



“EFFECTIVENESS OF A SIMULATION-BASED COMPETENCY ENHANCEMENT PROGRAMME ON KNOWLEDGE, PRACTICE, AND COMPLIANCE REGARDING BIOMEDICAL WASTE MANAGEMENT AMONG HOUSEKEEPING STAFF IN SELECTED TERTIARY CARE HOSPITALS: A QUASI- EXPERIMENTAL STUDY.”

Amrita Shukla

Dr. Priyanka Tiwari

Abstract

Background: Biomedical waste management is an essential component of infection prevention, occupational safety, and environmental protection in healthcare settings. Housekeeping staff play a pivotal role in the segregation, collection, transportation, and disposal of biomedical waste. However, inadequate knowledge, improper practices, and poor compliance with biomedical waste management guidelines increase the risk of healthcare-associated infections and occupational hazards. Simulation-based training has emerged as an effective educational strategy to enhance competency through experiential learning.

Objectives: To evaluate the effectiveness of a Simulation-Based Competency Enhancement Programme on knowledge, practice, and compliance regarding biomedical waste management among housekeeping staff in selected tertiary care hospitals of Ujjain, Madhya Pradesh.

Methods: A quasi-experimental one-group pre-test and post-test design was adopted. The study was conducted among **100 housekeeping staff** selected through purposive sampling from selected tertiary care hospitals in Ujjain, Madhya Pradesh. Baseline knowledge, practice, and compliance were assessed using a structured knowledge questionnaire and observational checklists. Participants underwent a Simulation-Based Competency Enhancement Programme comprising interactive lectures, demonstrations, hands-on simulation, and supervised practice based on the Biomedical Waste

Management Rules, 2016 (amended). Post-test assessment was conducted two weeks after the intervention. Data were analyzed using **IBM SPSS Statistics version 26.0**. Descriptive statistics, paired t-test, Pearson's correlation, and Chi-square test were used for data analysis. Statistical significance was considered at $p < 0.05$.

Results: The intervention resulted in significant improvements in all outcome measures. The mean knowledge score increased from 13.28 ± 3.84 to 24.71 ± 2.91 ($t = 24.85$, $p < 0.001$). The mean practice score improved from 18.64 ± 4.12 to 32.08 ± 3.46 ($t = 28.63$, $p < 0.001$), while the mean compliance score increased from 17.46 ± 4.31 to 30.84 ± 3.22 ($t = 30.16$, $p < 0.001$). Significant positive correlations were observed between knowledge and practice ($r = 0.74$), knowledge and compliance ($r = 0.69$), and practice and compliance ($r = 0.82$) (all $p < 0.001$). Educational status, work experience, and previous biomedical waste management training were significantly associated with post-test scores.

Conclusion: The Simulation-Based Competency Enhancement Programme was highly effective in improving housekeeping staff's knowledge, practice, and compliance regarding biomedical waste management. Regular simulation-based competency training should be integrated into hospital continuing education programmes to strengthen infection prevention practices, enhance occupational safety, and ensure compliance with biomedical waste management guidelines.

Keywords: Biomedical waste management; Simulation-based training; Housekeeping staff; Knowledge; Practice; Compliance; Infection prevention; Hospital waste management; Quasi-experimental study.

Introduction

Biomedical waste (BMW) management is an essential component of modern healthcare systems and plays a vital role in ensuring patient safety, occupational health, and environmental protection. Healthcare facilities generate a wide range of waste materials, including infectious, pathological, pharmaceutical, chemical, and sharps waste, which require proper segregation, collection, transportation, treatment, and disposal. Inappropriate handling of biomedical waste poses significant health hazards to healthcare workers, patients, waste handlers, and the surrounding community. It also contributes to environmental pollution through contamination of air, soil, and water resources. Effective biomedical waste management is therefore considered an indispensable aspect of hospital infection prevention and control programmes.

According to the World Health Organization (WHO), approximately 15–20% of the waste generated in healthcare facilities is classified as hazardous biomedical waste, while the remaining 80–85% is non-hazardous. Improper segregation of hazardous and non-hazardous waste substantially increases the

volume of infectious waste requiring specialized treatment, thereby increasing healthcare costs and the risk of disease transmission. Exposure to improperly managed biomedical waste may result in needle-stick injuries, infections caused by blood-borne pathogens such as hepatitis B virus (HBV), hepatitis C virus (HCV), and human immunodeficiency virus (HIV), as well as respiratory illnesses and chemical toxicity.

