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QUANTIFICATION AND CHARACTERIZATION OF MEDICAL SOLID WASTE AT ABUBAKAR TAFAWA BALEWA UNIVERSITY TEACHING HOSPITAL, BAUCHI, NIGERIA.

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Abstract: *This study aims to quantify and characterize the medical solid waste generated at Abubakar Tafawa Balewa University Teaching Hospital (ATBUTH), Bauchi, and to recommend possible integrated solid waste management strategies for sustainable disposal. The study lasted one month, during which questionnaires, interviews, and surveys were conducted to gather the necessary data. The ATBUTH Bauchi produced an average of 578.1 kg of solid waste weekly during the study period. The Maternity Ward generated the highest weekly volume at 137 kg. Conversely, the Administrative Block recorded the lowest waste output at 40.5 kg. Based on the mean waste composition, food waste, and medical/infectious waste being the largest portions at 26.4% and 21.7%, respectively, while dirt, ashes, and bricks made up the lowest at 4.3%. The mean per capita waste generation was approximately 0.42 kg/bed/day. It was observed that 35.6% of the total waste was recyclable, and 48.4% was biomass. When properly harnessed, this waste has the potential to reduce environmental pollution, create employment, and generate wealth for ATBUTH and its surrounding communities.*

Key words: Solid Waste Management, Medical, Hospital, Quantification, Characterization.

1 Introduction

Medical waste, generated by various healthcare locations like clinics and field hospitals (Abdullahi et al., 2023), poses a significant risk to people and the environment if not managed properly (Babanyara et al., 2013). This waste, which includes both solids and liquids from treating humans and animals, research, and biological testing (Mazumder et al., 2023), is often hazardous and can expose individuals to life-threatening infections (Oyebode et al., 2023). Inadequate hospital waste disposal is a major cause of pollution, infectious disease transmission, and safety dangers for both hospital staff and waste handlers (Ali et al., 2017).

Understanding how much waste a hospital generates is crucial for effective waste management planning. This information, provided by measuring waste generation, allows planners to anticipate the necessary capacity for containers, storage facilities, transportation logistics, and treatment methods (World Health Organization, 2024). The total amount of waste produced by a hospital is influenced by several factors, including the number of beds and patients, the facility's type, its existing waste

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management plan, and the activity level in various departments (Afolabi et al., 2017).

Separating medical waste is an absolutely vital component of proper healthcare waste management (HCWM). This is because the majority of waste generated in medical centers, approximately 75% to 90%, is non-hazardous and can be treated as general solid waste. The small remainder, 10% to 25%, is hazardous and includes infectious waste, which poses the greatest danger to human health (Appleton & Ali, 2020). If waste isn't properly separated, the volume of infectious material grows because any non-hazardous waste in contact with infectious components is then classified as infectious (De Titto et al., 2012). Consequently, Etim et al., 2021 suggested that waste segregation is a critical factor for achieving effective health care waste management (HCWM).

Effective sorting and segregation enhance the quality of waste streams, resulting in a cleaner, safer, and more cost-efficient system for subsequent management processes such as composting, recycling, and landfilling (Oli et al., 2015). Accordingly, this study aims to assess the existing solid waste management practices at ATBU Teaching Hospital, with particular emphasis on waste generation and segregation patterns. Based on the findings, the study seeks to develop sustainable and context-specific strategies to improve waste management efficiency within the hospital..

2 Materials and Methods

2.1. Study Area

Abubakar Tafawa Balewa University Teaching Hospital (ATBUTH), Bauchi, located in Bauchi metropolis, has a history dating back to 1917 when it started as a small clinic under colonial administration, initially focused on leprosy cases. It later became a general hospital in 1966 and then a specialized hospital in 1978. In 2010, it was taken over by the Federal Government and transformed into a teaching hospital affiliated with Abubakar Tafawa Balewa University (ATBU), Bauchi. ATBUTH now functions as a tertiary healthcare facility, providing medical services, training for medical students and various healthcare professionals, and conducting medical research. The hospital's establishment as a teaching hospital is closely linked to the growth and development of Abubakar Tafawa Balewa University, Bauchi, especially the founding of its College of Medical Sciences. ATBUTH offers a wide array of specialized medical services, including anesthesia, chemical pathology, community medicine, dental surgery, and more.

