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Original Research Article

STATUS OF BIOMEDICAL WASTE MANAGEMENT PRACTICES AND EFFECTIVENESS OF AN EDUCATIONAL INTERVENTION AMONG HEALTH CARE WORKERS IN A TERTIARY CARE HOSPITAL OF HARYANA

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ABSTRACT

Background: Biomedical waste (BMW) management is critical for protecting public health and the environment. Improper handling increases the risk of infections, occupational hazards, and environmental contamination. Despite the Biomedical Waste Management Rules (2016), compliance in India remains suboptimal due to inadequate training and awareness. This study assessed BMW management practices among junior resident doctors and nursing officers in a tertiary care hospital in Haryana and evaluated the effectiveness of an educational intervention.

Materials and Methods: A hospital-based educational interventional study was conducted at Pt. B. D. Sharma PGIMS, Rohtak, among 123 participants (61 junior residents and 62 nursing officers) from high waste-generating departments selected by simple random sampling. Knowledge, attitude, and practices were assessed using a structured questionnaire and an observational checklist. A lecture-demonstration based educational intervention following national BMW guidelines was delivered. Post-intervention assessment was conducted, and data were analysed using SPSS version 19.

Results: Prior to the intervention, only 22% of participants had adequate knowledge, while 45.5% had moderately adequate and 32.5% had inadequate knowledge (mean score: 6.04 ± 1.67). Attitudes towards BMW management were largely positive (97.6%). Post-intervention, significant improvements were observed in waste segregation practices, with correct disposal increasing for red (19.5%), yellow (20.7%), and blue bins (16.3%). Safe practices improved, including increased syringe nozzle destruction (20.5%) and reduced needle recapping (31.7%). Overall practice scores improved significantly ($p < 0.05$).

Conclusion: Educational intervention significantly improved BMW management practices. Persistent knowledge gaps highlight the need for regular training, monitoring, and strict implementation of BMW guidelines.

Keywords: Biomedical waste management, Educational intervention, Healthcare workers, Infection control.

INTRODUCTION

Healthcare waste poses a significantly higher risk of infection and injury than other types of waste, making safe management essential. Poor handling of biomedical waste (BMW) can endanger public health and cause serious environmental harm. Tertiary hospitals in developing countries generate

approximately 1.3–1.5 kg of waste per patient per day, compared to approximately 4.5 kg in developed countries.[1]

In India, the Biomedical Waste Management and Handling (BMW M&H) rules were revised in 2016 to cover all waste-generating facilities. Under these rules, "biomedical waste" is defined as any waste generated during the diagnosis, treatment, or immunization of humans or animals, or during research and production/testing of biologicals.[2]

Globally, about 85% of healthcare waste is non-hazardous and similar to household waste, originating largely from administrative and maintenance activities. The remaining 15% are hazardous and carry substantial risk to healthcare workers and the wider community.[3]

Hazardous waste is capable of transmitting infections such as HIV, Hepatitis B and C, and Tetanus, as well as contributing to environmental contamination. In India, healthcare facilities produce an estimated 3 million tons of medical waste annually, with an expected annual growth rate of 8%.[3]

The healthcare sector employs approximately 136 million workers worldwide, nearly 70% of whom are women.[4] Ensuring safe working conditions—including protection from biological, chemical, physical, ergonomic, and psychosocial hazards—is essential for both worker and patient safety.

Segregation at the source is considered the most critical step in BMW management. It involves separating waste categories at the point of generation, which reduces the risks, costs, and environmental impacts of disposal.[5] Proper segregation, aided by clearly labelled containers and biohazard symbols, helps prevent contamination, illegal reuse of materials, and supports recycling efforts, given that around 80% of hospital waste is general waste if kept uncontaminated.

