene (2001) and this may be due to the amount of clay (Andrade *et al.* 2011) and nature of the activities on the sites. The values of moisture content observed at control sites at all depths were similar to the report of Gebeyaw (2007). Bulk density values in dumpsites ranged from $1.31 \pm 0.28 \text{ g cm}^{-3}$ to $4.47 \pm 0.12 \text{ g cm}^{-3}$. Furthermore, bulk density

ranged from $1.16 \pm 0.30 \text{ gcm}^{-3}$ to $1.81 \pm 0.37 \text{ gcm}^{-3}$ across the depths in abattoirs. Bulk density ranged from 1.37 ± 2.00 to $1.49 \pm 0.13 \text{ gcm}^{-3}$ in fuel filling stations. Bulk density was highest at dumpsites at depth of 0-5 cm and lowest value obtained at hospital incinerator sites and control (forest/lawn) sites. Soil compaction resulting from different anthropogenic activities on the sites may have caused the relatively higher bulk density. The values of bulk density were below mean value of 2 gcm^{-3} reported by Onwerma *et al.* (2007), except for the $4.47 \pm 0.12 \text{ gcm}^{-3}$ recorded in dumpsite soil at 0-5 cm depth, but agreed with the report of Jintao *et al.* (2011). The reason for the low values at depths 0-5 cm and 5-10 cm at some of the sites could be due to low or less disturbance on the sites. Bulk density values obtained in this study were within the ranges expected in most mineral soils as indicated by Mbagwu (2003). High bulk density ($>1.5 \text{ gcm}^{-3}$) reduces water infiltration and plant root penetration resulting in increased surface water pollution (Ahmed, 2002). Particle size distribution at 0-5cm showed 66.98±13.77 % of sand, 25.28±11.96 % of silt and 7.75±3.22 % of clay in mechanic workshops. While, in hospital incinerators soil showed 48.25±3.53 % for sand, 3.13±0.46 % for clay and 48.25±4.33 % for silt at depth 0-5 cm. Particle

size distribution in this study showed that, sand fractions were predominant, while clay was very low in most sites. The clay contents obtained were lower than the report of Dauda and Odoh, (2012). Egharevba and Odjada (2002) reported similar observation of low % of clay in some soil samples. Soil texture plays an important role in mobility of metals in soil. The textural class for most of the sites were sandy loamy except fuel filling station which was sandy clay and two of the hospital incinerator sites that were loamy sandy. This was similar to the report of Osakwe (2014). Soil organic carbon in dumpsites decreased from $4.80 \pm 2.65 \%$ in depth 0-5 cm to $2.40 \pm 0.29 \%$ in depth 10-15 cm and the mean soil organic matter ranged from $4.12 \pm 1.74 \%$ in depth 10-15 cm to $8.25 \pm 4.56 \%$ in depth 0-5cm. Also soil organic carbon in abattoirs decreased with depths with average of $3.27 \pm 2.10 \%$ at 0-5 cm depth and $1.38 \pm 0.85 \%$ at 10-15 cm depth. However, mean values of both organic carbon and organic matter across depths were significantly ($p < 0.05$) different from each other in mechanic workshops. While, organic carbon level of the hospital incinerator soils increased with depth from 2.89 ± 1.49 at depth 0-5cm to $3.48 \pm 1.52 \%$ at depth 10-15 cm.

Table 1: Interval of contamination/pollution index of heavy metals in soil and its significance

