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BEYOND THE BIN: EXPLORING KNOWLEDGE ON BIOMEDICAL WASTE MANAGEMENT AMONG NORTHERN INDIA'S HEALTHCARE WORKERS

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ABSTRACT: Background: Poor management of biomedical waste (BMW) poses severe health and environmental risks, especially during the COVID-19 pandemic that saw an excess of infectious waste. The Biomedical Waste Management Rules of 2016, subsequently amended in 2018, provide guidelines for safe disposal; however, there remain considerable gaps in knowledge among healthcare personnel. The present research assessed and improved their knowledge, attitude, and practice (KAP) about COVID-19-related BMW via a structured teaching program (STP) at a tertiary care hospital in Northern India. **Methodology:** The quasi-experimental one-group pre-test post-test design was utilized in 50 health workers. Pre- and post-intervention KAP scores were quantitatively measured, correlations between demographic parameters such as age, education, and clinical experience were compared. **Findings:** A majority of the participants were aged 25–34, 56% of them had a master's degree, and 14% had 6–10 years of experience. Pre-intervention scores were as follows: knowledge – 70.83%, attitude – 80.83%, practice – 67.08%. Post-intervention, the knowledge increased to 78.83%, the attitude improved to 84.16%, and practice decreased slightly to 65%. There was a significant correlation between knowledge gain and some demographic variables. **Conclusion:** The systematic education program effectively improved the knowledge and attitude of health-care workers towards COVID-19 BMW management. These improvements, however, should be sustained by regular hands-on training and continuous professional development to have optimum and safe waste management practice in the healthcare facility.

INTRODUCTION: COVID-19, caused by the SARS-CoV-2 virus, was first identified in December 2019 ¹, and soon enough, the World Health Organization officially announced it as a pandemic on 11 March 2020 ².

To combat the arising health issues, governments and health organizations, such as the Indian Council of Medical Research (ICMR) ³, quickly responded by implementing comprehensive infection control measures.

These involved using obligatory personal protective equipment (PPE), applying rigorous hand hygiene procedures, implementing quarantine measures, and meticulous environmental cleaning to reduce the potential for transmission. Safe and effective handling of biomedical waste (BMW) is more important than ever in difficult times.

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COVID-19-generated waste such as soiled PPE, swabs, and other potentially infectious materials can become a significant health and environmental hazard if not handled, processed, and disposed of according to tested and tried guidelines. The Biomedical Waste Management Rules, brought out for the first time in 2016 and revised in 2018, have comprehensive procedures for colour coded segregation of wastes, onsite disinfection, and ultimate disposal. Though rules are established, studies indicate that most healthcare providers still don't quite understand these procedures. That results in their not adhering to the correct method, potentially raising the risk of contaminating the surroundings or endangering themselves.

Understanding healthcare workers' knowledge, attitudes, and practices (KAP) regarding COVID-19 biomedical waste management is essential to designing effective and targeted training programs. Studies conducted in India and globally indicate that KAP levels are quite diverse across various settings and populations.

India and global research illustrate that KAP levels differ extensively. While some health workers comprehend colour coding systems, others struggle with proper waste segregation or have wavering attitudes toward continuous training. These differences tend to be connected to the level of institutional support, resource availability, and the caliber of education initiatives. This research aims to identify knowledge, attitude, and practice gaps among healthcare workers, focusing on how tailored training programs can result in substantial improvements. Its purpose is to inform the development of policy and practice that promotes safer healthcare environments, reduces the risk of infection, and averts environmental contamination in the COVID-19 pandemic and beyond.

Hypotheses: Null Hypothesis (H_0): There is no difference between pre-test and post-test knowledge scores. Alternative Hypothesis (H_1): There is difference between pre-test and post-test scores.

METHODOLOGY:

Approach: Pre-test/post-test without control group, measuring knowledge prior to and following the STP.

Design: A quasi-experimental design with a single group pretest posttest design.

Sampling: Purposive sampling technique to select participants who meet inclusion criteria.

Population: If we assume a 95% confidence level, maximum variability among the population ($p=0.5$), and a margin of error of $\pm 12.5\%$. Out of 250 healthcare workers, about 50 for results.

Data Collection: A structured questionnaire assessing demographics and COVID-19 perioperative knowledge, comprising 30 multiple-choice questions. The study received ethical clearance from the Institutional Ethics Committee, Northern Hospital Sector, under IEC No. OT/TRG/RESEARCH/06/2024, dated 05 June 2024.

