

## Influence of Toxic Heavy Metals and Their Potential Sources in the Soil from Major Abattoirs in Zamfara State

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### ABSTRACT

Abattoirs play a vital role in meat production but can significantly impact environmental health due to improper waste management. This study investigated the levels of selected toxic heavy metals Pb, Cu, Cd, Zn, and Cr in soils from abattoir sites in Gusau, Kaura-Namoda and Talata Mafara LGAs of Zamfara State, Nigeria. The aim was to assess the impact of abattoir activities on soil quality and to determine the potential risks posed by heavy metal contamination. Soil samples were collected from four abattoir locations and a control site with no history of abattoir activity. Standard laboratory procedures were used to analyze the physicochemical properties of the soils, as well as the concentrations of the heavy metals. The results indicated that soils from the abattoir sites had slightly elevated pH, electrical conductivity, organic matter, and water holding capacity compared to the control, though all were within permissible limits. Heavy metal analysis showed that Pb, (12.54±0.0215 to 13.61±0.0421) Cu (6.84±0.0251 to 7.68±0.0313), and Cd (0.39±0.0439 to 0.41±0.0551), Zn (16.54±0.0417 to 18.62±0.0343) while Cr (6.21±0.0263 to 6.60±0.016) concentrations were higher in abattoir soils than in the control, with Cu and Pb showing high metal pollution index (MPI > 3), while Cd, Zn, and Cr exhibited moderate pollution (1 ≤ MPI < 3). Pollution assessment using Contamination Factor (CF), Degree of Contamination (Cdeg), and Pollution Load Index (PLI) revealed that contamination levels were generally low, though cadmium presented moderate contamination potential in some samples. The study concludes that while the current levels of heavy metals in abattoir soils do not pose immediate environmental threats, continuous discharge of untreated abattoir waste could lead to long-term soil degradation and potential health risks. Regular monitoring and improved waste management practices are recommended to prevent future environmental contamination.

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### INTRODUCTION

Abattoirs play a vital role in meat production but can significantly impact environmental health due to improper waste management (Adeleke *et al.*, 2021). Soil contamination, particularly with heavy metals, is a growing concern due to potential health risks and environmental degradation (Abeh *et al.*, 2017).

Soil contamination by heavy metals has become a growing environmental concern, particularly in areas where human and industrial activities are prominent. Abattoirs, or slaughterhouses, are known to contribute significantly to environmental degradation when waste management practices are inadequate. These facilities often release solid and liquid waste containing blood, fats, and other organic materials directly into the surrounding environment. When these wastes are improperly handled, they introduce various contaminants including heavy metals into the soil and the surrounding (Adeleke *et al.*, 2021).

Heavy metals are non-biodegradable and can accumulate in soils over time, metals such as lead (Pb), cadmium (Cd), chromium (Cr), zinc (Zn), copper (Cu), and nickel (Ni). While some heavy metals are essential micronutrients for plants and animals in micro amounts, their increase accumulation can be toxic and constitute risks to human health through direct contact and even the food chain, and water contamination. Heavy metals may have access to the soils through both natural processes and anthropogenic activities. In the context of abattoirs, potential sources include:

- i. Animal waste and blood: These may contain trace metals from feed additives or veterinary drugs.
- ii. Effluent discharge: Wastewater from cleaning activities may carry dissolved metals.
- iii. Slaughtering equipment: Corrosion and wear of metallic equipment can introduce iron, chromium, and other metals into the soil.
- iv. Improper disposal of solid waste: Bones, hooves, and tissues may accumulate in the soil and release metals upon decomposition.
- v. External inputs: Runoff from nearby roads, industrial zones, or urban settlements may contribute to the overall metal load (Amoah *et al.*, 2019).

It is therefore, essential to assess the concentrations of these metals and understand their potential sources to inform sustainable environmental management practices and reduce associated health risks. This study seeks to assess the concentrations of selected heavy metals (e.g., Pb, Cd, Cr, Zn, Cu).

### MATERIALS AND METHOD

**Sampling:** All samples were collected randomly within the study areas. Three composite soil samples were collected from two abattoir vicinities located in Gusau and one in Kaura Namoda and Talata Mafara Local Government Area. A

control soil sample was also collected from Damba Area of Gusau, Zamfara State. The samples were packed in well-labeled sample bottles, and conveyed to the laboratory for preparation and analysis.

