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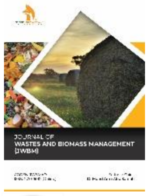

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RESEARCH ARTICLE

ENVIRONMENTAL RISK ASSESSMENT OF LEAD (Pb), COPPER (Cu), ZINC (Zn), AND CHROMIUM (Cr) IN DUSTE ABBATOIR DUMP SITE IN JIGAWA STATE, NIGERIA

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ABSTRACT

An inquiry was carried out to investigate the presence of chemical contaminants, like lead, copper, zinc, and chromium, in the garbage disposal sites of Duste Abattoir in Jigawa State. The research was spurred by the elevated levels of heavy metals frequently discovered in public waste disposal sites. Samples were gathered from both the Duste Abattoir and public waste disposal sites to address a knowledge gap in this field. The findings of the investigation show that all areas examined are vulnerable to heavy metal contamination, with lead (Pb) presenting the highest risk, followed by copper (Cu) and zinc (Zn). Chromium (Cr) has a lesser impact on the environment. Pollution indices suggest that Pb and Cu are the main contaminants, with Zn following closely behind. It was also established that the Abattoir site is more at risk of heavy metal contamination compared to the public site. Moreover, organic carbon and pH levels displayed a significant positive connection with chromium and zinc inorganic forms. It is crucial to consistently monitor waste materials from the abattoir and municipal sources to safeguard the environment and residents, particularly young children, from the risks associated with heavy metal pollution in the area. It is also suggested to decontaminate the abattoir waste before use for agricultural purposes.

KEYWORDS

Environment, Risk assessment, Heavy metals, Abattoir, Dumpsite

1. INTRODUCTION

The term "potentially toxic elements" is a recent concept that emphasizes not all elements are toxic at all concentrations to humans and plants. According to soil chemists, heavy metals are elements found between Group IIA and IIIA in the periodic table, possessing partial d-orbital filling (Bohr et al., 2001). These heavy metals have an atomic density greater than 6 g/cm3 and a specific gravity of more than five (Abdu, 2010). Copper, zinc, and some metals are considered important essential nutrients in biochemical reactions, whereas metals such as Pb or Cr are not viewed as plant nutrients (Sparks, 2002). The result found that after 8 years of sludge treatment, there was a notable migration of cadmium, chromium, lead, and zinc in the soils (Borgard et al., 2009). Likewise, showed that more than 90% of the heavy metals used were concentrated in the top 15cm of soil (Fonseca et al., 2013). Another study observed a minimal downward movement of cadmium and zinc in the soil profile, indicating the vertical transportation of heavy metals into groundwater by (Violante et al., 2010). This Analysis identified that heavy metals have the potential to leach into sandy, acidic, and low-organic soils during periods of heavy rainfall or irrigation (He and Ali, 2013). Abdu *et al.* (2012) discovered soil pH affects Cd, Cr, Cu, Pb, and Zn mobility. Reichman (2002) noted Cd and Zn move more than Cu and Pb in soil pH <6 >6.5.

Incorrect disposal of abattoir waste could lead to the spread of pathogens and harmful substances to humans, potentially leading to outbreaks of waterborne illnesses and cancer (Ubwa et al., 2013). Agrochemicals, biosolids, sewage sludge, and wastewater applications may introduce trace elements into agricultural soils (Abdu, 2010; Abdu et al., 2017). Agbenin and Atin (2003) reported an increase in total Pb by 19 and 17% owing to fertilization with NPK and farmyard manure, respectively, compared to the natural site in some Nigerian savanna. The transportation of metals in soil is a sophisticated process that is impacted by chemical factors like organic content and pH (Abdu et al., 2012). Research on soil indicates that consistent usage of organic wastes, fungicides, and pesticides can elevate the levels of heavy metals (Han et al., 2000). Soils with elevated concentrations of heavy metals are seen to produce enhanced runoff carrying these metals (Catlett, 2012).

According, an abattoir is a facility for slaughtering animals for meat, while elaborate on it as a place where meat products are processed, inspected, preserved, and stored for human consumption (Ubwa et al., 2013; Hornby, 2006). Regrettably, in Nigeria, meat processing often occurs in inadequate structures and is carried out by unskilled workers, resulting in the production of waste materials like blood, fat, solids, salts, and chemicals (Ubwa et al., 2013; Olanike, 2002). Research has also detected heavy metals in different parts of cattle (Jukna, 2006). A major challenge facing agricultural output is using municipal and abattoir discharges as a source of organic matter. Such would enhance the true productivity level of farmlands. Unknowingly, these waste materials are always rich in contaminated materials (Such as Pb, Zn, Cr, Cu, and so on) that are a risk to human health if care is not taken. The presence of organic matter significantly affected the availability of heavy metals in soil, as stated by (Hou et al., 2019). As noted, the humus layer acts as an important bio-geochemical barrier, preventing metal ions from permeating with seepage water and promoting element accumulation by (Sparks, 2012).

