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# Effects of Abattoir Activities in the Surrounding Soils within Abuja, Nigeria

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***Abstract:*** *The various activities taking place in abattoirs all over the world today can contaminate the environment through direct or indirect impacts. This study aims to investigate the impact of abattoir wastes on the environment. Soil samples from proximity to five selected abattoirs (Kubwa, Dei-Dei, Dutse Alhaji, Gwarimpa, Mpape) in Abuja were examined to ascertained the level of contamination in terms of the physicochemical properties and heavy metal contents of the soil. The results revealed that all the studied soils are acidic (5.2±0.0 - 5.9±0.1) Most physicochemical properties, including conductivity (18.9±0.2 µs/cm to 27.4±0.6 µs/cm), bulk density (1.4±0.0 gcm*$^{-3}$ *to 1.9±0.0 gcm*$^{-3}$*), salinity (15.3±0.0 mgkg*$^{-1}$ *to 20.0±0.0 mgkg*$^{-1}$*), organic matter (7.9±0.0 % and11.4±0.0 %), cation exchange capacity (57.3±0.1 cmol/kg to 76.4±0.3 cmol/kg) were observed to be higher in the studied abattoir soils than in the control (15.4±0.0 µs/cm), (1.3±0.2 gcm*$^{-3}$*), (11.5±0.0 mgkg*$^{-1}$*), (5.2±0.1 %), (34.6±0.1 cmol/kg) respectively. All the studied heavy metal ions (Ni, Fe, Cu, Zn, Cr, Pb and Cd) were higher in the abattoir soils than in the control site except that Fe was equally higher in the control and all were above the FEPA (1999) recommended. Some geochemical assessment techniques including Contamination factor (CF), Enrichment factor (EF), Geoaccumulation index (Igeo), Degree of contamination (Cdeg) and Pollution load index (PLI) as computed showed that all the abattoir soils studied were very highly contaminated (32 < Cdeg) with the studied metals (*$Cu^{2+}$ *>Zn2+ >*$Ni^{2+}$ *>*$Cd^{2+}$ *>*$Pb^{2+}$ *>*$Cr^{3+}$ *>*$Fe^{2+}$*) in that order with Cu being the most abundant metal.*

**Keywords:** *Abattoir, heavy metals, soil, organic matter, contamination factor*

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## 1.0 Introduction

Waste disposal on soil has been reported to have adverse environmental influence (Eddy *et* al., 2006). An abattoir is an environment or area where animals are butchered for human consumption. Almost every day in Nigeria, effective activities of animal slaughtering are going on, especially in Abuja where there is a large population and a high demand for meat. Consequently, there is a huge generation of wastes originating from the killing of the animals, washing of paunch, removal of animal skin or trimming, singeing of hide and clean-up operations (Neboh *et al*., 2013; Useh *et al*., 2015). The various activities taking place in abattoirs all over the world today can contaminate the environment directly or through indirect impacts such as transportation of toxic waste to the nearby water body (Abubakar and Tukur, 2014). In Nigeria, abattoir wastes are a class of waste that affects both urban and rural areas. In most nations of the world, the slaughtering of animals for human consumption is certain and it is dated back to antiquity. Public abattoir had been traced to the 15th century in Rome and France, where slaughter houses were among the public facilities provided by the State (Ubwa *et al.,* 2013; Ediene *et al.,* 2016) A law of 1890 required that public abattoirs be provided in all communities of more than 6000 people In Italy. In the late 18th century, similar reports were recorded in Denmark, Sweden, Norway, Romania and Netherlands (Chukwu and Anuchi, 2016; Emmanuel *et al.,* 2018; Godwin *et al.,* 2020). Osu and Okereke, 2015 reported that the disposal of waste products is a problem that has always dominated the slaughtering sector, and on the average, 45 % of each cow, 48 % of each sheep, and 34 % of each pig consist of non-meat substances. The characteristics of abattoir wastes and effluents vary from day to day depending on the number, types of stock being processed, and the processing method.

Generally, abattoir wastes typically comprise of grease, feathers, fat, paunch manure, shingle, whole grains, undigested feed, cellulose fibre, blood, long hairs, bones, large plant fragments, undigested protein, organic solids, inorganic solids, salts, chemicals added during processing operations, urine, aborted foetus, excess nitrogen from digested protein, mucus, residues from digested fluids, bacteria, worn-out cells from intestinal linings, waste minerals or metals and nonmetal ions such as iron, calcium, magnesium, phosphorous, sodium, etc. (Osu and Okereke, 2015; Dan *et al*., 2018; Godwin *et al.,* 2020) Due to non-compliance with abattoir laws, inhabitants around abattoir environs could be at a greater risk. The numerous waste and microbial organisms generated in the course of abattoir operations can pose a significant challenge to the effective management of the environment and the consequence is the adverse impact on public health. Studies have also shown that abattoir waste can alter the physicochemical of the soil and also introduce or increase the concentration of heavy metal ions in the soil (Ubwa *et al.,* 2013; Emmanuel *et al.,* 2018; Sumayya *et al.,* 2019). However, some farmers in Nigeria use abattoir wastes as organic manure in their farms for the cultivation of edible plants. This also implies that through the food chain, heavy metal ions in the abbatoir wastes may be transferred to other plants and animals (including man).

Reports from biomedical researches have associated some diseases with abattoir activities including malaria, asthma, pneumonia, respiratory tract infection, diarrhea, cardiac arrest, typhoid fever, wool sorter diseases etc (Auwalu *et al.,* 2015; Edori and Iyama, 2017). Pathogens present in animal carcasses may include *Salmonella typhi*, *Hepatitis E* virus, *Escherichia coli*, *Cryptosporidium parvum*, *Yersinia enterocolitica*, *Giardia lamblia*, *Campylobacter spp*, *Mycobacterium spp* and *Rotaviruses*. These zoonotic pathogens can exceed millions to billions per gram of faeces and may infect humans through various routes such as exposure to potential vectors (mosquitoes, flies and rodents), contaminated air, contact with livestock animals or their waste products, consumption of food or water contaminated by animal wastes (Neboh *et al.,* 2013; Auwalu *et al.,* 2015; Pan *et al.,* 2016). Waste effluents from abattoirs have been documented to have harmful effects on the soil media (Abubakar and Tukur, 2014; Chukwu and Anuchi, 2016; Sumayya *et al.,* 2019; Godwin *et al.,* 2020) There is little information about the level of contamination by abattoir activities on the soil media in the vicinity of Abuja. This study is therefore concerned with the assessment of the contamination levels of different soils exposed to abbatoir wastes in Abuja.

