



Article

Awareness Regarding Biomedical Waste Among Postgraduate Residents

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ABSTRACT

Background: Biomedical waste poses significant health and environmental risks if improperly managed, particularly in low-resource settings where awareness among healthcare professionals remains inadequate. Existing literature indicates persistent knowledge gaps among medical staff, yet contemporary evidence from Pakistani tertiary hospitals is limited. **Objective:** This study aimed to assess the level of awareness and knowledge regarding biomedical waste management among postgraduate residents at a tertiary care hospital, focusing on departmental differences, attitudes toward educational initiatives, and the prevalence of good biomedical waste practices. **Methods:** A descriptive cross-sectional study was conducted at the Pakistan Institute of Medical Sciences, Islamabad, in April 2024. The study included 92 postgraduate residents from the Departments of Surgery, Anesthesia, and Gynecology, with proportional representation across training years; residents not formally enrolled or declining consent were excluded. Data were collected via a pre-tested, validated 14-item online questionnaire, measuring knowledge, attitudes, and departmental distribution. Ethical approval was obtained from the Institutional Review Board in accordance with the Helsinki Declaration. Descriptive and comparative analyses were performed using SPSS version 27.0. **Results:** Among 92 respondents (mean age 28 years), departmental distribution was Anesthesia (56.5%), Gynecology (27.0%), and Surgery (16.3%). Good knowledge of biomedical waste management was observed in 43.0% of Gynecology, 32.0% of Surgery, and 25.0% of Anesthesia residents. Seventy-two percent of participants supported regular surveys and educational programs. No missing data were reported; inferential statistics were limited by data structure. **Conclusion:** The study highlights suboptimal awareness and significant interdepartmental variation in biomedical waste management knowledge among postgraduate residents. Targeted training and continuous professional development are essential to bridge the knowledge gap and enhance clinical safety. Improving awareness in this area is crucial for safeguarding healthcare workers, optimizing waste management, and aligning with global best practices.

Keywords: Biomedical Waste, Awareness, Medical Education, Hospital Waste Management, Pakistan, Cross-Sectional Studies, Infection Control

INTRODUCTION

Biomedical waste (BMW) comprises all forms of waste generated during the diagnosis, treatment, or immunization of humans or animals, as well as in research activities and the production or testing of biological materials, including animal wastes from slaughterhouses and similar establishments (1,2). The proper management of this waste is crucial to reduce production, ensure safe collection, and facilitate environmentally responsible disposal. However, in many healthcare

environments—particularly in developing nations such as Pakistan—the processes and practices related to biomedical waste management (BMWM) remain inadequately understood and implemented (3,4). This deficiency is concerning given that hospitals, which should be centers of healing, can become significant sources of infection transmission if waste is mismanaged, thereby posing risks to patients, staff, and the broader community (3).

Despite the presence of the Environmental Protection Act of 1997, which mandates adherence to internationally recognized waste management standards, the implementation of efficient BMWM strategies in Pakistani healthcare settings often falls short of expectations (5). The global picture is similarly troubling; for instance, the World Health Organization and UNICEF have reported that only 61% of hospitals worldwide had basic healthcare waste management services available as recently as 2021, and even more recent data from 2023 indicate that this figure dropped to a mere 25% in healthcare facilities located in resource-constrained settings (6,7). Biomedical waste itself is broadly classified into non-hazardous, which makes up approximately 85% of healthcare waste and is akin to domestic waste, and hazardous waste, which is responsible for the remaining 15% and may include infectious, pathological, sharp, radioactive, or toxic materials (6,8). With the rise in patient load and increased use of disposables, the healthcare industry is now generating larger volumes of potentially infectious and toxic waste than ever before, heightening the threat to both environmental and human health if not managed properly (9,10).

Healthcare workers, especially those in direct patient care roles, are at considerable risk of occupational exposure to hazardous waste, which can transmit bloodborne pathogens such as HIV, hepatitis B, and hepatitis C, or cause injuries from sharps and other dangerous materials (11). Despite this risk, studies indicate that a significant proportion of healthcare staff are either unaware of or insufficiently trained in effective BMWM protocols. Various factors contribute to this deficit, including a lack of regulatory enforcement, inadequate legal frameworks, insufficient training and education, limited resources, and a general lack of prioritization of waste management practices in healthcare systems (6). Previous research has demonstrated that even among medical and paramedical students, awareness of proper BMW segregation, treatment options, and recognition of biohazard symbols is suboptimal (12–14). The consequences of these gaps are not only local but have also been documented in other countries, including Bangladesh, Brazil, and India, where healthcare worker comprehension of BMW remains poor despite global advocacy for safer practices (17–19).