Additionally, heavy metals like lead, chromium, cadmium, and zinc are frequently found in public disposal facilities. These metals pose a

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considerable risk to both humans and animals as they can contaminate the environment through the ingestion of tainted water or plants. The dumpsite is usually contaminated with waste from municipalities and slaughterhouses, which are known to contain high concentrations of heavy metals (Smith, 2009). Public attention to assessing the risk presence of toxic elements has been significantly neglected in the study area. Information on environmental quality is of great importance as it can be utilized in preventing toxic materials from taking into farms and drinking water supply indeed from the Abattoir. The poisoning of groundwater due to some heavy metals like lead, chromium, copper, and zinc has been reported in almost all parts of Nigeria (Agbenin, 2001). Multiple studies have shown that activities at slaughterhouses contribute to the pollution of surface and underground water, air quality, and the overall health of residents in the surrounding area (Patra et al., 2007; Katarzyna et al., 2009; Ubwu et al., 2013). Metal ions, in particular, are cited as a significant concern due to their high toxicity, carcinogenic properties, and inability to biodegrade. Therefore, the analysis of pollution indices is essential in assessing the impact of metal ions on the environment. Soil contamination can negatively affect food security by reducing crop yields due to toxic levels of pollutants and rendering crops grown in polluted soil unsafe for consumption by animals and humans.

The primary aim of this research was to analyze the environmental impact of lead (Pb), copper (Cu), zinc (Zn), and chromium (Cd) in specific dumpsites located in Duste, Jigawa State, Nigeria.

2. Material and Methods

2.1 Study Area

The study took place in Duste, Jigawa state, with precise coordinates of latitude (11°45’ 22.25” N) and longitude (9°20’20.26” E). The city is situated in an area characterized by a tropical savanna climate, featuring distinct wet and dry seasons.

2.2 Soil sampling and preparation

Waste samples were collected in the selected main Abattoir discharge centers represented as location A while B is the municipal discharge center in Duste. Waste samples were gathered at a depth of 0-30 cm from designated sites, where each collection included 15 auger points. After collection, the samples were air-dried, blended well, crushed with a porcelain pestle and mortar, and sifted through a sieve with a pore size of less than 2mm for testing.

2.3 Laboratory analysis

The pH of the soil was tested in water and 0.01M $CaCl_2$ solution at a 1:1 ratio. Bases (Ca, Mg, K, Na) were determined with the NH_4OAc method by (Thomas, 1982). Organic carbon was estimated with the Walkley-Black method by (Nelson and Sommers, 1982).

2.4 Total heavy metals

A dried and ground sample (1g) was placed in a tube. Each sample received a mixture of $HClO_4$ (1cm^3), HNO_3 (5cm^3), and H_2SO_4 (0.5cm^3). According to method, the tube was swirled and heated until white fumes were observed, with digestion lasting for 10-15 minutes (Agbenin's, 1995).

After cooling, tubes were filtered into a 50 ml flask with a Whatman No. 42 filter. Water was then added to fill each flask. Heating with 0.5cm^3 HNO_3 caused a volume decrease. The digest was filtered, diluted, and prepared for analysis. A control digestion without a sample was done. Using AAS, lead, zinc, chromium, and iron concentrations were measured against FAO and WHO safety limits set (2008).

2.5 Inorganic concentrations of heavy metals

DTPA chelation method analyzed inorganic metal concentration. A 20g sample (<2mm) mixed with 20 ml 0.005 M DTPA solution was shaken for 2 hours, then filtered. Zn, Pb, Fe, and Cr levels were measured using AAS by (Lindsay and Norvell, 1978).

2.6 Statistical Analysis

The data underwent analysis of variance to determine the contamination level of heavy metals in the study samples using pollution indices such as the geo-accumulation index, enrichment factor, and contamination factor. Correlation Analysis was conducted with SAS to further analyze the data.