Biomedical waste is classified into yellow, red, white and blue categories, each with distinct handling protocols. Yellow bags hold anatomical waste, soiled waste, discarded medicines, chemicals, and lab waste, treated by incineration, plasma pyrolysis, deep burial, or pre-treatment for liquids. Red bags contain contaminated recyclable items like tubing, bottles, and gloves, which are sterilized (autoclaving/microwaving/hydroclaving) and sent for recycling. White puncture-proof containers store sharps, sterilized and shredded or encapsulated, while blue boxes hold glassware, disinfected or sterilized before recycling.[6]

Biomedical waste has significant environmental and health impacts, as its treatment and disposal can release pathogens, toxic pollutants, and hazardous emissions like dioxins, mercury, and heavy metals.[7] While alternatives such as autoclaving, microwaving, and proper segregation can reduce risks, challenges remain, including the debated classification of certain wastes like radioactive materials.[8] Despite established BMW management rules, poor compliance—driven by gaps in knowledge, skills and attitudes among healthcare workers—necessitates targeted interventions. Hence, the present study aimed to evaluate biomedical waste management practices among healthcare workers and to assess the effectiveness of an educational intervention in improving compliance with BMW guidelines.

MATERIALS AND METHODS

This hospital-based educational intervention was conducted over one year (2024-2025) at Pt. B.D. Sharma PGIMS, Rohtak, Haryana (2100 beds, 26 departments). Participants were 1st-year junior residents and nursing officers from nine high biomedical waste-generating departments, identified from hospital records.

A minimum of 60 doctors and 60 nursing officers were recruited, calculated using Karth R et al.,9 parameters (P_1 =47%, P_2 =72%, α=0.05, power=80%). Participants were selected using simple random sampling.

Departments were selected based on their biomedical waste generation, as reported by the hospital administration. Baseline assessment involved direct observation and verification of segregation, collection, storage and disposal practices using a checklist (19 items). The intervention consisted of an educational training program delivered through lecture-demonstration sessions with interactive components. Study materials included a 10-item close-ended knowledge questionnaire, 10 Likert-scale attitude statements and a practice assessment checklist; the questionnaire captured participants sociodemographic details, while the checklist assessed department-level biomedical waste management practices. Post-intervention assessment involved re-observation using the same checklist to evaluate the effectiveness of the training.

Data analysis: Data were compiled in MS Excel and analysed using SPSS version 19. The mean and percentage scores were calculated and appropriate statistical tests were applied to evaluate post-intervention changes.

RESULTS

A total of 123 healthcare workers participated, including 49.6% junior residents and 50.4% nursing officers. The mean age was 30.28 ± 4.09 years, with the majority (69.1%) between 26–32 years. Females constituted 58.5% of participants, and 82.1% resided in urban areas. Most respondents (71.5%) had less than 5 years of work experience and 63.4% had received prior training in biomedical waste management [Table 1].

[Table 2] summarizes participants knowledge of biomedical waste management. Awareness was highest for HCWs vaccination requirements 87.8% and biomedical waste logos 82.1%. Correct responses were moderate regarding disposal method of sharps 74%, blood bags 65% and expired drugs 62%. Around half the participants knew pharmaceutical

waste handling 52%, BMW storage rules 48%, hazardous waste proportion 50% and while fewer were aware of the autoclavable waste 28%.

Table 1: Socio-demographic characteristics of study participants (n = 123)

Variable	Categories	Frequency (n)	Percentage (%)
Age group (years)	25–30	54	43.9
	31–35	31	25.2
	36–40	24	19.5
	>40	14	11.4
Mean ± SD		30.28 ± 4.09	–
Gender	Male	51	41.5
	Female	72	58.5
Occupation	Junior residents	61	49.6
	Nursing officers	62	50.4
Place of Residence	Urban	101	82.1
	Rural	22	17.9
Work experience	< 5 years	88	71.5
	≥ 5 years	35	28.5
Prior training in BMWM	Yes	78	63.4
	No	45	36.6

Table 2: Knowledge of study participants regarding Biomedical waste management

Knowledge based questions		Correct responses n (%)
Q1	Knowledge regarding Biomedical Waste Storage rules?	59 (48)
Q2	Proportion of Hazardous Waste?	62 (50.4)
Q3	Disposal of Blood Bags in which color-coded container?	80 (65)
Q4	Pharmaceutical Waste Disposal?	64 (52)
Q5	Disposal of Sharps Waste?	91 (74)
Q6	Autoclaving or Disinfection of Biomedical Waste?	34 (27.6)
Q7	Awareness of Biomedical Logos?	101 (82.1)
Q8	Post-Surgery disposal of catheter of Hep-B positive patient?	68 (55.3)
Q9	Disposal of Cytotoxic and Expired Drugs?	76 (61.8)
Q10	Vaccination Requirement for Healthcare Worker?	108 (87.8)