Study Setting: Conducted in a tertiary care hospital located in Northern sector of India.

Inclusion Criteria:

1. Healthcare workers aged between 20 and 50 years.
2. Willing to participate in the study.
3. Available during data collection.

Exclusion Criteria:

1. Not present or on leave during the study period.
2. Unwilling to participate.
3. Assigned to essential duties that prevent participation.

Data Collection Tool & Techniques: A structured knowledge questionnaire to assess healthcare workers' understanding of biomedical waste management including COVID-19 patients at a selected tertiary hospital in Kolkata. This same instrument served as the basis for educational interventions.

RESULTS: Table 1 presents the socio-demographic profile of the study participants ($n = 50$). Fifty-six percent were females and 44% were males, and the 25–34 age group was the most prominent (46%). Educationally, most of them had

a bachelor's degree (56%), followed by diploma graduates (30%). Most had 1–5 years of experience (42%), and the nursing staff was the biggest departmental group (52%). Regarding marital status, 54% were married, and 40% were single. Remarkably, 66% had prior training on the subject matter of the study, showing a quite experienced and educated group.

TABLE 1: DISTRIBUTION OF SAMPLES BASED ON SOCIO-DEMOGRAPHIC VARIABLES

Variable	Category	Frequency (n)	Percentage (%)
Gender	Female	28	56%
	Male	22	44%
Age Group	<25	12	24%
	25–34	23	46%
	35–44	10	20%
	45+	5	10%
Education Level	Diploma	15	30%
	Bachelor's	28	56%
	Master's	7	14%
Years of Experience	<1 year	6	12%
	1–5 years	21	42%
	6–10 years	15	30%
Department	>10 years	8	16%
	Nursing	26	52%
	Pharmacy	9	18%
	Radiology	7	14%
Marital Status	Laboratory	8	16%
	Single	20	40%
	Married	27	54%
Training Received	Other	3	6%
	Yes	33	66%
	No	17	34%

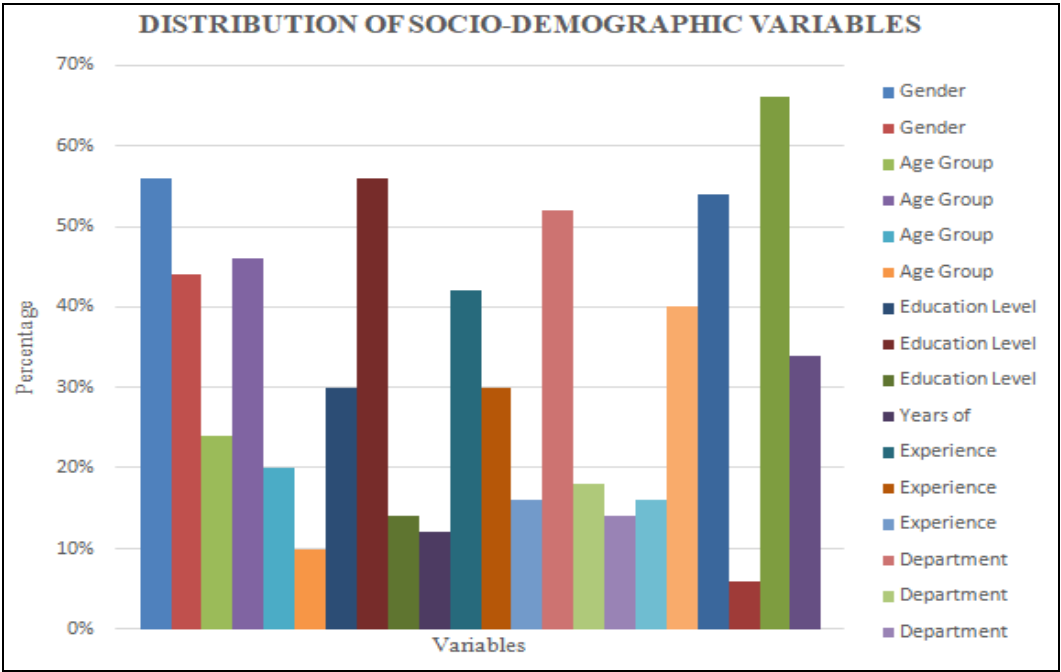


FIG. 1: SOCIODEMOGRAPHIC DISTRIBUTION

The bar chart illustrates the socio-demographic profile of healthcare professionals. Most were female, and the highest age group was 25–34 years. The majority possessed a bachelor's degree, followed by a diploma and master's degree holders. Experience-wise, the largest percentage had less than one year, followed by fewer with 6–10 years or more than 10 years' experience. Department-wise, the majority belonged to Pharmacy, followed by Nursing and Radiology.