3. Results and Discussion

3.1 Chemical Properties

The pHw of samples from both locations was alkaline (Figure 1). This is due to organic content in the dumpsite of the Abattoir. Similar results were observed with pHs. Location A has high organic content (mean value of 15.53g/kg) which is greater than the critical value, according to Esu (1991). The OC mean value (12.18g/kg) in location B is moderate (Esu, 1991). The samples from both locations are rich in Ca, Mg, and Na contents. This may be associated with organic content in all studied samples. This is in line with the observation of (Brady and Weil, 2002). The trend of all selected chemical properties is as follows: location A > location B but otherwise with Na content.

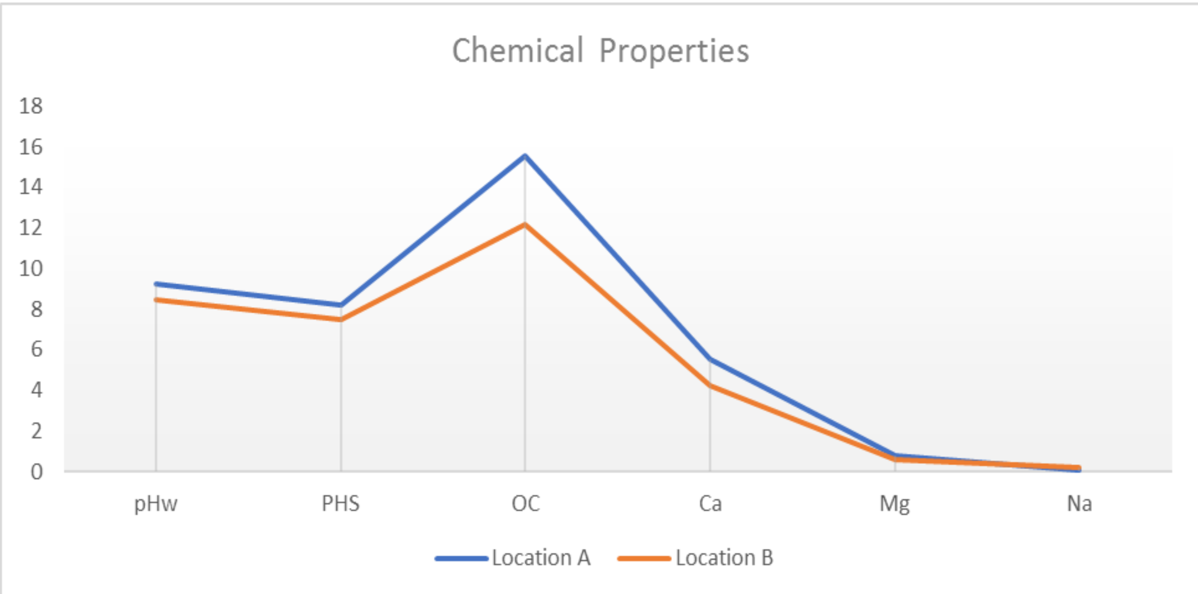

Figure 1: Selected Chemical Properties In Abattoir Waste Area.

3.2 Focus On The Concentrations Of Specific Heavy Metals

The mean Pb values (320.19 to 444.96 mg/kg) from all the studied locations (Table 1) were found to be above both the international threshold of 300 mg/kg for Pb in arable soils (Abdu, 2010) and the maximum allowable concentration of 85 mg/kg in Nigerian soils as stipulated by the Department of Petroleum Resources of Nigeria (DPR, 2002). Location A (Table 1) is at more risk of Pb toxicity compared to location B. Copper mean values in all locations are less than the international threshold of 200-300a mg/kg in soils with less maximum allowable value (DPR, 2002). The zinc means value in location A (Table 1) is greater than the international threshold of 80-200a in soils and location B with zinc concentration less than that of the international threshold as indicated above (Abdu, 2010; Yahaya et al., 2021). The concentrations of chromium in all the studied locations (Table 1) are less than that of the international threshold of 400mg/kg. The order of magnitude of the total and labile values of selected heavy metals could be arranged as follows: location A>location B (Table 1) and location B >location A (Figure 2), respectively. The formation of metal-organic complexes is the reason for having less value in the labile form of heavy metals in location A (Figure, 2), which serves as a center of abattoir waste materials. Heavy metals ranked: Pb > Zn > Cu > Cr. Several studies observed Pb as the most contaminant in their study sites (Abdu, 2010; Haris et al., 2017).

