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# Assessment of Biomedical Waste Management and Risk Perception among Health Care Workers at a Tertiary Care Hospital, Jamshoro

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## ABSTRACT

**Background:** Biomedical waste management is essential for infection prevention, occupational safety, and environmental protection in healthcare settings. Inadequate segregation, handling, and disposal of biomedical waste can increase the risk of sharps injuries, blood-borne infections, environmental contamination, and unsafe exposure among healthcare workers, patients, and waste handlers. **Objective:** To assess knowledge, risk perception, and practices regarding biomedical waste management among healthcare workers at a tertiary care hospital in Jamshoro. **Methods:** A descriptive cross-sectional study was conducted at Liaquat University Hospital, Jamshoro, from January 2026 to March 2026. A total of 131 healthcare workers, including staff nurses, doctors, and housekeeping staff, were recruited using non probability convenience sampling technique. Data were collected using an adopted pre-structured questionnaire which consists of demographic characteristics, biomedical waste segregation knowledge, risk perception, and practice indicators. Data were analyzed using SPSS version 27, and findings were summarized using frequencies, percentages, means, and standard deviations. **Results:** This current study founds moderate level of knowledge, risk perception and practice regarding Biomedical Waste Management among health workers (27.00 ± 3.84), (35.37 ± 6.03), and (7.63 ± 2.54). Moreover, formal biomedical waste management training was reported by 37.4% of participants, consistent PPE use by 38.2%, regular biomedical waste audits by 31.3%, and consistent availability of color-coded bins by 48.1%. **Conclusion:** Healthcare workers demonstrated moderate knowledge, risk perception, and practices regarding biomedical waste management at selected hospital; however, item-level findings revealed important gaps in training, PPE use, injury reporting, and institutional monitoring. Regular training, adequate resources, strict implementation of guidelines, and continuous audits are recommended.
**Keywords:** Biomedical waste management, healthcare workers, knowledge, risk perception, practices, infection control.

## EDITORIAL INFORMATION

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## INTRODUCTION

Biomedical waste management is an essential component of infection prevention, occupational safety, and environmental protection in healthcare systems. Biomedical waste includes materials generated during diagnosis, treatment, immunization, laboratory investigation, and related healthcare activities, and a proportion of this waste may contain infectious, toxic, sharp, chemical, pharmaceutical, or radioactive components. The World Health Organization has estimated that although most healthcare waste is non-hazardous, approximately 15% may be hazardous because of infectious, chemical, toxic, or radioactive properties, making improper segregation, handling, transport, treatment, and disposal a major concern for healthcare institutions (1). When biomedical waste is not managed according to recommended standards, it can contribute to needlestick injuries, blood-borne infections such as hepatitis B, hepatitis C, and HIV, environmental contamination, unpleasant odor, vector proliferation, and avoidable risks to healthcare workers, patients, attendants, waste handlers, and the surrounding community (2–4).

Healthcare workers occupy a central position in biomedical waste management because their daily practices determine whether waste is segregated correctly at the point of generation. Doctors, nurses, paramedical workers, laboratory staff, and housekeeping personnel may differ in their exposure level, training opportunities, perceived risk, and adherence to standard waste-handling procedures. In this context, knowledge alone is not sufficient unless it is translated into routine practice through proper color-coded segregation, safe handling of sharps, use of personal protective equipment, reporting of injuries, access to appropriate bins, and institutional monitoring. Previous studies have shown that inadequate biomedical waste management is often associated with limited awareness, inconsistent training, weak supervision, inadequate infrastructure, and poor compliance with established protocols, particularly in resource-limited healthcare settings (5–8).

Risk perception is an important behavioral determinant of safe biomedical waste management. Healthcare workers who recognize the seriousness of occupational exposure, sharps injuries, cross-contamination, and environmental hazards are more likely to follow safety protocols consistently. Conversely, low or moderate risk perception may reduce compliance with personal protective measures and proper disposal procedures even when workers have basic theoretical knowledge. Evidence from regional and international studies indicates that healthcare workers often possess general awareness of biomedical waste hazards but may still demonstrate gaps in correct segregation, injury reporting, post-exposure response, and use of protective equipment (9–12). This knowledge–practice gap is especially important in tertiary care hospitals, where patient load, multiple clinical departments, high waste generation, and varied staff categories increase the complexity of safe biomedical waste handling.