TABLE 2: KNOWLEDGE SCORES PRE- AND POST-TEST

Variable	Mean	Standard Deviation	Percentage
Pre-Test Score	8.36	2.97	41.8%
Post-Test Score	15.34	3.74	76.7%

(n = 50)

Table 2 shows participants' mean scores and standard deviation of knowledge before and following the intervention. The mean pre-test was 8.36 (SD= 2.97), reflecting the baseline levels of knowledge. The post-test scores significantly improved to 15.34 (SD= 3.74), reflecting a vast improvement in knowledge ($p < 0.05$).

The pie chart shows the proportionate knowledge scores of healthcare workers pre- and post-a structured teaching program carried out. The pre-test score represented 41.8% of the total, while the post-test scores significantly improved to 76.7%. This great improvement reflects the efficacy of the

educational intervention on improving participants' knowledge in this targeted intervention.

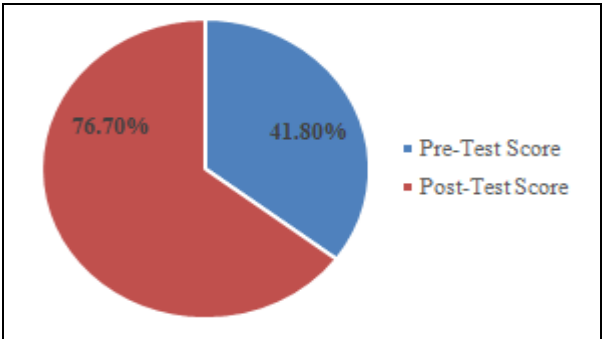


FIG. 2: KNOWLEDGE SCORES PRE-TEST AND POST TEST

TABLE 3: ATTITUDE SCORES PRE- AND POST-TEST

Variable	Mean	Standard Deviation	Percentage
Pre-Test Score	29.54	3.98	73.85
Post-Test Score	33.30	3.40	83.25

(n= 50)

Table 3 presents the pre-and post-intervention attitude scores. The pre-test mean score was 29.54 (SD = 3.98), which demonstrated baseline attitudes. Post-intervention, the post-test score rose to 33.30 (SD = 3.40), demonstrating a moderate yet statistically significant shift in attitude ($p < 0.05$).

The pie chart shows the attitude scores of the healthcare workers prior to and following the structured teaching program. The pre-test was 73.85%, whereas the post-test reached 83.25%. This increase demonstrates a positive change in participants' attitudes after the intervention, showing the effectiveness of the program in

promoting awareness and perception concerning the subject.

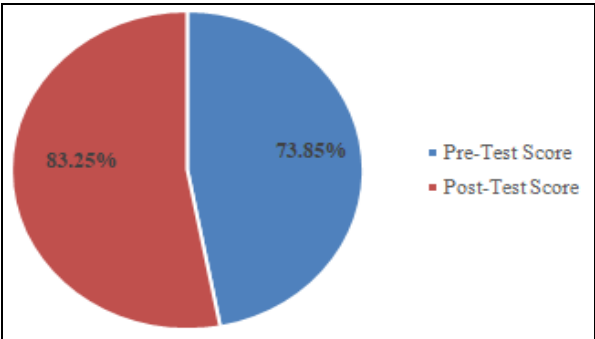


FIG. 3: ATTITUDE SCORES PRE-TEST AND POST-TEST

TABLE 4: PRACTICE SCORES PRE- AND POST-TEST

Variable	Mean	Standard Deviation	Percentage
Pre-Test Score	8.88	3.06	44.40%
Post-Test Score	14.40	4.01	72.0%

(n= 50)

Table 4 shows scores on practice before and after intervention. The mean score on the pre-test was 8.88 (SD = 3.06), which was used as the baseline practice. After intervention, the post-test mean score improved to 14.40 (SD = 4.01), a significant and statistically significant improvement in practice

($p < 0.05$). The pie chart shows the scores of practice among healthcare professionals prior to and after the structured teaching. The pre-test score was remarkably improved to 72.00% in the post-test.

