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Documentation and Quantification of Biomedical Waste Generation in a Tertiary Trauma Care Hospital of Delhi: A Research Study

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ABSTRACT

Background: Biomedical waste (BMW) management is a critical component of hospital infection control, environmental safety, and regulatory compliance. Accurate documentation of BMW generation is essential, particularly in tertiary trauma care hospitals where high patient acuity, intensive care services, and operative interventions significantly increase waste production.
Objectives: To quantify and document biomedical waste generation in a 259-bedded tertiary trauma care hospital in Delhi, expressed as kilograms per bed per day, and to analyze category-wise distribution of BMW into yellow, red, blue, and white streams.
Methods: A prospective observational study was conducted using standardized daily weighment and documentation of BMW generated from all patient care areas including wards, intensive care units (ICUs), and operating theatres (OTs). Waste was segregated as per Biomedical Waste Management Rules and weighed category-wise. Data were normalized to kg per bed per day.
Results: The total biomedical waste generation was 2.0 kg/bed/day. Of this, yellow category constituted 1.0 kg/bed/day, red category 0.5 kg/bed/day, blue category 0.3 kg/bed/day, and white category 0.2 kg/bed/day. Yellow waste formed the largest proportion (50%), followed by red (25%), blue (15%), and white (10%).
Conclusion: The study demonstrates a high burden of biomedical waste generation in a tertiary trauma care setting, emphasizing the need for meticulous documentation, effective segregation, and continuous monitoring to ensure regulatory compliance and environmental safety..

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INTRODUCTION

Biomedical waste (BMW) comprises all waste generated during the diagnosis, treatment, or immunization of human beings or animals, as well as waste produced during related research activities and the production or testing of biologicals.[1] Improper handling, segregation, documentation, and disposal of biomedical waste pose serious risks to healthcare workers, patients, waste handlers, the general public, and the environment. These risks include needle-stick injuries, transmission of blood-borne infections, environmental contamination, and long-term public health hazards.[2]

In response to these concerns, the Government of India notified the Bio-Medical Waste Management Rules, 2016, which mandate systematic segregation, collection, treatment, and documentation of biomedical waste in all healthcare facilities.[1] The rules emphasize maintenance of daily records of waste generation, category-wise quantification, and

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submission of periodic reports to regulatory authorities. Accurate documentation of BMW generation is therefore not merely an administrative requirement but a critical component of hospital infection control and environmental safety programs.[3]

India's rapidly expanding healthcare sector, coupled with increasing patient load and growing reliance on disposable medical supplies, has led to a substantial rise in the volume of BMW generated by hospitals.[4] Studies from various parts of the country have reported BMW generation ranging from 0.5 to 2.0 kg per bed per day, with higher values observed in tertiary care institutions.[5,6] The variation in waste generation is influenced by factors such as hospital size, case mix, availability of intensive care services, surgical workload, and adherence to waste segregation practices.[7]

Tertiary trauma care hospitals represent a distinct and high-risk category of healthcare facilities. These hospitals manage critically injured patients requiring emergency interventions, invasive monitoring, frequent surgical procedures, and prolonged intensive care unit (ICU) stays. Such activities significantly increase the consumption of single-use disposables, personal protective equipment, and invasive devices, resulting in a disproportionately higher generation of biomedical waste compared to general hospitals.[8] The presence of multiple operating theatres and large ICUs further amplifies the volume of infectious and hazardous waste streams, particularly yellow and red category waste.[9]

Documentation of BMW in standardized units such as kilograms per bed per day allows meaningful comparison between institutions and provides an objective basis for monitoring trends over time.[10] Category-wise documentation into yellow, red, blue, and white streams is especially important, as each category requires a specific treatment and disposal pathway. Inadequate documentation or misclassification can lead to inappropriate treatment, increased disposal costs, and heightened occupational and environmental risks.[11]

Despite clear regulatory guidelines, several studies have highlighted gaps in BMW documentation and segregation practices in Indian hospitals.[6,8] These gaps are more pronounced in high-pressure environments such as trauma centers, where clinical priorities may overshadow waste management practices. There remains a paucity of published data focusing specifically on BMW generation patterns in tertiary trauma care hospitals in India, particularly from metropolitan regions such as Delhi.[12]

Against this background, the present study was undertaken to document and quantify BMW generation in a 259-bedded tertiary trauma care hospital in Delhi. The study aimed to measure total and category-wise BMW generation expressed as kilograms per bed per day and to analyze the proportional contribution of yellow, red, blue, and white waste categories. Such data are essential for strengthening biomedical waste management systems, ensuring regulatory compliance, and guiding hospital administrators in planning effective waste reduction and segregation strategies.

