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A Study to Assess the Effectiveness of Educational Intervention on Knowledge and Practice among Bio-Medical Waste Handlers Working in Selected Hospital at Udaipur District

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ABSTRACT

This study aimed to assess the effectiveness of an educational intervention in improving the knowledge and practice of BMWHs working at a selected hospital in Udaipur. A quantitative, quasi-experimental one-group pre-test and post-test design was used. The total sample included 187 BMWHs selected through total enumeration. Tools for data collection included a demographic data sheet, a 25-item structured knowledge questionnaire, and a 33-point observational checklist. Pre-intervention results showed that 58.8% of participants had poor knowledge and 83.9% demonstrated poor practices. Post-intervention, there was a marked improvement, with 79.1% achieving excellent knowledge scores and 97.8% demonstrating good to excellent practice. The educational intervention significantly improved mean knowledge and practice scores across all demographic groups ($p < 0.001$). Educational status and job designation were significantly associated with post-test improvements ($p < 0.05$). Key areas such as waste segregation, color coding, disinfection, transportation, and use of protective equipment showed substantial improvement. However, some areas like immunization awareness and linen disinfection showed minimal change, indicating the need for ongoing reinforcement. In conclusion, the educational programme was highly effective in enhancing BMW-related knowledge and practices among handlers. Regular training initiatives, especially for low-literate and high-risk staff, are essential to ensure compliance with BMW protocols, thereby promoting occupational safety and public health.

KEYWORDS Assess, Effectiveness, Educational Intervention, Knowledge, Practice, Bio-Medical Waste, Handlers, Hospital

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INTRODUCTION

The rise of large hospitals has led to increased biomedical waste (BMW), with Indian hospitals generating 1–5 kg/bed/day[1]. This waste, including sharps, tissues, plastics, and chemicals, poses high infection and environmental risks. Key healthcare workers like sweepers and attendants are most exposed, yet often lack proper knowledge of BMW management[2]. India's BMW Rules (2000) mandate segregation and safe disposal, but about 56% of BMW is still mixed with municipal waste[3]. Needle stick injuries affect 2–3 million healthcare workers globally each year, risking transmission of HIV (0.3%)[4], Hepatitis B (30%), and Hepatitis C (10%). Risks are higher with poor protective measures. The COVID-19 pandemic increased waste, especially from non-degradable masks and gloves, worsening plastic pollution and microplastic formation[5]. Incinerators, though effective, release toxic gases and hazardous ash. Improper disposal also threatens waste handlers and the public. India produces 0.33 million tons of BMW annually. Proper training, awareness, and strict implementation of safety protocols are essential to protect healthcare workers, reduce infection risk, and safeguard the environment[6].

NEED FOR STUDY

Biomedical waste includes potentially infectious materials, sharps (needles, scalpels), plastics, pharmaceuticals, and hazardous chemicals from laboratories. Improper handling poses serious health risks, particularly to healthcare workers[7]. Globally, around 2 million needle stick injuries occur annually, potentially transmitting HIV (0.3% risk), Hepatitis C (up to 10%), and Hepatitis B (up to 30%). These risks increase with pre-existing wounds and lack of protective gear[8]. Studies show that 56% of biomedical waste is incorrectly disposed of with municipal waste[9]. Many waste handlers lack knowledge about waste categories, color coding, segregation, and disposal procedures[10]. Therefore, educational interventions are essential to improve their knowledge and practices. A study was conducted at PIMS Hospital, Udaipur, to evaluate the effectiveness of such training in enhancing the efficiency and safety practices of biomedical waste handlers.

PROBLEM STATEMENT

"A Study to Assess the Effectiveness of Educational Intervention on Knowledge and Practice among Bio-Medical Waste Handlers Working in Selected Hospital at Udaipur District."

OBJECTIVES

- To assess the status of knowledge and practice among bio-medical waste handlers regarding disposal of biomedical waste in PIMS Hospital, Udaipur.
- To assess the status of knowledge and practice among bio-medical waste handlers regarding disposal of biomedical waste after the educational Intervention.
- To determine the association of knowledge and practice among bio-medical waste handlers with selected sociodemographic variables.

HYPOTHESIS

H_{01}: The mean post-test score of knowledge and practices respectively of biomedical waste handlers on the topic of biomedical waste handling and management would be significantly higher than their mean pre-test and observation scores at 0.05 level of significance.

H_{02}: There will be a significant increase between pre and post of knowledge and pre and post observation practice score among biomedical waste handlers with selected sociodemographic variables.