## 2.0 Materials and Methods

### *2.1. Description of the Study Area*

Abuja is the capital and eighth most populous city of Nigeria and makes up approximately 6% of the land area of Nigeria. It has been reported to cover an area of approximately 1,769 km$^2$ (683 m$^2$) representing about 6.15% of Nigeria (Useh *et al.*, 2015). At the 2006 census, the city of Abuja had a population of 776,298 making it one of the ten most populous cities in Nigeria (placing eighth as of 2006). According to the United Nations, Abuja grew by 139.7% between 2000 and 2010, making it the fastest growing city in the country. As at 2021, the population of Abuja is estimated at 3,652,029 with a growth rate of 5.42% (Useh *et al.*, 2015). Abuja lies approximately between Longitude 7° 29' 28.6872" East and Latitude 9° 4' 20.1504" North of the equator. It has six Area Councils namely: Abaji, Abuja Municipal, Bwari, Gwagwalada, Kuje, and Kwali (Figure 1). The indigenous inhabitants of Abuja are the Gbagyi (Gwari), with the Gbagyi language formerly the major of the regional language, and others in the area being Bassa, Gwandara, Gade, Dibo, Nupe and Koro (Useh *et al.*, 2015). Abuja under the Köppen climate classification features a tropical wet and dry climate. The FCT experiences three weather conditions annually. This includes a warm, humid rainy season and a blistering dry season. In between the two, there is a brief interlude of harmattan occasioned by the northeast trade wind, with the main feature of dust haze and dryness. The rainy season begins from April and ends in October when daytime temperatures reach 28 °C (82.4 °F) to 30 °C (86.0 °F) and night-time lows hover around 22 °C (71.6 °F) to 23 °C (73.4 °F). In the dry season, daytime temperatures can soar as high as 40 °C (104.0 °F) and nighttime temperatures can dip to 12 °C (53.6 °F). Even the chilliest nights can be followed by daytime temperatures well above 30 °C (86.0 °F) (Useh *et al.*, 2015). The high altitudes and undulating terrain of the FCT act as a moderating influence on the weather of the territory.

### *2.2 Sample Collection, Handling and Preservation*

US EPA (SW-846) guidelines were applied, using composite sampling for collecting sediment samples where sub-samples were collected from randomly selected locations in an area. Fifty (50) soil samples were randomly collected using soil auger from the depth of 0-15 cm from five selected abattoir communities (Kubwa, Dei-Dei, Dutse Alhaji, Gwarimpa, Mpape and were coded P, Q, R, S and T respectively) and stored in sealed polythene bags. There were ten (10) replicates for each sampling site and the sub-samples were thoroughly mixed to obtain a representative sample of each. At each community, topsoil not close to a slaughter house was also collected as control samples. These were stored in well-labeled amber glass bottles with a Teflon-lined screw cap, held at 4°C immediately in a cooler of ice and transported to the laboratory for pre-treatment and analysis (USEPA, 2012; Useh and Dauda, 2018) The soil samples were air-dried for two weeks, rolled manually, mixed and sieved with 2 mm mesh to remove stones and debris. These were properly stored in well-labeled air-tight containers until analysis.

#### *2.2.1 Reagents*

All chemicals and reagents were of analytical grade and of the highest purity. They were supplied by BDH Labs (UK). BDH Chemicals Limited Poole England.

### *2.3 Physicochemical Analysis*

Physicochemical properties such as temperature, moisture content, pH, conductivity, bulk density, salinity, soil texture, organic matter, cation exchange capacity (CEC) were analysed. Moisture content was determined gravimetrically after drying the soils in an oven (Gallenkamp OV330) at 105 °C until a constant weight was obtained. The pH and electrical conductivity were measured in a soil suspension (1:10 w/v dilution) by digital pH meter (Jenway model 3015) and conductivity meter (Systronics-304), respectively. Bulk density was determined by the gravimetric method as described by (Ashraf *et al.*, 2012; Begum *et al.*, 2014). Salinity was determined following the method reported elsewhere (Dung *et al.*, 2013; Ghazaryan *et al.*, 2015). The texture of the soil was determined using the hydrometer method (Environmental analysis, 2016; Useh *et al.*, 2017) Organic matter was examined by the potassium dichromate titration method (Begum et al., 2014; Gasiorek *et al.*, 2017) Cation exchange capacity (CEC) of soil was determined using the procedure outlined by Useh and Dauda (2018).

**Fig. 1. Map of Abuja Showing the Study Area**

### *2.4 Heavy Metals Analysis*

A test portion of 1.00 g of each soil sample was digested using the conventional aqua regia (3:1, v/v, HCl to $HNO_3$) digestion procedure. The soil sample was weighed and transferred into the digestion vessel (250 ml glass beaker covered with watch glass). 20 ml of freshly prepared aqua regia mixture was added and mixed by swirling. This was moistened with a little deionized distilled water. Thereafter, the digestion vessel was placed on a heating mantle for 2 h at 110 °C until about 5 ml of digest remained in the flask. The vessel was removed and allowed to cool for 15 min. Then, another 20 ml of freshly prepared aqua regia mixture was added and boiling was repeated until the digest cleared up. After evaporation to near dryness, the sample was allowed to cool and was diluted with 20 ml of 2 % (v/v with $H_2O$)

$HNO_3$ and transferred into a 100 ml volumetric flask after filtering through Whatman no. 42 paper and was made to volume with deionized distilled water. The blank solutions were undergoing the same digestion procedure as that of the sample. All digestions were carried out in triplicates for each sample and the amounts of trace metals were recorded as the mean value. The extracts were analyzed for heavy metals (Ni, Fe, Cu, Zn, Cr, Pb and Cd,) using atomic absorption spectrophotometer (AAS) iCE 3000 Series at their respective wavelength (232.0, 248.3, 324.8, 213.9, 357.9, 283.3, 228.8)nm according to APHA method (APHA, 2009; Useh and Dauda, 2018).

