ASSESSMENT OF HEAVY METAL CONCENTRATION IN PROCESSED COW SKIN FROM ABATTOIRS IN UMUAHIA, ABIA STATE, NIGERIA

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ABSTRACT
This study evaluated the heavy metal concentrations, and environmental management practices associated with cow skin (*ponmo*) processing in selected abattoirs (Ubakala, Ndoru, and Okigwe Park) within Umuahia, Abia State, Nigeria. The data were collected between March and June 2025. Heavy metal analysis of cow skin processed with tyre and wood were evaluated and the result obtained revealed elevated concentrations of Pb (0.75 mg/kg), Cd (0.40 mg/kg), and Cr (0.3 mg/kg) in cow skin processed with tyres compared to wood and unprocessed controls, while Fe recorded the highest values (56.73 mg/kg). Socio-demographic data revealed that 90% of abattoir workers were male, 65% were aged 31–45, and 75% had secondary education, with over 7 years of experience. Singeing practices showed firewood as the dominant material (85%), while tyres, though less frequently used, were adopted due to cost-effectiveness. Waste management practices were inadequate, with 70% of abattoirs relying on open dumping and lacking recycling facilities. Hazard quotient (HQ) analysis revealed Cd levels exceeding the safety threshold (HQ > 1.0) in tyre-processed samples, with the highest value observed at Ubakala (1.1429). Hazard Index (HI) values exceeded unity in all tyre-processed samples (Ubakala: 1.8102; Ndoru: 1.6136), indicating potential non-carcinogenic health risks. The findings demonstrate that tyre-based singeing contributes to heavy metal accumulation, and environmental health risks. Sustainable interventions are urgently needed to safeguard public health and the environment.
Keywords: Abattoirs, cow skin, food, heavy metal, health risk, Hazard quotient, human health, meat, processed, tyre, unprocessed, and wood.

Introduction

Cow skin processing is an essential part of meat production, particularly for producing 'ponmo,' a popular delicacy in Nigeria. Oluwafemi and Adewale, (2022) explain that the processing involves dehairing, boiling, and preservation. Kumar and Yadav, (2021) note that processing cow skin also serves as a means of utilizing by-products efficiently. The specific techniques used in cow skin processing vary but typically involve traditional and modern methods. The processing of cow skins in Nigerian abattoirs follows several steps, including scalding, dehairing, and drying. According to Singh and Patel, (2023), scalding involves soaking the hide in hot water to facilitate hair removal. Traditional methods that involve burning the skin over an open flame to achieve the desired texture. The use of materials like tyres and firewood in this process, however, raises concerns regarding contamination. In many Nigerian abattoirs, the burning of tyres and firewood is a common practice for singeing cow skins. Adachi and Tainosho, (2018) report that burning tyres produce high temperatures that effectively remove hair and improve skin texture. However, Daramola and Olowoporoku, (2020) warn that this practice introduces toxic compounds into the processed meat. According to WHO, (2021), heavy metals such as lead, cadmium, and arsenic accumulate in biological tissues.

Abattoirs play a crucial role in meat production, but their operations can contribute to environmental pollution, particularly in terms of air quality and heavy metal contamination. The processes involved, such as burning cow hides, waste disposal, and the use of industrial equipment, can release pollutants into the air, potentially exposing workers and nearby communities to harmful substances. Cow skin, commonly consumed as a delicacy in various communities, is frequently subjected to processing methods that may introduce heavy metals such as lead (Pb), cadmium (Cd), and chromium (Cr). Prolonged consumption of contaminated cow skin can lead to adverse health effects, including neurological disorders, organ damage, and carcinogenic risks. By studying the levels of heavy metals in cow skin, this study aims to assess the heavy metal concentration in slaughtered cow skin. By identifying heavy metal concentrations, the study will help consumers make informed dietary choices, reducing the risk of toxic metal exposure. Additionally, public health recommendations based on the findings may lead to improved processing methods, ensuring safer consumption. The findings will help policymakers design and implement environmental management strategies to reduce harmful emissions and mitigate pollution risks.