MATERIALS AND METHODS

This prospective observational study was conducted in a 259-bedded tertiary trauma care hospital located in Delhi. The hospital comprises 60 ICU beds, six-fully functional OTs, emergency services, inpatient wards, and diagnostic and support areas. The study was designed to document and quantify BMW generation across different functional areas of the hospital using standardized daily weighing and recording methods, in accordance with the Bio-Medical Waste Management Rules, 2016.[1]

BMW data were collected over a continuous two-month period from 25 December 2025 to 26 January 2026. During this period, daily weighing of BMW was carried out from all major waste-generating areas of the hospital, including inpatient wards, ICUs, operating theatres, emergency department, and ancillary clinical areas. Waste segregation was performed at the point of generation into yellow, red, blue, and white categories using color-coded containers and bags as prescribed under national guidelines.[1,4]

All BMW generated during routine clinical activities was collected daily by trained waste handlers. Category-wise waste was weighed using calibrated digital weighing scales at the central waste collection area. In addition, waste generated from ICUs and operating theatres was weighed separately prior to consolidation to allow area-specific analysis. ICU waste was documented on a per-bed per-day basis, while operating theatre waste was documented on a per-OT per-day basis. Calibration of weighing scales was verified at regular intervals to ensure accuracy of measurements.

Daily BMW data were recorded in standardized registers, capturing the date of collection, source area, waste category, and weight in kilograms. The total daily waste generated was calculated by summing the weights of all categories. Hospital-wide BMW generation was normalized and expressed as kilograms per bed per day by dividing the total daily waste by the total number of hospital beds (259). ICU waste generation was similarly expressed as kilograms per ICU bed per day, and OT waste generation was expressed as kilograms per OT per day.

Data collected over the two-month study period were compiled and averaged to obtain representative daily waste generation values. Descriptive statistical analysis was performed to determine total and category-wise BMW

generation and the proportional contribution of each waste category. Results were summarized using means and percentages and are presented in tabular form for hospital-wide, ICU-specific, and operating theatre-specific BMW generation patterns.

The study involved no direct patient interaction and utilized routinely collected operational data; therefore, formal ethical approval was not required. Confidentiality of hospital operational data was maintained throughout the study period.

RESULTS

Overall Biomedical Waste Generation

The total BMW generated in the hospital was 2.0 kg per bed per day. Category-wise distribution showed that yellow waste constituted the highest proportion, followed by red, blue, and white waste. The detailed hospital-wide distribution is shown in Table 1.

Biomedical Waste Generation in Intensive Care Units

The hospital had 60 ICU beds, catering to critically ill trauma patients requiring invasive monitoring, mechanical ventilation, and strict infection control practices. BMW generation in ICUs was significantly higher compared to the overall hospital average.

The total BMW generation in ICUs was 3.5 kg per ICU bed per day. Yellow category waste constituted the largest proportion, reflecting frequent use of soiled materials, disposable linens, and infection control consumables.

Table 1: Category-wise biomedical waste generation (hospital average).

Waste category	BMW generated (kg/bed/day)	Percentage of total (%)
Yellow	1.0	50.0
Red	0.5	25.0
Blue	0.3	15.0
White	0.2	10.0
Total	**2.0**	**100.0**

Table 2: Category-wise biomedical waste generation in ICUs (kg/ICU bed/day).

Waste category	BMW generated (kg/ICU bed/day)	Percentage (%)
Yellow	1.8	51.4
Red	0.9	25.7
Blue	0.5	14.3
White	0.3	8.6
Total	**3.5**	**100.0**

Table 3: Category-wise biomedical waste generation in operating theatres (kg/OT/day).

Waste category	BMW generated (kg/OT/day)	Percentage (%)
Yellow	10.0	50.0
Red	5.0	25.0
Blue	3.0	15.0
White	2.0	10.0
Total	**20.0**	**100.0**

Biomedical Waste Generation in Operating Theatres

The hospital operated six fully functional OTs providing emergency and elective trauma surgeries. BMW generated from OTs was recorded separately on a per-OT per-day basis.

The average BMW generation was 20 kg per OT per day. Yellow waste formed the predominant category due to surgical dressings, blood-soaked materials, and anatomical waste, followed by red category plastic waste from disposable surgical items.

Comparative Analysis of BMW Generation

A comparison of BMW generation across hospital beds, ICU beds, and operating theatres demonstrated a progressive increase in waste generation with increasing intensity of care. ICU waste generation per bed per day was nearly 1.75 times higher than the overall hospital average, while operating theatres contributed a disproportionately high volume of yellow and red category waste.