Depth(cm)	0 - 5	5 - 10	10 - 15
pH	7.10±0.94 ^b	7.38±0.72 ^a	7.24±0.3 ^b
Moisture density	16.11±1.49 ^c	17.89±7.27 ^b	18.38±7.34 ^a
Bulk density	4.47±0.12 ^a	1.31±0.28 ^b	1.38±0.15 ^b
Sand %	73.18±15.76 ^b	73.42±15.80 ^a	73.25±15.79 ^b
Clay %	3.00±1.83 ^a	2.90±1.95 ^a	3.08±1.89 ^a
Silt %	23.30±16.15 ^b	23.75±16.19 ^a	23.68±16.26 ^a
OC %	4.80±2.65 ^a	3.71±2.54 ^b	2.40±0.29 ^c
OM %	8.25±4.56 ^a	6.38±4.6 ^b	4.12±1.74 ^c
Zn (mgkg ⁻¹)	254.13±114.33 ^c	395.43±144.84 ^b	444.29±248.06 ^a
Pb (mgkg ⁻¹)	154.50±71.41 ^a	132.00±60.70 ^b	99.94±31.85 ^c
Mn (mgkg ⁻¹)	281.06±72.89 ^c	364.94±117.14 ^a	315.50±81.13 ^b
Cd (mgkg ⁻¹)	1.13±0.88 ^c	1.38±1.13 ^b	1.63±1.38 ^a

Table 2: Physicochemical parameters and heavy metal levels of soil samples from selected dumpsites at different depths

< C.PI	Significance	Remark
0.1	Very slight contamination	No negative effect on soil, plant and environment
0.10 – 0.25	Slight contamination	
0.26 – 0.5	Moderate contamination	
0.5 – 0.75	Severe contamination	
0.76 – 1.00	Very severe contamination	
1.1 – 2.0	Slight pollution	Will pose negative effect on soil, plant and environment
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 Lactusu (2000); OC = organic carbon, OM = organic matters. ; *Means with the different superscript along the same row are significantly ($p < 0.05$) different from each other.; *Each value represents the mean of three determination ± standard deviation

Values of soil organic matter and organic carbon content obtained were higher than the control sites. This observation corroborated Oyedele *et al.* (2008) who reported that polluted sites had significant higher soil organic matter and organic carbon as compared to the control site. Similarly, Ayolagha and Onwugbuta (2001) also demonstrated that organic matter greater than 2.0% or organic carbon greater than 1.2% create great conducive medium for heavy metal chelation formation. Sites with relatively high soil organic carbon had higher concentration of heavy metals. Sites with relatively high amount of clay had relatively high organic matter and carbon, this agreed with the report of Quenea *et al.* (2009) that clay fraction had highest level of organic carbon and nitrogen. The decline in soil organic carbon in the control sites (lawn and forest) may be as a result of leaching problem that may be attributed to the relatively high sand content.

Table 3: Physicochemical parameters and heavy metal levels of soil samples from selected abattoirs at different depths.

Depth(cm)	0 - 5	5 - 10	10 - 15
pH	6.65±0.98 ^a	6.87±0.47 ^a	6.74± 0.74 ^a
Moisture content	21.89±7.65 ^a	17.61±4.07 ^c	19.50 ±6.62 ^b
Bulk density	1.16±0.30 ^c	1.42±0.33 ^b	1.81 ±0.37 ^a
Sand %	64.55±10.48 ^a	64.33±10.05 ^b	64.22±10.53 ^b
Clay %	5.48±3.89 ^b	5.65±3.73 ^b	6.50±3.49 ^a
Silt %	29.98±10.63 ^a	20.08±10.66 ^c	29.03±10.98 ^b
OC %	3.27±2.10 ^a	2.70±2.41 ^b	1.38±0.85 ^c
OM %	5.63±3.61 ^a	4.64±4.12 ^b	2.37±1.47 ^c
Zn(mgkg ⁻¹)	632.18±508.79 ^a	191.06±108.97 ^b	171.93±82.43 ^c
Pb(mgkg ⁻¹)	21.88±6.72 ^a	19.75±6.50 ^b	19.38±6.72 ^c
Mn(mgkg ⁻¹)	682.44±143.85 ^a	697.06±148.24 ^a	640±148.52 ^b
Cd(mgkg ⁻¹)	0.31±0.06 ^a	0.25±0.02 ^a	0.25±0.01 ^a

OC = organic carbon, OM = organic matter. : *Means with the different superscript along the same row are significantly (p<0.05) different from each other.; *Each value represents the mean of three determination ± standard deviation.