Materials and method

Study Area

The research was conducted in three abattoirs in Umuahia: Okigwe park with the coordinates 5.32'40''N and longitude 7.25'00''E, Ubakala with the latitude of the coordinates 5.29'00N and longitude 7.29'30''E, and Ndoru with the coordinates 5.29'00''N and longitude 7.34.00E of Umuahia North-South Nigeria, located in Abia State. The Umuahia region experiences a tropical climate with significant rainfall in most months of the year (NRCRI, 2014). The Ubakala abattoir is located at Mgbarakuma/Amuzu land close to Good friends borehole, which has existed for several years, killing an average of 20-25 cows per day except on Mondays which is not a market day. The animals are housed in a separate facility for keeping cows before taking them to slaughter. Water taps are installed around a built-in slab area to supply water while preparing the slaughter animal.

The Ndoru abattoir is situated inside the Ndoru market at the extreme north, where cows are slaughtered and roasted every day especially during the Nkwo market day for commercial purposes. The Okigwe Park abattoir, situated in a valley near the Okigwe Park transit hub, has been in operation for years, with an average daily kill of 1-2 cows. The abattoir doesn't have a facility for housing farm animals. Rather, they collaborate with Ubakala abattoir live cattle sellers, where they buy from and slaughter it before transporting them to their own location. They stay in their location to roast daily for commercial purposes. The map of the study area is presented in Figure 1 below;