Table 3: Knowledge category of study participants with mean ± SD

Domain	Indicator	Frequency (n)	Percentage (%)
Knowledge	Adequate knowledge	27	22
	Moderately adequate knowledge	56	45.5
	Inadequate knowledge	40	32.5
	Total	123	100
	Mean score (±SD)	6.04 ± 1.67	

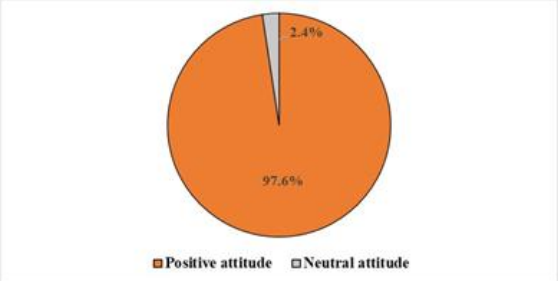

Figure 1: Attitude distribution among study participants

The mean knowledge score was 6.04 ± 1.67, with 67.5% of participants considered to have adequate knowledge [Table 3]. Regarding attitudes towards biomedical waste management, the majority of participants 97.6% demonstrated a positive attitude, 2.4% were neutral and none exhibited a negative attitude, indicating an overwhelmingly positive outlook towards BMW management [Figure 1]. Paired t-test [Table 4] analysis showed a mean difference of 9.95 [Figure 2], which was highly significant ($p < 0.001$), confirming the effectiveness of the intervention.

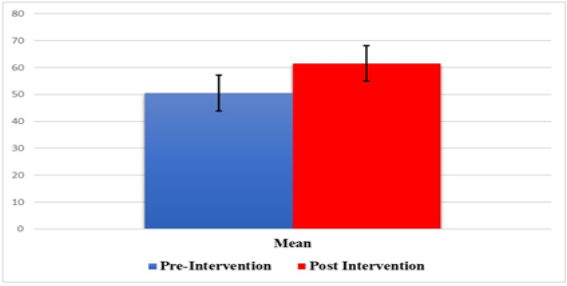

Figure 2: Pre- and post-intervention practice assessment scores (Mean and Std error mean).

Table 4: Pre/Post intervention practice assessment total score mean ± SD with SEM

Paired Samples analysis	Mean ± SD	Std. Error of Mean	p value
Pre-intervention total	50.50 ± 28.73	6.592	0.001

Post- intervention Total	61.54 ± 24.22	5.557	

Following the intervention [Table 5], availability of red, yellow and blue bins increased by 20.7%, 14.6% and 13.4%, respectively. Correct segregation of recyclable, infectious and glass waste improved by 19.5%, 20.7% and 16.3%, respectively. Safe sharp disposal and mutilation practices also showed marked gains, with avoidance of needle re-capping increasing by 31.7%. Paired t-tests confirmed these improvements to be statistically significant across segregation ($p = 0.03$), mutilation ($p = 0.02$) and overall practice scores ($p < 0.001$).

Table 5: Pre–Post Intervention Differences in Practice on Biomedical Waste Management

Condition of BMW containers	Pre-Intervention N (%)	Post-Intervention N (%)	Difference in practice N (%)	p value
Availability of poster guides near BMW disposal bins	54 (65.9)	58 (70.7)	↑ 4 (4.9)	0.01
Availability of Red color bin	64 (78.0)	67 (81.7)	↑ 3 (3.7)	
Availability of Yellow color bin	62 (75.6)	67 (81.7)	↑ 5 (6)	
Availability of Blue color bin	61 (74.4)	65 (79.3)	↑ 4 (4.9)	
Availability of White color bin	73 (89.0)	73 (89.0)	-	
Presence of red bags inside red bins	27 (32.9)	44 (53.7)	↑17 (20.7)	
Presence of yellow bags inside yellow bins	25 (30.5)	37 (45.1)	↑12 (14.6)	
Presence of blue bags inside blue bins	22 (26.8)	33 (40.2)	↑ 1 (1.2)	
Biohazard symbol printed over waste disposal bags	82 (100.0)	82 (100.0)	-	
Covering of waste disposal bins	38 (46.3)	39 (47.6)	↑ 1 (1.2)	
Foot-operated lids on covered bins	20 (24.4)	21 (25.6)	↑ 1 (1.2)	
Segregation of BMW				0.03
Only recyclable waste in red bins with red bags	15 (18.3)	31 (37.8)	↑ 16 (19.5)	
Only infectious waste in yellow bins with yellow bags	9 (11.0)	26 (31.7)	↑ 17 (20.7)	
Only glassware in blue bins with blue bags	6 (7.3)	19 (23.2)	↑ 13 (16.3)	
Only sharps materials in white puncture-proof containers	78 (95.1)	81 (98.8)	↑ 3 (3.7)	
Mutilation				0.02
Destruction of nozzle of used syringes	36 (43.9)	52 (64.4)	↑ 16 (20.5)	
Proper disposal of used hypodermic needles	31 (37.8)	40 (48.8)	↑ 9 (11)	
Non re-capping of hypodermic needles	36 (43.9)	62 (75.6)	↑ 26 (31.7)	
Non-reusage of used IV fluid plastic bottles	48 (58.5)	61 (74.4)	↑ 13 (15.9)	
N=82 (number of BMW disposal areas observed)				