Table 4: Physicochemical parameters and heavy metal levels of soil samples from selected fuel filling stations at different depths

Depth(cm)	0 - 5	5 - 10	10 - 15
pH	7.01±0.49 ^a	6.95±0.35 ^a	6.98±0.49 ^a
Moisture content	11.66±3.23 ^b	11.08±2.71 ^c	16.46± 8.76 ^a
Bulk density	1.37±2.00 ^a	1.43±0.60 ^a	1.49±0.13 ^a
Sand %	70.55±15.66 ^a	70.50±15.72 ^a	70.35±15.82 ^b
Clay %	8.28±9.34 ^a	8.45±9.21 ^a	2.90±3.48 ^b
Silt %	21.18±16.55 ^b	22.08±16.61 ^a	20.78±15.95 ^c
OC %	2.46±1.85 ^c	3.30±3.02 ^a	2.90±3.48 ^b
OM %	4.20 ±3.19 ^c	5.51±5.19 ^a	4.98±5.99 ^b
Zn(mgkg ⁻¹)	147.28±82.7 ^c	295.94±222.87 ^a	285.19±239.35 ^b
Pb(mgkg ⁻¹)	76.56±39.48 ^b	70.13±28.34 ^c	99.50±70.14 ^a
Mn(mgkg ⁻¹)	182.69±61.95 ^c	266.13±85.62 ^b	479.50±253.25 ^a
Cd(mgkg ⁻¹)	0.25±0.01 ^b	0.44±0.19 ^b	1.06±0.81 ^a

OC = organic carbon, OM = organic matter.; *Means with the different superscript along the same row are significantly (p<0.05) different from each other. *Each value represents the mean of three determination ± standard deviation.

Table 5: Physicochemical parameters and heavy metal levels of soil samples from selected mechanic workshops

Depth(cm)	0 - 5	5 - 10	10 - 15
pH	6.70±0.97 ^a	6.58±1.35 ^{ab}	6.48±1.43 ^b
Moisture content	10.19±4.65 ^b	11.18±7.06 ^a	7.90±4.34 ^c
Bulk density	1.73±0.15 ^a	1.45±0.42 ^b	1.50±0.34 ^b
Sand %	66.98±13.77 ^b	67.35±14.45 ^a	66.70±13.50 ^c
Clay %	7.75±3.22 ^c	8.35±3.14 ^b	9.38±1.21 ^a
Silt %	25.28±11.96 ^a	25.05±12.26 ^b	25.18±12.13 ^{ab}
OC %	5.98±3.24 ^a	2.95±1.91 ^b	1.52±0.77 ^c
OM %	10.28±5.58 ^a	5.07±3.34 ^b	2.61±1.33 ^c
Zn(mgkg ⁻¹)	406±127.62 ^a	254.44±62.74 ^b	122.69±30.04 ^c
Pb(mgkg ⁻¹)	88.56±62.72 ^a	58.63±34.73 ^b	22.75±9.10 ^c
Mn(mgkg ⁻¹)	304.50±84.23 ^b	320.50±60.82 ^a	185.63±10.58 ^c
Cd(mgkg ⁻¹)	0.25±0.01 ^a	0.25±0.02 ^a	0.25±0.01 ^a

OC = organic carbon, OM = organic matter.; *Means with the different superscript along the same row are significantly (p<0.05) different from each other. *Each value represents the mean of three determination ± standard deviation.

Table 6: Physicochemical parameters and heavy metal levels of soil samples from selected hospital incinerator sites