2.2. Study Design

According to the Environmental Sanitation Unit of the Department of Community Medicine, ATBUTH Bauchi, a total of forty-six (46) solid waste dumpsites were identified within the hospital premises. Following a preliminary assessment, six representative zones were selected as sampling points: the Maternity Ward, Emergency Ward, Male Ward, Female Ward, Administrative Block, and Staff Residential Quarters.

Trained laborers were engaged to assist in waste segregation. Each assistant was assigned to sort specific waste categories, including food remnants, nylon/polythene, plastics/rubber, garden leaves, paper/cardboard, tin cans, dirt/ash, and medical/infectious waste (e.g., syringes, needles, scalpels, and bandages). An electronic computing price scale (Model MJ-PEPS-002) with a maximum capacity of 300 kg and a precision of 100 g was used to weigh the separated waste components.

To replicate the storage conditions of the collection bins, the segregated samples were compacted prior to measurement. The percentage composition by mass and the as-discarded density of each component were determined using the following expressions:

$$\text{Density} = \text{Mass/Volume}\ (\text{kg/m}^3) \quad (1)$$

$$\text{Percentage (\%)component of waste} = (\text{Mass of component / Total Mass}) * 100 \quad (2)$$

The six selected locations of solid waste measures as in the percentage distributions except that the waste was not compacted in above previous experiment. The preserved (kg/m³) analyzed as:

$$\textit{Bulk density } \rho = \frac{W_2 - W_1}{V_1}\ kg/m^3 \quad (3)$$

Where: - W_1 = Weight of container, W_2 = Total weight of waste sample plus the container, V_1 = Total volume

The daily per capita waste generation was quantified based on the specific departments or wards in which the waste originated. Three functional zones were selected for assessment: the maternity ward, male ward, and female ward. From each ward, ten beds were randomly chosen, yielding a total of 30 sampling points. The average patient occupancy was six in the maternity ward, five in the male ward, and four in the female ward, respectively.

$$\text{Waste Generation rate kg/ward/day} = \frac{\text{Mean total no of days}}{\text{Total no of waste generated}} \quad (4)$$

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$$\text{Waste Generation rate kg/bed/day} = \frac{\text{Mean total no of beds}}{\text{Total no of waste generated}} \quad (5)$$

The dataset was organized and analyzed using Microsoft Excel. Waste components were categorized based on their characterization, and descriptive statistical methods were applied to quantify and summarize the distribution patterns.

3 Results and Discussions

3.1 Waste generation rate

The study conducted at Abubakar Tafawa Balewa University Teaching Hospital (ATBUTH), Bauchi, over one month in June 2025, found that the facility produced an average of 578.1 kg of medical solid waste per week. Waste generation varied significantly across different locations within ATBUTH, as summarized in Table 1. The Maternity Ward generated the highest weekly volume at 137 kg, a quantity attributed to the high volume of patients and visitors in that area. Conversely, the Administrative Block recorded the lowest waste output at 40.5 kg. This low figure is likely due to the small number of administrative staff and the fact that staff are typically off on weekends (Saturday and Sunday), with only security personnel present.

The Male and Female Wards maintained consistent waste generation throughout the week, reflecting the continuous nature of their clinical activities, with a significant value of 107.1 kg and 110.6 kg. In addition, the research discovered that other locations contributing significant amounts included: Staff Residential Areas: 94.1 kg; Emergency Wards: 88.8 kg, respectively.