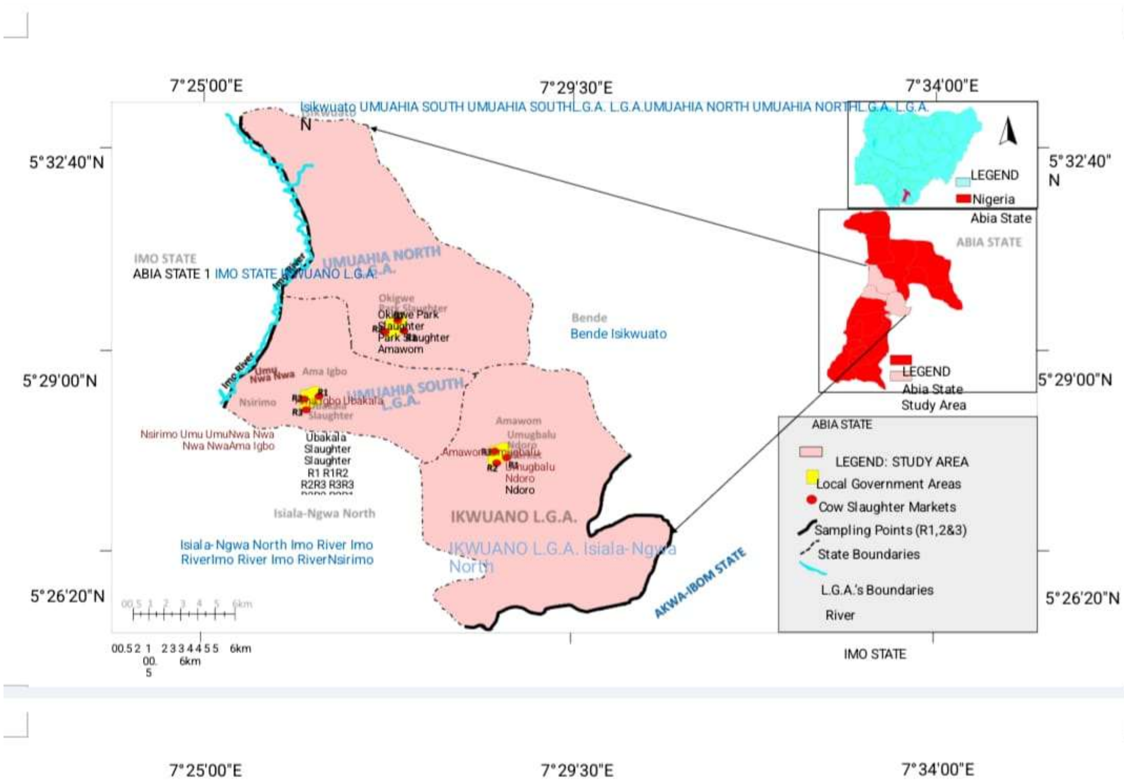

Figure 1: Map of the Study area
Source: Created by Author (Utah Juliet) using QGIS software and data from GPS, 2025

Sample Collection

In the first stage, three abattoirs were purposively selected due to the high level of animal slaughtering activities in these locations. These locations include Ndoru Abattoir, Okigwe Park, and Ubakala Abattoir. Cow skin samples were purchased weekly for 3 weeks, three random butchers were chosen in each abattoir to remove bias. Each cow skin was assigned sample code namely: UB, ND, and OP for Ubakala, Ndoru and Okigwe Park respectively. The cow skin samples were preserved in a refrigerator before experiment.

Heavy metal analysis

The concentration of heavy metals was determined by Atomic Absorption Spectrophotometer (AAS) model: ASTM D 1971. The digested cow skin sample was used for heavy metals analysis. The AAS system was powered on an element cathode lamp which was placed in the lamp holder. For each sample batch being processed, a method blank was carried throughout the entire sample preparation and analytical process; a smaller sample was taken through an entire procedure and re-analysed for cases where the upper linear range of metal is exceeded to get good-quality results.

Statistical analysis

The concentration of heavy metals was expressed as mean and standard deviation (STD). The data collected was analysed using Analysis of Variance (ANOVA), while Duncan Multiple Range Test (DMRT) was adopted for mean separation. Correlation analysis was also conducted to assess the relationship between various air quality parameters and heavy metal concentrations in processed cow skins.

Furthermore, descriptive statistics were used to analyse and present data obtained from the field survey. All computations and data analysis was performed using Microsoft Excel 2024 and SPSS 22.0.

Health risk assessment

The Estimated Daily Intake (EDI) was calculated using the average concentrations of heavy metals in the cow skin samples and a daily average consumption rate of 0.0112 kg/person/day for cow skin, assuming an adult body weight of 65kg. The values was measured in µg/g/day body weight (bw). The EDI was calculated using the equation:

$$EDI = \frac{(C\times IR)}{BW} \quad \text{...............Eq 1}$$

Where C is the heavy metal concentration of selected cow skin samples; IR is the daily average intake of cow skin as Stated by the FAO; BW is the body weight in kg.

The Target Hazard Quotient (THQ) for Pb, Cr, Cd, Ni, and as was calculated using the equation below;

$$THQ = \frac{Efr\times ED\times IR\times C}{RfDo\times BWaverage\times ATn(Efr\times ED).} X\ 10^3 \quad \text{...Eq 2}$$

EF is the exposure frequency 365 days/year, ED is the exposure duration, equivalent to the average life expectancy of a Nigerian 53years, RfDo is the reference dose and the applied RfD for Pb, Cd, Cr, As, and Ni is 4.0×10^{-3}, 1.0×10^{-3}, 3.1×10^{-3}, 3.0×10^{-4}, 2×10^{-2}) respectively measured in mg/kg/day. IR is the cow meat ingestion rate (kg/person/day), which is considered to be 0.0112 kg/person/day in Nigeria (FAO, 2024). C is the trace metal concentration in foodstuffs (mg/kg).