### *2.4.1 Preparation of calibration standards*

For calibration of the instruments, a series of five standard solutions were prepared by serial dilution of the stock standard solutions (1000 mg/l) of the metals to be analyzed.

### *2.5 Toxicity Assessment of Metals in the Studied Samples*

Some geochemical assessment techniques, including Contamination factor (CF), Enrichment factor (EF), Geoaccumulation index (Igeo), Degree of contamination (Cdeg) and Pollution load index (PLI) were used to determine the levels of metal contamination in the sediments in focus (Jiang *et al.*, 2014; Al-Anbari *et al.*, 2015; Baran *et al.*, 2018).

### *2.5.1 Contamination Factor (CF):*

CF is a quantification of the degree of contamination relative to either the average crustal composition of a respective metal or to the measured background values from the geologically similar and uncontaminated area. The CF can provide a guide about the anthropogenic contribution of heavy metals in the soil. It is expressed as follows:

$$CF = Cm/Bm \qquad (1)$$

where CF is the contamination factor, Cm is the concentration of the metal in the studied sample, and Bm is the background concentration of metal either from literature (average crustal abundance) or directly determined from a geologically similar area.

The different classes of CF according to Hakanson (1980) are as follows:

- $CF < 1$ - Low contamination
- $1 < CF < 3$ - Moderate contamination
- $3 < CF < 6$ - High contamination
- $6 > CF$ - Very high contamination

### *2.5.2 Enrichment factor (EF)*

The computation of enrichment factor (EF) has been adopted to evaluate the impact of anthropogenic activities related to the metal abundance in sediments. In other words, EF normalizes the trace element content concerning a sample reference metal, such as Fe or Al.

According to Moez *et al.* (2018), EF is defined by the equation (2),

$$EF = \frac{(Cx/CFe)\ sample}{(Cx/CFe)control} \qquad (2)$$

Fe (iron) is chosen as a natural element of the reference

- $(C_X/C_{Fe})$ sample is the ratio between the concentration of the element "X" and that of Fe in the sediment sample
- $(C_X/C_{Fe})$ control is the ratio between the concentration of the element "X" and that of Fe in the unpolluted reference baseline.

The calculated EF values could be interpreted as follows:

- $EF \leq 1$: no enrichment
- $1 < EF < 3$: minor enrichment
- $3 < EF < 5$: moderate enrichment
- $5 < EF < 10$: moderate-to-severe enrichment
- $10 < EF < 25$: severe enrichment
- $25 < EF < 50$: very severe enrichment
- $EF > 50$: extremely severe enrichment.

### *2.5.3 Geoaccumulation Index (Igeo)*

Geochemical index (Igeo) was used to determine and define metal contamination in sediments by comparing current concentrations with pre-industrial levels, Igeo is calculated as:

$$Igeo = Log\ 2(Cn/1.5Bn) \qquad (3)$$

where Cn is the concentration of the metal (n) in sampled and analyzed sediment and Bn is the background concentration of the same metal (n) and factor 1.5 is the background matrix correction factor due to lithogenic effects (Kowalska *et al.*, 2016; Gasiorek *et al.*, 2017). According to Muller (1969), calculated Igeo values could be interpreted into 7 classes as follows:

- Class 0 = $I_{geo} \leq 0$: Uncontaminated
- Class 1 = $0 < I_{geo} < 1$: From uncontaminated to moderately contaminated
- Class 2 = $1 < I_{geo} < 2$: Moderately contaminated
- Class 3 = $2 < I_{geo} < 3$ : From moderately contaminated to strongly contaminated
- Class 4 = $3 < I_{geo} < 4$ : Strongly contaminated
- Class 5 = $4 < I_{geo} < 5$ : From strongly to extremely contaminated
- Class 6 = $I_{geo} > 5$ : Extremely contaminated

### *2.5.4 Degree of contamination (Cdeg)*

Degree of contamination (Cdeg) denotes the summation of all the CFs of trace metals for a particular abattoir soil and was determined using equation (4.0) as reported by Pekey *et al.* (2004) and by Sayadi *et al.* (2015).

The degree of contamination of each location was calculated as follows:

$Cdeg = \sum CF$ (4.0)

where CF is the contamination factor for all the studied metals at a particular location.

The different classifications of Cdeg according to Kowalska *et al.* (2016), are as follows:

- Cdeg < 8 = low degree of contamination
- 8 < Cdeg < 16 = moderate degree of contamination
- 16 < Cdeg < 32 = considerable degree of contamination
- 32 < Cdeg = very high degree of contamination

### *2.5.5 Pollution load index (PLI)*

For the total assessment of the degree of contamination in soil, the PLI is also used. This index provides an easy way to prove the deterioration of the soil conditions as a result of the accumulation of heavy metals (Varol, 2011; Simeon and Friday, 2018) Pollution load index (PLI) of metals in a particular location was obtained using equation (5.0) according to the procedure of Tomlinson *et al.*(2012)

$PLI = (CF1 \text{ x } CF2 \text{ x } CF3 \text{ x } . \times CFn)^{1/n}$ (5)

where CF represents the contamination factor for the metals at each location and n is the number of analyzed heavy metals.

