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Original Research Article

Studies on Abattoir Waste Generation and Management at Sokoto Modern Abattoir, Nigeria

Sarkin Fulani H.A[1]*, Maishanu H.M[1], Adamu T. [1], Rabah A.B[1] & Lema A.M[1]
[1]Department of Biological Sciences, Faculty of Science, Usmanu Danfodiyo University, Sokoto, Nigeria
**Corresponding author: hafsataliyu23@gmail.com*

Abstract: Abattoir activities generate substantial quantities of organic solid and liquid wastes, and inadequate management of these wastes can create environmental and occupational health risks. This study assessed waste generation and management practices at Sokoto Modern Abattoir, Sokoto State, Nigeria. A descriptive cross-sectional design involving structured questionnaires, direct field observations and waste-generation measurements was adopted. A total of 110 questionnaires were administered to abattoir workers, while slaughter and waste-generation records were obtained during a seven-day observation period. Data were analyzed using descriptive statistics. Traders constituted the largest occupational group among respondents (30.0%), followed by butchers (24.5%), while all respondents were male. Rumen content was the most frequently reported waste type, followed by blood, wastewater and intestinal contents. Blood was predominantly collected by buyers for blood-meal production, whereas rumen content was mainly disposed of in the central waste pile. Intestinal contents were largely discharged into gutters, while wastewater was mainly discharged through open drains. During the observation period, 970 animals were slaughtered. Estimated monthly generation included 504,720 L of wash water, 25,313.28 L of blood, 26,259.44 L of intestinal fluid and 66,430.24 kg of rumen content. The findings indicate considerable waste-generation pressure and inadequate management of major organic waste streams. Improved waste segregation, collection, treatment and resource-recovery systems are recommended for sustainable abattoir management.

Keywords: *Abattoir waste; waste generation; waste management; rumen content; wastewater; Sokoto; Nigeria.*

1. Introduction

Human activities within natural and built environments inevitably result in the generation of wastes as by-products of production, consumption, and service delivery systems which is closely linked to patterns of resource use, economic activity, and population growth (Ferronato & Torretta, 2019). Waste is broadly defined as any material or substance that is discarded, intended to be discarded, or required to be discarded due to loss of usefulness or value which originates from multiple sources, and exists in solid, liquid, and gaseous forms (UNEP, 2019). Abattoirs are important components of livestock production and food-supply systems, providing meat for urban and rural populations where slaughtering and carcass-processing activities generate considerable quantities of organic solid and liquid wastes (Silva *et al*., 2020).. The quantity and composition of these wastes depend on the number and species of animals slaughtered, processing practices and the efficiency of waste-management systems (Ezeoha & Ugwuishiwu, 2017; Arowolo *et al*., 2021).

Abattoirs plays role in meat supply chains, where their operations generate substantial quantities of solid and liquid wastes that are often poorly managed in many Nigerian cities. Recent studies indicate that abattoir waste management systems in Nigeria remain inadequate due to limited infrastructure, weak enforcement of environmental regulations, and high slaughter throughput (Arowolo *et al*., 2021; Adeyamo, 2019). At such facilities, routine slaughtering activities result in continuous generation of waste, yet organized systems for waste segregation, treatment, and productive utilization remain limited (Bello *et al*., 2017). Poor handling and disposal of abattoir waste have led to environmental degradation around slaughter facilities, including accumulation of solid wastes and discharge of untreated effluents into surrounding environments results in nutrient loading, offensive odour, and surface water pollution, which compromise the ecological balance of the environment (Garba *et al*., 2020; Thomas *et al*., 2024).

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Corresponding Author: Sarkin Fulani H.A

Sokoto Modern Abattoir is an important slaughtering facility serving Sokoto Metropolis and surrounding communities. Despite its role in meat supply, there is limited site-specific information on the quantity and composition of wastes generated and the management practices employed at the facility. Such information is necessary for developing appropriate collection, treatment, recovery and disposal strategies. Therefore, this study assessed the types and quantities of wastes generated at Sokoto Modern Abattoir, current waste-handling and management practices, waste-collection systems and major challenges associated with abattoir waste management.