The relative distribution of waste categories remained similar across settings, with yellow category waste consistently forming the largest proportion, indicating effective segregation practices but a high burden of infectious waste inherent to trauma and surgical care.

DISCUSSION

The present study documents BMW generation in a tertiary trauma care hospital and demonstrates a total BMW generation of 2.0 kg per bed per day, which is higher than that reported in many general hospitals in India but consistent with figures reported from tertiary and high-acuity healthcare facilities.[3,6,12] Trauma hospitals cater to critically ill patients, require emergency surgical interventions, and depend heavily on invasive procedures and disposable medical supplies, all of which contribute to increased waste generation.

The predominance of yellow category waste (1.0 kg/bed/day; 50%) observed in this study is in accordance with findings from previous studies conducted in tertiary care hospitals, where infectious and soiled waste constitutes the largest proportion of BMW.[8,9,13] Trauma patients frequently require repeated dressing changes, management of open wounds, blood product usage, and isolation precautions, leading to increased generation of yellow category waste. This underscores the importance of robust infection control practices and strict adherence to segregation protocols to minimize occupational and environmental hazards.

The red category waste (0.5 kg/bed/day; 25%) reflects extensive use of disposable plastic items such as intravenous tubing, catheters, syringes without needles, and personal protective equipment. Studies have shown that inappropriate segregation of red category waste into yellow streams significantly increases treatment costs and reduces recycling efficiency.[11,14] The relatively high proportion of red waste in the present study highlights opportunities for waste minimization through improved segregation training and rational use of disposables.

BMW generation in intensive care units (3.5 kg/ICU bed/day) was substantially higher than the hospital average. Similar observations have been reported by other authors, who noted that ICUs generate two to three times more waste per bed than general wards due to continuous monitoring, invasive devices, higher staff-to-patient ratios, and stricter infection control measures.[7,15] The consistent category-wise distribution pattern in ICUs, with yellow waste predominating, further reinforces the inherent waste-intensive nature of critical care services.

Operating theatres contributed a disproportionately large volume of biomedical waste, with an average of 20 kg per OT per day. Surgical waste is known to be a major contributor to hospital BMW, particularly yellow and red categories, owing to blood-soaked materials, surgical drapes, disposable instruments, and packaging waste.[16] Studies from surgical and trauma centers have emphasized that operating theatres, despite occupying limited physical space, account for a substantial share of hospital waste and should be a primary focus for waste reduction strategies.[17]

The standardized expression of BMW generation in kilograms per bed per day and kilograms per OT per day enabled meaningful comparison across hospital areas and with previously published studies.[10,18] Daily weighing over a two-month period provided reliable average values and minimized the influence of day-to-day variability in patient load and surgical volume. Such documentation is essential for regulatory reporting, capacity planning for waste treatment facilities, and benchmarking institutional performance.

Overall, the findings of this study highlight the significant BMW burden associated with tertiary trauma care hospitals and emphasize the need for continuous monitoring, regular staff training, and periodic audits to ensure effective BMW management in accordance with national guidelines.[1,4,19]

Strengths and Limitations

This study has several strengths. First, it employed prospective daily weighing of BMW over a continuous two-month period, which enhances the reliability, and representativeness of the data. Second, area-specific documentation of waste generation from general wards, ICUs, and operating theatres allowed a detailed understanding of waste generation patterns in a tertiary trauma care setting. Third, the use of standardized units (kg per bed per day and kg per OT per day) facilitates comparison with national and international studies and supports hospital-level benchmarking.

The study also has certain limitations. It was conducted in a single tertiary trauma care hospital, which may limit the generalizability of findings to other healthcare settings. Seasonal variations beyond the study period were not assessed and may influence waste generation patterns. Additionally, the study focused on quantitative documentation of waste and did not evaluate the microbiological or chemical composition of biomedical waste. Despite these limitations, the study provides valuable baseline data for trauma care hospitals in urban Indian settings.

CONCLUSION

The present study documents a high burden of biomedical waste generation in a 259-bedded tertiary trauma care hospital in Delhi, with a total generation of 2.0 kg per bed per day. Yellow category waste constituted the largest proportion, followed by red, blue, and white categories. Intensive care units and operating theatres were identified as major contributors to overall BMW generation. Accurate and continuous documentation using standardized metrics is essential for regulatory compliance, occupational safety, environmental protection, and cost-effective waste management. The findings underscore the need for targeted interventions focusing on high-waste-generating areas, particularly ICUs and operating theatres, to strengthen BMW management practices in tertiary trauma care hospitals.

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