The different categories of PLI are as follows:

- PLI < PLI < 2: No pollution,
- 2 < PLI < 3: Heavy pollution and
- 3 < PLI: Extremely heavy pollution

## 3.0 Results and Discussion

### 3.1 *Physicochemical properties analysis*

The results for the physicochemical properties of studied soils are presented in Table 1. The temperature of the studied soils ranged between 28.7±0.2 °C and 33.4±0.1 °C with no significant difference from that of the control which was 30.1±0.1 °C. The reasons for the differences in the temperatures among the abattoir soils may be attributed to factors such as variation in water content of the abattoir soils, cover and soil relief (Abubakar and Tukur, 2014 Kowalska *et al.*, 2016). The temperature range for the abattoir soils obtained in this work is higher than (18.80 – 21.43) °C reported by Ubwa *et al.*, 2013 for abattoir soils from Gboko and lower than (33.60 – 35.30) °C reported by Edori and Iyama (2017), for abattoir soils from Rivers State, Nigeria. The moisture content in this study varied from 9.7±0.0 % to 14.3±0.1 % for abattoir soils which were higher than that of the control soil, 5.8±0.1 %. The variations in these values between the abattoir soils and the control may be due to the effect of the abattoir effluent on the studied soils. The result for moisture content in studied abattoir soils is higher than (7.03 – 9.54) % reported by Chukwu and Anuchi, 2016 but lower than (17.91 – 19.50) % obtained by Abubakar and Tukur, 2014 in abattoir soils. The observations of higher moisture content in abattoir soils than in control are inconsistent with the report of Ediene *et al.*(2016) which could be due to the presence of paunch manure with a moisture content of about 88 %.

The pH of the studied abattoir soils varied significantly between 5.2±0.0 and 5.9±0.1 with that of the control, 6.2±0.0 which is lower than the WHO recommended limits of 6.5 – 8.5 for abattoir soils. The determination of the availability of nutrients in the soil to plant and the type of organism found in the soil depends greatly on the pH (Chukwu and Anuchi, 2016). The results indicated that all the studied soils were acidic, with the control soil showing lower acidities than the abattoir soils. However, the obtained ranges reported in this work are lower than 6.22 – 7.44 reported by Chibuzor *et al.*(2017) but are consistent with 4.99 – 6.73 obtained by Emmanuel *et al.*(2018) in abattoir soils though with some differences. Also, the result of higher pH for abattoir soils than in the control soil obtained in this work is in line with the findings of Abubakar and Tukur(2014). . This could be attributed to the type of wastes such as fats, dung, animal trimmings, urine, blood and stomach content that are generated from the abattoir resulting in reduced anaerobic activities in these soils.

The electrical conductivity, EC of the studied soils varied from 18.9±0.2 µs/cm to 27.4±0.6 µs/cm with 15.4±0.0 µs/cm in the control site showing that EC was higher in the studied soils than the control, hence, portrayed a negative impact of abattoir wastes on studied soils. However, the EC values recorded in this study are within the WHO recommended limit of < 100 µs/cm. This EC range is lower than 38.62 µs/cm to 40.60 µs/cm obtained by Ediene *et al.*(2016) and higher than 2.03 µs/cm to 2.54 µs/cm obtained by Edori and Iyama (2017) in similar studies. The observations of higher EC in abattoir soils than in control are consistent with the report of Chibuzor et al. (2017), which could be attributed to the presence of heavy metals and variations in the rate of formation of metallic salts and organic matter complexes. The bulk density for the studied soils varied from 1.4±0.0 gcm$^{-3}$ to 1.9±0.0 gcm$^{-3}$ which was slightly higher than that of the control, 1.3±0.2 gcm$^{-3}$ which could be connected to the variability of the soil texture and organic matter contents of the soils. The range of bulk density obtained in this study is in line with 1.50 gcm$^{-3}$ to 1.65 gcm$^{-3}$ reported by Ubwa *et al.*(2013) but lower than 1.16 gcm$^{-3}$ to 1.81 gcm$^{-3}$ recorded by Chibuzor et al., 2017 in similar studies.

**Table 1. Selected Physicochemical Parameters of the Soil Samples**

| PARAMETERS | Site P | Site Q | Site R | Site S | Site T | Control |
|---|---|---|---|---|---|---|
| Temperature (°C) | 31.6±0.0 | 28.7±0.2 | 30.4±0.2 | 30.7±0.0 | 33.4±0.1 | 30.1±0.1 |
| Moisture Content (%) | 10.8±0.0 | 10.2±0.0 | 9.7±0.0 | 14.3±0.1 | 12.4±0.0 | 5.8±0.1 |
| pH | 5.9±0.1 | 5.2±0.0 | 5.3±0.4 | 5.7±0.1 | 5.5±0.1 | 6.2±0.0 |
| Conductivity(µs/cm) | 25.7±0.0 | 22.6±0.1 | 18.9±0.2 | 21.6±0.0 | 27.4±0.6 | 15.4±0.0 |
| Bulk Density (gcm$^{-3}$) | 1.8±0.2 | 1.4±0.0 | 1.5±0.0 | 1.7±0.5 | 1.9±0.0 | 1.3±0.2 |
| Salinity(mgkg$^{-1}$ ) | 18.5±0.1 | 15.8±0.0 | 17.6±0.1 | 15.3±0.0 | 20.0±0.0 | 11.5±0.0 |
| Soil Texture | Sandy clay | Sandy loam | Sandy clay | Sandy clay loam | Sandy clay loam | Sandy clay loam |
| Sand (%) | 57.9±1.0 | 72.5±0.0 | 64.6±0.0 | 55.8±0.1 | 68.3±0.1 | 60.5±0.0 |
| Silt (%) | 15.3±0.2 | 10.7±0.1 | 12.9±0.0 | 18.4±0.0 | 12.4±0.1 | 20.2±0.5 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Clay (%) | 20.4±0.1 | 25.6±0.0 | 22.5±0.3 | 16.7±0.4 | 23.7±0.0 | 17.6±0.0 |
| Organic Matter (%) | 7.9±0.0 | 10.8±0.0 | 9.1±0.2 | 11.4±0.0 | 8.6±0.1 | 5.2±0.1 |
| CEC (mg/kg) | 76.4±0.3 | 57.3±0.1 | 65.5±0.0 | 63.2±0.0 | 67.8±0.0 | 34.6±0.1 |