In Pakistan, biomedical waste management remains a continuing concern because tertiary care hospitals generate substantial volumes of infectious and non-infectious waste, while staff training, waste segregation systems, monitoring mechanisms, and reporting practices may vary across institutions. Although studies from different regions have examined knowledge, attitudes, and practices related to biomedical waste management, local institutional assessments remain necessary because waste generation patterns, departmental workflows, availability of color-coded bins, staff composition, and supervisory systems differ from one hospital to another (13,14). Evidence from a tertiary care hospital in Jamshoro is therefore important for identifying practical gaps among frontline healthcare workers and for guiding targeted training, resource allocation, and monitoring strategies within the local healthcare setting.

The present study was conducted to assess knowledge, risk perception, and practices regarding biomedical waste management among healthcare workers at Liaquat University Hospital, Jamshoro. The study specifically aimed to evaluate healthcare workers' understanding of biomedical waste segregation, determine their perceived risk related to biomedical waste exposure, and describe their self-reported practices concerning safe handling, personal protective equipment use, injury reporting, availability of color-coded bins, and institutional monitoring. The research question guiding this study was: what are the levels of knowledge, risk perception, and biomedical waste management practices among healthcare workers working in a tertiary care hospital in Jamshoro?

## MATERIAL AND METHODS

This study utilize a descriptive cross-sectional study to assess knowledge, risk perception, and practices regarding biomedical waste management among healthcare workers at Liaquat University Hospital, Jamshoro, a tertiary care teaching hospital that provides multidisciplinary clinical services and generates biomedical waste from several inpatient and outpatient units. The duration of this study was Three months from January 2026 to March 2026.

The target population comprised healthcare workers employed at Liaquat University Hospital, Jamshoro either full or part time workers, including doctors, staff nurses, and housekeeping staff who were directly involved in patient care or biomedical waste handling. Participants were eligible for inclusion if they were working in the hospital during the study period, available at the time of data collection, belonged to one of the selected healthcare worker categories, and provided voluntary informed consent. Healthcare workers such as administrative staff, those not involved in biomedical waste management or patient-care-related waste handling, who were on leave or absent and individuals who declined consent were excluded from the this study. In this stud we employed a non-probability convenience sampling technique to recruit participants.

The sample size was calculated using the Raosoft sample size calculator. Based on an accessible population of 196 healthcare workers, a 95% confidence level, and a 5% margin of error, the minimum required sample size was calculated as 131 participants. Recruitment was carried out after permission was obtained from the hospital administration.

Data were collected using a structured paper-based questionnaire adapted from previous biomedical waste management assessment tools and aligned with the objectives of the present study. The questionnaire consisted of four domains: demographic and professional information, knowledge of biomedical waste segregation, risk perception regarding biomedical waste exposure, and biomedical waste management practices with injury-reporting indicators. The demographic and professional section collected information on age, gender, job role, department, years of service, previous work in other healthcare settings, contact with biomedical waste, and previous formal training in biomedical waste management. The knowledge section included items related to the selection of appropriate color-coded bins for common biomedical and general waste categories, including soiled dressings and gauze, used gloves, plastic intravenous fluid bottles, needles and blades, human anatomical waste, cytotoxic drugs, expired medications, microbiology laboratory cultures, discarded blood bags, and general kitchen waste. The risk perception section assessed perceived risk related to improper segregation, handling sharps without personal protective equipment, exposure to airborne waste pathogens, overflowing bins, inappropriate cytotoxic waste disposal, visitor contact with waste, contaminated plastics in general waste, sharps injury during waste collection, transmission of infection to patients or self, cross-contamination through reusable bins, and transport of waste through patient areas. The practice section assessed previous sharps injury, injury during biomedical waste handling, injury reporting, post-exposure prophylaxis, consistent use of personal protective equipment, availability of color-coded bins, observation of improper disposal by coworkers, regular biomedical waste audits or checks, and willingness to receive additional training.