**Sample Preparations:** Soil samples were air-dried to constant weight at room temperature to remove moisture from the sample and then oven-dried at 60°C for one hour to fully remove moisture. Soil samples were then grounded using a mortar and pestle and sieved with a mesh of 2 mm in diameter to remove stones and debris. The sample (0.5g) was measured out into a 250 ml beaker using an analytical weighing balance, and 0.5 ml of concentrated nitric acid was added directly to the soil sample and stirred. One hundred (100mL) milliliters of distilled water were added and stirred. The mixture was then heated to evaporate below boiling point using a heating mantle placed inside a fume cupboard until the volume was reduced to 20 ml and allowed to cool. The mixture was then filtered using Whatman No. 42 filter paper into a 100 ml volumetric flask, and distilled water was added up to mark. Heavy metal concentration was determined using an atomic absorption spectrophotometer. The heavy metal analysis was run in duplicates including the control sample.

### Heavy Metal Analysis for the Soil Samples

Pollution assessment: Mazurek *et al.* (2017) highlighted the significant role of pollution indices in conducting a comprehensive assessment of soil pollution levels. These indices serve as valuable tools for evaluating the extent of soil contamination. Three major geochemical indices: contamination factor (CF), degree of contamination (Cdeg), and pollution load index (PLI) were considered for this study to assess the pollution level based on toxic metal concentrations in the soil samples.

The below geochemical contamination indices were considered:

**Metal Pollution Index:** can be categorized in three main stages (Alberto Then *et al.*, 2023),

$$MPI = \frac{\text{Concentration of metal in the study soil}}{\text{Concentration of metal in control soil}} \quad (1)$$

these stages are as follows:

- i. MPI < 1: Indicates Low Pollution Level
- ii.  $1 \leq MPI < 3$ : Indicates Moderate Pollution Level
- iii. MPI > 3: Indicates Highest Pollution Level

**Contamination Factor (CF):** is a metric used to determine the degree of contamination or pollution in a given sample.

The contamination factor of the sample was calculated using the general equation

$$CF = \frac{C_m}{B_m} \quad (2)$$

Where CF is the contamination factor,  $C_m$  is the concentration of the metal in the studied sample, and  $B_m$  is the background concentration of metal either from literature (average crustal abundance) or directly determined from a geologically similar area. Hakanson (1980) categorized the contamination factor into various classes, which are as follows:

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

### Degree of Contamination

The degree of contamination (Cdeg) is simply the sum of all the contamination factors of heavy metals for a particular abattoir soil and was determined using an equation as reported by Sayadi *et al.*, (2015) and Pekey *et al.*, (2004).

The degree of contamination at each location was calculated as in equation

$$= \sum CF \quad (3)$$

Where CF denotes the contamination factor for all the studied metals at a particular location.

The four classes of Cdeg as highlighted by Amoah *et al.*, (2019) are as follows: Cdeg < 8 = low degree of contamination;  $8 < Cdeg < 16$  = moderate degree of contamination;  $16 < Cdeg < 32$  = considerable degree of contamination and  $32 < Cdeg$  = very high degree of contamination

**Pollution load index (PLI):** PLI is also used for the total assessment of the degree of contamination in soil. 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, 2017). The equation based on the procedure of Tomlinson *et al.*, (1980) was employed to calculate the pollution load index (PLI) of heavy metals for each abattoir.

$$PLI = \sqrt[n]{CF_1 \times CF_2 \times CF_3 \dots \times CF_n} \quad (4)$$

Where CF denotes 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 < 2: No pollution,  $2 < PLI < 3$ : Heavy pollution and  $3 < PLI$ : Extremely heavy pollution

## RESULTS AND DISCUSSION

**Table 1: Physicochemical Properties of the Abattoir soil in Gusau, Kaura-Namoda and Talata Mafara LGAs**

| Parameters                                    | Gusau1       | Gusau 2      | Kaura-Namoda | Talata Mafara | Control      | WHO Std. 1998 |
|-----------------------------------------------|--------------|--------------|--------------|---------------|--------------|---------------|
| pH                                            | 7.32±0.0131  | 6.92±0.0142  | 6.66±0.0213  | 6.98±0.0112   | 6.03±0.0544  | 6.4 – 8.5     |
| Electrical conductivity (µScm <sup>-1</sup> ) | 85.5±0.0332  | 81.4±0.0532  | 74.5±0.0216  | 83.3±0.0513   | 60.5±0.0215  | Below 100     |
| Water holding capacity g/cm                   | 34.56±0.0232 | 32.53±0.0332 | 36.23±0.0311 | 34.66±0.0426  | 41.12±0.0211 |               |
| Organic matter %                              | 6.4±0.0211   | 6.2±0.0243   | 6.6±0.0313   | 6.4±0.0152    | 5.34±0.0117  |               |