Compared to other hospitals both nationally and internationally, the weekly average of 578.1 kg per week of medical solid waste generated by ATBUTH, Bauchi, appears relatively high compared to amounts reported by Oyebode et al. (2023) for other Nigerian hospitals, which included: Babalola University Multi-System Hospital (AMSH): 31.5 kg per day; Ekiti State University Teaching Hospital (EKSUTH): 53.6 kg per day. However, the value in this study was lower than Federal Teaching Hospital Ido-Ekiti (FETHI): 135.1 kg per day, respectively.

Similarly, the ATBUTH rate is also lower than the daily waste generation reported by Nazish Huma KHAN et al. (2023) in District Swabi, Pakistan. Their study showed that large public hospitals produced 120–130 kg per day, while the value is higher than smaller private hospitals generated 30–50 kg per day (though the private facilities had better waste handling). The Potential Reasons for Variation could be due to several factors, including: the overall size of the hospital, the income level of the local population, regional socio-economic differences, and the consumption and disposal habits of the people served.

Table 1: *Percentage composition and mean distribution of solid waste components across different functional areas of ATBUTH. Food and medical/infectious wastes constitute the dominant fractions, reflecting significant biodegradable and hazardous waste streams requiring specialized management*

	Area/locations: Percentage (%) by weight (kg)						
Components	Maternity Ward	Emergency Ward	Male ward	Female Ward	Admin Block	Staff Quarters	Mean of Waste Components, kg
Food waste	39.3	21.2	30.8	32.6	1.1	33.4	26.4
Nylon/ Polythene	22.4	11.4	15.2	14.1	12.8	19.3	15.9
Plastic/ rubber	8.7	7.5	10.8	6.5	5.1	13.2	8.6
Garden Leaves	16.2	8.1	11.2	14.1	7.3	15.2	12
Paper/ Cardboard	4.8	6.4	4.1	5.9	9.6	3.1	5.7
Tin cans	8.2	4.1	6.3	6.1	3.2	4.4	5.4
Dirt, Ashes, Brick	0	0	0	0	0	4.3	4.3
Medical/ infectious waste	37.4	30.1	28.7	31.3	1.4	1.2	21.7
Total	137	88.8	107.1	110.6	40.5	94.1	100

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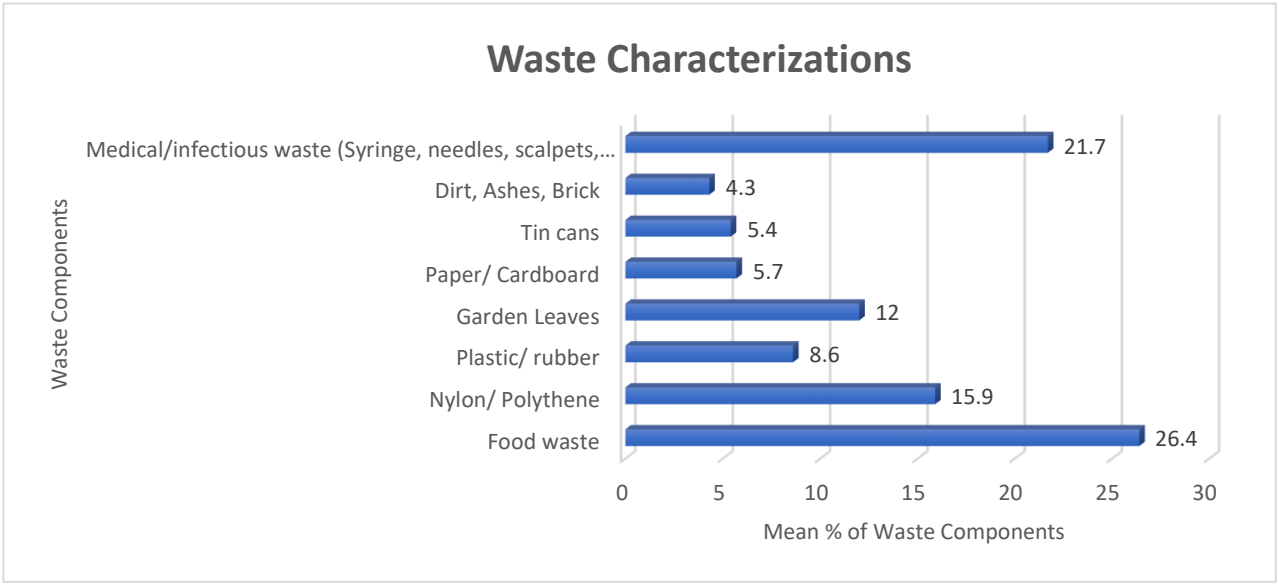