Depth(cm)	0 - 5	5 - 10	10 - 15
pH	6.69±0.21 ^a	6.59±0.33 ^a	6.59±0.24 ^a
Moisture density	6.84±1.86 ^{ab}	6.99±1.75 ^a	7.09±1.76 ^a
Bulk density	1.34±0.09 ^a	1.35±0.16 ^a	1.36±0.25 ^a
Sand %	48.85±3.35 ^a	48.45±3.31 ^c	48.68±3.05 ^b
Clay %	3.13±0.46 ^a	3.13±0.74 ^a	2.98±0.91 ^a
Silt %	48.25±4.33 ^a	48.43±4.04 ^a	48.35±4.49 ^a
OC %	2.89±1.49 ^b	2.54±0.72 ^c	3.48±1.52 ^a
OM %	4.98±2.58 ^b	4.36±1.24 ^c	6.00±2.62 ^a
Zn(mgkg ⁻¹)	548.56±315.92 ^c	642.94±393.51 ^a	577.66±354.85 ^b
Pb(mgkg ⁻¹)	113.94±64.43 ^c	133.56±81.42 ^a	114.94±73.68 ^b
Mn(mgkg ⁻¹)	447.50±22.95 ^a	447.44±10.30 ^a	414.25±30.58 ^b
Cd(mgkg ⁻¹)	0.94±0.47 ^c	1.50±0.95 ^a	1.13±0.71 ^b

OC = organic carbon, OM = organic matter.; *Means with the different superscript along the same row are significantly (p<0.05) different from each other. *Each value represents the mean of three determination ± standard deviation.

This is apparent because the clay particles unlike the sand particles have substantial exchange surface areas and therefore adsorb and stabilize organic matter and heavy metals (Dara, 2000). Considering the three soil depths, the highest average soil organic carbon was observed at 0-5 cm depth, followed by depth 5-10 cm and lowest at 10-15 cm depth, hence the soil organic carbon decreasing as the depth increases.

Mean values of organic matter content at dumpsites agreed with Bamgbose *et al.* (2000).

Heavy metal Concentrations in soil samples from selected locations across the depths:

Mean concentrations of heavy metals of the soil samples are shown in Tables 2 – 6. Zinc had highest average concentration across the depths followed by Mn, Pb and Cd in dumpsites. Average concentration of Pb, and Mn decreased with depths, while Zn and Cd concentrations increased with depth in dumpsites (Table 2). Increase in concentration of manganese in the dumpsites may be attributed to the metal scraps dumped around some of the sites (Idugboe *et al.*, 2014). The concentration of cadmium obtained at dumpsites may be due to the dumping of Poly vinyl chloride (PVC), nickel-cadmium batteries. Concentrations of Cd obtained at dumpsites and hospital incinerator sites were similar to concentrations reported from soil samples of industrialized environment (Chimezi *et al.* 2013), dumpsite soil of Markudi (Wuana and Okieimen, 2011), also soils from fuel filling station (Dauda and Odoh, 2012). The highest mean concentration of Pb was obtained in dumpsites and lowest in abattoir sites. In abattoir the concentrations of Zn, Pb, Mn and Cd were 632.18±508.79 mgkg⁻¹, 21.88±6.72 mgkg⁻¹, 682.44±143.85 mgkg⁻¹, and 0.31±0.06 mgkg⁻¹ at depth of 0-5cm and at 5-10cm depth were 191.06±108.97 mgkg⁻¹, 19.75±6.50 mgkg⁻¹, 697.06 ±148.24 mgkg⁻¹, and 0.25±0.02 mgkg⁻¹ while at 10-15cm depth were 171.93 ±82.43 mgkg⁻¹, 19.38±6.72 mgkg⁻¹, 640.00±148.52 mgkg⁻¹ and 0.25±0.01 respectively (Table 3).

Relative abundance patterns of the metals at all depths were in the order Mn>Zn>Pb>Cd in the abattoir and their mean

concentrations were significantly different from each other. Concentrations of Pb at abattoir were lower than concentration reported by Yahaya *et al.* (2009) while Zn concentrations were higher. Pb concentration decreases as the depth increases for most of the sites. Mean concentrations of Mn obtained at abattoirs were slightly higher than concentration reported by Yahaya *et al.* (2000). Manganese

concentration at abattoir may be as result of disposal of rumen which contain green grasses that are still in their early stage of digestion, this contains chlorophyll which contain manganese and iron.