MATERIALS AND METHODS

Research Approach: A quantitative research approach was adopted to evaluate the effectiveness of an educational intervention.

Research Design: The study employed a quasi-experimental pre-test and post-test design with a single group of participants.

Sample & Sampling Technique: Out of 187 identified biomedical waste handlers, all were included in the study using a total enumeration sampling technique after obtaining informed consent.

Setting: The study was conducted at PIMS Hospital, Udaipur, Rajasthan, from December 2022 to June 2023.

Population: The target population included all biomedical waste handlers (permanent and daily wage workers) employed at PIMS Hospital during the study period.

Description of tool:

Part-I: Demographic Data Sheet – Collected background information such as age, sex, education, work experience, and designation to analyze their influence on knowledge and practice.

Part-II: Knowledge Questionnaire – Included 25 multiple-choice questions (1 mark each). Scores were categorized as Poor (0–10), Good (11–18), and Excellent (19–25) to assess participants' knowledge of biomedical waste management.

Part-III: Observational Checklist – Consisted of 33 standard practice items, observed during routine work. Each correct practice earned 1 mark. Scores were classified as Poor (0–11), Good (12–22), and Excellent (23–33).

Ethical consideration

- Ethical clearance was obtained from the Institutional Ethical Committee of Sai Tirupati University, Udaipur.
- Permission was secured from the Dean, PIMS Hospital.
- Informed consent was taken from each participant.
- Confidentiality and anonymity were maintained.

Plan for data analysis

The collected data were coded, tabulated, and analyzed using descriptive and inferential statistics:

- **Descriptive statistics** such as frequency, percentage, mean, and standard deviation were used to describe demographic characteristics, pre- and post-intervention knowledge and practice scores.
- **Inferential statistics** such as paired t-test and ANOVA were used to compare knowledge and practice scores before and after the educational intervention across various demographic variables (age, sex, education, designation, and experience).
- **Tukey's post-hoc test** was applied to determine pair wise differences between groups where ANOVA was significant.

RESULTS AND DISCUSSION

The data obtained are divided into sections for easy and accurate interpretation of data. The data finding has organized under the following section:

Section A: Demographic Characteristics of Biomedical Waste Handlers (BMWHs)

Section B: Knowledge Scores Before and After Educational Intervention

Section C: Practice Scores Before and After Educational Intervention

Section D: Question-Wise Knowledge Improvement

Section E: Practice Observation Before and After Training

Section F: Association and Group-Wise Analysis

Section A: Demographic Characteristics of Biomedical Waste Handlers (BMWHs):

This section presents the distribution of participants based on demographic variables. The demographic characteristics of the respondents are presented in the table, which includes variables such as age, sex, education level, years of work experience, and designation.

Table 1 Description of the demographic variables of samples **N = 187**

S. N.	Demographic Variables		Frequency (n)	Percentage (%)
1	Age (in years)	18–24	15	8.02
		25–34	32	17.11
		35–44	69	36.90
		> 45	71	37.97
2	Sex	Female	41	21.93
		Male	146	78.07
3	Educational Status	Illiterate	12	6.42
		1st to 7th Std	61	32.62
		8th to 10th Std	93	49.73
		11th to 12th Std	21	11.23
4	Experience (in years)	< 10	55	29.41
		11–20	80	42.78
		21–30	52	27.81
5	Designation	Attendant	24	12.83
		Sweeper	60	32.09
		Ward Ayas	25	13.37
		Ward Boy	78	41.71

1. Age (in years): The age distribution of the biomedical waste handlers indicates that the majority of participants were in the age group of more than 45 years, with 71 individuals (37.97%). This was closely followed by those in the 35–44 years age group, comprising 69 participants (36.90%). The 25–34 years group included 32 participants (17.11%), while the youngest group, aged 18–24 years, had the smallest representation with 15 participants (8.02%). This shows that a large proportion of the workforce comprises middle-aged and older adults.

2. Sex: In terms of gender distribution, the vast majority of the biomedical waste handlers were male, accounting for 146 individuals (78.07%), whereas female participants were comparatively fewer, numbering 41 (21.93%). This highlights a gender imbalance in the workforce, with male workers dominating the field of biomedical waste management.

3. Educational Status: The educational background of the participants showed that 93 BMWHs (49.73%) had completed education up to 8th to 10th standard, making it the most common education level. This was followed by 61 individuals (32.62%) who had completed education up to 1st to 7th standard. A smaller number of participants, 21 (11.23%), had completed education up to 11th to 12th standard, and 12 participants (6.42%) were illiterate. This indicates that while the

majority of BMWHs had some level of formal education, a substantial portion had only basic or no formal education.