2. Materials and Methods

The Study Area

The study was conducted at Sokoto Modern Abattoir, located in the Gandu area of Sokoto Metropolis, north-western Nigeria. Sokoto State lies within the Sudan–Sahel savanna ecological zone between approximately 12°00′N and 13°58′N and 4°08′E and 6°54′E. The state covers approximately 25,973 km² and shares a boundary with the Niger Republic to the north and with Kebbi and Zamfara States within Nigeria (Ibrahim *et al.,* 2020). The area experiences a long dry season from approximately October to May and a relatively short rainy season from June to September, with annual rainfall generally ranging from 500 to 1,000 mm (Oluwaseun and Idris, 2022).

Research Design

A descriptive cross-sectional study design was adopted. Data were collected using structured questionnaires, direct field observations and waste-generation measurements. The questionnaire assessed waste types, handling and disposal practices, waste minimization, collection and transportation systems, and challenges associated with waste management. Direct observations were used to complement questionnaire responses and document slaughter activities and waste-generation practices.

Sampling Population and Technique

The study population comprised workers directly involved in abattoir operations, including veterinary staffs, butchers, waste handlers, traders, cleaners and by-product processors. Respondents were selected using a simple random sampling method, whereby questionnaires were administered to workers who were present and willing to participate during the study period. The distribution of respondents across occupational categories was determined after data collection and expressed as percentages to reflect the workforce composition of the abattoir, as adopted in similar abattoir-based studies (Garba *et al*., 2018; Adeyemo, 2019).

Sample Size

The minimum sample size was determined using Cochran's formula (Cochran, 1977):

$$n_0 = \frac{z^2 \times p \times (1-p)}{e^2}$$

Where:

- n_0 = sample size when population is unknown
- Z= standard normal deviate at 95% confidence level (1.96)
- p = estimated proportion of attribute present in the population (0.5)
- e= acceptable margin of error (0.1)

Therefore,

$$n_0 = \frac{(1.96)^2 \times 0.5 \times (1-0.5)}{(0.1)^2} = \frac{3.8416 \times 0.5 \times 0.5}{0.01} = \frac{0.9604}{0.01} = 96.04$$

However, 96.04 sample sizes were obtained, and a total of 110 questionnaires were administered to improve the accuracy and reliability of the data.

Data Collection

A structured questionnaire comprising four sections was administered to respondents. Information collected included respondents' occupational characteristics, abattoir sections and activities, types of wastes generated, waste-handling practices, disposal methods, waste minimization, collection and transportation systems, and management challenges. Face-to-face administration was used where necessary, with questions explained in the local language to facilitate understanding. Direct observations were conducted using a structured field sheet to record slaughtering activities, animal numbers, waste types and management practices.

Estimation of Waste Generation

Abattoir's waste generation was estimated through direct observation, field inquiry and measurement. For each species (cattle, camel, sheep, and goat), animals were categorized into three sizes small, medium, and large based on body size estimation routinely used by butchers at the abattoir. Mean waste quantities were calculated separately for small, medium, and large animals to account for size-related variation in waste generation. Rumen content, skins, hooves, and horns were collected into known containers and weighed using a calibrated digital weighing scale. Wastewater generation was estimated through direct field inquiry and observation where number of jerrycans of water used during washing and dressing of each animal were asked and observed.

The volume of wastewater generated per animal was estimated by multiplying the number of jerrycans used by the jerrycan capacity. Daily slaughter records were used to estimate weekly and monthly waste generation using standard estimation methods reported in abattoir waste quantification studies (Iriso *et al*., 2018; Abubakar *et al*., 2021).

Daily waste generation (DWG) = Average Quantity per Animal × Number of Animals Slaughtered.

Weekly waste generation (WWG) = DWG × 7

Monthly waste generation (MWG) = DWG × 30 or WWG × 30/7

Data Analysis

Descriptive statistics were used to summarize the questionnaire responses, where frequencies and percentages were used to summarize categorical variables. Waste generation data were summarized using mean quantities and estimated daily, weekly and monthly generation results were presented using tables.