Questionnaire responses were checked for completeness before data entry. Knowledge, risk perception, and practice responses were coded and converted into composite domain scores, with higher scores representing better biomedical waste management knowledge, higher perceived risk, and better practice indicators. Based on the observed score ranges in the study data, knowledge scores were categorized as low or poor from 19 to 26, moderate or good from 27 to 34, and high or excellent from 35 to 39. Risk perception scores were categorized as low from 23 to 33, moderate from 34 to 43, and high from 44 to 53. Practice scores were categorized as low or poor from 1 to 4, moderate or good from 5 to 9, and high or excellent from 10 to 13. For descriptive interpretation, item-level frequencies and percentages were reported alongside composite scores to avoid relying only on summary scores.

To improve content validity, the questionnaire was reviewed by nursing and healthcare education experts for clarity, relevance, and alignment with the study objectives. A pilot assessment was conducted among healthcare workers who were not included in the final analysis to evaluate clarity, flow, and feasibility of questionnaire administration. Data collectors checked completed questionnaires for missing or unclear responses at the time of collection to reduce avoidable data loss. Selection bias was minimized by approaching eligible healthcare workers across different departments and staff categories during the study period, although the use of convenience sampling was recognized as a methodological limitation. Reporting bias and social desirability bias were addressed by ensuring anonymity, avoiding personal identifiers, and informing participants that responses would be used only for academic research purposes.

Data were entered and analyzed using Statistical Package for Social Sciences version 27. Descriptive statistics were used to summarize participant characteristics and study variables. Frequencies and percentages were calculated for categorical variables, including gender, job role, department, training status, contact with biomedical waste, item-level knowledge responses, risk perception categories, and practice indicators. Means and standard deviations were calculated for composite knowledge, risk perception, and practice scores. Data were reviewed for completeness and consistency before analysis. Missing or inconsistent responses were handled through case-wise review of the relevant variable, and denominators were retained according to available valid responses. The results were presented using clearly numbered tables and descriptive narratives to provide an organized overview of demographic characteristics, knowledge responses, risk perception patterns, practice indicators, and composite score distributions.

The study was conducted according to ethical principles for human participant research. Permission was obtained from the hospital administration before data collection. Written informed consent was obtained from all participants after explaining the study purpose, procedures, voluntary nature of participation, confidentiality safeguards, and right to withdraw. No personal identifiers such as names or employee numbers were recorded in the dataset. Completed questionnaires and electronic data files were kept secure and used only for research purposes. The study involved no physical intervention and posed minimal risk to participants. Respect, dignity, privacy, confidentiality, and anonymity were maintained throughout the research process.

## RESULTS

A total of 131 healthcare workers participated in the study. The demographic and professional profile of participants is presented in Table 1.

*Table 1. Demographic and Professional Characteristics of Participants*

| Variable | Category | n (%) |
|---|---|---|
| **Age group, years** | 22–25 | 33 (25.2) |
| | 26–30 | 68 (51.9) |
| | 31–35 | 24 (18.3) |
| | 36–39 | 6 (4.6) |
| **Gender** | Male | 93 (71.0) |
| | Female | 36 (27.5) |
| | Not recorded | 2 (1.5) |
| **Job role** | Staff nurse | 87 (66.4) |
| | Doctor | 34 (26.0) |
| | Housekeeping staff | 10 (7.6) |
| **Department** | Pediatrics ward | 36 (27.5) |
| | Gynecology | 25 (19.1) |
| | Medicine ward | 20 (15.3) |
| | Neurology ward | 14 (10.7) |
| | Pediatric ICU | 12 (9.2) |
| | Surgical Unit 1 | 7 (5.3) |
| | Surgical Unit 2 | 4 (3.1) |
| | Urology | 4 (3.1) |
| | ENT | 3 (2.3) |
| | Orthopedics | 3 (2.3) |