DISCUSSION

Biomedical waste mismanagement poses serious risks to healthcare workers, the general public and the environment, as underscored by global agencies such as WHO and CDC.[10] Healthcare workers play a central role in ensuring safe disposal, yet multiple studies have highlighted persistent knowledge and practice gaps that compromise infection control and occupational safety.[11] Recognizing these challenges, the present study not only assessed baseline knowledge, attitudes, and practices of healthcare workers but also evaluated the effect of a structured training intervention. This dual focus allows assessment of both existing deficiencies and the potential of targeted educational strategies to strengthen biomedical waste management.

Knowledge: Knowledge serves as the foundation for effective biomedical waste (BMW) management. In this study, only 22% of participants demonstrated adequate knowledge, while 45.5% had moderately adequate knowledge and 32.5% were inadequate. Awareness varied across domains: 48% knew the permissible storage time, 50.4% identified the proportion of hazardous waste, 65–74% were aware of correct disposal for blood bags and sharps, and 87.8% recognized the Hepatitis B vaccination mandate. However, only 55.3% identified the correct disposal method for catheters from HBsAg-positive patients. Junior residents performed marginally better than nursing officers.

Comparable findings have been reported in the literature. Pravinraj et al,[12] found similar recognition of hazardous waste 50.3% but stronger knowledge of symbols 98.4%. In contrast, Shivashankarappa et al,[13] reported markedly lower awareness, with only 15.3% identifying infectious waste proportions. International studies also highlight variability like Hosny et al,[14] reported only 48.8% awareness of Hepatitis B vaccination mandates, while Letho et al,[15] found strong understanding of sharps but poor knowledge of cytotoxic waste.

These differences reflect variations in institutional training and emphasis on occupational safety. While sharp disposal and vaccination awareness were relatively better in this study, persistent gaps in pharmaceutical and cytotoxic waste management highlight the need for periodic refresher training and stricter dissemination of BMW guidelines.

Attitude

In the present study, 97.6% of participants expressed a positive attitude towards BMW management, with most emphasizing its importance for safe healthcare delivery, adherence to color-coded segregation, and the need for regular training. Pravinraj et al,[12] noted near-universal support for PPE use 97.7% and segregation at the point of generation 96.6%. Similarly, Deress et al,[16] observed strong agreement

on teamwork 84% and PPE use 89.9%, while Dalui et al,[17] reported comparatively lower support, with 69% favouring PPE use and 82.1% segregation.

The overwhelmingly positive attitude observed in the present study aligns with much of the existing literature, though regional differences highlight the influence of workload and infrastructure. This favourable outlook offers an opportunity to reinforce compliance further through structured training, continuous supervision, and institutional support.

Association of Knowledge and Attitude on Biomedical waste management with place of residence, years of experience and prior training received.

In the present study, no significant association was found between knowledge or attitude towards biomedical waste management and place of residence, years of work experience, or prior training received. Similar findings were reported by Singh et al,[18] that no association with selected sociodemographic characteristics. In contrast, Pravinraj et al,[12] and Rojas et al,[19] reported a positive association between prior training and improved BMW related knowledge and practices, while Thirunavukkarasu et al,[20] and Akkajit et al,[21] observed better practices among healthcare workers with longer work experience. Furthermore, Dev et al,[22] and Reddy et al,[23] emphasized the role of institutional support and reinforcement in shaping favourable attitudes towards BMW management.