While in fuel filling stations Mn had highest (479.50±253.25 mgkg⁻¹) concentrations at depth 10-15 cm, while, highest (295.94±222.87 mgkg⁻¹) concentration of Zn was recorded at 5-10 cm depth (Table 4). Zn is the second most abundant in soils around the petrol stations. Pb concentrations at 0-5 cm, 5-10 cm and 10-15cm were 76.56±39.48 mgkg⁻¹, 70.13±28.34 mgkg⁻¹, and 99.50±70.14 mgkg⁻¹ respectively. However, lower levels of Cd were observed with 0.25±0.00 % at depth 0-5 cm, 0.44±0.19 mgkg⁻¹ at depth 5-10 cm and 1.06±0.18 mgkg⁻¹ at depth 10-15 cm. The relatively high concentrations of Mn at fuel filling stations may be attributed to leakages of burning fuels (kerosene and diesel) which contain manganese additive. High Pb concentration observed at all depths might be due to oil spills or leakage of petrol containing lead additive. Pb concentrations obtained were lower than the report of Dauda and Odoh (2012) but had the same result for Zn at depth 0-5 cm from a similar study. High Pb concentrations in fuel filling station soil samples could be linked up to automobile tail pipe and the use of tetraethyl lead (IV) as an additive in oil processing. In mechanic workshops Zn was quite high in concentration at 0-5cm depth. The average Zn concentration at this depth was 406.5±127.62 mgkg⁻¹. It decreased with depth to reflect concentration of 254.44 ±62.74 mgkg⁻¹ at depth 5-10 cm and 122.69±30.04 mgkg⁻¹ at depth 10-15 cm. Average Mn concentration varied between 185.63±10.58 mgkg⁻¹ to 320.50±60.82 mgkg⁻¹. Average Pb concentration varied between 22.75±9.10 to 88.56±72.72 mgkg⁻¹ and Cd had lowest concentration of 0.25±0.00 mgkg⁻¹ at all depths (Table 5). Highest

concentration of Pb was obtained at mechanic workshop for all depths studied showing that motor vehicles constitute principal source of Pb. Lead concentration greater than 1.0 mgkg⁻¹ is generally indicated a local source of pollution. Presence of lead in mechanic workshop may be due to fall-out of lead from batteries or lead acid accumulators. Pb is derived mostly from exhausts of vehicles, which it is used in Nigeria as minor additives to gasoline and various auto-lubricants. Low concentrations of Pb obtained from some of the contaminated sites may be due to gradual decrease in metal concentration which could arise from the fact that the metals were leached away from the site (Ayodele and Modupe, 2007). The concentrations of manganese at mechanic workshop were lower than concentration reported by Eddy *et al.* (2003) and Osakwe (2014). The high Mn concentrations at mechanical workshop could be attributed to the fact that Mn forms a part of batteries, welding works and spray paintings of the vehicles. The concentration of manganese found in mechanic workshop sites were similar to level of Mn in soils that received significant impact of crude oil in Nigeria (Iwegbue *et al.*, 2009b). The concentration obtained at fuel filling station may be due to regular discharge of petroleum products around these filling stations (Dauda and Odoh, 2012). The concentration of cadmium at mechanic workshop may be due to disposal of engine oil and some other automobile waste and process of vulcanization around these workshops. It was reported that the cadmium level in car tyres is in the range of 20-90 mgg⁻¹ as associated with cadmium contamination in the process of vulcanization (Akpoveta *et al.*, 2010).

Table 7: Physicochemical parameters and heavy metal levels of soil samples from selected soil samples from control sites