Values are mean ± standard deviation

From the results (Table 1) the pH values recorded for the soil samples ranged from 6.66±0.0213 to 7.32±0.0131. The pH values of all sites were slightly above the control site (6.03±0.0544). However, these values all fell within the WHO 1988 set limit (6.4 -8.5). Interestingly, there appears a

significant increase in pH when compared to the pH value of soils within Niger Delta region as reported. Iwegbue *et al.*, (2009), and Ovasogie and Ofomaja (2007) which are known to be quite acidic. This increase in pH could be attributed to the type of the wastes deposited from the slaughter houses

which results in reduced anerobic in the soils (Odu *et al.*, (1985).

Conductivity values ranged from  $74 \pm 0.0216 \mu\text{Scm}^{-1}$  to  $85.5 \pm 0.0332 \mu\text{Scm}^{-1}$ . These values were comparatively higher when compared to previous works of Onwuka and Uzoukwu 2008. However, when compared to WHO 1998 the values all fell within acceptable standard limit and thus indicating that irrespective of the activities within the abattoir sites, the concentration of dissolvable ions did not exceed the standard set limit.

#### Water Holding Capacity

The water holding capacity of all the soil sample ranged from  $32.53 \pm 0.0332$  to  $36.23 \pm 0.0311$  g/cm. the control site has slightly higher water holding capacity than the three abattoirs sites investigated. The reason for the highest or lowest water holding capacity could be kind of soil or texture of soil present in respective site. Different soil particle has different water holding capacity. The coastal area could be having for sandy soil and residential area having more clay particle in the soil which has the maximum capacity to hold the water. As it is rich in organic matter. Soil organic matter is another factor

that can help increase water holding capacity. If the farm increases the percentage of soil organic matter, the soil water holding capacity will increases.

#### Organic Matter

The organic matter of all the soil sample ranged from  $6.2 \pm 0.0243$  to  $6.6 \pm 0.0313\%$ . The control site has slightly lower organic matter than the four abattoirs' sites investigated. Less content of organic matter indicates that the soil lacks micro flora and fauna which ultimately results in organic matter. The surrounding atmosphere could affect it. There is proven method to reduce losses of organic matter from given field. One of these is conservation tillage that means reducing soil disturbance, which consequently slows decomposition rate. Erosion control is another method for reducing the amount of soil organic matter lost from the soil. Organic matter can be increased by increasing inputs of organic material or decreasing losses. Organic matter has a vital role in soil. It supplies plant nutrient, improve the soil structure, improves the water infiltration and retention. It contributes positively to higher crop yields.

**Table 2: Results of Heavy Metals Present in Abattoir Soils from Gusau, Kaura-Namoda Talata Mafara LGAs**

| Sample location | Pb MgKg <sup>-1</sup> | Cu MgKg <sup>-1</sup> | Cd MgKg <sup>-1</sup> | Zn MgKg <sup>-1</sup> | Cr MgKg <sup>-1</sup> |
|-----------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Gusau 1         | $13.61^a \pm 0.0421$  | $7.68^a \pm 0.0313$   | $0.37^a \pm 0.0631$   | $16.54^a \pm 0.0417$  | $6.56^a \pm 0.0211$   |
| Gusau 2         | $12.86^b \pm 0.0724$  | $7.44^a \pm 0.0379$   | $0.39^a \pm 0.0439$   | $17.86^b \pm 0.0455$  | $6.21^a \pm 0.0263$   |
| Kaura-Namoda    | $12.54^b \pm 0.0215$  | $6.84^b \pm 0.0251$   | $0.41^a \pm 0.0551$   | $18.62^b \pm 0.0343$  | $6.60^a \pm 0.0616$   |
| Talata Mafara   | $11.967^b \pm 0.0711$ | $7.64^a \pm 0.0271$   | $0.38^a \pm 0.0332$   | $17.91^b \pm 0.0431$  | $6.11^a \pm 0.0213$   |
| Control         | $4.11^c \pm 0.0361$   | $2.17^c \pm 0.0311$   | $0.26^b \pm 0.0361$   | $14.21^c \pm 0.0333$  | $2.25^b \pm 0.0731$   |
| FEPA Std, 1998  | 15.0 – 25.0           | 7.0 – 80.0            | 2.0 – 3.0             | 130.0 – 140.0         | 0.0 – 100.0           |

Values are mean  $\pm$  standard deviation (n =4). Values on the same column with different superscript letters are significantly different as revealed by one-way analysis of variance (ANOVA) and least significant different test ( $p \leq 0.05$ ).