The lack of association observed in the present study may indicate variability in the quality, frequency and effectiveness of training programs, emphasizing the need for regular, standardized and monitored educational interventions.

Post-Intervention Practices

i. Condition of Waste Containers

The present study demonstrated improvements in container conditions after the intervention. Poster guides increased by 4.9%, whereas red, yellow and blue bins improved by 3.7%, 6.0%, and 4.9%, respectively. Use of color-coded bags showed the most substantial increase, with red, yellow, and blue bags increasing by 20.7%, 14.6%, and 13.4%, respectively. These results align with those of Pravinraj et al,[12] and Basavaraj et al,[24] who reported high compliance with segregation. In contrast, Letho et al,[15] reported limited availability, with only 45.2% of bins present and 58.1% covered, underscoring contextual variability and the need for continuous reinforcement.

ii. Segregation Practices

Segregation practices also improved significantly. Correct segregation of recyclable waste in red bins increased by 19.5%, infectious waste in yellow bins by 20.7%, and glassware in blue bins by 16.3%. Sharp segregation in puncture-proof containers increased slightly 3.7%, maintaining a high compliance of 98.8%. Akkajit et al,[21] and Basavaraj et al,[24] reported similar high levels, while Hosny et al,[14] documented a sharp reduction in errors post-intervention. Pravinraj et al,[12] also reported 94.5% adherence to infectious and non-infectious waste segregation. Improvements in the present study likely stem from heightened awareness of infection risks and motivating better practices.

iii. Mutilation Practices

Mutilation practices have also improved substantially. Destruction of syringe nozzles rose by 20.5%, proper disposal of hypodermic needles by 11%, avoidance of needle recapping by 31.7%, and non-reuse of IV fluid bottles by 15.9%. These results are consistent with Basavaraj et al,[24] and Akkajit et al,[21] Deress et al,[16] observed higher adherence among nurses than among physicians, while Dalui et al,[17] reported moderate compliance, with only 54.4% avoiding recapping. The present improvements may be attributed to increased recognition of the risks of needlestick injuries, underscoring the importance of safe sharp handling.

Strengths and Limitations: This interventional study focused on two key healthcare worker groups—junior residents and nursing officers—allowing meaningful comparison of training outcomes across professional roles. The combined use of structured questionnaires and direct observation provided a balanced assessment of both knowledge and actual biomedical waste (BMW) management practices. Pre- and post-intervention evaluations demonstrated the measurable impact of structured training, while on-site observations enhanced the validity of findings. Targeting departments with high BMW generation improved the practical relevance of the study. However, as the study was conducted in a single tertiary care centre and limited to selected departments, generalizability is restricted. The absence of long-term follow-up limits assessment of sustainability, and data collection during busy clinical hours may have introduced minor reporting bias.

Recommendations: Effective BMW management should begin with strict segregation at the point of generation, supported by adequate colour-coded bins, bags, and visible instructional displays. Training programs must be continuous, role-specific, and include hands-on demonstrations for critical practices such as sharps disposal and personal protective equipment use. Regular audits, surprise inspections, and clear labelling systems are essential to strengthen compliance. Coordination with municipal authorities is necessary to ensure safe transport and final disposal of waste. Establishing dedicated BMW management committees within hospitals can improve accountability and monitoring. Investment in infrastructure, coupled with strict enforcement of guidelines and ongoing supervision, is crucial for sustaining improved practices.

CONCLUSION

This study highlights the effectiveness of structured educational interventions in improving biomedical waste management practices among junior residents and nursing officers. Significant post-intervention

improvements were observed in waste segregation, mutilation, and appropriate container use, underscoring the value of targeted, role-specific training. While baseline practices showed some influence of prior training, no significant association was found with work experience or place of residence, emphasizing the need for regular training across all staff categories.

The findings indicate that positive attitudes alone are insufficient to ensure safe practices without continuous sensitization, hands-on training, and supportive institutional systems. Sustained compliance with BMW guidelines requires periodic refresher training, routine monitoring, and strict enforcement. Although the study was limited to a single tertiary care centre and lacked long-term follow-up, it provides practical insights into strengthening biomedical waste management in high-burden healthcare settings.

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