BW average = average body weight, which is 65kg, and ATn is the average exposure time for non-carcinogens

To determine the overall potential risk of adverse health effects posed by more than one metal, the individual THQs of heavy metals detected in the cow skin sample will be summed to generate a Hazard Index (HI). When the HI value is ≥1, it signifies that there is a possibility of adverse health effects caused by heavy metals through the average dietary consumption of cow skin while values ≤1 depict very little to no non-carcinogenic health effects.

$$HI = \sum THQ_{Pb} + THQ_{Cd} + THQ_{Cr} + THQ_{Ni} + TH_{QAs} \quad \text{..Eq 3}$$

Results and Discussion

Heavy metal concentration of processed cow skin using tyre and wood

The result on Table 1 presents the heavy metal concentration of the cow skin processed using tyre and wood across the three selected locations (Ubakala, Ndoru, and Okigwe Park). The result revealed that the lead concentrations in the samples ranged from 0.19 mg/kg in OC (unprocessed cow skin from Okigwe Park) to 0.75 mg/kg in UT (tyre-processed sample from Ubakala). The significant ($p < 0.05$) elevation of Pb levels in tyre-processed samples compared to both wood-processed and unprocessed samples suggests that tyre-burning contributes to lead contamination. These findings align with the observations of Adebisi *et al*., (2020), who reported high lead levels in cow skin processed with scrap tyres, indicating atmospheric deposition and direct contamination from lead-containing tyre materials. Similarly, Ologhobo and Jimoh, (2022) found lead concentrations between 0.48 and 0.90 mg/kg in tyre-processed animal products, suggesting a widespread contamination trend. This trend also aligns with the findings in Nigerian cattle meat, where higher Pb concentration was observed in cattle from industrial areas, Demirezen and Uruc, (2006); Oladipo and Okareh, (2015). The, WHO/FAO, (2011) permissible limit for lead in food is 0.3 mg/kg, meaning that samples UT (0.75 mg/kg), NT (cow skin processed with tyre at Ndoro) (0.71 mg/kg), and even NW (0.59 mg/kg) far exceed the safety threshold.

Cadmium levels of the cow skin samples ranged from 0.06 mg/kg (OC – unprocessed cow skin from Okigwe Park) to 0.40 mg/kg (UT). Tyre-processed skins (UT and NT) had significantly higher Cd concentration relative to controls ($p < 0.05$). These findings collaborates with the work of Ajani and Olayemi, (2019), who noted cadmium accumulation in smoked and processed animal skins exceeding regulatory limits. Ezeonyejiaku *et al*., (2023) similarly highlighted cadmium concentrations of up to 0.36 mg/kg in tyre-exposed meat samples. The, WHO/FAO, (2011) permissible limit for cadmium in food is 0.2 mg/kg. All samples in this study exceeded this limit, posing serious concerns regarding nephrotoxicity and carcinogenic potential from prolonged consumption. UT at 0.40 mg/kg and NT at 0.34 mg/kg exceed this threshold, indicating potential toxicity risks, consistent with general concerns over Cd as a non-essential and carcinogenic heavy metal (JECFA, 2010)

Chromium content ranged from not detected (ND) in OC (unprocessed cow skin from Okigwe Park) to 0.31 mg/kg in NT (cow skin processed with tyre at Ndoro). While the tyre-processed samples (UT, NT) generally had higher Cr levels, wood-processed and unprocessed samples showed significantly lower concentrations ($p < 0.05$). This findings are in line with reports by Ofori-Attah and Mensah, (2021), who documented Cr levels between 0.15 and 0.34 mg/kg in thermally processed animal products. Cr toxicity has been linked to dermal irritation, respiratory issues, and possible carcinogenic effects when accumulated over time. The, FAO/WHO, (2011) maximum allowable limit for Cr in food is 0.1 mg/kg, indicating that UT (tyre-processed sample from Ubakala) (0.29 mg/kg) and NT (cow skin processed with tyre at Ndoro) (0.31 mg/kg) surpass this threshold. The increased levels in tyre-burned samples may be due to the presence of Cr compounds in tyre materials used as additives during production.