Figure 1: *Mean percentage distribution of solid waste components generated at ATBUTH. Food waste and medical/infectious waste represent the largest proportions, highlighting the dominance of biodegradable and hazardous materials in the hospital's waste stream.*

3.2 Waste characterization

Based on the mean waste composition analysis by weight at ATBUTH Bauchi, the largest single component of the municipal solid waste (MSW) stream is Food waste, accounting for approximately 26.4%. This is followed closely by Medical/infectious waste (such as syringes, needles, scalpels, and bandages), which makes up 21.7%. Other major components include Nylon/Polythene at 15.9%; Garden Leaves at 12.0%; and Plastic/Rubber at 8.6%. The smallest categories comprised: Paper/Cardboard at 5.7%; Tin Cans at 5.4% and Dirt, Ashes, and Brick at 4.3% as seen in Figure 1.

3.2.1 Organic waste

Garden waste, which includes lawn cuttings, leaves, and trimmings from green areas, makes up an average of 12.0% of the total waste at the facility. This is likely due to ATBUTH's substantial size, which features a large landmass with numerous trees and extensive green spaces that require regular maintenance. Food waste is the largest component of the solid waste stream, averaging 26.4%. This high concentration is generally attributed to the large volume of patients and visitors at the hospital. The data shows that the highest percentage of food waste (33.4%) was found in the staff residential area, likely because of the intensive cooking habits of staff families. Lastly, when comparing the results among the hospital wards, the Maternity Ward (39.3%) recorded the highest volume, followed by the Female Ward (32.6%) and the Male Ward (30.8%) respectively.

3.2.2 Nylon/Polythene

Nylon and Polythene, specifically Low-Density Polyethylene (LDPE) and High-Density Polyethylene (HDPE), are a major part of the plastic waste produced at hospitals. These materials constitute a significant amount of the total waste generated at ATBUTH, averaging 15.9%. They are primarily used for packaging, including sterile wrappers, plastic films, and bags for medical supplies, instruments, medications, and various drink sachets. Notably, this category represents the largest portion of recyclable municipal solid waste (MSW) at ATBUTH Bauchi. The Maternity ward (22.4%) and staff quarters (19.3%) generated the highest percentages of this waste. In contrast, the emergency ward recorded the lowest percentage at 11.4% (see Table 1).

3.2.3. Plastic/Rubber waste

Plastics and rubber make up a major part of the solid waste produced by hospitals and other healthcare facilities. This is primarily because of the need for infection control, which necessitates the use of sterile, disposable items such as syringes, tubing, catheters, IV sets, and personal protective equipment (PPE) like gloves, gowns, and masks. At ATBUTH, plastics and rubber accounted for an average of 8.6% of all waste. The highest concentration was found in the staff quarters at 13.2%. This elevated percentage is likely due to staff disposing of packaging from drinks (water, soft drinks, liquor) and broken household items like plastic chairs, buckets, and cooking utensils. In contrast, the lowest amount was found in the administrative block areas at 5.1%. This lower figure

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is thought to be the result of cleaners sorting and collecting recyclable materials to sell for income, effectively removing a portion of the plastic/rubber waste from the general stream.

3.2.4. Paper/Cardboard

Paper and cardboard, categorized as non-hazardous waste, made up 5.7% of the total waste stream at ATBUTH. The hospital generates substantial quantities of this material because daily deliveries of equipment, food, supplies, and medication arrive in numerous cardboard boxes and paper cartons. Despite efforts toward digitalization, paper is still heavily consumed for patient records and internal communication, while patient meals and bulk kitchen supplies also contribute significantly to this waste stream.