3. Results

Socioeconomic Characteristics of the Respondents

A total of 110 respondents participated in the study. Traders constituted the largest occupational group (30.0%), followed by butchers (24.5%), by-product workers (12.7%) and waste handlers (11.8%). All respondents were male. Secondary education was the most common educational level (36.3%), while 32.7% had no formal education. Most respondents (84.6%) had five years or more of experience working at the abattoir (Table 1).

Table 1: Socioeconomic Characteristics of the Respondents of Sokoto Modern Abattoir.

Variables	Number of Respondents (n=110)	Percentage (%)
Category of respondents		
Butchers	27	24.5
Waste handlers	13	11.8
Veterinary staff	11	10.0
Managers	1	1.0
By-products workers	14	12.7
Lairage Attendants	3	2.7
Meat transporters	8	7.3
Traders	33	30
Gender		
Male	110	100
Educational level		
Primary	22	20
Secondary	40	36.3
Tertiary	12	11.0
None	36	32.7
Years of experience		
<1	0	0
1–4 years	17	15.4
5 years and Above	93	84.6

Abattoir Sections and their Activities, Waste Types and Busiest Slaughtering Days

The large-ruminant section had the highest representation (44.5%). Slaughtering was the most common activity (22.7%), followed by washing/dressing (19.1%) and intestine cleaning (18.2%). Rumen content was the most frequently reported waste type (23.6%), followed by blood (22.7%), wastewater (19.1%) and intestinal contents (18.2%). Tuesday was reported as the busiest slaughtering day (47.3%) (Table 2).

Table 2: Abattoir Sections and their Activities, Waste Type and Busiest Slaughtering Days

Variables	Number of Respondents (n=110)	Percentage (%)
Section worked in		
Large ruminant area	49	44.5
Small ruminant area	16	14.5
Trippery	17	15.4
Treatment area	4	3.60
By-product area	13	12.0
Others	11	10.0
Main Activity		
Lairage	3	2.7
Slaughtering	25	22.7
Evisceration	15	13.6
Intestine cleaning	20	18.2
Skinning	12	11.0
Washing/dressing	21	19.1
Waste handling	14	12.7
Types of Wastes produced		
Dung	3	2.7
Blood	25	22.7
Rumen content	26	23.6
Intestinal content	20	18.2
Skin, Hooves and Horns	15	13.6
Wastewater	21	19.1
Bones	0	0
Busiest Days of Slaughtering		
Sunday	10	9.1
Monday	15	13.6
Tuesday	52	47.3
Wednesday	12	10.9
Thursday	10	9.1
Friday	5	4.5
Saturday	6	5.5

Wastes Types Handling and Management practices

Blood was predominantly collected by buyers for blood-meal processing (89.1%), whereas rumen content was mainly disposed of at the central waste pile (76.4%). Intestinal contents were mainly discharged through gutters (81.8%). Skins, hooves and horns were largely reused as by-products (84.5%). Wastewater was primarily discharged through open gutters or drains (39.1%) or applied to farmland (34.5%) (Table 3).

Table 3: Wastes Types Handling and Management.

Variables	Number of Respondents (n=110)	Percentage (%)
Bones Handling and Management		
Separated and discarded inside the abattoir	35	31.8
Transported with meat and later discarded near the abattoir	73	66.4
Taken outside the abattoir and discarded elsewhere	2	1.8
Blood Handling and Management		
Collected by buyers for processing blood meal	98	89.1
Disposed in Gutters	12	10.9
Rumen content Handling and Management		

Disposed in abattoir pile	84	76.4
Taken to farms as manure	26	23.6
Disposed in bins	0	0
Intestinal content Handling and Management		
Disposed in Gutters	90	81.8
Taken to farms	3	2.7
Collected by buyers	17	15.5
Skin, Hooves and Horns Handling and Management		
Reused as by-products	93	84.5
Disposed as waste	5	4.5
Burnt onsite	12	11.0
Wastewater Handling and Management		
Open gutters/drains	43	39.1
River/stream	19	17.3
Settling tank	10	9.1
Applied to farmland	38	34.5

Waste Collection and Management Challenges

Waste traders and buyers accounted for the majority of waste collection activities (84.5%), compared with 15.5% collected by abattoir staff. The major management challenges were lack of training (35.4%), poor logistics and infrastructure (31.0%), inadequate treatment facilities (20.0%) and proximity to residential areas (13.6%). Reported health-related experiences included malaria (35.4%), skin infections (30.0%) and injuries from sharp objects (20.0%) (Table 4).