The Zinc concentrations in all samples varied from 6.38 mg/kg in OW to 10.95 mg/kg in NT. There were no significant differences ($p > 0.05$) among locations or processing methods, indicating that processing may not significantly influence Zn retention. This result is consistent with the observations of Nduka *et al*., (2020), who reported similar Zn values (7–13 mg/kg) in processed meat products, regardless of thermal treatment method. All values fall within the WHO/FAO recommended limit of 60 mg/kg for Zn (Zinc) in food (FAO/WHO, 2011), suggesting minimal toxicological risk. Zinc is an essential trace element involved in enzymatic activities, and its presence in these levels is considered nutritionally beneficial. This is consistent with the observations of Nduka *et al*., (2020), who reported similar Zn values (7–13 mg/kg) in processed meat products, regardless of thermal treatment method.

The iron levels recorded in the sample in this study varied from 33.77 mg/kg (OT – cow skin processed with tyre at Okigwe) to 56.73 mg/kg (UW – cow skin processed with wood at Ubakala). Iron concentration was significantly higher ($p < 0.05$) in some wood-processed samples such as UW (cow skin processed with wood at Ubakala) and NW (cow skin processed with wood at Ndoru), suggesting that combustion residues may have contributed to iron enrichment. Although there is no explicit WHO/FAO limit for Fe in food, the observed values are comparable to those reported in studies by Adeoti *et al*., (2021), who found Fe (Iron) concentrations between 32.1 and 59.8 mg/kg in fire-processed animal hides. Iron is vital for haemoglobin synthesis and oxygen transport, but excessive intake can result in oxidative stress or hemochromatosis in susceptible individuals (NRC, 2005). The detected levels, although not immediately toxic, warrant caution due to cumulative exposure potential.

Nickel content in the singed samples varied from 0.08 mg/kg in OC to 0.23 mg/kg in UT (cow skin processed with tyre at Ubakala). Tyre-processed samples consistently showed elevated levels of nickel compared to other treatments, indicating possible leaching from metallic components of tyres during combustion. These results agree with the findings of Bello *et al*., (2022), who reported nickel levels of up to 0.25 mg/kg in tyre-smoked animal products. Chronic exposure to nickel is associated with nephrotoxicity, dermatitis, and respiratory distress. The, WHO /FAO permissible limit for Ni (Nickel) in food is generally accepted to be 0.2 mg/kg (WHO, 2011). Hence, samples UT (cow skin processed with tyre at Ubakala) and NT (cow skin processed with tyre at Ndoro) slightly exceeded this threshold.

Table 1: Heavy metal concentration of processed cow skin using tyre and wood

S/N	Pb	Cd	Cr	Zn	Fe	Ni
UT	$0.75^{a} \pm 0.10$	$0.40^{a} \pm 0.09$	$0.29^{a} \pm 0.09$	$9.51^{a} \pm 0.70$	$44.47^{b} \pm 5.28$	$0.23^{a} \pm 0.05$
UW	$0.64^{ab} \pm 0.07$	$0.24^{ab} \pm 0.10$	$0.12^{b} \pm 0.04$	$9.48^{a} \pm 0.80$	$56.73^{a} \pm 2.72$	$0.16^{b} \pm 0.03$
UC	$0.50^{b} \pm 0.09$	$0.11^{b} \pm 0.11$	$0.02^{b} \pm 0.04$	$9.28^{a} \pm 0.29$	$42.60^{b} \pm 2.03$	$0.15^{b} \pm 0.03$
NT	$0.71^{a} \pm 0.07$	$0.34^{a} \pm 0.05$	$0.31^{a} \pm 0.04$	$10.95^{a} \pm 0.56$	$42.29^{b} \pm 5.61$	$0.22^{a} \pm 0.04$
NW	$0.59^{a} \pm 0.09$	$0.27^{a} \pm 0.05$	$0.15^{b} \pm 0.04$	$9.80^{b} \pm 0.44$	$53.93^{a} \pm 3.73$	$0.17^{a} \pm 0.02$
NC	$0.42^{b} \pm 0.05$	$0.17^{b} \pm 0.02$	$0.09^{b} \pm 0.05$	$9.28^{b} \pm 0.29$	$40.32^{b} \pm 2.78$	$0.10^{b} \pm 0.05$
OT	$0.52^{a} \pm 0.07$	$0.22^{b} \pm 0.05$	$0.22^{a} \pm 0.04$	$6.71^{a} \pm 0.44$	$33.77^{a} \pm 5.38$	$0.18^{a} \pm 0.04$
OW	$0.41^{a} \pm 0.08$	$0.13^{b} \pm 0.04$	$0.10^{b} \pm 0.04$	$6.38^{a} \pm 0.64$	$40.12^{a} \pm 7.77$	$0.14^{ab} \pm 0.02$
OC	$0.19^{b} \pm 0.07$	$0.06^{a} \pm 0.04$	ND^{c}	$6.62^{a} \pm 0.83$	$40.61^{a} \pm 8.07$	$0.08^{b} \pm 0.04$
WHO Limit (2011)	0.3	0.2	0.1	60		0.1