The Administrative Block (9.6%) and the Emergency Ward (6.4%) produced the largest percentages of paper/cardboard waste. In contrast, the staff quarters recorded the lowest percentage at 5.1% (see Table 1). The low values in residential areas and others may be because this waste is easily recyclable; therefore, cleaners likely engage in informal waste sorting to sell the recyclables and supplement their income.

3.2.5 Medical/infectious waste

Regulated Medical Waste (RMW), also known as Biomedical Waste, requires specific handling and treatment to prevent both injury and the spread of infection. At ATBUTH, this hazardous waste constituted an average of 21.7% of the total waste generated. This figure aligns with general healthcare waste findings (Appleton & Ali, 2020), which state that while 75% to 90% of total medical center waste is non-infectious, the remaining 10% to 25% is infectious and poses the greatest risk to people. The highest proportions of this infectious waste at ATBUTH came from the Maternity (37.4%) and Female Wards (31.3%) (see Table 1), likely due to the high volume of clinical diagnoses and treatments performed in these areas.

3.3 High Potential for Recycling at ATBUTH

A significant portion of the Municipal Solid Waste (MSW) generated at ATBUTH is recyclable or has the potential to be recycled. The study found that an average of 35.6% of the entire waste stream could be recycled. This potential is evident across various sections of the hospital, which show strong recyclability ratings: The Maternity Ward demonstrated the highest potential at 44.1%. The staff residential areas followed closely with 40.0%. The Male Ward and Female Ward also had high potential at 36.4% and 32.6%, respectively. The Administrative Block had a potential of 30.7%. The Emergency Ward recorded the lowest potential for recycling at 29.4%, as seen in Figure 2. The major recyclable components comprised of Nylon/ Polythene, Plastic/ rubber, Paper/ Cardboard and tin cans. Despite this high potential, ATBUTH currently does not recycle, reuse, or recover from any of its waste categories.

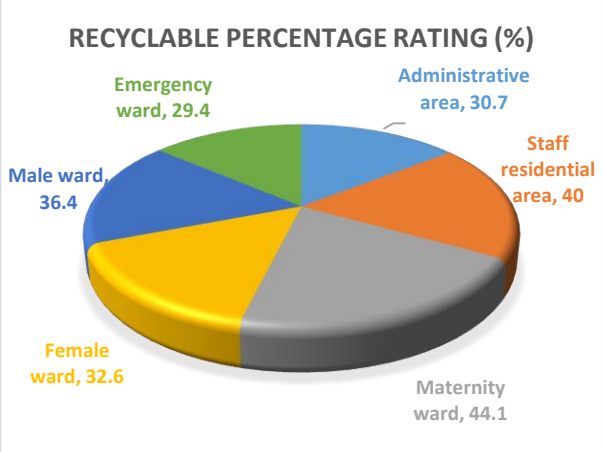

Figure 2: *Recyclable waste percentage distribution across functional areas of ATBUTH. The maternity ward and staff residential area exhibited the highest proportions of recyclable materials, indicating significant potential for waste recovery and resource optimization*

3.4 Biomass Energy Potential at ATBUTH

The waste generated at ATBUTH represents a significant, untapped source of renewable energy due to its high average biomass content of 48.4%. Harnessing this organic waste properly could lead to substantial cost savings on grid electricity for the hospital. The biomass potential is high across most areas: The Maternity Ward and staff residential areas show the greatest potential, with biomass contents of 60.3% and 56.0%, respectively. The Female Ward (52.6%) and Male Ward (46.1%) also show a strong potential. The Emergency Ward (35.7%) and Administrative Areas (18.0%) have the lowest ratings (Figure 3).