Table 4: Waste Collection, Health challenges and Abattoir challenges.

Variable	Number of Respondents (n=110)	Percentage (%)
Waste Collection		
Abattoir staff	17	15.5
Waste traders/buyers	93	84.5
Others	0	0
Health Challenges		
Malaria	39	35.4
Skin infections	33	30.0
Diarrhea	12	11.0
Injuries from sharp objects	22	20.0
Respiratory issues	4	3.6
None	0	0
Abattoir Challenges		
Lack of treatment facilities	22	20.0
Poor logistics/infrastructure	34	31.0
Lack of training	39	35.4
Weak regulatory enforcement	0	0
Close to residential areas	15	13.6

Slaughter Numbers and Waste Generation

A total of 970 animals were recorded during the seven-day observation period, comprising 89 camels, 673 cattle, 115 sheep and 93 goats. Tuesday recorded the highest number of slaughtered animals (210), while Friday recorded the lowest (87). Waste quantities varied according to species and animal size. Camels recorded the highest average quantities of wash water (250 L), blood (21 L), intestinal fluid (17.67 L), rumen content (33.67 kg), skin (42.3 kg) and hooves (2.33 kg). Cattle followed with 150 L of wash water, 6.17 L of blood, 5.67 L of intestinal fluid and 19.00 kg of rumen content per animal.

The estimated weekly generation of wash water was 126,180 L, equivalent to approximately 504,720 L monthly. Blood generation was estimated at 6,328.32 L weekly and 25,313.28 L monthly, while intestinal fluid amounted to 6,564.86 L weekly and 26,259.44 L monthly. Rumen content was estimated at 16,607.56 kg weekly, equivalent to approximately 66,430.24 kg monthly.

Table 5: Estimated Daily Record of Slaughtered Animals Generated in Sokoto Modern abattoir**.**

Days	Camel (M)	Camel (F)	Cattle (M)	Cattle (F)	Sheep (M)	Sheep (F)	Goat (M)	Goat (F)	Total Animals Slaughtered/Day
Sunday	8	-	55	23	11	5	5	1	108
Monday	11	1	89	19	6	8	9	4	147
Tuesday	24	3	103	33	15	11	18	3	210
Wednesday	11	-	86	11	14	3	8	4	137
Thursday	16	2	109	8	12	6	17	2	172
Friday	4	3	53	9	7	3	6	2	87
Saturday	5	1	58	17	12	2	9	5	109
Total	79	10	553	120	77	38	72	21	970

4. Discussion

Traders and butchers formed the largest occupational groups at the Sokoto Modern Abattoir, reflecting a workforce centered on meat processing and marketing. This finding aligns with that of Alhaji *et al*. (2023), who reported that operational staff constituted the majority in North-central Nigerian abattoirs. The complete male dominance observed among respondents mirrors the findings of Nwoye *et al*. (2022), who documented that abattoir work in northern Nigeria is almost exclusively performed by men due to the physically demanding nature of the tasks and socio-cultural norms that restrict female participation in slaughterhouses. In terms of education, most workers had secondary schooling, while only a small fraction possessed tertiary qualifications, a pattern that aligns with Nwoye *et al*., (2022). This suggests that abattoir employment is driven by informal training and practical skill acquisition rather than formal academic qualifications, which may limit workers' exposure to modern hygiene and environmental safety training (Agu *et al*., 2021). The long working experience of most respondents, with none having less than a year and the majority exceeding five years, indicates a stable workforce.

The large-ruminant section had the highest representation, reflecting the importance of cattle production and beef consumption in northern Nigeria (Adeoti *et al*., 2017; Bello *et al.,* 2022). Rumen content was the major waste type, while dung was least generated, consistent with findings from Hadejia and other Nigerian abattoirs (Sabo *et al*., 2025). The substantial contribution of wastewater indicates intensive water use during slaughter and dressing, while limited treatment infrastructure increases the likelihood of environmental pollution (WHO, 2018; Iriso *et al*., 2024). Tuesday was the busiest slaughtering day and Friday the least busy, probably reflecting livestock supply, market patterns and local cultural schedules (FAO, 2019; Komolafe *et al*., 2024).