The improvement of 27.6% reflects an increase in practical application after intervention, proving the statistical efficiency of training program in enhancing biomedical waste management practices.

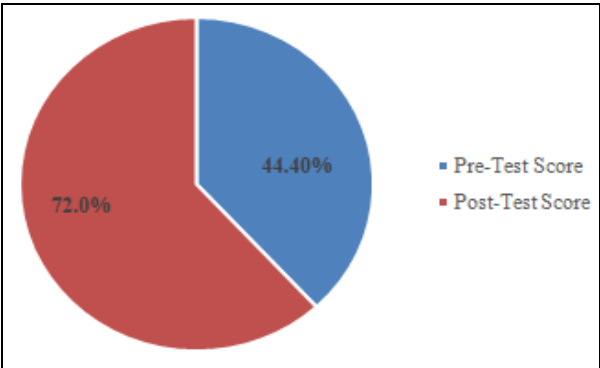


FIG. 4: PRACTICE SCORES PRE-TEST AND POST-TEST

TABLE 5: IMPROVEMENT OF KNOWLEDGE, ATTITUDE, AND PRACTICE SCORES PRE- AND POST-TEST							
Variable	Pre-Test Mean (SD)	Pre-Test %	Post-Test Mean (SD)	Post-Test %	Mean Difference	% Improvement	Statistical Significance (p-value)
Knowledge Score	8.36 (2.97)	41.8%	15.34 (3.74)	76.7%	6.98	83.5%	< 0.05
Attitude Score	29.54 (3.98)	73.9%	33.30 (3.40)	83.3%	3.76	12.7%	< 0.05
Practice Score	8.88 (3.06)	44.4%	14.40 (4.01)	72.0%	5.52	62.2%	< 0.05

(n = 50)

Table 5 presents a comparative analysis of pre- and post-test scores for knowledge, attitude, and practice among participants (N = 50). There was a statistically significant improvement in all three domains following the intervention. The score for knowledge increased significantly from a mean of 8.36 (SD = 2.97) to 15.34 (SD = 3.74), which represents an 83.5% improvement. Equally, the attitude score increased from 29.54 (SD = 3.98) to 33.30 (SD = 3.40), which represents a 12.7% improvement. The practice score also increased markedly from 8.88 (SD = 3.06) to 14.40 (SD = 4.01), an improvement of 62.2%. All the improvements were statistically significant with p-values < 0.05, indicating that the intervention successfully enhanced knowledge, attitudes, and practices of participants.

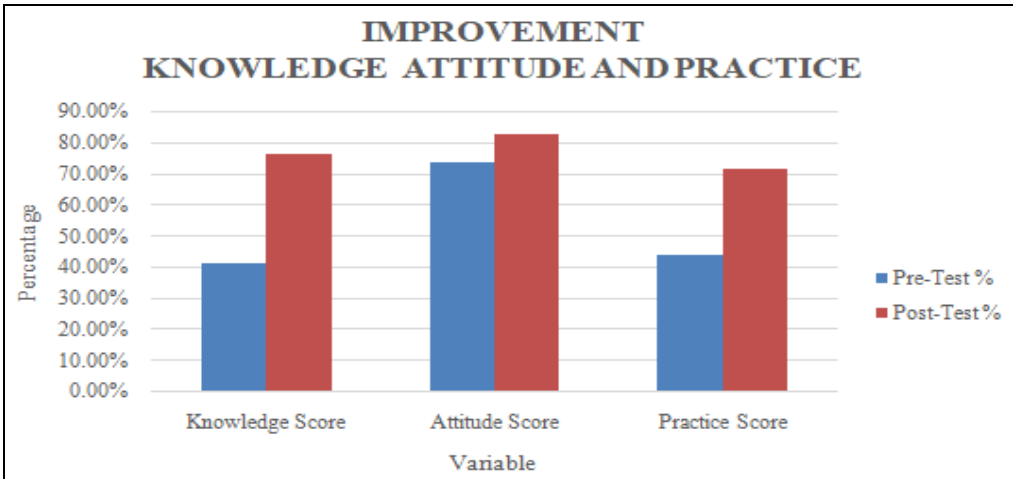


FIG. 5: IMPROVEMENT OF KNOWLEDGE, ATTITUDE, AND PRACTICE SCORES PRE- AND POST-TEST

The bar chart shows a comparison of pre-test and post-test percentages in knowledge, attitude, and practice (KAP) among health workers after a systematic teaching program. Knowledge scores had a significant rise from 41.80% to 76.70%, a rise of 34.9%. Attitude scores had a rise from