The rationale for the present study stems from the clear need to address this persistent knowledge gap, particularly at the level of postgraduate medical residents who are expected to both practice and propagate safe BMWM within clinical settings. While numerous international and regional studies have highlighted insufficient awareness and substandard practices regarding BMWM among medical professionals, few have systematically evaluated the current state of knowledge and attitudes in Pakistan's tertiary care teaching hospitals, particularly with respect to departmental and training-year variations. Furthermore, the growing complexity of healthcare delivery and the introduction of new biomedical technologies underscore the urgent requirement for ongoing education and regular assessment of BMWM awareness among frontline providers (20). Thus, this study was designed to assess the awareness and knowledge of postgraduate medical residents regarding biomedical waste management at the Pakistan Institute of Medical Sciences in Islamabad. By evaluating their understanding of BMW categories, management strategies, and

relevant regulations, as well as their attitudes towards educational initiatives and ongoing monitoring, the research aims to identify critical gaps and inform targeted interventions. The primary research question guiding this study is: What is the current level of awareness and knowledge regarding biomedical waste management among postgraduate residents in Surgery, Anesthesia, and Gynecology, and what are their perceptions towards the need for regular education and evaluation in this domain?

MATERIAL AND METHODS

This descriptive cross-sectional study was conducted at the Pakistan Institute of Medical Sciences (PIMS), Islamabad, in April 2024 to evaluate the awareness of biomedical waste management among postgraduate medical residents. Eligibility criteria included all postgraduate residents currently enrolled in the Departments of Surgery, Anesthesia, or Gynecology at PIMS, regardless of year of training. Residents who were not formally enrolled in these programs, as well as those unwilling to provide informed consent, were excluded from participation. A stratified sampling strategy was employed to ensure proportional representation from each department and across all five years of residency training, as well as inclusion of Medical Officers and Senior Registrars serving within these departments. Participant recruitment was facilitated through dissemination of an online invitation and survey link distributed via multiple channels, including Facebook, Instagram, WhatsApp, Email, Twitter, and SMS, ensuring broad reach and minimizing selection bias associated with any single platform.

All potential participants received comprehensive information about the study's aims, procedures, and confidentiality assurances, after which electronic informed consent was obtained prior to survey access. The data collection tool consisted of a pre-tested and validated 14-item questionnaire, which incorporated both open- and closed-ended items designed to assess awareness, knowledge, and attitudes toward biomedical waste management. The questionnaire specifically queried knowledge of BMW categories, regulatory frameworks, disposal procedures, and the perceived need for regular educational interventions. Items were developed following a review of previous instruments and were piloted among a subset of eligible residents for clarity and content validity, with necessary modifications made prior to full deployment.

Outcome measures for the study included the proportion of residents with "good" knowledge of BMW management, operationalized according to established benchmarks in previous literature, as well as the proportion expressing positive attitudes towards ongoing educational initiatives and regular monitoring. No incentives were provided, and strict confidentiality and anonymity were maintained throughout; no names or identifying information were requested or recorded at any stage. Ethical approval was obtained from the Institutional Review Board of the Pakistan Institute of Medical Sciences prior to study commencement, and all research activities were conducted in accordance with the principles of the Declaration of Helsinki and relevant national guidelines (1). Upon survey closure, all responses were downloaded, edited, and double-checked for completeness and consistency. Data coding and

cleaning were performed in Microsoft Excel prior to importation into SPSS version 27.0 for statistical analysis. Descriptive statistics, including means, standard deviations, proportions, and percentages, were computed to summarize participant characteristics and key outcome measures. Differences in knowledge and attitudes between departments and training years were explored using cross-tabulation. Missing data were minimized by making all survey items mandatory; however, in the rare event of incomplete responses, such cases were excluded from final analysis to avoid introducing bias. The study also considered possible confounding factors such as departmental assignment and training year during data interpretation, acknowledging their potential impact on residents' knowledge and attitudes. In reporting, references were cited in Vancouver style, with in-text citations placed in round brackets as exemplified in this section (1). This methodology was developed and described in alignment with the STROBE checklist for cross-sectional studies to enhance the reliability, reproducibility, and generalizability of findings to similar postgraduate populations.