*Values are mean scores± Standard deviation of triplicate

*Data in the same column bearing different superscripts differ significantly ($p < 0.05$)

UT; cow skin processed with tyre at Ubakala, UW; cow skin processed with wood at Ubakala, UC; unprocessed cow skin from Ubakala, NT; cow skin processed with tyre at Ndoru, NW; cow skin processed with wood at Ndoru, NC; unprocessed cow skin from Ndoru, OT; cow skin processed with tyre at Okigwe Park, OW; cow skin processed with wood at Okigwe Park, OC; unprocessed cow skin from Okigwe Park.

Health risk assessment of heavy metal concentration in processed cow skin using tyre and wood

Table 2 presents the result of the human health risk assessment via hazard quotient (HQ) of cow skin processed using tyre and wood. The result showed that the HQ values for lead (Pb) in the cow skin samples ranged from 0.0792 (Okigwe Park Control) to 0.3078 (Ubakala Tyre). All values were below the safety threshold of 1, indicating no immediate non-carcinogenic risk from Pb ingestion through cow skin consumption. However, values from tyre-processed samples were significantly higher than those from control and wood-processed samples.

This elevated HQ for Pb in tyre-burnt samples is consistent with findings by Olaolu *et al*., (2022), who reported high levels of Pb in smoked meat processed with tyres, citing the high lead content in tyre components as a primary source. Similarly, Chukwu *et al*., (2021) observed higher Pb accumulation in edible animal tissues processed with synthetic fuels. Despite the values being below the risk threshold, chronic consumption could lead to bioaccumulation and neurotoxicity, especially in children (WHO, 2021).

Cadmium exhibited the highest HQ values across all metals, with values ranging from 0.1629 (Okigwe Park Control) to 1.1429 (Ubakala Tyre). Notably, Ubakala Tyre (1.1429) exceeded the safe limit, while Ndoru Tyre (0.9629) samples approached the safety threshold of 1, indicating a significant potential health risk. This finding aligns with Udebuani *et al*., (2023) who reported elevated cadmium levels in smoked fish processed using waste tyres. Cadmium exposure is linked to kidney damage, skeletal demineralization, and increased cancer risk (Jarup and Akesson, 2009). The significantly lower Cd HQ values in control and wood-burnt samples, especially in Okigwe Park, suggest that processing material is a key determinant of cadmium exposure in cow skin products.

Hazard quotient values for Cr ranged from 0 (Okigwe Park Control) to 0.1462 (Ndoru Tyre). All values were well below 1, suggesting no immediate non-carcinogenic risk. However, values from tyre-burnt samples were consistently higher than those from other sources, supporting the assertion by Akinrinmade *et al*., (2022) that Cr (VI) is a combustion by-product of rubber materials. Though Cr is an essential trace element in small quantities, hexavalent chromium is known for its carcinogenic and mutagenic effects when inhaled or ingested over prolonged periods (ATSDR, 2012).