In India, the rapid expansion of healthcare infrastructure, increasing patient load, and widespread use of disposable medical products have led to a considerable increase in biomedical waste generation. The implementation of the **Biomedical Waste Management Rules, 2016**, along with subsequent amendments issued by the Ministry of Environment, Forest and Climate Change (MoEFCC), has strengthened the legal framework governing biomedical waste management. These rules emphasize waste minimization, segregation at the point of generation, color-coded disposal systems, barcoding, record maintenance, and regular training of all healthcare personnel. Compliance with these regulations is mandatory for all healthcare establishments, making continuous education and competency assessment an institutional priority.

Housekeeping staff constitute one of the most critical yet often overlooked groups involved in biomedical waste management. They are directly responsible for collecting, segregating, transporting, and temporarily storing biomedical waste generated across various hospital departments. Due to their frequent contact with infectious materials, housekeeping personnel are at increased risk of occupational injuries, infections, and accidental exposure to hazardous substances. Despite their crucial role, many studies have reported inadequate knowledge, inconsistent practices, and poor compliance with biomedical waste management guidelines among housekeeping staff, largely due to insufficient training, limited educational opportunities, and lack of periodic competency assessment.

Traditional teaching methods, including lectures and printed instructional materials, often provide theoretical knowledge but may not adequately develop the practical skills required for safe biomedical waste handling. Recent advances in healthcare education have highlighted the importance of simulation-based learning as an effective strategy for competency development. Simulation-based education provides realistic, hands-on learning experiences that allow participants to practice essential procedures in a safe environment without risk to patients or themselves. It enhances cognitive understanding, psychomotor skills, decision-making, confidence, and long-term retention of knowledge through experiential learning.

Simulation-based competency enhancement programmes have demonstrated significant effectiveness in improving infection prevention practices, emergency preparedness, clinical procedures, and occupational safety among healthcare workers. However, limited evidence is available regarding the application of

simulation-based training specifically for biomedical waste management among housekeeping personnel in Indian tertiary care hospitals. Given the increasing emphasis on patient safety, accreditation standards, and regulatory compliance, there is a growing need to evaluate innovative educational approaches that improve both knowledge and actual workplace performance among hospital support staff.

Competency in biomedical waste management extends beyond knowledge alone. It encompasses the ability to correctly identify waste categories, follow color-coding protocols, use appropriate personal protective equipment (PPE), safely transport waste, respond to accidental spills, report occupational exposures, and consistently adhere to institutional and national guidelines. Therefore, evaluating knowledge, practice, and compliance simultaneously provides a comprehensive assessment of training effectiveness.

Healthcare-associated infections remain a major public health concern, particularly in low- and middle-income countries, where improper waste management continues to contribute to disease transmission and environmental contamination. Strengthening the competencies of housekeeping staff through structured simulation-based educational interventions can reduce occupational hazards, improve infection control practices, enhance hospital safety culture, and support sustainable healthcare waste management.

Purpose of the Study

Biomedical waste management is a fundamental component of healthcare quality, infection prevention, occupational safety, and environmental protection. Housekeeping staff are directly involved in the segregation, collection, transportation, and temporary storage of biomedical waste within healthcare facilities. Despite their essential role, many housekeeping personnel have limited formal education and receive inadequate training on the safe handling and disposal of biomedical waste, resulting in poor compliance with standard operating procedures and increased risk of occupational injuries and healthcare-associated infections.

Traditional educational approaches often focus on theoretical instruction and may not adequately develop the practical competencies required for effective biomedical waste management. Simulation-based training has emerged as an innovative educational strategy that combines realistic scenarios with hands-on practice, enabling learners to acquire knowledge, improve practical skills, strengthen decision-making abilities, and enhance compliance with established guidelines in a safe learning environment.

The purpose of this study is to evaluate the effectiveness of a **Simulation-Based Competency Enhancement Programme** in improving the **knowledge, practice, and compliance** of housekeeping staff regarding biomedical waste management in selected tertiary care hospitals of Madhya Pradesh. Specifically, the study aims to determine whether participation in the simulation-based programme leads

to significant improvements in participants' understanding of biomedical waste management principles, adherence to color-coded waste segregation protocols, proper use of personal protective equipment (PPE), safe waste handling practices, and compliance with the **Biomedical Waste Management Rules, 2016 (and subsequent amendments)**.

