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EVALUATION OF HOSPITAL WASTE MANAGEMENT PRACTICES AND COMPLIANCE WITH BIOMEDICAL WASTE RULES – A CASE STUDY AT SELECTED RURAL TERTIARY TEACHING HOSPITAL

Mrs. Varsha Nilesh Lokhande
PGDHHM Student, School of Public Health and Social Medicine, Pravara Institute of Medical Sciences (Deemed to be University), Loni, Maharashtra, India
Under the Guidance of Dr. Yashwant M. Palghadmal, Assistant Professor, School of Public Health and Social Medicine, PIMS-DU, Loni;
Co-Guidance: Dr. Ojas Dagade, Assistant Professor, General Surgery, PIMS-DU, Loni

Abstract

Biomedical waste management (BMWM) is an essential component of hospital administration and public health practice. Improper segregation, handling, transportation, storage, treatment, and disposal of biomedical waste can increase the risk of infection transmission, occupational hazards, and environmental contamination. This study evaluated hospital waste management practices and compliance with the Biomedical Waste Management Rules (2016) in a selected rural tertiary teaching hospital. A descriptive cross-sectional quantitative study was conducted among healthcare workers and waste-generating departments. A total of 385 participants were included. Data were collected using a structured questionnaire and observation checklist assessing biomedical waste management practices, compliance indicators, and training requirements. Data were analyzed using Microsoft Excel and R software; descriptive statistics and inferential tests including ANOVA and Welch's t-test were applied. Among 385 participants, 53.0% were female and 47.0% were male. The mean age was reported as 29.9 ± 7.73 years and mean work experience was 3.93 years. Only 35.3% had attended biomedical waste management training. Department-wise compliance ranged from 63.9% to 93.6%, while the overall mean compliance score was 69.4%. A statistically significant difference in compliance was observed across departments ($F = 5.99$, $p = 0.014$). In addition, 94.8% of valid respondents reported the need for additional training, and training attendance was significantly associated with compliance ($t = 2.75$, $p = 0.006$). The study indicates moderate compliance with Biomedical Waste Management Rules in the selected hospital, with variation between departments. Regular training, monitoring, documentation, departmental supervision, and strengthened institutional support may improve biomedical waste management practices and safer hospital environments.

Index Terms—Biomedical Waste Management, Compliance, Biomedical Waste Rules 2016, Hospital Waste, Healthcare Workers, Training Needs, Rural Tertiary Care Hospital.

I. INTRODUCTION

Biomedical waste management (BMWM) has emerged as an important public health and environmental concern, particularly in developing countries where healthcare infrastructure is expanding. Biomedical waste is generated during diagnosis, treatment, immunization, and healthcare-related research. Hospitals, laboratories, blood banks, operation theatres, intensive care units, outpatient departments, and other healthcare facilities generate substantial quantities of biomedical waste. This waste includes infectious materials, sharps, pathological waste, pharmaceutical waste, chemical waste, and contaminated plastics. If not managed properly, it can contribute to infection transmission, occupational hazards, environmental pollution, and risks to patients, healthcare workers, waste handlers, and the community.

According to the study background, approximately 85% of hospital waste is non-hazardous and about 15% is hazardous, with the hazardous fraction potentially infectious, toxic, or radioactive. Needle-stick injuries and exposure to infectious materials are important occupational risks. In India, increasing healthcare utilization, population growth, expansion of healthcare institutions, and the COVID-19 pandemic have contributed to increased biomedical waste generation.

Biomedical waste management includes segregation, collection, transportation, storage, treatment, and final disposal. Segregation at the point of generation is a critical step because incorrect segregation can increase contamination and make safe disposal more difficult. The study describes colour-coded systems including yellow bags for anatomical and infectious waste, red bags for contaminated recyclable waste, white puncture-proof containers for sharps, and blue containers for glassware and metallic implants.