Depth(cm)	FUNAAB Forest (Control 1)			FUNAAB Lawn (Control 2)		
	0 - 5	5 - 10	10 - 15	0 - 5	5 - 10	10 - 15
pH	7.68±0.2 ^a	7.64±0.1 ^a	7.56±0.30 ^a	6.93±0.10 ^b	7.39±0.30 ^a	7.28±0.10 ^a
Moisture content	15.65±0.9 ^a	13.02±1.2 ^b	12.00±0.80 ^c	23.20 ^a	20.50 ^b	19.00 ^c
Bulk density	1.14±0.9 ^b	1.45±0.4 ^a	1.49±0.20 ^a	1.26±0.20 ^a	1.36±0.10 ^a	1.38±0.10 ^a
Sand %	7.90±2.50 ^c	75.40±2.00 ^b	75.90±2.10 ^a	66.70±1.30 ^a	66.50±0.40 ^b	66.20±0.09 ^c
Clay %	3.80±0.10 ^a	3.80±0.10 ^a	3.50±0.10 ^b	5.10±0.40 ^a	5.10±0.10 ^a	5.00±0.20 ^a
Silt %	20.30±0.50 ^c	20.80±0.30 ^a	20.60±5.00 ^b	28.20±0.40 ^b	28.40±0.30 ^a	5.00±0.50 ^c
OC %	1.68±0.15 ^a	1.59±1.22 ^a	0.84±0.95 ^b	2.47±1.31 ^a	1.51±1.42 ^b	0.96±2.01 ^c
OM %	2.89±0.32 ^a	2.73±2.41 ^a	1.44±1.31 ^b	4.25±2.51 ^a	2.60±2.53 ^b	1.65±3.90 ^c
Zn(mgkg ⁻¹)	44.50±12.11 ^a	30.00±9.00 ^c	35.50±9.50 ^b	15.00±0.95 ^c	19.00±1.25 ^a	17.00±2.11 ^b
Pb(mgkg ⁻¹)	0.03±0.01 ^a	0.13±0.01 ^a	0.03±0.10 ^a	7.75±1.13 ^c	14.00±2.00 ^b	31.00±2.20 ^b
Mn(mgkg ⁻¹)	450.25±4.02 ^c	532.75±1.13 ^a	500.50±10.41 ^b	686.75±14.21 ^a	612.50±20.14 ^b	600.50±32.50 ^b
Cd(mgkg ⁻¹)	< BDL	< BDL	< BDL	< BDL	< BDL	< BDL

OC = organic carbon, OM = organic matter, < BDL = Below detection limit; ^aMeans with the different superscript along the same row are significantly (p<0.05) different from each other. ^bEach value represents the mean of three determination ± standard deviation.

Zn had highest average concentration of $642.94 \pm 353.51 \text{ mg kg}^{-1}$ at depth 5-10 cm in hospital incinerators. Relative abundance of the metals at all depths was $\text{Zn} > \text{Mn} > \text{Pb} > \text{Cd}$ in hospital incinerators (Table 6). All concentrations obtained from all depths and sites were far higher than control sites. High concentration of zinc was observed at hospital incinerator sites and mechanic workshops corroborated with the report of Quenea *et al.* (2009). The health implications of elevated level of zinc are well documented (Ubwa *et al.*, 2012) and the enhanced concentrations observed at mechanic workshops may be attributed to the presence of additives (consisting of metals in various proportion) in lubricants used by automobile, for example zinc dithiophosphates (Akpoveta *et al.*, 2010). Similar levels of zinc as obtained in this study were at par with that reported by Eddy *et al.* (2006). The concentrations of zinc in this study were relatively higher than level reported by Jung, (2008); Qishlaqi *et al.* (2009); Al-Trabulsy *et al.* (2013); Iwegbue *et al.* (2013). Zinc is involved in various metabolic activities of many organisms and is also one of the micronutrients essential for normal plant growth, but its increased level can cause many health disorders. Zinc can interrupt the activity of microorganisms and earthworms, thus retarding the breakdown of organic matter (Greany, 2005). Manganese concentrations at hospital sites were lower than concentrations reported by Sunday and Agbaji (2012) and Iwegbue *et al.* (2013). High concentration of manganese at the control site may have originated from decomposition of leaves and grasses, since manganese plays important role in chlorophyll production. High concentrations of manganese may result in kidney failure, liver and pancreas malfunction but its optimum concentration is very essential for respiratory enzymes and connective tissues development (Osakwe, 2014). The concentration of cadmium obtained at hospital incinerator sites were higher than concentration reported by Sunday and Agbaji (2012), but were lower than Odoh *et al.* (2012). The relatively high concentration of the cadmium in hospital incinerator sites may be due to disposal of Poly Vinyl Chloride (PVC) injection syringes (Jarup, 2003). Cadmium concentrations in most of the studied sites were lower than concentrations reported by Davaki *et al.* (2013) and Iwegbue *et al.* (2013) but agreed with the findings of Asawalaam and Eke (2006) and Njoku and Ayoka (2007).