| Variable | Category | n (%) |
|---|---|---|
| | Plastic surgery | 3 (2.3) |
| **Years of service** | 1–2 | 18 (13.7) |
| | 2–3 | 49 (37.4) |
| | 3–4 | 31 (23.7) |
| | 4–5 | 15 (11.5) |
| | ≥6 | 18 (13.7) |
| **Previous work in another healthcare setting** | Yes | 82 (62.6) |
| | No | 48 (36.6) |
| | Not recorded | 1 (0.8) |
| **Contact with biomedical waste** | Yes | 39 (29.8) |
| | No | 92 (70.2) |
| **Formal biomedical waste management training** | Yes | 49 (37.4) |
| | No | 82 (62.6) |

Most participants were aged 26–30 years, representing 68 of 131 respondents (51.9%), followed by 33 participants aged 22–25 years (25.2%). The sample was predominantly male, with 93 participants (71.0%), while 36 participants (27.5%) were female and gender was not recorded for 2 participants (1.5%). Staff nurses formed the largest professional group, accounting for 87 participants (66.4%), followed by doctors at 34 participants (26.0%) and housekeeping staff at 10 participants (7.6%). The largest departmental representation came from the pediatrics ward with 36 participants (27.5%), followed by gynecology with 25 participants (19.1%) and the medicine ward with 20 participants (15.3%). Most participants had 2–3 years of service (37.4%), and 82 participants (62.6%) reported previous work experience in another healthcare setting. Only 39 participants (29.8%) reported direct contact with biomedical waste, while 49 participants (37.4%) had received formal biomedical waste management training.

*Table 2. Responses on Biomedical Waste Segregation by Color-Coded Disposal Category*

| Waste category | Yellow n (%) | Red n (%) | Green n (%) | Blue n (%) | Black n (%) | White n (%) |
|---|---|---|---|---|---|---|
| **Soiled dressings and gauze** | 15 (11.5) | 26 (19.8) | 59 (45.0) | 13 (9.9) | 12 (9.2) | 6 (4.6) |
| **Used gloves** | 19 (14.5) | 28 (21.4) | 65 (49.6) | 11 (8.4) | 7 (5.3) | 1 (0.8) |
| **Needles and blades** | 25 (19.1) | 54 (41.2) | 34 (26.0) | 13 (9.9) | 5 (3.8) | 0 (0.0) |
| **Human anatomical waste** | 4 (3.1) | 41 (31.3) | 25 (19.1) | 26 (19.8) | 35 (26.7) | 0 (0.0) |
| **Cytotoxic drugs** | 2 (1.5) | 35 (26.7) | 48 (36.6) | 27 (20.6) | 19 (14.5) | 0 (0.0) |
| **Expired medication** | 29 (22.1) | 27 (20.6) | 6 (4.6) | 41 (31.3) | 28 (21.4) | 0 (0.0) |
| **Microbiology laboratory cultures** | 7 (5.3) | 85 (64.9) | 26 (19.8) | 12 (9.2) | 1 (0.8) | 0 (0.0) |
| **Discarded blood bags** | 61 (46.6) | 58 (44.3) | 7 (5.3) | 2 (1.5) | 3 (2.3) | 0 (0.0) |
| **General kitchen waste** | 18 (13.7) | 45 (34.4) | 35 (26.7) | 17 (13.0) | 16 (12.2) | 0 (0.0) |

The biomedical waste segregation responses showed substantial variation across disposal categories. For soiled dressings and gauze, the most frequently selected option was the green bin, reported by 59 participants (45.0%), followed by red in 26 participants (19.8%) and yellow in 15 participants (11.5%). For used gloves, 65 participants (49.6%) selected green, while 28 participants (21.4%) selected red and 19 participants (14.5%) selected yellow. For needles and blades, red was the most frequently selected category, reported by 54 participants (41.2%), followed by green in 34 participants (26.0%) and yellow in 25 participants (19.1%). For microbiology laboratory cultures, red was selected by 85 participants (64.9%), representing the highest single-category response in the segregation table. For discarded blood bags, responses were concentrated in yellow and red categories, selected by 61 participants (46.6%) and 58 participants (44.3%), respectively. Overall, the distribution of responses indicates variability in segregation knowledge across different biomedical waste categories.