The Government of India introduced Biomedical Waste Management Rules in 1998 and subsequently revised the framework through the Biomedical Waste Management Rules, 2016, with later amendments. The rules emphasize source segregation, barcoding, pre-treatment of laboratory waste, personal protective equipment, staff training, immunization, record maintenance, and appropriate treatment and disposal. Despite the regulatory framework, gaps in segregation, colour coding, training, monitoring, documentation, PPE availability, and supervision have been reported in healthcare institutions.

Rural tertiary teaching hospitals may face additional operational challenges because of resource limitations, infrastructure constraints, shortages of trained personnel, and monitoring difficulties. Pravara Rural Hospital, PMT, Loni is a rural tertiary care teaching hospital serving rural and semi-urban populations and includes multiple waste-generating clinical and diagnostic units. Assessment of its biomedical waste management practices is therefore relevant for identifying operational gaps, strengthening compliance, and supporting safer healthcare delivery.

II. REVIEW OF LITERATURE

Previous research has identified biomedical waste management as an integral part of infection prevention, occupational safety, environmental protection, and healthcare quality. The literature reviewed in the thesis indicates that approximately 15% of healthcare waste is hazardous and that poor segregation and disposal may increase risks of injuries and infections among healthcare workers and waste handlers.

Studies in India have reported variable compliance with Biomedical Waste Management Rules. Research among doctors, nurses, laboratory technicians, and housekeeping personnel suggests that knowledge and awareness may be better among professional healthcare workers than among housekeeping and waste-handling staff, while actual implementation may remain inconsistent. Reported gaps include incorrect segregation, colour-coding errors, improper sharps management, inadequate documentation, insufficient PPE use, and deficiencies in transportation and storage.

Training and capacity building are repeatedly identified as important components of effective biomedical waste management. Regular training, practical demonstrations, visual reminders, periodic audits, and supportive supervision can reinforce correct practices. Infrastructure is also important; hospitals require appropriate colour-coded bins, puncture-proof containers, transport equipment, designated storage areas, and systems for treatment and disposal.

Occupational safety is another major theme in the reviewed literature. Waste handlers and other healthcare workers may experience needle-stick injuries, cuts, infectious exposures, and contact with hazardous substances. The literature therefore supports integration of biomedical waste management with infection prevention, occupational health, vaccination, PPE, and post-exposure management.

The review identified a research gap concerning rural tertiary care teaching hospitals, particularly studies that assess departmental practices, regulatory compliance, and staff training needs together. The present study was designed to address this gap in a rural tertiary teaching hospital setting.

III. RESEARCH METHODOLOGY

Study Area and Design

The study was conducted at Pravara Rural Hospital, PMT, Loni, located in Rahata Taluka of Ahmednagar (Ahilyanagar) district, Maharashtra. The hospital is attached to Pravara Institute of Medical Sciences (Deemed to be University) and provides preventive, promotive, curative, and rehabilitative services to rural and semi-urban populations. Waste-generating units included OPDs, inpatient wards, ICUs, operation theatres, laboratories, emergency services, CSSD, radiology, and other clinical and diagnostic areas.

A descriptive cross-sectional quantitative study design was adopted. This design enabled assessment of existing biomedical waste management practices, compliance levels, and training needs at a specific point in time. Data were collected through structured observation and an interviewer-administered questionnaire, supported by documentary review.

Population, Sampling and Sample Size

The study population included departments and wards generating biomedical waste and healthcare workers involved in waste generation, handling, and management. Staff categories included doctors, nurses, laboratory technicians, housekeeping/support staff, waste-handling/portering staff, and relevant OPD support personnel. Major waste-generating areas were observed through complete enumeration, while staff for the questionnaire component were selected using stratified sampling. Staff working in the hospital for at least six months and willing to participate were eligible. Departments not generating biomedical waste and staff meeting the stated exclusion criteria were excluded. The final study included 385 participants.