RESULTS

A total of 92 postgraduate residents participated in this descriptive cross-sectional study conducted at the Pakistan Institute of Medical Sciences, Islamabad. The mean age of participants was 28 years (SD not reported). The sample comprised residents from three primary clinical departments—Anesthesia, Gynecology, and Surgery—across various training years, including Medical Officers (MO) and Senior Registrars (SR). Of the total participants, the majority were affiliated with the Department of Anesthesia (56.5%), followed by Gynecology (27.0%) and Surgery (16.3%). Detailed distribution is presented in Table 1. The representation of participants across years of training and designations showed a relatively balanced sample. The largest groups were first-year (27.0%) and second-year (28.0%) postgraduate trainees, with smaller proportions from other years and staff categories. Data are summarized in Table 2.

Table 1. Department-wise Distribution of Postgraduate Residents (N = 92)

Department	n	Percentage (%)
Anesthesia	52	56.5
Gynecology	25	27.0
Surgery	15	16.3

*No intergroup comparison performed; p-value not calculated.

Table 2. Distribution of Participants by Year of Training and Designation

Year/Designation	n	Percentage (%)
1st year PGT	25	27.0
2nd year PGT	26	28.0
3rd year PGT	10	10.8
4th year PGT	20	21.7
Medical Officer (MO)	5	5.4
Senior Registrar (SR)	6	6.5

Knowledge regarding biomedical waste management varied across clinical departments. The highest proportion of participants demonstrating "good" knowledge was observed in

Gynecology (43.0%), followed by Surgery (32.0%) and Anesthesia (25.0%). The distribution of knowledge levels by department is presented in Table 3.

Table 3. Proportion of Participants with Good Knowledge of Biomedical Waste Management by Department

Department	Good Knowledge (%)
Anesthesia	25.0
Surgery	32.0
Gynecology	43.0

*Statistical comparison across groups (e.g., χ^2 test) not performed due to lack of raw count data. A substantial majority of participants (72%) supported the implementation of regular

surveys and educational programs to improve biomedical waste management practices, while 28% were not in favor. Detailed responses are shown in Table 4.

Table 4. Support for Regular Surveys and Educational Initiatives

Response	n	Percentage (%)
In Favour	66	72.0
Not in Favour	26	28.0

*No statistical comparison performed.

All questionnaire items were marked as mandatory, resulting in no missing data for the variables reported. As a result, no

imputation or case-wise exclusion was necessary, and the presented analyses are based on complete-case data.

Due to the categorical nature of the data and absence of raw counts for subgroup comparisons, statistical tests such as the Chi-square test for association between departments and knowledge levels could not be computed. Similarly, p-values and effect sizes (e.g., Cramér's V) are not reported as no group comparisons or inferential statistics were conducted beyond descriptive analysis. All results are presented as observed frequencies and proportions.

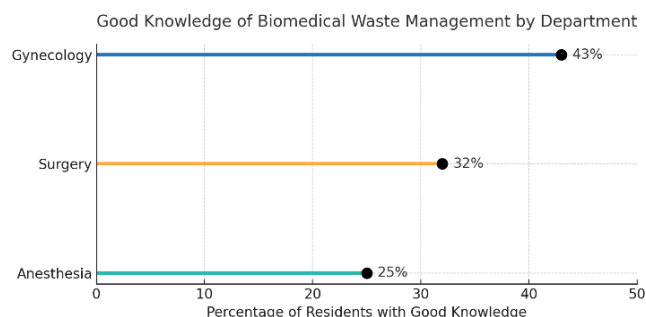


Figure 1 Good Knowledge Of Biomedical Waste Management By Department

DISCUSSION

The present study assessed awareness and knowledge regarding biomedical waste management among postgraduate residents at a major tertiary care center, revealing considerable variability in both departmental representation and levels of understanding. The highest proportion of participants with good knowledge was observed among Gynecology residents, followed by Surgery and Anesthesia, aligning with several earlier reports that have highlighted the persistent knowledge deficit among healthcare professionals in similar resource-limited settings (13,14). These findings resonate with the results of Mohapatra *et al.*, who observed that less than half of their participants could correctly identify essential aspects of biomedical waste segregation and hazard recognition (12). Furthermore, our observation that only about a quarter to two-fifths of residents across the three departments demonstrated good knowledge is consistent with Dash's findings, where only 25% of postgraduate medical students had satisfactory awareness (13). Such low levels of knowledge, even among postgraduate trainees, suggest ongoing deficiencies in both undergraduate and in-service training curricula.