4. Experience (in years): Regarding work experience, the largest group of BMWHs had 11–20 years of experience, comprising 80 individuals (42.78%). Those with less than 10 years of experience accounted for 55 participants (29.41%), while 52 individuals (27.81%) had been working in this field for 21–30 years. This suggests that a significant portion of the workforce has long-term experience in biomedical waste handling.

5. Designation: In terms of job designation, the highest number of participants were ward boys, comprising 78 individuals (41.71%). This was followed by 60 sweepers (32.09%), 25 ward ayas (13.37%), and 24 attendants (12.83%). This distribution shows that ward boys make up the largest share of biomedical waste handlers in the study setting, reflecting the operational roles involved in waste handling.

Section B: Knowledge Scores Before and After Educational Intervention:

This section presents the distribution of biomedical waste handlers (BMWHs) based on their knowledge levels before and after the structured educational intervention. The data highlights the effectiveness of the intervention in significantly enhancing knowledge regarding biomedical waste management among the participants.

Table 2 Distribution of samples according to knowledge scores before and after educational intervention N = 187

Knowledge Level	Pre-Test (f/%)	Post-Test (f/%)
Poor (0–10)	110 (58.8%)	0 (0%)
Good (11–18)	76 (40.6%)	39 (20.8%)
Excellent (19–25)	1 (0.5%)	148 (79.1%)
Total	**187 (100.0%)**	**187 (100.0%)**

Table 2 displays the before educational intervention, a large proportion of BMWHs—110 individuals (58.8%)—were found to have poor knowledge (scores between 0–10), indicating a significant gap in understanding of biomedical waste management. 76 participants (40.6%) demonstrated good knowledge (scores between 11–18), and only 1 participant (0.5%) achieved an excellent knowledge score (19–25), reflecting very limited high-level knowledge prior to the training. After the intervention, there was a remarkable improvement in the knowledge levels. The number of participants with excellent knowledge rose dramatically to 148 (79.1%), showcasing the success of the structured teaching. Additionally, 39 participants (20.8%) achieved a good knowledge score, while none remained in the poor knowledge category. This dramatic shift from poor to excellent knowledge levels clearly demonstrates the positive impact of the educational

programme on the awareness and understanding of biomedical waste management practices among BMWHs.

N = 187

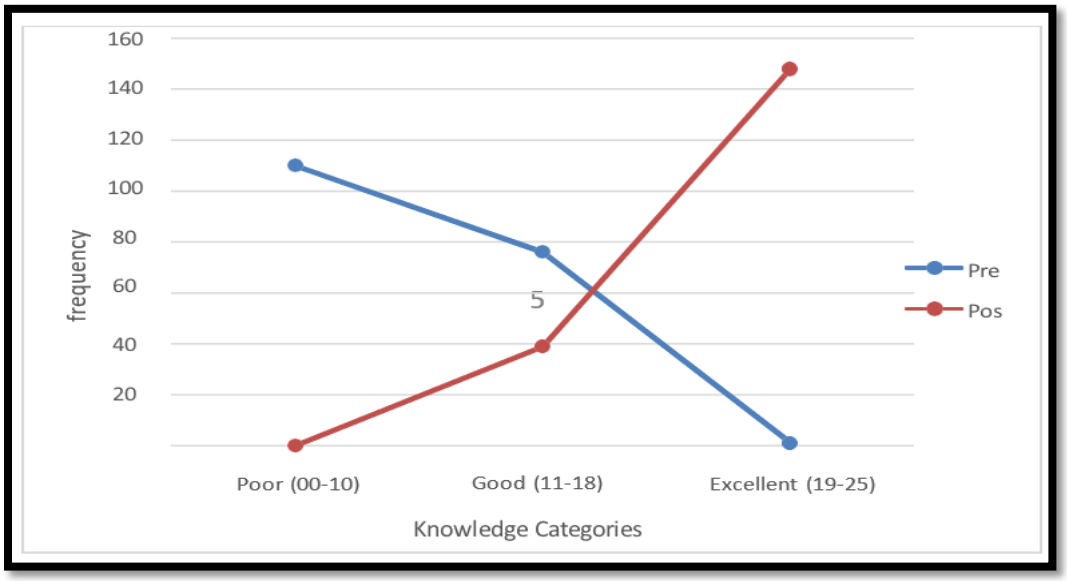

Figure 1 Frequency distribution of samples according to knowledge categories before and after educational intervention

Section C: Practice Scores Before and After Educational Intervention:

This section illustrates the changes in biomedical waste handlers' (BMWHs) practical performance regarding biomedical waste management before and after the structured educational intervention. The results reflect a substantial enhancement in real-world waste handling practices following the training programme.