*Note: The results are means of triplicate determination ± standard deviation. Kubwa = Site P, Dei-Dei = Site Q, Dutse Alhaji = Site R, Gwarimpa = Site S and Mpape = Site T*

The salt content of the studied abattoir soils ranged from 15.3±0.0 mgkg$^{-1}$ to 20.0±0.0 mgkg$^{-1}$ which was higher than the value recorded for the control, 11.5±0.0 mgkg$^{-1}$. Although, salinity in soil isis caused by other natural factors such as weathering, continuous irrigation and leachate from abattoir wastewater on soil can also increase the salinity of the soil since such water contains some dissolved salts. The salinity obtained in this study is lower than 29.00 mgkg$^{-1}$ to 59.00 mgkg$^{-1}$ reported by Karim *et al.,* 2015 but they are within the recommended limits of 200 mgkg$^{-1}$ established for soils. The low values of salinity recorded in this study are profitable since high salinity in soil usually leads to reduced plant growth and lower soil microbial activity.

The soil texture analysis was carried out to reveal the physical properties of the soil such as water holding capacities, the permeability of the soils studied among others which is important for the growth of biotic components in the soil. From the result, all the studied soils fell within the sandy-clay and sandy-clay-loam class of soils with a higher percentage of sand, followed by clay and then silt showing that the studied soils have the potential of holding more water within the particles. The percentage sand, silt and clay in the studied soil samples ranged from 55.8±0.1 % to 60.5±0.1 % (sand), 10.7±0.1 % to 18.4±0.0 % (silt) and 16.7±0.4 % to 25.6±0.0 % (clay); while their controls were 60.5±0.0 % (sand), 20.2±0.5 % (silt) and 17.6±0.0 % (clay). The percentages of sand, silt and clay obtained for abattoir soils in this work agree with 50 % to 58 % (sand), 8 % to 15 % (silt) and 20 % to 25 % (clay) recorded by Emmanuel *et al.* (2018) but in contrast with 76 % to 83 % (sand), 1.5 % to 2.0 % (silt) and 13 % to 23% (clay) reported by Dan *et al.,* 2018 in similar studies.

The range of organic matter, OM in this study was between7.9±0.0 % and11.4±0.0 % which was higher than the control counterpart, 5.2±0.1 % probably due to the considerable volume of biodegradable wastes present in the abattoir soils than the control. These values are in line with similar work carried out by Begum *et al.*(2014) with OM content of 6.3 % to 12.4 % but in contrast with the values, 0.7 % to 7.4 % reported by Godwin *et al.*(2020). Organic matter is an important soil property that may influence metal availability, cation exchange, and complex formation. The cation exchange capacity, CEC of the studied soils ranged from 57.3±0.1 cmol/kg to 76.4±0.3 cmol/kg while that of the control was 34.6±0.1 cmol/kg. From the result, the studied abattoir soils recorded higher CEC than the control which may be attributed to the high organic contents of the studied soils due to the impact of abattoir activities. This result is in agreement with the reports of other researchers (Simeon and Friday, 2018; Godwin *et al.,* 2020). CEC is a measure of the ability of the soil to hold positively charged ions and it is essential to plant as it influences the stability of soil structure, pH, nutrient availability, etc. Although most crops do well in soil with low CEC. However, other food crops like vegetables perform best in soil with moderate CEC.

### *3.2 Heavy Metals Distribution in the Studied Soils*

Heavy metals are useful for biological growth and development but when they are introduced at higher concentrations via leaching or chemical reactions from abattoir activities etc. into the environment, they become toxic. From the results, the levels of nickel ion obtained in this study ranged from 54.3±0.0 mg/kg in site R to 73.0±0.4 mg/kg in site T which was higher than that of the control site (8.6±0.1 mg/kg). The ranges for nickel obtained here are higher than 8.84 – 10.21 mg/kg recorded for nickel ion by Kierczak *et al.* (2016).

**Table 2. Heavy metals concentrations of the samples (mg/kg)**

| Heavy Metals | Site P | Site Q | Site R | Site S | Site T | Control |
|---|---|---|---|---|---|---|
| Ni | 57.4±0.3 | 68.7±0.3 | 54.3±0.0 | 59.1±0.2 | 73.0±0.4 | 8.6±0.1 |
| Fe | 89252.1±0.4 | 87461.4±0.0 | 79783.1±0.0 | 76645.4±0.1 | 89517.6±0.2 | 21394.1±0.1 |
| Cu | 1516.4±0.2 | 1437.0±1.0 | 1046.7±2.4 | 1452.3±0.3 | 1163.5±0.4 | 61.5±2.3 |
| Zn | 3262.8±1.0 | 3541.5±0.0 | 3092.5±2.0 | 2680.6±0.5 | 3485.3±2.1 | 452.8±0.5 |
| Cr | 37.4±0.0 | 46.8±1.1 | 43.7±0.0 | 39.4±0.0 | 35.1±0.0 | 7.5±0.0 |
| Pb | 28.2±0.5 | 24.3±0.0 | 17.9±0.0 | 29.5±1.0 | 22.7±0.4 | 4.1±0.0 |
| Cd | 47.5±0.0 | 45.5±0.2 | 51.3±0.1 | 34.2±0.0 | 58.2±0.1 | 7.9±1.3 |

*Note: The results are means of triplicate determination ± standard deviation*

*Kubwa = Site P, Dei-Dei = Site Q, Dutse Alhaji = Site R, Gwarimpa = Site S and Mpape = Site T*