Data Collection Tools

A structured observation checklist assessed segregation, colour coding, bin availability, PPE, waste transport, storage, documentation, and treatment/disposal practices. A structured questionnaire assessed awareness, training, perceptions, and compliance-related practices. Documentary review covered waste-generation logs, transport/disposal records, annual reports, training logs, audit reports, and BMW authorisations. The observation checklist and questionnaire were developed from the literature and Biomedical Waste Management Rules, 2016, and were reviewed

by experts in Hospital Administration, Public Health, and Biomedical Waste Management. A pilot study was conducted among approximately 10% of the estimated sample to assess feasibility and clarity.

Ethical Considerations and Data Analysis

Institutional Review Committee approval was obtained (IRC letter No. PIMS/SPHSM/IRC/2026/449/22; dated 18/11/2025). Informed consent was obtained from participants, confidentiality was maintained through anonymous coding, and participants were informed of their right to withdraw. Data were entered into Microsoft Excel and analyzed using R statistical software. Frequencies, percentages, means, and standard deviations were used for descriptive analysis. ANOVA and Welch's two-sample t-test were used where applicable, with statistical significance considered at $p < 0.05$.

IV. RESULTS AND DISCUSSION

Participant Characteristics and Biomedical Waste Management Practices

A total of 385 healthcare workers participated. Females constituted 53.0% and males 47.0%. The mean work experience was 3.93 years, and 35.3% of participants reported previous biomedical waste management training. The participants represented doctors, nurses, laboratory technicians, and housekeeping staff from different hospital service areas.

Table 1. Distribution of participants by designation

Designation	Frequency (n)	Approx. %
Doctor	48	12.5
Nurse	211	54.8
Lab Technician	59	15.3
Housekeeping	67	17.4
Total	385	100.0