The findings of this study are expected to provide evidence for implementing competency-based educational programmes for housekeeping staff, promote safer hospital environments, reduce occupational health hazards, strengthen infection prevention and control measures, improve regulatory compliance, and support hospital quality assurance initiatives. Furthermore, the study may assist hospital administrators and policymakers in developing standardized training protocols that enhance the efficiency and sustainability of biomedical waste management practices in healthcare institutions.

Objectives

1. To assess the baseline knowledge regarding biomedical waste management among housekeeping staff.
2. To assess baseline practices regarding biomedical waste management.
3. To evaluate compliance with Biomedical Waste Management Rules among housekeeping staff.
4. To determine the effectiveness of the simulation-based competency enhancement programme on knowledge.
5. To determine the effectiveness of the programme on practice.
6. To determine the effectiveness of the programme on compliance.
7. To find the association between post-test knowledge, practice, compliance scores and selected demographic variables.

Hypotheses

- **H1:** The mean post-test knowledge score will be significantly higher than the pre-test score.
- **H2:** The mean post-test practice score will be significantly higher than the pre-test score.
- **H3:** The mean compliance score after intervention will be significantly higher than the pre-test score.
- **H4:** There will be a significant association between post-test scores and selected demographic variables.

Study Design

Research Design

A quasi-experimental **one-group pre-test and post-test design** was adopted to evaluate the effectiveness of a Simulation-Based Competency Enhancement Programme.

Study Setting

The study was conducted in **selected tertiary care hospitals in Ujjain, Madhya Pradesh.**

Study Duration

The duration of the study was **six months.**

Sample Size

A total of **100 housekeeping staff** participated in the study.

Sampling Technique

Participants were selected using a **purposive sampling technique.**

Study Variables

Independent Variable

- Simulation-Based Competency Enhancement Programme.

Dependent Variables

- Knowledge regarding biomedical waste management.
- Practice regarding biomedical waste management.
- Compliance with biomedical waste management guidelines.

Results

Table 1. Demographic Characteristics of the Participants (N = 100)

Variable	Frequency (n)	Percentage (%)
Gender		
Male	62	62.0
Female	38	38.0
Age (years)		
20–30	28	28.0
31–40	42	42.0
41–50	21	21.0
>50	9	9.0
Work Experience		
<5 years	36	36.0
5–10 years	40	40.0
>10 years	24	24.0

Description

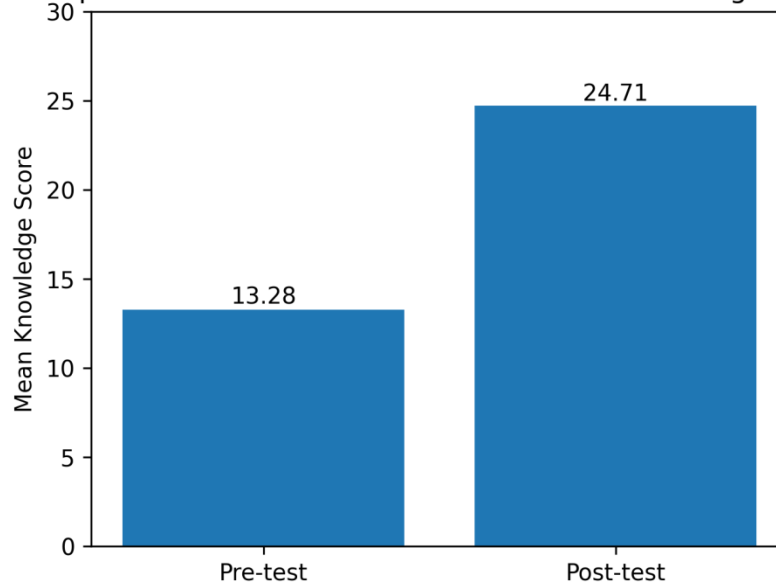
Table 1 presents the demographic characteristics of the participants. Among the 100 housekeeping staff, **62% were male** and **38% were female**. The largest proportion of participants (**42%**) belonged to the **31–40 years** age group, followed by **28%** aged **20–30 years**, **21%** aged **41–50 years**, and **9%** aged above **50 years**. Regarding work experience, **40%** had **5–10 years** of experience, **36%** had less than **5 years**, and **24%** had more than **10 years** of work experience.