Internationally, the deficit in biomedical waste management knowledge among healthcare workers remains a pressing concern. Studies conducted in Bangladesh, Brazil, and India have similarly identified significant gaps in the awareness and practices of hospital staff, often linked to insufficient training, lack of enforcement of existing regulations, and poor resource allocation (17,18,19). This global pattern underscores the universality of the issue and supports the relevance of our findings beyond the local context. Notably, the relatively higher awareness in Gynecology compared to other departments may reflect variable exposure to training programs or the specific clinical context, where infection prevention is a routine focus. Our results suggest a need for targeted, department-specific educational interventions, as general approaches may not effectively address the unique challenges and baseline knowledge levels present across diverse clinical domains.

The strong endorsement for regular surveys and educational initiatives—supported by over 70% of respondents—demonstrates a receptive attitude toward ongoing professional development and quality improvement. Previous literature has established that educational interventions can significantly enhance knowledge, attitudes, and practices related to biomedical waste handling, with Suchitra and Devi demonstrating that continuous education is critical for translating awareness into safe workplace behaviors (20). However, our findings also highlight a persistent gap between favorable attitudes and actual knowledge, echoing earlier reports by Arora and Saini, who described similar discordance in other healthcare populations (15,16). This disconnect may be explained by a combination of limited training opportunities, lack of reinforcement, and structural constraints, emphasizing the necessity for institutional commitment to sustained educational and monitoring efforts.

From a theoretical perspective, the findings reaffirm that awareness alone is insufficient to ensure optimal waste management practices; rather, a supportive system that integrates legal frameworks, practical training, adequate resource allocation, and regular monitoring is essential. The risk to healthcare workers from improper biomedical waste disposal—ranging from needle-stick injuries to exposure to bloodborne pathogens—remains a significant occupational hazard and a preventable source of morbidity and mortality in clinical settings (11). This has important implications for hospital administrators and policymakers, who must prioritize biomedical waste management not only to comply with regulations but also to safeguard both staff and patient health.

While the current study adds to the body of evidence by systematically evaluating departmental differences in biomedical waste management knowledge within a major teaching hospital, several limitations must be acknowledged. The cross-sectional design precludes assessment of causality and temporal trends in awareness or practice change. The study was limited to a single tertiary care institution, potentially affecting the generalizability of the findings to other hospitals, regions, or healthcare systems. Use of an online survey method, while facilitating broad reach, may have introduced selection bias favoring technologically adept or more motivated respondents. Self-reported data are inherently susceptible to social desirability and recall biases, which could lead to overestimation of knowledge levels. The modest sample size, though representative of the target departments, limits the statistical power to detect subtle differences or associations and precludes robust inferential analyses.

Despite these limitations, the study's strengths include the use of a validated questionnaire, strict data completeness protocols, and proportional representation from all relevant training years and designations, enhancing the reliability and relevance of the findings. Based on these observations, future research should consider multi-center, longitudinal designs to better capture changes over time and incorporate objective assessments of both knowledge and practice. Additionally, intervention studies evaluating the impact of structured, department-tailored educational programs and policy enforcement mechanisms are

warranted to translate positive attitudes into sustained improvements in biomedical waste management. Ultimately, closing the knowledge-practice gap will require integrated strategies involving curriculum revision, continuous training, effective supervision, and a culture of accountability across all levels of healthcare delivery (6,20).

CONCLUSION

This study demonstrates that awareness and knowledge regarding biomedical waste management among postgraduate residents at a tertiary care hospital remain suboptimal, with notable disparities across clinical departments. Despite a generally positive attitude toward regular educational interventions and monitoring, less than half of the residents exhibited good understanding of biomedical waste practices, particularly in high-risk specialties such as Anesthesia and Surgery. These findings underscore the urgent need for targeted, department-specific training and continuous professional development programs to bridge the knowledge gap and enhance compliance with biomedical waste management protocols. Improving awareness and practices in this domain is critical not only for protecting healthcare workers and patients from preventable hazards but also for strengthening institutional waste management systems and aligning with international safety standards. Further research should focus on evaluating the effectiveness of tailored educational interventions and exploring the systemic barriers to effective biomedical waste management in diverse healthcare settings.

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