73.85% to 83.25%, an increase of 9.4%. Practice scores also had a significant rise from 44.40% to 72.00%, showing a gain of 27.6%. Statistically, these findings confirm the efficacy of the intervention in improving KAP concerning biomedical waste management.

DISCUSSION: In the present study, 50 healthcare workers including nurses, housekeeping staff, and laboratory personnel participated, with the majority being female (56%), aged 25–34 years (46%), and having 1–5 years of experience (42%). Nursing staff represented the largest professional group (52%). These demographic patterns mirror those reported by Mathur *et al.*⁴ in India and Magwe⁵ in Tanzania, where middle-aged nursing personnel with moderate experience predominated, as well as the findings of Basavaraj *et al.*⁶ in a COVID dedicated Indian hospital and Deress *et al.*⁷ in Ethiopia, and Manikandan *et al.*²⁶, who similarly noted a heavy reliance on frontline staff with limited formal training for waste handling.

Knowledge scores improved markedly from a pre-test mean of 8.36 ± 2.97 to 15.34 ± 3.74 post intervention ($p < .05$), with 68% of participants achieving “good” knowledge. This aligns with Olaifa *et al.*⁸ and Mundhe *et al.*²⁷ (81% awareness of colour coding) and Mitiku *et al.*⁹ (significant gains post training), though contrasts with (50% adequate knowledge in Bangladesh) and (27% correct responses), underscoring variability due to institutional training rigor. Gawande *et al.*²⁸ similarly found moderate knowledge levels in Western Maharashtra, underscoring the regional variability in awareness levels. Despite gains in theoretical knowledge, practical translation often lags, a point highlighted by Keerthika *et al.*⁶ and CDC guidelines³⁰.

Attitude also shifted positively, rising from 29.54 ± 3.98 to 33.30 ± 3.40 ($p < .05$), with 72% holding favourable views toward waste management findings consistent with Tiwari *et al.*¹¹ and Aravind *et al.*¹⁰. The strong correlation between knowledge and attitude echoes findings by Khashaba *et al.*¹⁴ in Egypt, reinforcing the notion that knowledge acquisition is a prerequisite for attitudinal change. Practice exhibited the largest gain (8.88 ± 3.06 to 14.40 ± 4.01 ; $p < .05$), yet only 60% of participants correctly applied segregation

protocols. This level of compliance is comparable to Rao *et al.*¹⁵ in Punjab (64.5%) but falls short of optimal standards, highlighting persistent gaps documented by Dey¹⁶ in India. Suboptimal hepatitis B vaccination rates (<55%) reflect concerns raised by Pandave *et al.*¹⁸, and the lingering stigma and resource constraints reported by Mitiku *et al.*⁹ during the COVID-19 era further emphasize the need for targeted interventions. Singh *et al.*²⁹ explored this further among students, finding that postgraduates demonstrated significantly better understanding than undergraduates, highlighting the role of advanced training in shaping responsible waste practices.

Taken together, and in line with global evidence from Mathur *et al.*⁴, Mitiku *et al.*⁹, and Mannocci *et al.*¹⁹, our findings underscore that while structured training significantly boosts KAP scores, sustained improvements in practice require reinforced institutional support, adequate infrastructure, and ongoing behavioural nudges. Future courses ought thus to incorporate periodic refresher modules, intensive supervision, and supply chain guarantees to confirm that improved knowledge and attitudes are conveyed into regular, safe waste management practice.

CONCLUSION: This study confirms that workers generally understand the importance of biomedical waste management, and most have the right attitude and practices in place. Even though there's been some progress, there's still a gap between what people know and what they do regularly. This means ongoing training, better supervision, and strong institutional support are still needed. To really get this right, a comprehensive approach is needed that involves the right infrastructure and strict enforcement to keep waste management safe and effective in healthcare settings.

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CONFLICT OF INTEREST: The authors declare that there is no conflict of interest.

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