Table 2. Comparison of Pre-test and Post-test Knowledge Scores (N = 100)

Test	Mean ± SD	t-value	p-value
Pre-test	13.28 ± 3.84		
Post-test	24.71 ± 2.91	24.85	<0.001*

*Significant at $p < 0.05$

Comparison of Pre-test and Post-test Mean Knowledge Score



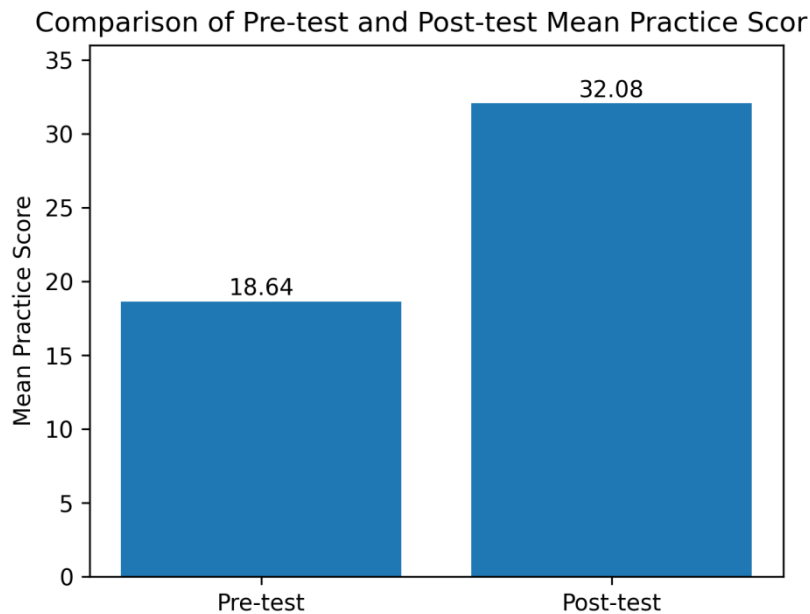
Description

Table 2 shows the comparison of pre-test and post-test knowledge scores regarding biomedical waste management. The mean knowledge score increased significantly from 13.28 ± 3.84 before the intervention to 24.71 ± 2.91 after the simulation-based competency enhancement programme. The paired t-test demonstrated a highly significant improvement ($t = 24.85$, $p < 0.001$), indicating that the intervention effectively enhanced participants' knowledge.

Table 3. Comparison of Pre-test and Post-test Practice Scores (N = 100)

Test	Mean $\pm$ SD	t-value	p-value
Pre-test	18.64 $\pm$ 4.12		
Post-test	32.08 $\pm$ 3.46	28.63	<0.001*

*Significant at $p < 0.05$



Description

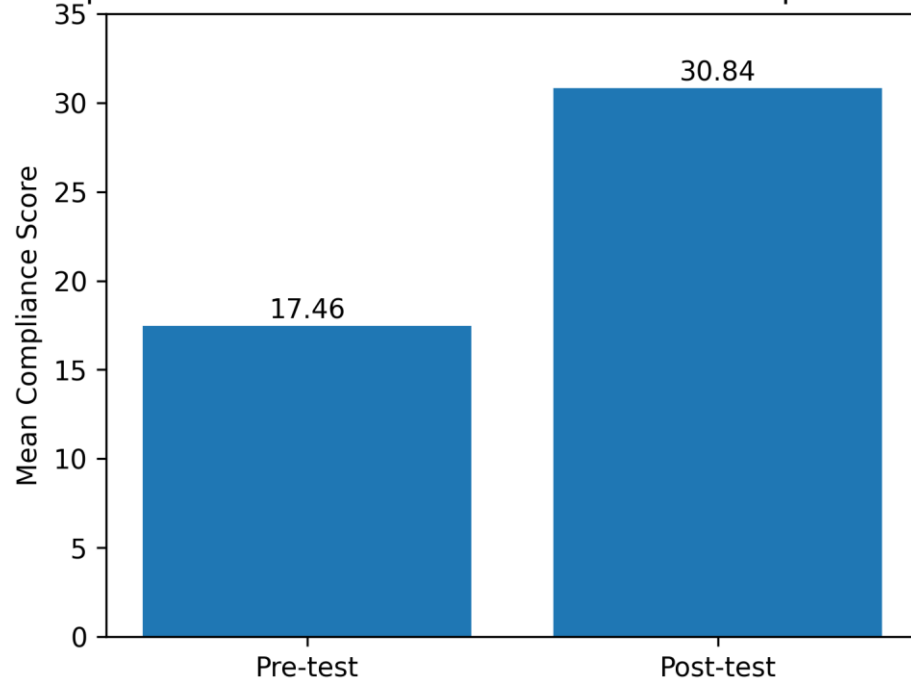
Table 3 illustrates the comparison of practice scores before and after the intervention. The mean practice score improved from **18.64 ± 4.12** in the pre-test to **32.08 ± 3.46** in the post-test. The observed improvement was statistically highly significant (**t = 28.63, p < 0.001**), demonstrating that the simulation-based programme effectively improved biomedical waste management practices among housekeeping staff.