As the hospital's organic waste decomposes, it has the potential to produce methane gas. This gas is both a valuable fuel source and a serious environmental and safety hazard because it is colorless, odorless, and can cause explosions if it ignites after seeping into homes. To address this, new regulations are needed to require landfills to be equipped to collect this deadly gas. Once collected, it can be purified and used as fuel. Methane can also be safely and productively extracted by fermenting the waste in biogas digesters (similar to

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Table 2: Per Capita Solid waste generation rates across selected wards of ATBUTH. The maternity ward recorded the highest total waste generation, while the male ward showed the highest waste generation rate per bed per day, reflecting variations in patient load and service intensity

Sampling locations	Total waste generated	No of Patient	Generation rate kg/ward /day	Generation rate kg/bed /day
Maternity Ward	137	60	19.6	0.43
Male Ward	107.1	50	15.3	0.47
Female Wards	110.6	40	15.8	0.36
Mean Values				0.42

processing agricultural and human waste). The resulting methane-rich gas can then be used to produce a considerable amount of energy for electricity, cooking, and lighting. In conclusion, the municipal solid waste from Nigerian health institutions like ATBUTH has the potential to become a valid and sustainable fuel source for the urban energy mix of the future.

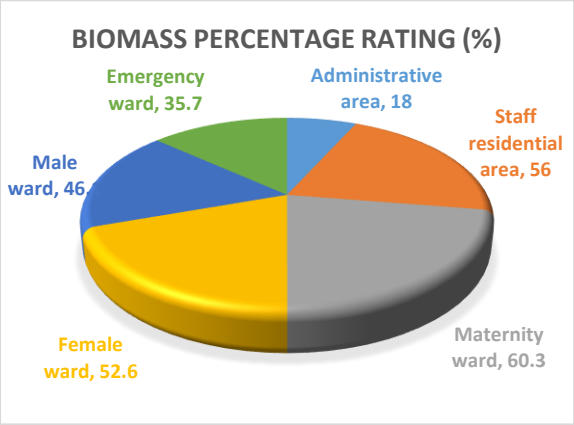

Figure 3: Biomass waste percentage distribution across functional areas of ATBUTH. The maternity ward and staff residential area exhibited the highest biomass content, underscoring their potential contribution to organic waste-to-energy recovery initiatives

3.5 Per Capita Waste Generation at ATBUTH

The study found a variation in the per capita waste generation (kilograms per person per day or kg/c/d) across the surveyed areas, which reflects differences in activities, patient care needs, and the nature of consumable materials used. The Male Wards produced the highest amount of waste at 0.47 kg/c/d. This was closely followed by the Maternity Wards with an average of 0.43 kg/c/d. The Female Wards generated the least amount of waste, averaging 0.36 kg/c/d as seen in Table 2.

4 Conclusion and Recommendations

The study, conducted over one month, found that ATBUTH Bauchi generated an average of 578.1 kg of solid waste weekly, with a per capita generation rate of approximately 0.42 kg per day. The largest components of the waste stream were food waste (26.4%) and medical/infectious waste (21.7%), and Dirt, ashes, and brick represented the smallest portion at 4.3%. similarly, the rate and composition of waste varied significantly across different hospital areas, with the Female Ward generating the most total waste (110.6 kg) and the Maternity Ward generating the least (37.4 kg). Other areas included the Male Ward (107.1 kg), Emergency Ward (88.8 kg), Staff Residence (94.1 kg), and Administrative Block (40.5 kg).

The hospital's waste has high potential for resource recovery, with a potential of 35.6% of the total waste being recyclable, and 48.4% of the waste is biomass, indicating a strong potential for Waste-to-Energy (WtE) technologies. Implementing these technologies could allow the hospital to generate a substantial amount of its own electricity.

To improve waste management at ATBUTH, the study concluded that a strategic policy framework and full participation from the entire hospital community are essential. These efforts should focus on reduction at the source, recycling, reuse, and composting. Ultimately, this detailed understanding of ATBUTH's waste generation is intended to drive more sustainable waste management strategies and stimulate similar studies across other Nigerian hospitals.

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