Table 3 Distribution of samples according to knowledge scores before and after educational intervention N = 187

Practice Level	Pre-Test (f/%)	Post-Test (f/%)
Poor (0–11)	157 (83.9%)	4 (2.1%)
Good (12–22)	30 (16.0%)	100 (53.5%)
Excellent (23–33)	0 (0%)	83 (44.3%)
Total	**187 (100.0%)**	**187 (100.0%)**

Table 3 displays the prior to the educational intervention, the majority of BMWHs—157 individuals (83.9%)—demonstrated poor practice (scores between 0–11), indicating unsafe or incorrect waste handling behaviors. Only 30 participants (16.0%) fell under the good practice category (scores between 12–22), and none exhibited excellent practice (scores between 23–33). This suggests an urgent need for proper training to ensure safety and compliance with biomedical waste management guidelines. Following the intervention, the number of BMWHs demonstrating excellent practice increased significantly to 83 (44.3%), and 100 participants (53.5%) exhibited good practice levels. Importantly, only 4 individuals (2.1%) remained in the poor practice category.

These findings clearly indicate that the structured training and audiovisual education had a positive and transformative effect on the participants' ability to practice safe and effective biomedical waste management.

N = 187

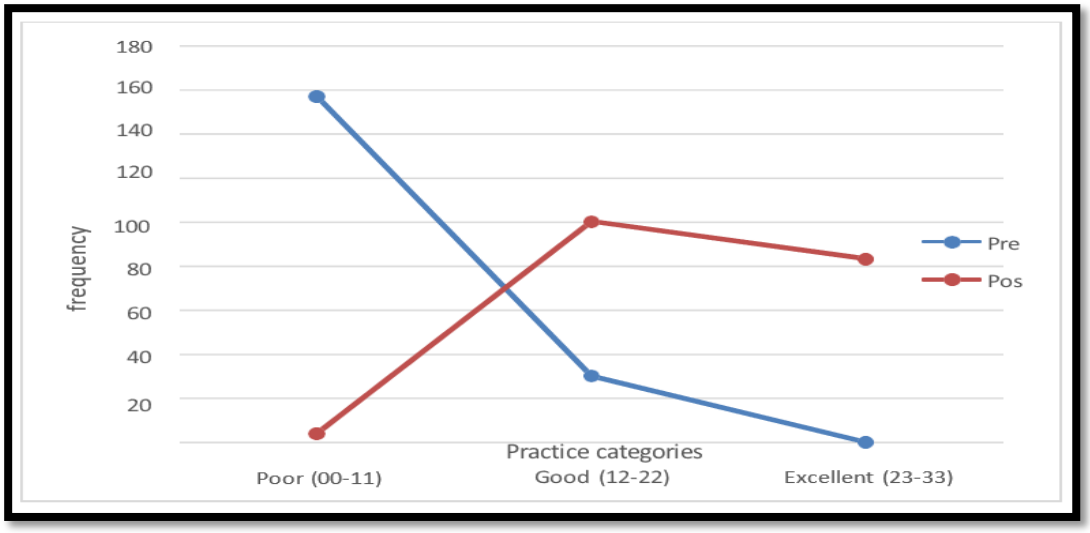

Figure 2 Frequency distribution of samples according to practice before and after educational intervention

Section D: Question-Wise Knowledge Improvement

This section presents a detailed breakdown of the knowledge improvement among Biomedical Waste Handlers (BMWHs) across 25 specific questions. The table reflects the number and percentage of correct responses before and after the educational intervention, along with the percentage difference, thus identifying strong and weak knowledge areas.