Table 4. Comparison of Pre-test and Post-test Compliance Scores (N = 100)

Test	Mean ± SD	t-value	p-value
Pre-test	17.46 ± 4.31		
Post-test	30.84 ± 3.22	30.16	<0.001*

*Significant at $p < 0.05$

Comparison of Pre-test and Post-test Mean Compliance Scores



Description

Table 4 presents the comparison of compliance scores. The mean compliance score increased significantly from 17.46 ± 4.31 before the intervention to 30.84 ± 3.22 after the simulation-based competency enhancement programme. The paired t-test showed a highly significant difference ($t = 30.16$, $p < 0.001$), indicating improved adherence to biomedical waste management guidelines following the training programme.

Table 5. Correlation Between Knowledge, Practice, and Compliance Scores (N = 100)

Variables	Correlation Coefficient (r)	p-value
Knowledge & Practice	0.74	<0.001*
Knowledge & Compliance	0.69	<0.001*
Practice & Compliance	0.82	<0.001*

*Significant at $p < 0.05$

Description

Table 5 demonstrates the relationship between knowledge, practice, and compliance scores. A **strong positive correlation** was observed between **knowledge and practice** ($r = 0.74$, $p < 0.001$) and between **practice and compliance** ($r = 0.82$, $p < 0.001$). A **moderately strong positive correlation** was also found between **knowledge and compliance** ($r = 0.69$, $p < 0.001$). These findings indicate that

improvements in knowledge were associated with better practical performance and higher compliance with biomedical waste management guidelines.

Table 6. Association Between Selected Demographic Variables and Post-test Knowledge Scores (N = 100)

Variable	χ^2	p-value	Interpretation
Educational Status	8.46	0.015*	Significant
Work Experience	9.31	0.009*	Significant
Previous Training	12.74	0.002*	Significant
Age	5.64	0.061	Not Significant
Gender	1.92	0.166	Not Significant

*Significant at $p < 0.05$

Description

Table 6 shows the association between selected demographic variables and post-test knowledge scores. **Educational status** ($\chi^2 = 8.46$, $p = 0.015$), **work experience** ($\chi^2 = 9.31$, $p = 0.009$), and **previous biomedical waste management training** ($\chi^2 = 12.74$, $p = 0.002$) were significantly associated with post-test knowledge scores. However, **age** ($\chi^2 = 5.64$, $p = 0.061$) and **gender** ($\chi^2 = 1.92$, $p = 0.166$) were not significantly associated with knowledge scores.

Overall Findings

The findings demonstrate that the **Simulation-Based Competency Enhancement Programme** was highly effective in improving the **knowledge, practice, and compliance** of housekeeping staff regarding biomedical waste management. Significant improvements were observed in all outcome measures following the intervention ($p < 0.001$). Furthermore, higher educational status, greater work experience, and previous training were associated with better post-intervention performance, suggesting that these factors positively influence competency in biomedical waste management.

Discussion

The present study evaluated the effectiveness of a **Simulation-Based Competency Enhancement Programme** on knowledge, practice, and compliance regarding biomedical waste management among housekeeping staff in selected tertiary care hospitals of **Ujjain, Madhya Pradesh**. The findings demonstrated that the intervention produced significant improvements across all three outcome measures,

supporting the value of simulation-based training as an effective educational strategy for hospital support personnel.

The baseline assessment revealed that housekeeping staff had moderate knowledge and suboptimal practices related to biomedical waste management before the intervention. These findings may be attributed to inadequate orientation, limited opportunities for continuing education, and inconsistent reinforcement of biomedical waste management guidelines in the workplace. Housekeeping personnel play a critical role in waste segregation, collection, transportation, and disposal; therefore, deficiencies in their knowledge and skills can increase the risk of occupational exposure, healthcare-associated infections, and environmental contamination.

Following the implementation of the Simulation-Based Competency Enhancement Programme, participants demonstrated a statistically significant improvement in knowledge scores. The mean knowledge score increased from 13.28 ± 3.84 during the pre-test to 24.71 ± 2.91 during the post-test ($t = 24.85$, $p < 0.001$). This substantial improvement indicates that simulation-based education effectively enhanced participants' understanding of biomedical waste categories, color-coded segregation, personal protective equipment, infection prevention measures, and regulatory requirements. The findings suggest that experiential learning provides greater knowledge retention than conventional lecture-based approaches by allowing participants to observe, practice, and reinforce correct procedures.