Table 1: Average Of Specified Heavy Metal Elements

Heavy metal	Location A	Location B	UK (mg/kg)	Remark
Lead (Pb)	444.96	320.19	300	> IAPL
Copper (Cu)	196.37	166.67	200-300[a]	< IAPL
Zinc (Zn)	241.19	172.14	80-200[a]	< IAPL
Chromium (Cr)	16.99	5.39	400	< IAPL

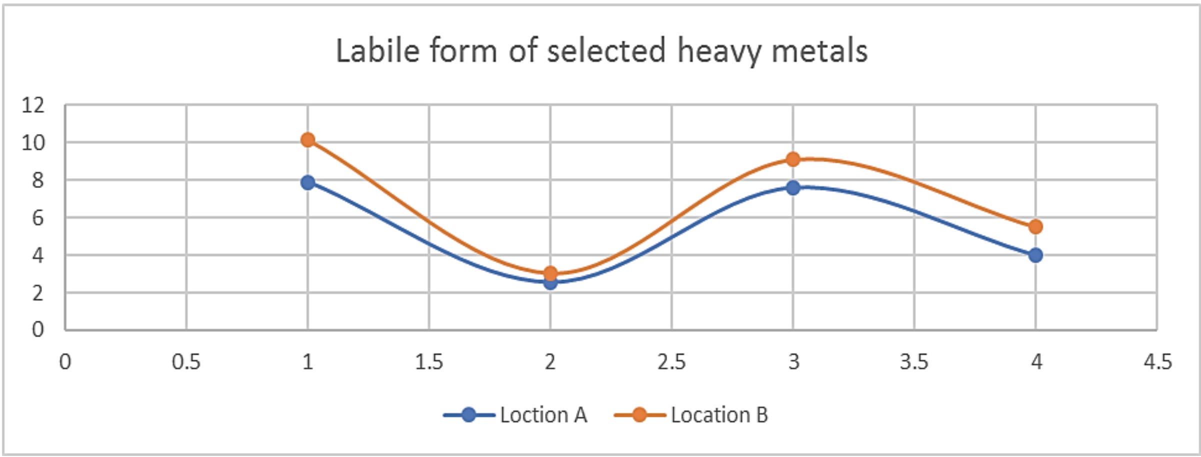

Figure 2: Labile Form Of Heavy Metals

4. Pollution Indices

4.1 Contamination Factor

In this study, the degree of chemical pollutants in the analyzed samples was assessed using the contamination factor (Table 2). Lead (Pb) values showed that location A has a strong contamination factor while location B varied from moderate to a strong level of contamination factor. Copper and Zinc values indicated that all the studied locations have strong and none to medium contamination factors, respectively (Table 2). The chromium value has fallen under none to medium as in Zinc. The pollution analysis indicated that lead and copper are most prevalent in the locations and reflect the impact of anthropogenic activity.

Table 2: Contamination Factor

Heavy metal	Location A	Remark	Location B	Remark
Lead (Pb)	5.23	ST	3.77	MC – ST
Copper (Cu)	5.45	ST	4.63	ST
Zinc (Zn)	1.72	N-M	1.23	N-M
Chromium (Cr)	0.16	N-M	0.05	N-M

ST=Strong contamination; MC-ST= Moderate to strong contamination; N-M= none to medium contamination

4.2 The Enrichment Factor

The enrichment factor for particular heavy metals is displayed in Table 3 for all locations whereas location B has a high value of the studied elements (Pb, Cu, and Zn). Lead, Copper, and Zinc have strong and moderate enrichment factors, respectively (Table 3) while Chromium has fallen under deficient enrichment factors. The order of enrichment contamination could be arranged as Copper>Lead>Zinc>Chromium.The vast majority of chemical pollutants come from anthropogenic activities such as sand mining, construction, waste disposal, agriculture, and discharge from municipal, residential, or industrial activity (Wei and Yang 2010; Balogh et al., 2016; Haris et al., 2017).

Table 3: Enrichment Factor

Heavy metal	Location A	Remark	Location B	Remark
Lead (Pb)	11.55	STE	11.75	STE
Copper (Cu)	12.07	STE	14.49	STE
Zinc (Zn)	3.80	ME	3.83	ME
Chromium (Cr)	0.38	DE	0.17	DE

STE= Strong Enrichment; ME= Moderate Enrichment; DE= deficient Enrichment

4.3 Geoaccumulation index

According to the Geoaccumulation index (Table 4), the concentrations of lead and copper in the two study areas fell into the categories of highly and moderately polluted, respectively. Regardless of location, zinc concentrations have displayed a geoaccumulation index that ranges from Unpolluted to Moderately Polluted. All of the chromium concentrations were within the geoaccumulation index's unpolluted category. High levels of lead and copper, however, point to anthropogenic contamination of these metals at the locations.