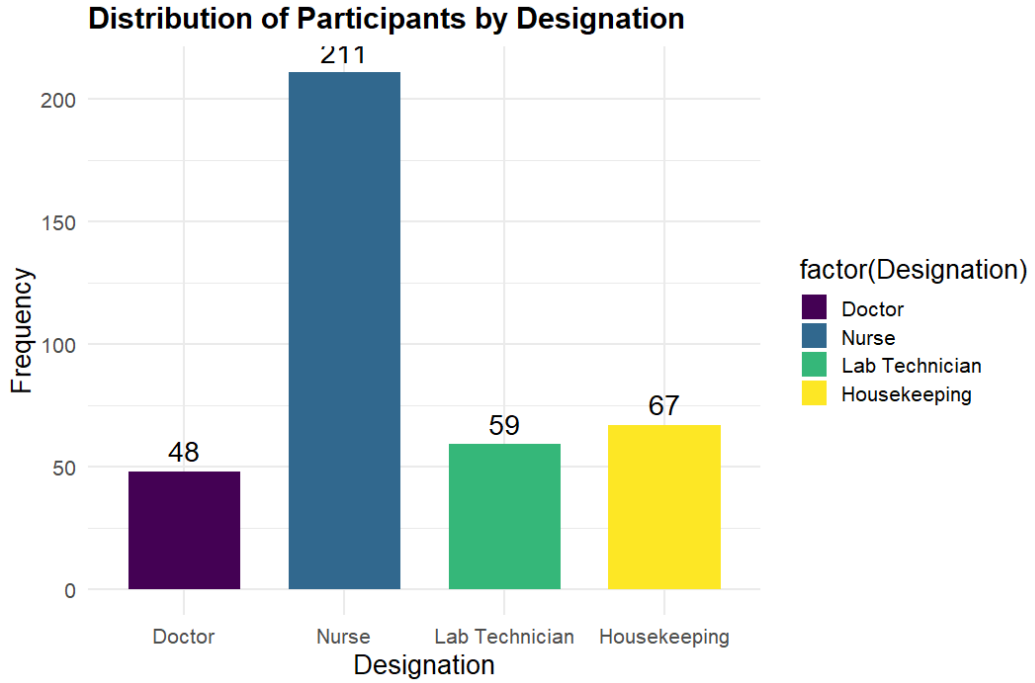

Figure 1. Distribution of participants by designation

Department-wise biomedical waste management practice scores were based on indicators such as segregation, colour coding, bin availability, PPE use, safe transport, sharps disposal, storage, and documentation. The available departmental results showed variation in compliance, with reported mean scores of 63.9%, 76.1%, 67.6%, and 93.6% for Departments 1, 2, 3, and 7 respectively.

Table 2. Department-wise biomedical waste management practice score

Department	Mean Compliance (%)	SD
1	63.9	36.8
2	76.1	39.6
3	67.6	37.2
7	93.6	9.98

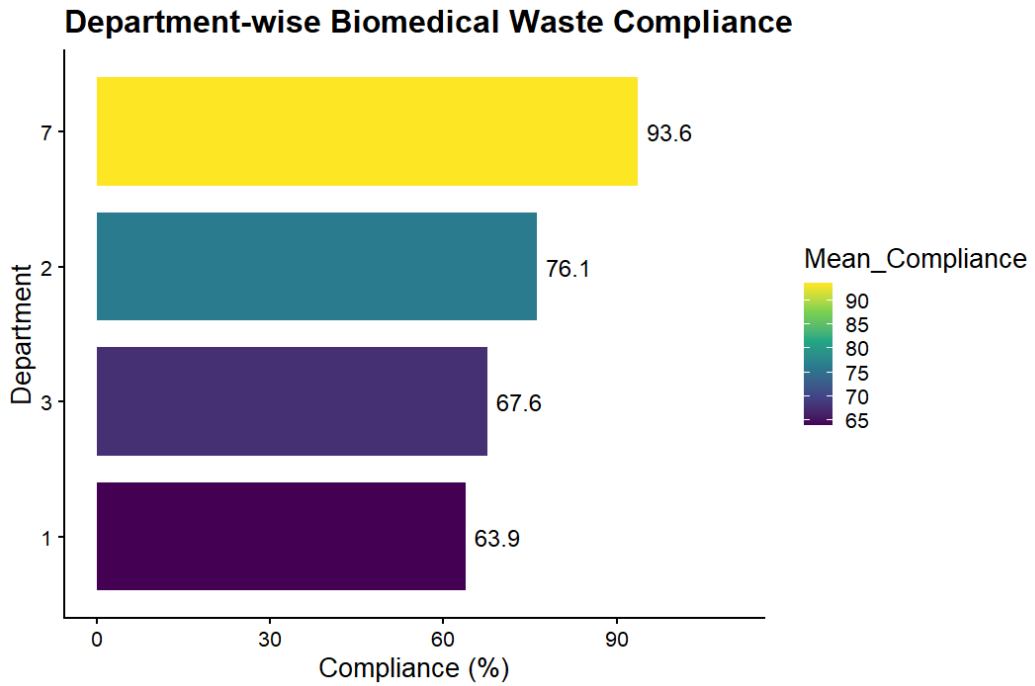

Figure 2. Department-wise biomedical waste compliance

Department 7 showed the highest reported compliance score (93.6%), while Department 1 showed the lowest among the departments presented (63.9%). The variation indicates that biomedical waste management implementation was not uniform across departments and may require department-specific monitoring, supervision, and reinforcement of standard procedures.

Overall Compliance with Biomedical Waste Management Rules (2016)

Table 3. Overall compliance with Biomedical Waste Management Rules (N = 385)

Compliance Indicator	Score (%)
Minimum compliance	0.0
Mean compliance	69.4
Maximum compliance	100.0

The overall mean compliance score was 69.4%, indicating a moderate level of adherence to the Biomedical Waste Management Rules (2016) in the study setting. The minimum observed score was 0% and the maximum was 100%, showing wide variation among observed responses or areas.