Zinc HQ values ranged narrowly from 0.0304 (Okigwe Park Wood) to 0.0522 (Ndoru Tyre). All values were significantly below 1, indicating no potential health risk. Zinc, while essential for enzymatic and immune functions, can pose health concerns in excessive amounts. This findings are in line with the report of Ezeonu *et al*., (2020), who observed low HQ values for Zn in various processed meat products, and suggest that cow skin consumption is unlikely to pose a zinc-related toxicity risk under typical dietary exposure.

The HQ for iron varied from 0.0689 (Okigwe Park Tyre) to 0.1158 (Ubakala Wood), remaining below the risk threshold. While iron is crucial for haemoglobin synthesis and oxygen transport, excessive intake may result in iron overload, especially in individuals with genetic predispositions (Nemeth and Ganz, 2006). Interestingly, wood-processed samples had slightly higher Fe HQ values compared to tyre-processed and control samples, which may be due to metal leaching from firewood ash or utensils used in traditional processing, as also noted by Nwosu and Ekezie, (2021).

Nickel HQ values ranged from 0.0300 (Okigwe Park Control) to 0.0836 (Ubakala Tyre), with tyre-burnt samples again recording the highest values. Though all values were below the safety threshold, Ni exposure can result in dermatological reactions, renal toxicity, and respiratory problems over prolonged intake (ATSDR, 2005). Tyre combustion contributes significantly to Ni release, as documented by Igwe *et al*., (2022), who attributed elevated Ni content in meat products to incomplete tyre combustion during traditional processing.

Table 2 Hazard quotient (HQ) of the heavy metal in the processed cow skin samples

S/N	Location	Pb	Cd	Cr	Zn	Fe	Ni
	Ubakala	0.3078	1.1429	0.1400	0.0453	0.0908	0.0836
Tyre	Ndoru	0.2886	0.9629	0.1462	0.0522	0.0863	0.0775
	Okigwe Park	0.2122	0.6200	0.1033	0.0320	0.0689	0.0643
	Ubakala	0.2612	0.6857	0.0590	0.0451	0.1158	0.0586
Wood	Ndoru	0.2424	0.7714	0.0714	0.0467	0.1101	0.0621
	Okigwe Park	0.1661	0.3629	0.0476	0.0304	0.0819	0.0514
	Ubakala	0.2057	0.3257	0.0095	0.0442	0.0869	0.0525
Control	Ndoru	0.1714	0.4857	0.0414	0.0442	0.0823	0.0371
	Okigwe Park	0.0792	0.1629	0.0000	0.0315	0.0829	0.0300

An HQ value greater than 1 suggests potential for non- carcinogenic health effects.

Waste management methods and environmental practices in the study abattoirs

Table 3 provides a comprehensive overview of the waste management practices and the extent of environmental management systems implemented in the abattoirs within the study area. The findings highlight significant deficiencies in organized waste handling, environmental awareness, and sustainable practices. The majority of respondents (70%) reported that waste in the abattoir is stored in open spaces, while 30% indicated the use of buckets. The lack of sealed or covered waste receptacles not only increases the risk of vector infestation and odour nuisance but also suggests a general neglect of hygiene and public health considerations within the facility.

Regarding waste disposal methods, a troubling 100% of the participants confirmed that abattoir waste is dumped openly, with no instances of burning, off-site disposal, or any alternative methods recorded. This method is environmentally unsustainable and contributes to the degradation of soil and water quality through leachates, in addition to posing serious public health risks due to the exposure of humans and animals to raw biological waste. Notably, recycling of waste takes place but are sometimes rare from the abattoir's operations, as confirmed by all respondents. Despite this, 85% of participants revealed that waste generated is sold, predominantly to industries (60%) and farmers (40%). This indicates that while formal recycling structures are missing, informal waste recovery and reuse systems are present. However, these transactions appear unregulated and undocumented, posing potential biosecurity and traceability concerns.