**Table 3: Heavy Metal Pollution Index for the Different Locations of Abbatoirs**

| Element | Gusau 1 | Gusau 2 | Kaura-Namoda | Talata Mafara |
|---------|---------|---------|--------------|---------------|
| Pb      | 3.3114  | 3.1290  | 3.0511       | 3.2191        |
| Cu      | 3.5392  | 3.4286  | 3.1521       | 3.3134        |
| Cd      | 1.4231  | 1.5000  | 1.5759       | 1.4921        |
| Zn      | 1.1640  | 1.2569  | 1.3103       | 1.1226        |
| Cr      | 2.9156  | 2.7600  | 2.9333       | 2.6611        |

From the interpretation of the MPI, table 3 shows that Gusau 1 has moderate pollution and kaura Namoda abattoir. While the Level of Cd, Zn and Cr are moderate since their MPI is greater than 1 and less than 3. While Pb and Cu shows high pollution level since their MPI is greater than 3.

MP<1: indicates low pollution level,  $1 \leq \text{MPI} < 3$ : indicates moderate pollution level  
MPI.3; indicates highest pollution level

**Table 4: Heavy Metal Contamination Factor**

| Elements | Gusau 1 | Gusau 2 | Kaura-Namoda | Talata Mafara |
|----------|---------|---------|--------------|---------------|
| Pb       | 0.6805  | 0.1429  | 0.1393       | 0.1521        |
| Cu       | 0.1707  | 0.0729  | 0.1520       | 0.0763        |
| Cd       | 1.2333  | 1.3000  | 1.3667       | 1.3041        |
| Zn       | 0.1714  | 0.1880  | 0.1960       | 0.1782        |
| Cr       | 0.0729  | 0.0690  | 0.0733       | 0.0780        |

From the interpretation of the contamination factors presented in table 4, it revealed that there is a general low contamination across the four abattoir sites except for Cd which shows moderate contamination across the four abattoirs site studied.

Cf<1: Low contamination  $1 < \text{Cf} < 3$ : Moderate contamination  $3 < \text{Cf} < 6$ : High contamination  $6 > \text{Cf}$ : Very high contamination

**Table 5: Degree of Contamination of the Abattoir**

| Location      | Degree of contamination |
|---------------|-------------------------|
| Gusau 1       | 2.3315                  |
| Gusau 2       | 1.8652                  |
| Kaura Namoda  | 1.9273                  |
| Talata Mafara | 1.8746                  |
| Control       | 1.1352                  |

From the interpretation of the degree and contamination presented table 5 it shows that all the four abattoirs investigated has a general low degree of contamination. Degree of contamination

Cdeg<8: Low degree of contamination, 8< Cdeg< 16: Moderate degree of contamination  
16<cdeg<32: Considerable degree of contamination, 32<deg: Very high degree of contamination

**Table 6: Showing pollution Load Index (PLI)**

| Location      | PLI    |
|---------------|--------|
| Gusau 1       | 0.2830 |
| Gusau 2       | 0.2853 |
| Kaura-Namoda  | 0.4734 |
| Talata Mafara | 0.2921 |
| Control       | 0.1532 |

Table 6, showing Pollution Load Index (PLI) of locations studied. The result revealed that there is a general low pollution status

i.  $PLI < 2$ : No pollution ii.  $2 < PLI < 3$ : Heavy pollution iii.  $3 < PLI$ : Extremely heavy pollution.

Generally, the result of the pollution indices indicates that there is no pollution on the studied abattoir but continuous use of the abattoir may increase the concentrations of the heavy metals and other metals that are not investigated in this research which will eventually increase the contamination level of the studied sites.

**Pb:** The way ANOVA conducted on the result shows that there is no difference ( $P \leq 0.05$ ) down the column across the different location.

**Cu:** One way analysis of variance conducted on the result that there is a significant difference ( $P \leq 0.05$ ) down to column between Gusau, Kaura Namoda and Talata Mafara locations.

**Cd:** Analysis of variance revealed that there is no significant different ( $P \leq 0.05$ ) down the column across the different locations except with the control site which has a significant difference.