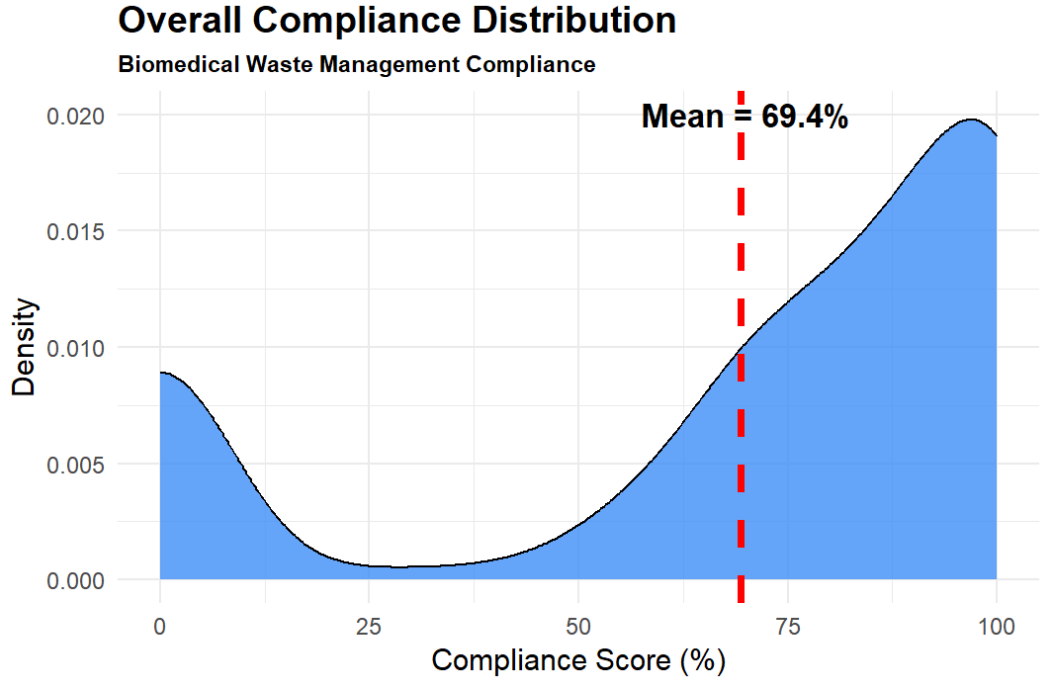

Figure 3. Overall biomedical waste management compliance distribution

Inferential Analysis

Table 4. Inferential analysis of compliance and training

Test	Value
ANOVA F value	5.99
p value	0.014
Welch's t value	2.75
p value	0.006

ANOVA demonstrated a statistically significant difference in compliance scores across departments ($F = 5.99$, $p = 0.014$). The study therefore reported rejection of the null hypothesis for the departmental comparison. A Welch's two-sample t-test examining training attendance and compliance produced $t = 2.75$ with $p = 0.006$, indicating a statistically significant association between training attendance and compliance scores.

Training Needs

Table 5. Need for additional biomedical waste management training

Response	Frequency (n)	Percentage (%)
No	16	5.2
Yes	290	94.8
Total valid responses	306	100.0
Missing responses	79	—

Among the 306 valid responses, 94.8% of participants reported a need for additional biomedical waste management training, while 5.2% reported that additional training was not required. The large proportion requesting further training indicates an institutional need for refresher education and capacity building.

