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Assessment of Compliance and Occupational Risk Perception among Biomedical Waste Handlers at A Common Biomedical Waste Treatment Facility in Punjab: A Mixed-Methods Study

Seep Sonali[1], Sumreen Bhatia[2], Navjot Singh[3]

[1]Department of Sports Sciences and Medicine, Amritsar, Punjab, India

[2]University Centre of Excellence & Research, Baba Farid University of Health Sciences, Faridkot, Punjab, India

[3]Department of Community Medicine, Guru Gobind Singh Medical College & Hospital, Faridkot, Punjab, India

ABSTRACT

Background: Biomedical waste handlers are at increased risk of occupational exposure due to inadequate compliance with safety practices. This study assessed compliance with biomedical waste management practices and explored perceived risks among waste handlers.

Methods: A cross-sectional observational study with a mixed-methods approach was conducted at a Common Biomedical Waste Treatment Facility in Punjab. Fifteen biomedical waste handlers were included. Data were collected using an observational checklist based on CPCB and WHO guidelines and structured interviews. Descriptive statistics and thematic analysis were performed.

Results: Overall compliance with biomedical waste management practices was 32%. Compliance was satisfactory for waste segregation, labeling, and use of color-coded containers. However, major gaps were observed in PPE usage, hand hygiene, sharps handling, and spill management. Poor environmental conditions, including inadequate ventilation and lighting, were also noted. Qualitative findings highlighted lack of protective clothing, insufficient vaccination, improper container closure, and inadequate equipment maintenance as key concerns.

Conclusion: Significant deficiencies exist in biomedical waste management practices, increasing occupational risks among handlers. Strengthening PPE availability, improving workplace conditions, and ensuring regular training and vaccination are essential to enhance safety and compliance.

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CORRESPONDING AUTHOR:
Seep Sonali
(seep.myas@gmail.com)

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INTRODUCTION

Biomedical waste (BMW) management is a critical component of healthcare systems, ensuring the safe handling, treatment, and disposal of waste generated during medical activities. Improper management of biomedical waste poses significant risks to healthcare workers, waste handlers, patients, and the community, as well as to the environment, due to its potential to transmit infections and cause injury.[1] Effective BMW management practices are therefore essential to minimize occupational hazards and environmental contamination.

In India, the management of biomedical waste is governed by the Biomedical Waste Management Rules, 2016, which provide detailed guidelines on segregation, collection, transportation, treatment, and disposal of healthcare waste.[2] Despite the existence of these regulations, compliance with recommended practices remains inconsistent across

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healthcare facilities, particularly in resource-constrained settings. Studies have highlighted gaps in adherence to safety protocols, especially regarding the use of personal protective equipment (PPE), safe handling of sharps, and proper waste segregation.[3]

Biomedical waste handlers constitute a particularly vulnerable group due to their direct and continuous exposure to hazardous materials. Inadequate use of PPE, poor training, and lack of awareness further increase their susceptibility to injuries, infections, and long-term health consequences.[4] Additionally, unsafe working conditions, including poor ventilation, inadequate lighting, and insufficient availability of safety equipment, further exacerbate occupational risks.[5]

While several studies have assessed knowledge, attitudes, and practices related to biomedical waste management among healthcare workers, limited research has focused specifically on compliance and risk perception among biomedical waste handlers working in Common Biomedical Waste Treatment Facilities (CBWTFs). Understanding both observed compliance and perceived risks is essential for identifying gaps and designing targeted interventions.

Therefore, the present study was conducted to assess compliance with biomedical waste management practices and explore perceptions of occupational risk among biomedical waste handlers at a Common Biomedical Waste Treatment Facility in Punjab.

MATERIALS AND METHODS

Study Design: Cross-sectional observational study with a mixed-methods approach.

Study Setting: The study was conducted at a Common Biomedical Waste Treatment Facility (CBWTF), M/s Enviro Care System (P) Ltd., located in Amritsar, Punjab.

Study Population: Biomedical waste handlers directly involved in the collection, segregation, transportation, and processing of biomedical waste at the facility.

Sample Size and Sampling Technique: A total of 15 biomedical waste handlers were included in the study. Since the workforce at the facility was limited, complete enumeration of all eligible workers was done.

Data Collection Tools and Technique: Quantitative data were collected using a pre-designed observational checklist based on Central Pollution Control Board (CPCB) and World Health Organization (WHO) guidelines for healthcare waste management. Structured interviews were conducted with participants to explore qualitative insights.