**Zn:** There is a significant difference ( $P \leq 0.05$ ) down the column across different location between Gusau 1, Gusau 2, Kaura Namoda and Talata Mafara. **Cr:** The result of Cr revealed that there is no significant different down the column across the three location of abattoir studies.

**Pb:** There is a general metal pollution of both Pb and Cu across all the four locations studied since their metal pollution index is greater than 3. While Cd, Zn and Cr constitute moderate pollution level across all the four locations since their metal pollution index is less than 8 equals to 3.

The observed concentration in this present study is comparatively higher than 0.0011 to 0.0067 mg/kg found in soil from three abattoirs (Agip, Iwafa and Mile III) in Port Harcourt. The high levels of observed cadmium might be as a result of processing animals that were fed with certain grains and vegetables that contain cadmium such that cadmium can enter the soil through waste product. Applications of fertilizer containing cadmium on the soil close to the studied area might also be responsible for the elevated levels of cadmium in the studied location. High levels of cadmium can also be caused by the use of cadmium-containing materials such that when these materials corrode over time, they can contaminate the soil. The observed values in this study might pose health risk to the inhabitants of Gusau, Kaura Namoda and Talata mafara

main Abattoir and environment. Increase in soil cadmium might result in an increase in uptake by vegetables.

The concentration of copper in the control location is lower than the permissible limit of 36 mg/kg set by WHO, 2001. This revealed that the control location is not contaminated with atmospheric deposited copper through air borne particles from vehicles exhaust or long- ranged transport of dust containing copper. The experimental values are fairly in good agreement with reported literature value of 9.07 mg/kg. This therefore shows that, the observed levels of copper across all locations will not pose health risk to the inhabitants of the main abattoir for the time being. Nonetheless, bioavailability of copper cannot be confirmed based on total concentration alone.

The level of chromium analyzed was higher than the values of 0.00- 0.05 mg/kg found in soil from major road networks of Dass, Bauchi State, Nigeria and 0.009 mg/kg found in soil of residential area Chromium salts such as chromium sulphate are used in tanning processes. In an effort to reduce contamination of soil with chromium, this method can be used to switch to alternative tanning processes such as vegetables tanning which can significantly decrease chromium level in soil. The cumulative levels of chromium in the studied area and that of the control are lower than the permissible dose of 100.00 mg/kg. This indicates that there is no chromium contamination in both the abattoir and control soil presently. The levels of lead recorded are in fairly good agreement with the range values of 15.60 - 30.09 mg/kg found in soil of abattoir dumping site in Nigeria and also lower than the target values of 85 mg/kg, but greater than the values of 0.005 0.051 mg/kg found in soil of Bauchi Metropolis, Nigeria. Lead do not have known bio-importance in human biochemistry, physiology and consumption of lead even at a very low concentration can be toxic. The inhabitants of Bauchi main abattoir might not therefore be at risk of lead contamination for now.

## CONCLUSION

This study assessed the concentration of selected heavy metals (Pb, Cu, Cd, Zn, and Cr) in soils collected from four abattoir sites in Gusau, Kaura-Namoda and Talata Mafara Local Government Areas, Zamfara State, Nigeria, and compared them with a control site. The evaluation included determination of physicochemical properties, pollution indices such as Contamination Factor (CF), Degree of

Contamination (Cdeg), Metal Pollution Index (MPI), and Pollution Load Index (PLI). The findings revealed that pH, electrical conductivity, organic matter, and water holding capacity of the abattoir soils were slightly higher than the control, but all within acceptable limits as recommended by WHO (1998). Concentrations of heavy metals in all abattoir soils were higher than in the control soil, with cadmium (Cd), copper (Cu), and lead (Pb) showing relatively higher values, though still within FEPA (1998). Standard Pollution indices indicated: Pb and Cu posed a high pollution risk ( $MPI > 3$ ), Cd, Zn, and Cr showed moderate pollution levels ( $1 \leq MPI < 3$ ), CF values were low for most metals except Cd, which showed moderate contamination, Degree of contamination (Cdeg) was generally low across all abattoir sites ( $Cdeg < 8$ ), Pollution Load Index (PLI) values were less than 2, indicating no overall pollution.

Generally, while the abattoir soils are not currently heavily polluted, the presence of moderate levels of heavy metals, especially cadmium, and elevated MPI values for Pb and Cu, suggest that continued and unregulated abattoir activities could result in significant environmental and public health risks over time.

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