Contamination and Pollution index: Contamination and Pollution index (C/PI) showed that dumpsites were slightly polluted with Pb, Cd and Zn to

moderate pollution while Mn showed severe contamination.

Table 8: Contamination/Pollution Index of the Metals in the Soil Samples

Sites	Depths	Pb	Zn	Mn	Cd
Dumpsites	0-5	1.86	1.74	0.64	1.41
	5-10	1.55	2.71	0.84	1.73
	10-15	1.18	3.04	0.72	2.04
Abattoirs	0-5	0.26	4.33	1.56	0.39
	5-10	0.23	1.31	1.60	0.31
	10-15	0.23	1.95	1.46	0.70
Petrol Stations	0-5	0.90	2.78	0.42	0.31
	5-10	0.38	2.03	0.61	0.55
	10-15	1.17	1.95	1.10	1.33
Mechanic Workshops	0-5	1.04		0.70	0.31
	5-10	0.69	1.74	0.73	0.31
	10-15	0.27	0.84	0.42	0.31
Hospital Incinerators	0-5	1.34	3.76	1.02	1.18
	5-10	1.57	4.40	1.02	1.18
	10-15	1.35	3.95	0.95	1.64

At 0-5 cm, the pollution indices were 1.86, 1.74, 0.64 and 1.41 for Pb, Zn, Mn and Cd respectively (Table 8). Abattoirs were slightly contaminated with Pb, moderately and severely polluted with Zn, slightly polluted with manganese and moderately contaminated with Cd. Fuel filling stations were severely contaminated with Pb and Mn, slightly polluted with Cd and moderately polluted with Zn. Mechanic workshops were severely contaminated and slightly polluted with Pb having PI of 1.04 at 0-5 cm depth and moderately polluted with Zn having PI of 2.78 at the same depth, severely contaminated with Mn (0.74) and moderately contaminated with Cd (0.31). Soil from hospital incinerators were slightly polluted with Pb having PI ranged from 1.34-1.57 and severely polluted with Zn having PI ranged from 3.76-4.40 and slightly polluted with Mn(0.95- 1.02) and Cd (1.18-1.64) at 0-15 cm, 5-10 cm and 10-15 cm depths respectively.

Conclusion: The concentrations of selected metals in the soils studied were generally higher than control sites, indicating some degrees of contamination. At some sites the concentrations were higher than natural ranged concentrations and stipulated values of United State Environmental Protection Agency (USEPA, 2002). Zinc and Manganese were the most abundant heavy metals in the studied sites. It was also observed that increase in pH decreases the concentration of heavy metals in the soil. Mean concentrations of heavy metals studied in the soil samples at all depths measured from abattoir, dumpsite, petrol station, hospital incinerator, and mechanic workshop were found to be in increasing order as $(\text{Mn} > \text{Zn} > \text{Pb} > \text{Cd})$, $(\text{Zn} > \text{Mn} > \text{Pb} > \text{Cd})$, $(\text{Mn} > \text{Zn} > \text{Pb} > \text{Cd})$, $(\text{Mn} > \text{Zn} > \text{Pb} > \text{Cd})$ respectively. The order from abattoir and petrol station followed the same order with control site $(\text{Mn} > \text{Zn} > \text{Pb} > \text{Cd})$. Heavy metal concentrations had significant difference ($p < 0.05$) on physical and

chemical properties of soil determined. Contamination and pollution index showed that all anthropogenic sites were moderately polluted and severely contaminated with heavy metals studied. Therefore, there is need for regular monitoring of these anthropogenic activities in order to forestall the impending health risk from heavy metals.

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