Data Analysis: Quantitative data were entered and analyzed in Microsoft Excel. Descriptive statistics were used to summarize compliance percentages in each category. Qualitative Analysis was done through obtaining interview responses and thematically analyzed to identify common barriers to compliance and areas for potential improvement.

RESULTS

Compliance with PPE usage was generally poor. While the use of protective footwear was satisfactory, other essential components such as gloves, face masks, protective eyewear, and protective clothing were largely inadequate or absent. Compliance was relatively better in waste handling practices. Proper waste segregation, use of color-coded containers,

Section A: Personal Protective Equipment (PPE)	*Section B:* Waste Handling Procedures	*Section C:* Safety Practices	*Section D:* Work Environment	*Section E:* Equipment and Supplies
Gloves	Proper Waste Segregation	Hand Hygiene	Adequate Ventilation in Work Area	PPE Availability
Face Mask	Color-coded Container Usage	Sharps Handling	Proper Lighting in Work Area	Waste Cart Maintenance
Protective Eyewear	Container Filling and Labeling Practices	Use of Mechanical Aids	Walkway Clearance	Spill Kit Availability
Footwear	Proper Closure of Containers	Spill Management	Safety Signage	Cleaning Supplies Storage
Clothing	Correct Labeling of Waste Containers	PPE Removal and Disposal	Handwashing Facilities	Safety Equipment Functionality

Compliant Non-Compliant

Figure 1: Assessment of safety and domain-wise compliance in Biomedical Waste Management practices



Figure 2: Section-wise compliance rate of Biomedical Waste Management practices.

and labeling practices were generally followed. However, improper closure of waste containers was frequently observed, posing a risk of spillage and environmental contamination. Critical safety practices showed poor compliance. Hand hygiene, safe sharps handling, spill management, and appropriate PPE removal techniques were inadequately practiced. The working environment was suboptimal. Inadequate ventilation and poor lighting were commonly observed. While walkway clearance was generally maintained, deficiencies were noted in safety signage and availability of handwashing facilities. Although spill kits were available, maintenance and proper storage of essential equipment such as PPE, waste carts, and cleaning supplies were inadequate.

The overall compliance with biomedical waste management practices was found to be 32%, indicating substantial gaps in adherence to recommended safety protocols.

Thematic analysis of interview responses identified several key concerns. Participants reported prolonged exposure to biomedical waste without adequate protective clothing, increasing vulnerability to infections and injuries. Despite adherence to segregation practices, improper closure of containers was identified as a major safety concern, increasing the risk of spillage and exposure. Workers perceived themselves to be at high risk due to continuous exposure to hazardous materials, compounded by inadequate vaccination coverage. Inadequate ventilation and lighting were frequently reported, contributing to discomfort, reduced efficiency, and potential long-term health effects. Irregular maintenance and improper storage of equipment were identified as barriers to safe and efficient biomedical waste handling.

DISCUSSION

The present study revealed substantial gaps in biomedical waste management practices, particularly in areas of personal protective measures, waste handling procedures, vaccination coverage, environmental safety, and equipment maintenance. These findings are consistent with several studies conducted in both national and international settings, indicating that despite the existence of guidelines, effective implementation remains inadequate.

A study conducted in South India reported relatively better compliance with biomedical waste management practices, with higher proportions of healthcare workers adhering to appropriate waste segregation and personal protective equipment usage; however, inconsistencies in risk perception and adherence to protocols were still evident.[6] In contrast, the present study demonstrated poorer compliance, particularly in protective clothing usage and vaccination status, suggesting variability in implementation across healthcare settings. Similarly, a study conducted in a tertiary care hospital in Chhattisgarh found that although healthcare workers possessed adequate knowledge and a positive attitude toward biomedical waste management, actual practices were suboptimal.[7] This supports the findings of the present study, where procedural lapses were noted despite awareness, highlighting a persistent knowledge–practice gap**.**

The importance of training in improving compliance has been emphasized across multiple studies. A cross-sectional study conducted in Sri Lanka reported that 66.6% of healthcare workers had received training and demonstrated comparatively better compliance with waste management practices.[8] Furthermore, training, experience, and knowledge were identified as significant predictors of safe practices. In comparison, lower levels of structured training in the present study may explain the observed deficiencies, emphasizing the need for regular capacity-building programs.