Also, the values of nickel recorded in the studied soils are higher than the recommended limits of 35 mg/kg in soils. The concentration of nickel obtained in this study is significant especially since abattoir soils studied are already used by farmers in planting crops. It is reported that when the recommended amounts are exceeded, it is unsafe because it is a major source of cancer (Auwalu *et al.*, 2015). The result revealed that iron was highest ranging from 89517.6±0.2 mg/kg in site T to 89252.1±0.4 mg/kg in site P of all studied metals. It has been confirmed that natural soils contain a significant concentration of iron (Useh *et al.*, 2017). This range is higher than 623.88 to 887.80 mg/kg recorded by Osu and Okereke (2015) and 2569.00 to 4130.00 mg/kg obtained by Al-Anbari *et al.*(2015) in similar studies. The suggestion has been made that the contamination of the environment by iron cannot be conclusively linked to waste materials like abattoir waste alone but to other natural sources as well (Edori and Iyama, 2017; Useh and Dauda, 2018). This can be confirmed from the significant amount of iron (21394.1±0.1 mg/kg) recorded in the control site. However; levels of $Fe^{2+}$ in both studied abattoir soils and control are higher than 400.00 mg/kg recommended by FEPA (1999) for Nigerian soils. Nonetheless, the availability of $Fe^{2+}$ in soil for plant uptake may not be guaranteed as iron oxides (the major form of $Fe^{2+}$ in soil) are highly insoluble in soil.

The highest concentration of copper (1516.4±0.2 mg/kg) was recorded in site P, while the lowest level of copper ion (1046.7±2.4 mg/kg) was obtained in abattoir soil from site R. Concentrations of $Cu^{2+}$ in studied abattoir soils were far higher than values obtained at the control site (61.5±2.3 mg/kg) which was expected due to availability of copper ion containing waste materials in abattoir waste-impacted soils. This is in agreement with the findings by Olayinka *et al.* (2017) in abattoir soils but in contrast with the work of Osu and Okereke (2015) in similar studies within Umuahia, Nigeria. The recorded Copper values are also higher than 36.0 mg/kg recommended for Nigerian soils (FEPA, 1999). Copper is an important micronutrient that is needed in the development of both crops and animals, it also assists in the synthesis of blood (Mahmoudabadi *et al.*, 2015). However, it is reported that high concentrations of copper ion is can lead to blood deformation, liver disease, kidney diseases and gastric problems (Inengite *et al.*, 2015; Auwalu *et al.*, 2015). Nonetheless, the bioavailability and toxicity of copper ion could not be confirmed based on total concentration alone and researches have shown that when copper ion enters the environment it quickly becomes stable and transforms into a compound that is not too dangerous to the environment (Liu et al., 2016; Mazurek *et al*., 2017). Results obtained showed that zinc ion ranged from 3541.5±0.0 mg/kg in site Q to 2680.6±0.5 mg/kg in site S while that of the control was recorded 452.8±0.5 mg/kg. The control soil had the lowest $Zn^{2+}$ concentration and this is in agreement with the report of Mahmoudabadi *et al.*(2015) who also reported a higher level of $Zn^{2+}$ in soils than in control soils but the ranges of zinc ion obtained in this study are higher than 140.0 mg/kg recommended limits as well as 50.91 – 92.50 mg/kg obtained by Mmolawa *et al.*(2015) and 171.93 mg/kg obtained by Neboh *et al.*(2013). It has been reported that excess doses of Zn in the soil retard the breakdown of organic matter by influencing the activity of microorganisms and earthworms (Karim *et al.*, 2015). The highest concentration of Chromium (46.8±1.1 mg/kg) was obtained in abattoir soil from site Q, while the lowest concentration (35.1±0.0 mg/kg) was in site S abattoir soil which was still higher than what was recorded in the control site, 7.5±0.0 mg/kg. Further, all the values recorded were above the WHO limits of 5.0 mg/kg recommended for soils though in agreement with findings reported by Kierczak *et al.* (2016) in abattoir soils. It is reported that chromium can easily leach from the soil to surface waters by surface runoffs and it can be absorbed from the soil into the groundwater (Dung et al., 2013). Also, Chromium has been linked with allergic dermatitis in human beings (Auwalu *et al.,* 2015).

The results revealed that site S had the highest concentration (29.5±1.0 mg/kg) of lead ion while site R had the lowest (17.9±0.0 mg/kg) concentration which however was still higher than the control site (4.1±0.0 mg/kg). But in all, the values of lead ion recorded were above the recommended limit of 5.0 mg/kg in soil. The observations of higher lead ionin abattoir soils than in the control soil are in agreement with the work of Chukwu and Anuchi(2016) and that of Neboh *et al*. (2013) in related studies. Inhalation and ingestion are the two main routes of Lead exposure to humans and other vertebrates. When lead ions accumulate in the brain, it could lead to death, gastrointestinal tract, kidney as well as central nervous system disorder. Lead ion has been reported to be responsible for growth retardation in children (Useh *et al.,* 2017). Other health risks associated with lead include loss of memory, nausea, insomnia and anorexia. The values of cadmium ion recorded in the study areas ranged from 58.2±0.1 mg/kg in site T to 34.2±0.0 mg/kg in site S. Cadmium concentrations at the control site was 7.9±1.3 mg/kg which was below the values obtained from abattoir soils. The Cd values in the study area were relatively higher than 9.11 mg/kg recorded from abattoir soils by Adepoju *et al* (2012) but significantly higher than 0.52 mg/kg obtained by Liu *et al* (2016). Also, levels of cadmium obtained in this study were above the recommended limits of 2.0 – 3.0 mg/kg for soils which shows that studied abattoir soils were overloaded with cadmium.

The mean concentrations of all the heavy metals were higher in the studied soils than in the control plot which could be attributed to the elevated organic matter content and the metals being components of animal feeds and processing methods. Several authors confirmed that abattoir wastes can deplete biodiversity; affect human health; and pollute the air, water, and soil with toxic metals (Neboh *et al.,* 2013; Osu and Okereke, 2015; Karim *et al.,* 2015; Edori and Iyama, 2017; Godwin *et al.,* 2020). The prevalence of typhoid fever, diarrhea and coughing have been reported within the abattoir vicinity as their common problems in which 33.9% believed it to be associated with abattoir activities (Auwalu *et al.*, 2015) Hence, this study has revealed

that abattoir activities have the potential of elevating the concentrations of metals in the environment if not properly managed.