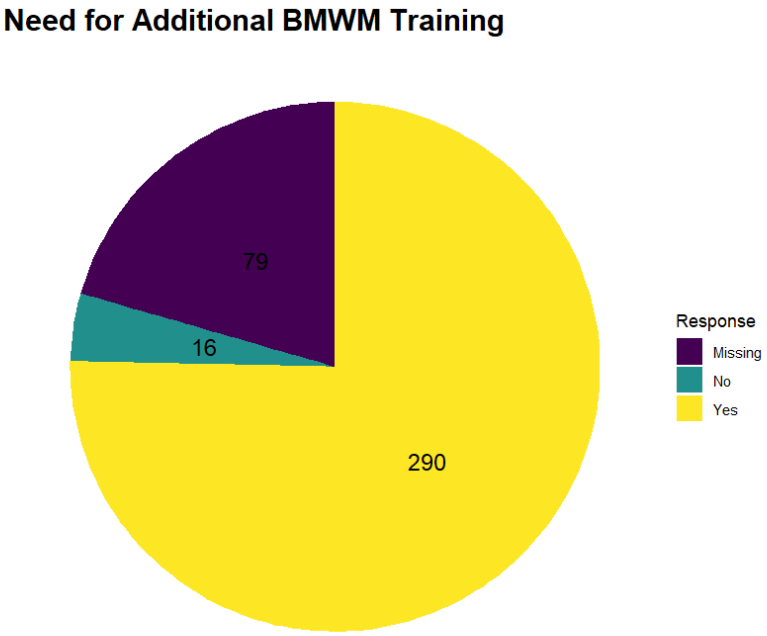

Figure 4. Need for additional biomedical waste management training

Discussion

The present study demonstrates that biomedical waste management is functioning within the selected rural tertiary teaching hospital, but implementation varies between departments. The overall mean compliance of 69.4% indicates that important elements of the BMW management system are being implemented, while the range of departmental scores shows that standardisation is not uniform.

Only 35.3% of participants reported having attended biomedical waste management training, whereas 94.8% of valid respondents expressed the need for additional training. The significant association between training attendance and compliance ($p = 0.006$) supports the importance of continuing education, refresher training, and practical reinforcement for healthcare workers.

The findings are consistent with the literature reviewed in the thesis. Shrestha et al. reported gaps in segregation, colour coding, and monitoring; Gawande et al. highlighted the need for regular reinforcement through training; Bhaskar et al. emphasized institutional monitoring and periodic assessment; and Mehta et al. reported the influence of knowledge and training on biomedical waste management practices. The present study similarly indicates the relevance of departmental audits, training, supervision, and infrastructure.

From the Donabedian framework described in the thesis, structure includes infrastructure, PPE, storage and transport resources; process includes segregation, collection, transportation, storage, documentation, treatment and disposal; and outcome includes compliance, occupational safety, environmental protection, and identification of training needs. The findings indicate that strengthening structure and process components may support improved outcomes.

The study has limitations. It was conducted in a single rural tertiary care teaching hospital, limiting generalizability. Some data were self-reported and may be subject to response bias. The cross-sectional design did not permit assessment of long-term changes, and repeated observations were limited by time and resources.

V. CONCLUSION

The study concluded that biomedical waste management practices in the selected rural tertiary care teaching hospital demonstrated a moderate level of compliance with Biomedical Waste Management Rules (2016). Departmental compliance varied, with reported scores ranging from 63.9% to 93.6% among the departments presented. Training was an important factor associated with compliance, and most valid respondents expressed a need for additional training.

Recommendations

- Conduct regular biomedical waste management training and refresher programmes.
- Strengthen departmental monitoring and compliance audits.
- Ensure availability and maintenance of colour-coded bins and appropriate waste-management resources.
- Develop and reinforce standard operating procedures for waste handling.
- Improve record keeping and documentation systems.
- Introduce periodic feedback mechanisms for staff and departments.
- Promote continuous supervision through infection control and hospital quality mechanisms.

Future Research

- Conduct multicentre studies across rural and urban hospitals.
- Assess the long-term effectiveness of biomedical waste management training interventions.
- Explore barriers to compliance using mixed-method approaches.
- Compare compliance across different types of healthcare institutions.
- Evaluate digital monitoring and waste-tracking systems for biomedical waste management.

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