Table 4 Question wise frequencies of correctly answered questions showing the strong and weak areas in knowledge

N = 187

S. N.	Area Covered by the Questions	Before (f)	Before (%)	After (f)	After (%)	Difference (%)
1	"Bio Medical Waste" Means	71	37.9	170	90.9	53
2	Solid Biomedical Waste Include	25	13.3	170	90.9	77.6
3	The Highest Risk from Biomedical Waste Is	26	13.9	127	67.9	54
4	"Bio Medical Waste Treatment Facility" Means	105	56.1	173	92.5	36.4
5	4th Class Workers Must Know BMW Protocols Because	97	51.8	160	85.5	33.7
6	Biomedical Waste Management Process Includes	102	54.5	180	96.2	41.7
7	Waste from Laundry Is Considered As	28	14.9	169	90.3	75.4
8	Human Anatomical Waste Is Included in Which Category	42	22.4	54	28.8	6.4
9	Disinfection of Plastic Waste (Syringes, Catheters, etc.)	99	52.9	175	93.3	40.4
10	4th Class Workers Should Collect All Waste from Wards	127	67.9	174	93	25.1
11	Most Ideal Container for General Waste Collection	51	27.2	181	96.7	69.5
12	Specimens of AIDS/Hepatitis B Should Be	72	38.5	155	82.8	44.3
13	Ward Disinfection Methods	17	9	163	87.1	78.1
14	Action After Needle Stick Injury	49	26.2	61	33.1	6.9

15	Sodium Hypochlorite Solution Should Be Changed	101	54	145	77.5	23.5
16	Hand Washing Is Done	100	53.4	170	90.9	37.5
17	All 4th Class Workers Should Be Immunized Against	76	40.6	161	86	45.4
18	Color Coding & Container for Chemical Waste	64	34.2	154	82.3	48.1
19	Blue Plastic Bag / Puncture Proof Container Used For	65	34.7	156	83.4	48.7
20	General Non-Hazardous / Non-Infectious Waste Are	33	17.6	171	91.4	73.8
21	Handling Infectious Waste Without PPE May Cause	55	29.4	117	62.5	33.1
22	BMW Should Always Be Handled After	51	27.2	174	93	65.8
23	Yellow Color Plastic Bags Used for Disposing	49	26.2	166	88.7	62.5
24	Treatment & Disposal of Human/Animal Waste	90	48.1	141	75.4	27.3
25	Label of Biomedical Waste Is	39	20.8	174	93	72.2

Table 4 displays the pre- and post-test frequencies and percentages of correct responses to each knowledge item. A notable improvement was observed across most areas following the educational intervention. For instance, only 25 (13.3%) participants correctly identified solid biomedical waste before the training, which increased dramatically to 170 (90.9%) after the intervention—an improvement of 77.6%. Similarly, understanding of ward disinfection methods increased from 9.0% to 87.1%, marking a 78.1% rise, while knowledge about general non-hazardous waste improved by 73.8%. A significant rise in correct answers was also recorded for topics such as use of yellow plastic bags (62.5%), handling BMW after necessary precautions (65.8%), and the correct container for general waste (69.5%). However, some areas showed comparatively low improvement. For example, knowledge about human anatomical waste category increased by only 6.4%, and responses related to needle stick injury management improved by a modest 6.9%. These indicate areas needing further emphasis during future training. Overall, the table demonstrates that the educational intervention had a strong positive impact, significantly improving the participants' understanding of key biomedical waste management practices.

Section E: Practice Observation Before and After Training:

This section presents the observation of 33 key biomedical waste management practices among Biomedical Waste Handlers (BMWHs) before and after the educational intervention. The comparison highlights the degree of improvement in compliance with standard waste handling protocols.

Table 5 An observational check list wise correctly observed practices showing strong and weak areas in relation to practices N = 187

S. No.	Observation	Before (f)	Before (%)	After (f)	After (%)	Difference (%)
1.1	Segregates waste into infectious and non-infectious at source	132	70.5	183	97.8	27.3
1.2	Disposes sharps in puncture-proof container	128	64.4	182	97.3	32.9
1.3	Disposes infected plastic waste in red plastic bags	131	70	185	98.9	28.9