Table 4: Geoaccumulation Index

Heavy metal	Location A	Remark	Location B	Remark
Lead (Pb)	3.89	HP	3.42	HP
Copper (Cu)	1.54	MP	1.31	MP
Zinc (Zn)	0.76	UP-MP	0.28	UP-MP
Chromium (Cr)	- 2.94	UP	-4.64	UP

HP=Highly polluted; MP= Moderately polluted; UP-MP=Unpolluted to moderately polluted; UP= Unpolluted

4.4 Correlation Between Selected Heavy Metals And Chemical Properties

According to the results of the correlation study (Table 5), pHw had a high and significant correlation with pHs (0.940**) and Na (0.928**), but a strong and negative correlation with ZnL (-0.953**). According to this, pHw has increased with increasing pHs and Na while decreasing with increasing ZnL. The mean pHs value had a substantial negative correlation with ZnL (-0.830*) and a positive correlation with Ca (0.845*). This confirms the idea that pH has a significant impact on Zn bioavailability. A study also reported an increase in Zn with increasing pH. OC has a significant positive (0.863*) and negative (-0.831*) correlation with CrT and CrL, respectively (Reichman, 2002). This might be ascribed to the chelating effect of organic matter. The CrT availability increased with increasing organic matter and organic matter reduced the bioavailability of CrL. The Ca had a negative significant correlation with CuL (-0.958*). This finding is contrary to the results reported, who found a positive correlation between extractable Cu and Ca. CuL is less readily available as Ca increases by (Hassan et al., 2016). According to several studies (, Ca has a competitive advantage over CuL. Mg and ZnT showed a positive but very significant relationship (0.953**). This suggests that ZnT increased as Mg increased.

Table 6: Correlation

Parameter	PHw	pHs	OC	Ca	Mg	Na	PbT	CuT	ZnT	CrT	PbL	CuL	ZnL	CrL
pHw														
pHs	0.940**													
OC	0.463	0.503												
Ca	0.708	0.845*	0.038											
Mg	0.657	0.610	0.067	0.631										
Na	0.928**	0.796	-0.573	-0.456	-0.700									
PBT	0.160	0.195	0.400	0.109	0.594	-0.375								
CUT	0.511	0.733	-0.221	0.604	-0.027	-0.324	-0.026							
ZNT	0.524	0.463	-0.671	-0.221	0.953**	-0.531	0.483	-0.176						
CRT	0.647	0.673	0.863*	0.247	0.382	-0.713	0.345	-0.120	0.090					
PBL	0.574	-0.379	-0.242	-0.080	-0.618	0.712	-0.142	0.214	-0.482	0.608				
CUL	0.589	-0.765	-0.036	-0.958*	-0.412	0.307	-0.058	-0.704	-0.431	-0.114	-0.189			
ZNL	-0.953**	-0.830*	-0.526	-0.517	0.722	0.996**	-0.326	-0.704	-0.563	-0.704	0.722	0.361		
CRL	-0.368	-0.280	-0.831*	0.224	0.260	0.473	-0.001	-0.461	0.475	-0.596	0.1823	-0.176	0.427	1

** = correlation is significant at the 0.01 level

* = correlation is significant at the 0.05 level

The pH in both water and salt is alkaline in all the locations. The concentrations of OC in all the locations are generally high. Lead is the most dominant chemical contaminant in the studied samples with values greater than the international threshold of 300mg/kg, followed by Copper and Zinc. Chromium concentrations are not a problem in the sites. Lead and copper serve as the most contaminant elements in the studied sites followed by Zinc based on pollution indices analysis (Contamination, Enrichment, and Geoaccumulation factors, respectively). Pearson correlation indicated that Zinc labile had a negative but significant correlation with both samples' pH. OC had an inverse relationship with CrL and a direct correlation with CrT.

5. Conclusions and Suggestions

The data indicates that heavy metal contamination, particularly with Pb, Cu, and Zn, is a potential concern in all locations due to human activities. However, location A shows a higher risk of contamination compared to location B. Pb and Cu has the highest contamination, enrichment, and geoaccumulation values in all locations, with Zn following closely behind. It is essential to limit waste disposal near the abattoir to protect the environment and residents, especially children, from heavy metal pollution. Government regulations should prevent farmers from using abattoir waste as fertilizer until a suitable alternative is found. Remediation of all locations is strongly encouraged to reduce environmental risks.

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