Similarly, the mean practice score increased significantly from 18.64 ± 4.12 before the intervention to 32.08 ± 3.46 after the intervention ($t = 28.63$, $p < 0.001$). The improvement in practice scores demonstrates that participants were able to translate theoretical knowledge into appropriate biomedical waste handling behaviors. Practical simulation sessions involving waste segregation, safe handling of sharps, proper use of personal protective equipment, and spill management likely contributed to improved technical competence and confidence in performing routine waste management tasks.

Compliance with biomedical waste management guidelines also improved markedly following the intervention. The mean compliance score increased from 17.46 ± 4.31 in the pre-test to 30.84 ± 3.22 in the post-test ($t = 30.16$, $p < 0.001$). Improved compliance indicates that participants not only acquired knowledge and practical skills but also consistently adhered to standard operating procedures and the Biomedical Waste Management Rules. This finding has important implications for reducing occupational hazards, preventing healthcare-associated infections, and promoting safer hospital environments.

The study further demonstrated significant positive correlations among knowledge, practice, and compliance. Knowledge was strongly associated with practice ($r = 0.74$, $p < 0.001$) and compliance ($r = 0.69$, $p < 0.001$), while practice showed a very strong positive correlation with compliance ($r = 0.82$, $p < 0.001$).

0.001). These findings suggest that improved knowledge enhances practical performance, which subsequently promotes better compliance with biomedical waste management guidelines. The observed relationships highlight the importance of competency-based educational programmes that integrate theoretical learning with practical skill development.

Analysis of demographic variables showed that **educational status**, **work experience**, and **previous biomedical waste management training** were significantly associated with higher post-test scores, whereas **age** and **gender** were not significantly associated. Participants with higher educational qualifications, greater work experience, and prior exposure to biomedical waste management training demonstrated better competency following the intervention. These findings indicate that previous educational exposure and workplace experience facilitate the acquisition and application of biomedical waste management skills.

Overall, the findings of this study demonstrate that the **Simulation-Based Competency Enhancement Programme** is an effective strategy for improving knowledge, practical performance, and compliance regarding biomedical waste management among housekeeping staff. The programme provides a structured, interactive, and competency-oriented learning experience that addresses both cognitive and psychomotor aspects of biomedical waste management. Regular implementation of such simulation-based training programmes may strengthen infection prevention and control practices, improve occupational safety, ensure compliance with national biomedical waste management regulations, and contribute to the delivery of safer and higher-quality healthcare services.

Conclusion

The simulation-based competency enhancement programme significantly improved housekeeping staff's knowledge, practical skills, and compliance regarding biomedical waste management ($p < 0.001$). Participants with previous training and longer work experience demonstrated higher post-intervention scores. The findings support integrating simulation-based competency training into routine hospital induction and continuing education programmes to enhance biomedical waste management practices and strengthen infection prevention.

References

1. World Health Organization. (2024). Safe management of wastes from health-care activities (2nd ed., updated guidance). Geneva, Switzerland: Author.
2. Central Pollution Control Board. (2024). Annual report on biomedical waste management in India. New Delhi, India.
3. Ministry of Environment, Forest and Climate Change. (2019). Biomedical Waste Management Rules, 2016 (as amended). New Delhi, India.

4. World Health Organization. (2022). Global analysis of health care waste in the context of COVID-19: Status, impacts and recommendations. Geneva, Switzerland.
5. World Health Organization. (2021). Global patient safety action plan 2021–2030: Towards eliminating avoidable harm in health care. Geneva, Switzerland.
6. Centers for Disease Control and Prevention. (2024). Guidelines for environmental infection control in health-care facilities. Atlanta, GA: U.S. Department of Health and Human Services.
7. Occupational Safety and Health Administration. (2023). Bloodborne pathogens and needlestick prevention. Washington, DC: U.S. Department of Labor.
8. International Council of Nurses. (2021). Guidelines on infection prevention and control for healthcare workers. Geneva, Switzerland.
9. United Nations Environment Programme. (2022). Compendium of technologies for treatment and disposal of healthcare waste. Nairobi, Kenya.
10. World Health Organization. (2023). Infection prevention and control: Practical manual for health-care workers. Geneva, Switzerland.