1.4	Disposes anatomical waste in yellow plastic bags	128	64.4	183	97.8	33.4
1.5	Disposes general waste in green/black bags	116	62	184	98.3	36.3
1.6	No mixing of infectious and non-infectious waste	119	63.5	179	95.7	32.2
2.1	Collects waste in covered bins	134	71.6	174	93.3	21.7
2.2	Fills only 3/4th of the bin	93	49.7	175	93.5	43.8
2.3	Cleans/disinfects bins regularly	83	44.3	104	55.6	11.3
2.4	Stores waste beyond 48 hours	17	9	29	15.5	6.5
3.1	Transports waste in secure containers	82	43.8	181	96.7	52.9
3.2	Uses dedicated trolleys for waste transport	64	34.2	180	96.2	62
3.3	Uses predefined route for waste transport	25	13.3	180	96.2	82.9
4.1	Ensures disinfection/mutilation before disposal	16	8.5	155	82.8	74.3
4.2	Incinerates/buries anatomical waste	22	11.7	181	96.7	85
4.3	Disinfects syringes at source before disposal	10	5.3	172	91.9	86.6
4.4	Disinfects/recycles plastic waste	12	6.4	171	91.4	85
4.5	Sends untreated general waste to municipal dump	16	8.5	174	93	84.5
5.1	Disposes broken glass in sharps pit	8	4.5	32	17.1	12.6
5.2	Disposes metal sharps in sharps pit	15	8	22	11.7	3.7
5.3	Disinfects sputum cups/slides before disposal	8	4.5	130	69.5	65
5.4	Disposes sputum cups in pit & drains liquids in sewage	8	4.2	132	70.5	66.3
5.5	Punctures blood bags before disinfection	9	4.8	99	52.9	48.1
5.6	Disinfects spills before cleaning	8	4.2	96	51.3	47.1
5.7	Destroys empty disinfectant containers	13	6.9	116	62	55.1
5.8	Disinfects instruments used to puncture blood bags	9	4.8	123	65.7	60.9
5.9	Dilutes disinfectants before disposal	15	8	129	68.9	60.9
5.1	Wears personal protective equipment	6	3.2	22	11.7	8.5
5.1	Washes hands before and after waste handling	2	1	156	83.4	82.4
5.1	Wears headgear, eye cover, mask, apron, gloves, boots	6	3.2	22	11.7	8.5
5.1	Takes Hepatitis B and Tetanus vaccination	11	5.8	11	5.8	0
5.1	Adds disinfectant to soiled linen	6	3.2	6	3.2	0
5.2	Uses hot water and soap for cleaning floors	9	4.8	11	5.8	1

Table 5 relieves that in the area of hospital waste segregation, notable improvements were observed. Before the intervention, only 132 (70.5%) participants consistently segregated infectious and non-infectious waste at the source, which increased to 183 (97.8%) after training. Proper disposal of sharps in puncture-proof containers rose from 128 (64.4%) to 182 (97.3%). Similarly, disposal of soiled plastic waste in red bags improved from 131 (70.0%) to 185 (98.9%), and anatomical waste disposal in yellow bags increased from 128 (64.4%) to 183 (97.8%). The practice of keeping general waste in green/black bags rose from 116 (62.0%) to 184 (98.3%), and ensuring no mixing of waste types improved from 119 (63.5%) to 179 (95.7%).

In the collection and storage category, 134 (71.6%) participants collected waste in covered bins before training, which increased to 174 (93.3%) post-training. Filling bins only up to three-fourths capacity saw a notable jump from 93 (49.7%) to 175 (93.5%), indicating a 43.8% improvement. Regular cleaning of bins showed a smaller improvement from 83 (44.3%) to 104 (55.6%). The number of handlers storing waste beyond 48 hours increased slightly from 17 (9.0%) to 29 (15.5%), which may suggest either a misunderstanding or logistical constraint needing future intervention.

Regarding transportation practices, secure transport in closed containers rose dramatically from 82 (43.8%) to 181 (96.7%). Use of dedicated trolleys increased from 64 (34.2%) to 180 (96.2%), and transporting waste through a predefined hospital route improved significantly from 25 (13.3%) to 180 (96.2%).

In the domain of treatment and disposal, several practices saw substantial improvement. Ensuring disinfection/mutilation before disposal rose from only 16 (8.5%) to 155 (82.8%). Incineration or burial of anatomical waste increased from 22 (11.7%) to 181 (96.7%). The practice of cutting and disinfecting syringes at the source improved from 10 (5.3%) to 172 (91.9%). Likewise, disinfecting and recycling plastic waste rose from 12 (6.4%) to 171 (91.4%). The disposal of untreated general waste into municipal dumps also increased appropriately from 16 (8.5%) to 174 (93.0%).

Under waste stream management, improvements were also encouraging. Disinfection and disposal of broken glass in sharps pits improved from 8 (4.5%) to 32 (17.1%), while the handling of metal sharps showed a minor increase from 15 (8.0%) to 22 (11.7%). Disinfection of sputum cups and slides before disposal rose sharply from 8 (4.5%) to 130 (69.5%), and proper disposal into burial pits improved from 8 (4.2%) to 132 (70.5%). Practices like puncturing blood bags before disinfection rose from 9 (4.8%) to 99 (52.9%), and spill disinfection improved from 8 (4.2%) to 96 (51.3%).