On the issue of waste collection responsibility, 90% of the respondents identified livestock sellers or owners as being responsible for managing waste, while only 10% acknowledged any involvement by government agencies. There was no participation from private waste management firms or scavengers, pointing to the absence of structured municipal or contracted waste management systems. This decentralized responsibility model often results in inconsistent practices and poor compliance with environmental guidelines. When assessing the effectiveness of waste collection, 80% described it as "not effective," and 20% as "fairly effective." No respondents rated the system as very effective, clearly indicating dissatisfaction and inefficiency in waste handling operations. This inefficiency is further emphasized by the reported frequency of waste collection, with 70% indicating monthly collection, 10% once a week, and 20% giving unspecified frequencies—none of which align with best practices for managing high-volume organic waste.

Furthermore, none of the respondents reported paying for waste collection services, reinforcing the idea that waste handling is done informally and without financial commitment. When asked about the range of charges, 80% of participants responded with "others", while 20% indicated no specific amount, further confirming the absence of a standard or formal fee-based system for waste management services. Only 10% of respondents were aware of environmental impacts—such as smoke, odour, and contamination—arising from singeing and other operations. This shows a critical gap in environmental consciousness among abattoir workers and operators. Even more concerning is the complete absence of awareness programs or training sessions on safer singeing practices, as reported by 100% of the participants. This lack of environmental education leaves workers ill-equipped to recognize or mitigate the harmful effects of their activities on both human health and environmental sustainability.

Table 3: Waste management methods and environmental management systems adopted in the study area.

S/N	Frequency	Percentage (%)
Type of waste storage receptacles are available in the abattoir		
Open space	84	70
Bucket	36	30
Others	0	0
Methods of waste disposal are employed by the abattoir		
Burning	0	0
Dumping in an open space	20	100
Disposal outside the abattoir	0	0
Others	0	0
Recycling of waste within the abattoir		
Yes	0	0
No	20	100
Selling of the waste generated in the abattoir		
Yes	17	85
No	3	15
Who are mostly the buyers of these wastes?		
Industries	72	60
Farmers	48	40
Others	0	0
Agency responsible for the collection of waste generated in the abattoir		
Government agencies	12	10
Private waste management firm	0	0
Livestock seller/owner	108	90
Scavengers	0	0
Others	0	0
Effectiveness of waste collection in the abattoir		
Not effective	92	80
Fairly effective	28	20
Very effective	0	0
Frequency of waste collection in the abattoir		
Once a week	12	10
Twice a week	0	0
Monthly	84	70
Others	24	20
Payment for the collection of waste in the abattoir		
Yes	0	0
No	20	100
Awareness of environmental impacts (e.g., smoke, foul odour, contamination) caused by singeing activities		
Yes	12	10
No	108	90
Awareness of programs or training sessions on safer singeing methods		
Yes	0	0
No	120	100

Conclusion

This study clearly shows that the processing of cow skin using different singeing materials has significant implications on food safety, air quality, occupational health, and environmental sustainability in Umuahia and its environs. The analysis of heavy metals revealed that cow skins processed with tyres contained higher concentrations of lead, cadmium, and chromium compared to wood-processed and control samples. The calculated hazard quotient values confirmed that these metals, particularly cadmium, pose potential non-carcinogenic health risks, as values exceeded the safety threshold of unity in tyre-processed samples.

Waste management systems in the abattoirs were equally found to be inadequate. The reliance on open dumping of abattoir waste poses risks of soil and water contamination, as well as facilitating the spread of diseases. The absence of recycling or organized collection systems, as well as a governmental monitoring force, worsens the environmental impact of abattoir operations.

The findings of this study provide strong evidence that cow skin processing with tyres not only compromises food quality but also presents multi-dimensional risks spanning human health, occupational safety, and environmental degradation. If left unaddressed, these risks may have long-term implications on public health, given the high consumption rate of cow meat (*ponmo)* in Nigeria.

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