### *3.3 Assessment of Pollution Status of Heavy Metals in the Studied Abattoir Soils*

The anthropogenic effect of heavy metals was assessed by using the Contamination factor (CF). The CF of all the analysed heavy metals is summarized in Fig. 2. According to the different classes of CF predicted by Hakanson (1980) all the sites were found to be highly contaminated (3 < CF < 6) with Fe and Cr except Site Q in the case of Cr. Site Q, R, and T were highly contaminated with Pb and Site Q and S were highly contaminated with Cd as determined with the CF range between 3 and 6, while all the sites were found to be very highly contaminated with $Ni^{2+}$, $Cu^{2+}$, $Zn^{2+}$ except Site S in the case of $Zn^{2+}$. Site P, R, and T were found to be very highly contaminated with $Cd^{2+}$ and Site P and S with $Pb^{2+}$ as determined with the CF range > 6.

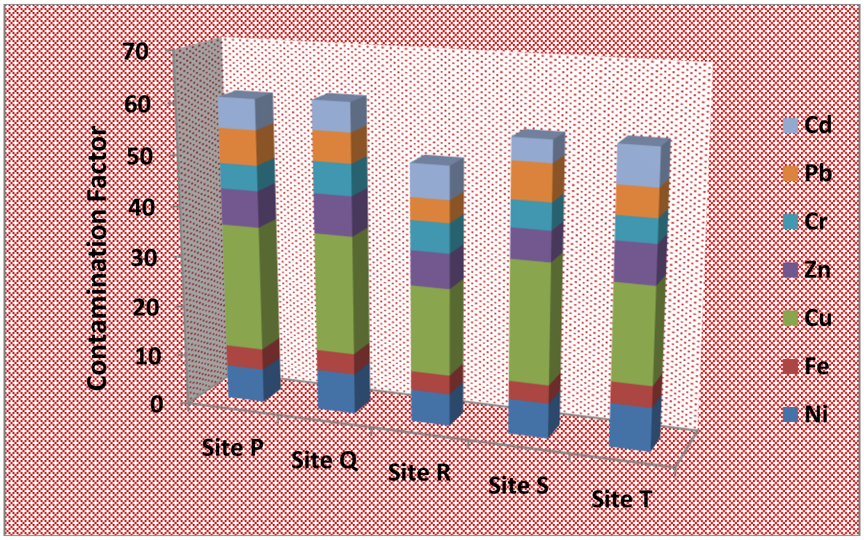

**Fig. 2. Graphical representation of the Contamination Factor across the study sites**

The enrichment factor evaluated for the studied samples is presented in Fig.3. Enrichment factors (EF) of the heavy metals were calculated for the abattoir soils using the continental crust average where Fe was used as a reference element for normalization (Table 2). Fe unveiled an EF value of 1.00 in all the abattoir soils studied signifying that a greater proportion of $Fe^{2+}$ may have emanated from natural soil forming processes (Godwin *et al.,* 2020). The EF values of all other analysed heavy metals except $Cu^{2+}$ in all the sites showed minor enrichment while sites R and T were moderately enriched with $Cu^{2+}$ and sites P, Q and S showed moderate-to-severe enrichment with Cu. Since the EF of all the heavy metals in abattoir soils studied were greater than 1.0 except that of $Fe^{2+}$, this indicated that these trace metals are from anthropogenic sources (Useh and Duada, 2018).

For the geo-accumulation index (Igeo), the results of heavy metals in studied abattoir soils are presented in Fig. 4. From the results, all the sites were moderately contaminated (Class 2) with $Fe^{2+}Cr^{+3}$ and $Pb^{2+}$ ($1 < I_{geo} < 2$) except site P in the case of Fe which was in Class 1, then site Q in the case of $Cr^{3+}$ and site P and S in the case of $Pb^{2+}$ which fell within Class 3. As for $Ni^{2+}$ and $Zn^{2+}$, sediment quality fell within Class 3 which varied from moderately contaminated to strongly contaminated ($2 < I_{geo} < 3$) in all the sites except site S in the case of Zn. Further, Site P, R and T were moderate to strongly contaminated ($2 < I_{geo} < 3$) with $Cd^{2+}$ while all the sites were strongly contaminated ($3 < I_{geo} < 4$) with $Cu^{2+}$ (Class 4) except site P that fell within Class 5 which was strong to extremely contaminated ($4 < I_{geo} < 5$).

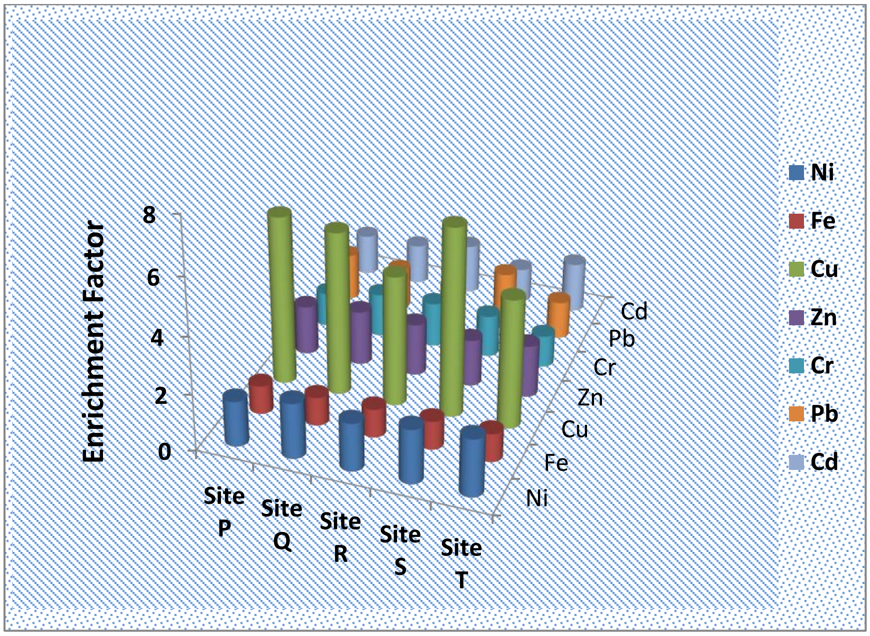

**Fig. 3. Graphical representation of the Enrichment Factor across the study sites**

The results of the degree of contamination (Cdeg) as determined are presented in Fig. 5. Cdeg was used to assess the extent of contamination of the studied abattoir soils. From the results, the degree of contamination of all the abattoir soils studied belongs to the very high degree of contamination class (32 < Cdeg) based on the model predicted by Hakanson (1980).