The destruction of empty disinfectant containers increased from 13 (6.9%) to 116 (62.0%), and disinfecting cutting instruments used for puncturing blood bags improved from 9 (4.8%) to 123 (65.7%). Similarly, diluting disinfectants before drainage rose from 15 (8.0%) to 129 (68.9%).

Personal hygiene and safety practices also saw improvement, though modest in some areas. The number of handlers using personal protective gear rose from 6 (3.2%) to 22 (11.7%). Handwashing before and after waste handling increased significantly from 2 (1.0%) to 156 (83.4%). Use of full protective attire (headgear, eye cover, mask, gloves, etc.) also improved from 6 (3.2%) to 22 (11.7%).

However, some practices remained unchanged. Immunization against Hepatitis B and Tetanus stayed stagnant at 11 (5.8%), and adding disinfectant to soiled linen before washing remained at 6 (3.2%). Routine cleaning of floors with hot water and soap showed only a minor rise from 9 (4.8%) to 11 (5.8%).

In summary, the observational findings reveal that the educational intervention effectively improved the majority of biomedical waste handling practices among BMWHs, particularly in

segregation, transport, treatment, and disposal. Nonetheless, certain areas like immunization and linen disinfection require further reinforcement and monitoring.

Section F: Association and Group-Wise Analysis:

This section presents a comparative analysis of pre- and post-intervention knowledge and practice scores in relation to demographic variables of biomedical waste handlers. Statistical tools such as t-tests and ANOVA were applied to assess the significance of improvements across different groups.

Table 6 Demographic group wise mean and std. deviation of knowledge and practice scores before and after educational intervention

Demographic Variable		Frequency (%)	Knowledge		t-value	p-value	Practice		t-value	p-value
			Before E.I. (Mean ± SD)	**After E.I. (Mean ± SD)**			**Before E.I. (Mean ± SD)**	**After E.I. (Mean ± SD)**		
Age (in years)					**F = 0.66**	**p = 0.58**			**F = 0.89**	**p = 0.45**
	18 – 24	15 (8.02%)	8.53 ± 3.18	19.2 ± 2.65	8.25	<0.001	7.8 ± 4.16	20.2 ± 3.88	10.02	<0.001
	25 – 34	32 (17.11%)	8.66 ± 3.60	20.3 ± 2.36	14.59	<0.001	8.72 ± 3.86	21.9 ± 4.19	20.03	<0.001
	35 – 44	69 (36.90%)	9.64 ± 3.98	20.0 ± 2.27	21.06	<0.001	7.9 ± 4.03	22.0 ± 4.38	19.67	<0.001
	> 45	71 (37.97%)	9.32 ± 3.99	20.0 ± 2.51	21.6	<0.001	7.41 ± 3.42	21.4 ± 2.87	29.92	<0.001
Sex					**F = 0.77**	**p = 0.51**			**F = 1.11**	**p = 0.35**
	Female	41 (21.93%)	9.69 ± 3.56	19.2 ± 2.65	30.62	<0.001	7.99 ± 3.77	21.67 ± 3.49	37.79	<0.001
	Male	146 (78.07%)	7.71 ± 4.46	19.76 ± 2.77	16.62	<0.001	7.34 ± 3.84	21.49 ± 4.79	14.66	<0.001
Educational Status					**F = 3.45**	**p = 0.02**			**F = 4.86**	**p = 0.003**
	Illiterate	12 (6.42%)	9.16 ± 3.84	20.22 ± 2.55	29.29	<0.001	6.45 ± 3.33	21.11 ± 3.58	36.78	<0.001
	1st – 7th	61 (32.62%)	7.33 ± 3.59	19.39 ± 1.75	12.2	<0.001	10.94 ± 2.46	21.11 ± 5.82	6.44	<0.001
	8th–10th	93 (49.73%)	10.21 ± 3.81	19.47 ± 2.12	13.63	<0.001	11.00 ± 2.88	23.74 ± 2.61	20.8	<0.001
	11th – 12	21 (11.23%)	12.40 ± 1.52	20.2 ± 2.17	9.75	<0.001	11.60 ± 2.19	22.8 ± 2.68	6.77	<0.001
Experience (in years)					**F = 1.77**	**p = 0.17**			**F = 0.55**	**p = 0.58**
	< 10	55 (29.41%)	8.64 ± 3.46	20.1 ± 2.43	19.08	<0.001	8.04 ± 4.04	21.33 ± 4.38	21.79	<0.001
	11 – 20	80 (42.78%)	9.85 ± 4.02	19.8 ± 3.00	22.48	<0.001	7.94 ± 3.72	21.55 ± 3.90	22.74	<0.001
	21–30	52 (27.81%)	9.01 ± 3.93	20.0 ± 2.34	18.37	<0.001	7.5 ± 3.65	22.08 ± 2.91	25.15	<0.001
De gi					**F = 2.82**	**p = 0.04**			**F = 11.02**	**p < 0.001**