Observational studies conducted in Indian tertiary care hospitals also demonstrate similar deficiencies. Malgaonkar *et al*. reported that only 3.85% of units had trained personnel, with 73.07% showing mixing of infectious and non-infectious waste and 60.86% disposing of untreated syringes, indicating serious lapses in compliance.[9] Likewise, Shrestha *et al*. observed improper segregation, inadequate disinfection practices, and poor adherence to protective measures, with only 24% using masks and 6% using aprons.[10] These findings



Figure 3: Key Occupational Risks and Compliance Gaps in Biomedical Waste Management among Waste Handlers.

are comparable to the present study, where inadequate protective practices and improper waste handling were also observed. A study conducted in Karnataka further reported that although a high proportion of healthcare workers had received training and access to color-coded bins, gaps persisted in waste disposal practices, with delays in disposal and incomplete adherence to guidelines.[11] This suggests that training alone is insufficient unless supported by effective monitoring and infrastructure.

International evidence also supports these findings. A study conducted in Kenya reported extremely low compliance levels (1.54%), with significant associations between compliance and factors such as training, availability of personal protective equipment, and waste segregation practices.[12] Similarly, qualitative research has highlighted systemic challenges such as inadequate supervision, poor infrastructure, and lack of administrative support as major barriers to effective biomedical waste management.[13] The COVID-19 pandemic has further highlighted the weaknesses in biomedical waste management systems. Studies have reported increased waste generation and challenges in safe disposal during the pandemic, emphasizing the need for robust and adaptable waste management systems.[14]

Another important observation across studies, including the present study, is the inconsistent use of personal protective equipment. While glove usage is often relatively high, the use of masks, aprons, and other protective gear remains inadequate.[10,11] This significantly increases the risk of occupational exposure to infectious hazards. Additionally, insufficient vaccination coverage among healthcare workers further exacerbates this risk. Environmental and infrastructural deficiencies also contribute significantly to poor compliance. Studies have reported improper waste storage, lack of designated areas, and inadequate ventilation and lighting, which were also observed in the present study.[10,13] Such deficiencies not only compromise worker safety, but also pose a risk to the community and environment.

Overall, the findings of the present study are consistent with existing literature, demonstrating that biomedical waste management is influenced by a combination of individual factors (knowledge, attitude), institutional factors (training, supervision), and systemic factors (infrastructure, policy implementation). Addressing these gaps requires a comprehensive approach involving regular training, strict monitoring, adequate resource allocation, and enforcement of biomedical waste management rules.

CONCLUSION

The present study highlights significant deficiencies in compliance with biomedical waste management practices among biomedical waste handlers at a Common Biomedical Waste Treatment Facility. The overall compliance rate of 32% reflects substantial gaps in adherence to recommended safety protocols, particularly in the use of personal protective equipment, safety practices, and workplace conditions. These deficiencies place workers at considerable risk of occupational exposure, injuries, and infections.

The qualitative findings further emphasize the high perceived risk among workers, driven by inadequate protective measures, lack of vaccination, and poor environmental conditions. Despite acceptable compliance in certain areas such as waste segregation and labeling, critical gaps remain that require urgent attention.

RECOMMENDATIONS

Based on the findings of the study, the following measures are recommended:

1. Strengthening PPE Availability and Usage: Ensure adequate and consistent supply of essential PPE, including gloves, masks, protective clothing, and eyewear, along with strict enforcement of their use.
2. Training and Capacity Building: Conduct regular training programs and refresher sessions on biomedical waste management practices, focusing on safety protocols and risk prevention.
3. Improving Waste Handling Practices: Emphasize proper closure of waste containers and adherence to standard operating procedures to prevent spillage and contamination.
4. Enhancing Workplace Conditions: Improve ventilation, lighting, and availability of basic facilities such as handwashing stations and safety signage.
5. Vaccination and Occupational Health Measures: Implement routine vaccination programs (e.g., Hepatitis B, Tetanus) and periodic health check-ups for biomedical waste handlers.
6. Regular Monitoring and Supervision: Strengthen monitoring mechanisms to ensure compliance with Biomedical Waste Management Rules, 2016.
7. Equipment Maintenance: Ensure regular maintenance and proper storage of equipment and supplies to minimize operational hazards.

DECLARATIONS

Availability of data and materials: All data generated or analysed during this study are included within this manuscript.

Consent to Participate: The research was conducted by the principles of the Declaration of Helsinki. Informed consent was obtained from all participants. Confidentiality and anonymity were maintained

Consent for publication: Not applicable.

Competing interests: The authors declare that they have no competing interests.

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