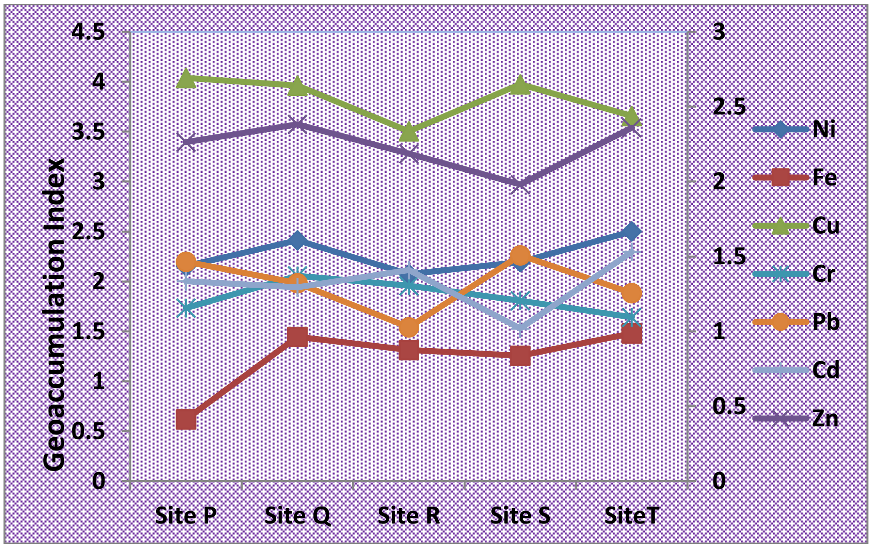

**Fig. 4. Graphical representation of the Cdeg and PLI across the study sites**

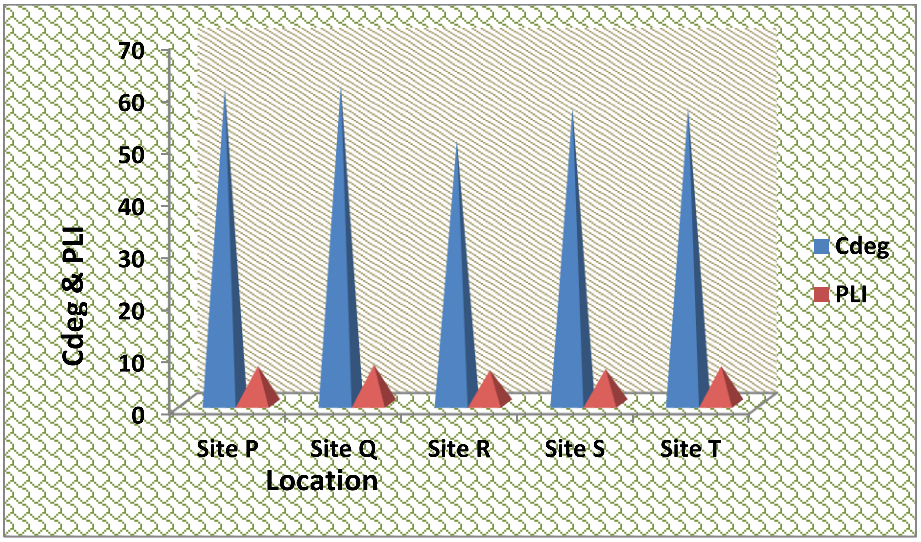

**Fig. 5. Graphical representation of the Cdeg and PLI across the study sites**

The pollution load index (PLI), as an aggregative explanation of the overall level of metal pollution, was investigated and the results obtained are shown in Fig. 5. Fig. 6 revealed that all studied abattoir soils have PLI values greater than 2, they were all in the category of extremely heavy pollution (3 < PLI) with the highest value of 7.463 for site Q. This showed that the level of these metals in the surrounding environment has increased tremendously in the past decades as a result of human input and abattoir activities.

## 4.0 Conclusion

This study was carried out to assess the effect of abattoir activities in the surrounding soils within Abuja including Kubwa, Dei-Dei, Dutse Alhaji, Gwarimpa and Mpape. From the results, it was revealed that soil samples within the vicinity of abattoirs were heavily polluted by the heavy metals with Cu as the most abundant metal in the sediments and then Zn. This is due to the abattoir activities within these areas that generated a lot of waste. Further, the toxicity assessments (contamination factor, enrichment factor, geo-accumulation index, degree of contamination and pollution load index) were also conducted using empirical pollution models. All these contamination indices showed a significant degree of contamination which suggests anthropogenic origins and confirmed the effects of abattoir activities within these areas. From the results, it is deduced that steps should be taken to minimize the impact of these elements in the environment to forestall the associated problems along the food chain.

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### Ethics approval and consent to participate

There is no bridge of ethics and consent to participate in this manuscript based on the Nigerian laws.

### Consent for publication

Not Applicable

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There is no competing interests

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This work was carried out in collaboration with all authors. Mercy Uwem Useh designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Mercy Uwem Useh and Danlami Uzama carried out the analyses of the study while Patrick Obigwa managed the literature searches. All authors read and approved the final manuscript.