Attendant	24 (12.83%)	10.71 ± 3.26	20.67 ± 1.66	12.31	<0.001	4.29 ± 2.39	21.4 ± 2.39	20.99	<0.001
Sweeper	60 (32.09%)	8.78 ± 3.63	19.98 ± 2.46	19.49	<0.001	8.23 ± 3.28	21.2 ± 4.44	23.05	<0.001
Ward Ayas	25 (13.37%)	7.88 ± 4.40	19.12 ± 2.82	13.83	<0.001	7.12 ± 4.38	21.4 ± 4.98	10.56	<0.001
Ward Boy	78 (41.71%)	9.63 ± 3.87	20.09 ± 2.38	21.57	<0.001	8.87 ± 3.41	22.0 ± 3.16	27.66	<0.001

1. Age (in years): Participants across all age groups showed significant improvement in both knowledge and practice scores after the educational intervention (E.I.), with the highest post-test practice mean (22.0 ± 4.38) observed in the 35–44 age group. Though the F-value for knowledge ($F = 0.66$, $p = 0.58$) and practice ($F = 0.89$, $p = 0.45$) were not statistically significant, within-group paired t-tests revealed highly significant improvements ($p < 0.001$) for all age groups.

2. Sex: Both male and female participants demonstrated a highly significant improvement ($p < 0.001$) in knowledge and practice after the intervention. Female participants had higher mean post-test scores in both knowledge (19.2 ± 2.65) and practice (21.67 ± 3.49) compared to males, indicating slightly better outcomes in females, although the between-group differences were not statistically significant ($F = 0.77$ for knowledge, $F = 1.11$ for practice).

3. Educational Status: Education had a statistically significant association with both knowledge ($F = 3.45$, $p = 0.02$) and practice ($F = 4.86$, $p = 0.003$). Participants with higher education levels (11th–12th Std) achieved the highest post-test mean scores in both knowledge (20.2 ± 2.17) and practice (22.8 ± 2.68), indicating a strong link between educational status and the ability to understand and implement biomedical waste management protocols effectively.

4. Experience (in years): Although the F-values for both knowledge ($F = 1.77$, $p = 0.17$) and practice ($F = 0.55$, $p = 0.58$) were not significant, the within-group improvements were highly significant ($p < 0.001$). The highest practice post-test mean (22.08 ± 2.91) was recorded in the 21–30 years experience group. This suggests that experience alone may not account for variance in knowledge/practice, but educational interventions were effective regardless of years of experience.

5. Designation: Designation was significantly associated with both knowledge ($F = 2.82$, $p = 0.04$) and practice ($F = 11.02$, $p < 0.001$). All designations showed marked improvement ($p < 0.001$), but attendants demonstrated the highest increase in practice (from 4.29 ± 2.39 to 21.4 ± 2.39), indicating that less trained personnel benefitted most from the training. Ward boys showed the highest post-intervention practice mean (22.0 ± 3.16).

The educational intervention had a significantly positive impact on knowledge and practice across all demographic groups. Although some variables such as education and designation showed stronger associations with outcomes, the overall effect of the intervention was universally significant and effective in enhancing biomedical waste management practices.

CONCLUSION

The study demonstrated a significant improvement in both knowledge and practice among biomedical waste handlers (BMWHs) following a structured educational intervention. Prior to training, a majority of participants exhibited poor knowledge and unsafe waste handling practices. Post-intervention data revealed a marked shift, with 79.1% achieving excellent knowledge and 97.9% demonstrating good to excellent practices. The intervention was especially impactful among less-educated and lower-designation staff like attendants and sweepers. Statistically significant improvements were observed across all demographic groups ($p < 0.001$). Educational status and designation showed strong associations with post-test performance. Key knowledge areas like color coding, segregation, and disinfection improved notably. Practice observations confirmed enhanced compliance with standard BMW protocols. Despite modest gains in immunization awareness, overall training effectiveness was high. The study confirms that targeted educational programs can significantly improve biomedical waste management in hospital settings, thereby promoting safety and environmental health.

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