Waste management practices revealed both resource recovery and inappropriate disposal. Blood was predominantly collected by buyers for blood-meal production, while skins, hooves and horns were largely reused as by-products, demonstrating useful resource-recovery practices (Ogunwole *et al*., 2020; Bodinga & Malami, 2025). In contrast, most rumen content was deposited at the central waste pile despite its potential for composting, soil amendment and biogas production (Iriso *et al.*, 2018; Ihoeghian *et al*., 2023). Intestinal content was mainly discharged through gutters, a practice that may contribute to eutrophication and deterioration of surrounding water quality (Adeoti *et al*., 2017; Oyinlola *et al*., 2023). Similarly, reliance on open drains and limited use of settling tanks indicate inadequate effluent management (Ajanaku *et al*., 2018). Waste collection was mainly undertaken by external traders or buyers, highlighting the important role of informal waste-recovery systems in Nigerian abattoirs (Nwanta *et al*., 2020; Badiora, 2021). Reported health challenges included malaria, skin infections and injuries from sharp objects, which are consistent with occupational risks associated with poor drainage, inadequate protective equipment and unsafe waste handling (Adzitey, 2017; Nnaji *et al*., 2023). Lack of training, poor infrastructure and inadequate treatment facilities were the major challenges, indicating weaknesses in institutional capacity for effective waste management (Muhammad *et al*., 2025; Bello *et al*., 2023).

Male animals predominated in the slaughter records across all species. This pattern is likely associated with

the preference for males for meat production because of their greater body weight and market value, while females are commonly retained for breeding and herd replacement (Garba *et al*., 2018; Bello *et al*., 2022; Nafarnda *et al*., 2021). The highest slaughter numbers occurred on Tuesday and the lowest on Friday, further demonstrating the influence of market demand, livestock supply and cultural schedules on slaughter activities (FAO, 2019; Komolafe *et al*., 2024; Sabo *et al*., 2025). Waste generation increased with animal size, with camels producing the highest quantities, followed by cattle, sheep and goats. This pattern is attributable to differences in body mass, gastrointestinal capacity and blood volume among species. Similar positive relationships between animal size and waste output have been reported in Nigerian abattoirs (Adeyemo *et al*., 2019; Ojo *et al*., 2022). The size-related variation is important for determining appropriate waste collection, storage and treatment capacity.

The estimated waste quantities demonstrate the substantial waste burden generated by the abattoir. Monthly wash-water generation exceeded 500,000 L, while rumen content exceeded 66,000 kg, indicating intensive water consumption and considerable accumulation of organic solid waste. Similar high volumes have been reported in Nigerian abattoirs and attributed to continuous washing, manual scrubbing and high slaughter throughput (Nwanta *et al*., 2020; Nkwocha *et al*., 2021). The higher waste quantities recorded on Tuesday corresponded with the higher number of animals slaughtered, confirming that waste generation is strongly influenced by slaughter volume (Iriso *et al*., 2018). The generation of skins, hooves and horns, particularly from cattle and sheep, also represents an important resource-recovery opportunity because these materials can be utilized for leather, handicrafts and other value-added products (FAO, 2019; Limeneh *et al*., 2022; Thomas *et al*., 2024). Camels produced skins and hooves but no horns, consistent with their biological characteristics. The absence of measurable goat skin and horn waste may be related to the common Nigerian practice of singeing goats, whereby the skin remains attached to the carcass for consumption rather than entering the waste stream (Garba & Kudi, 2018; Nafarnda *et al*., 2021)

5. Conclusion

This study revealed that Sokoto Modern Abattoir generates substantial quantities of solid and liquid wastes, with rumen content constituting the most dominant solid waste stream due to the predominance of large ruminant slaughtering. Waste management practices at the abattoir remain largely informal, with partial recovery of economically valuable by-products and inadequate handling of major waste fractions such as rumen content, intestinal waste, and wastewater. These practices contribute to environmental degradation and occupational health risks. It is therefore important to use improved waste segregation, collection, treatment and resource-recovery systems are recommended for sustainable abattoir management.

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