*Table 3. Risk Perception Regarding Biomedical Waste-Related Hazards*

| Risk perception item | No risk n (%) | Low risk n (%) | Moderate risk n (%) | High risk n (%) | Very high risk n (%) | Missing n (%) |
|---|---|---|---|---|---|---|
| **Improper segregation of waste** | 3 (2.3) | 7 (5.3) | 39 (29.8) | 35 (26.7) | 47 (35.9) | 0 (0.0) |
| **Exposure to airborne waste pathogens** | 14 (10.7) | 26 (19.8) | 20 (15.3) | 25 (19.1) | 46 (35.1) | 0 (0.0) |
| **Overflowing bins in patient areas** | 15 (11.5) | 38 (29.0) | 41 (31.3) | 19 (14.5) | 18 (13.7) | 0 (0.0) |
| **Disposal of cytotoxic waste into red bags** | 8 (6.1) | 60 (45.8) | 37 (28.2) | 19 (14.5) | 7 (5.3) | 0 (0.0) |
| **Contact with waste by visitors** | 7 (5.3) | 54 (41.2) | 42 (32.1) | 17 (13.0) | 11 (8.4) | 0 (0.0) |
| **Discarding contaminated plastics with general waste** | 31 (23.7) | 47 (35.9) | 28 (21.4) | 15 (11.5) | 10 (7.6) | 0 (0.0) |

| Risk perception item | No risk n (%) | Low risk n (%) | Moderate risk n (%) | High risk n (%) | Very high risk n (%) | Missing n (%) |
|---|---|---|---|---|---|---|
| **Risk of sharps injury while collecting waste** | 21 (16.0) | 42 (32.1) | 35 (26.7) | 16 (12.2) | 17 (13.0) | 0 (0.0) |
| **Risk of transmitting infection to patients** | 26 (19.8) | 37 (28.2) | 29 (22.1) | 22 (16.8) | 17 (13.0) | 0 (0.0) |
| **Risk of transmitting infection to self** | 21 (16.0) | 34 (26.0) | 40 (30.5) | 16 (12.2) | 20 (15.3) | 0 (0.0) |
| **Cross-contamination via reusable bins** | 20 (15.3) | 31 (23.7) | 42 (32.1) | 16 (12.2) | 1 (0.8) | 21 (16.0) |
| **Transport of waste through patient areas** | 21 (16.0) | 32 (24.4) | 38 (29.0) | 20 (15.3) | 20 (15.3) | 0 (0.0) |

Risk perception varied across biomedical waste-related hazards. Improper segregation of waste was perceived as very high risk by 47 participants (35.9%) and high risk by 35 participants (26.7%), indicating that most respondents recognized this as an important hazard. Exposure to airborne waste pathogens was also frequently rated as very high risk by 46 participants (35.1%) and high risk by 25 participants (19.1%). In contrast, disposal of cytotoxic waste into red bags was most commonly rated as low risk by 60 participants (45.8%), and discarding contaminated plastics with general waste was rated as no risk or low risk by 78 participants collectively (59.5%). For cross-contamination via reusable bins, 42 participants (32.1%) rated the risk as moderate, while 21 responses (16.0%) were not available from the reported data. These findings indicate that perceived risk was higher for visibly hazardous or infection-related exposures but lower or more variable for waste-system and segregation-related hazards.

*Table 4. Biomedical Waste Management Practice and Institutional Safety Indicators*

| Practice or safety indicator | Yes n (%) | No n (%) |
|---|---|---|
| **Previous needlestick or sharps injury** | 44 (33.6) | 87 (66.4) |
| **Injury occurred during biomedical waste handling** | 47 (35.9) | 84 (64.1) |
| **Injury was reported** | 49 (37.4) | 82 (62.6) |
| **Post-exposure prophylaxis was offered** | 61 (46.6) | 70 (53.4) |
| **Consistent use of PPE while handling biomedical waste** | 50 (38.2) | 81 (61.8) |
| **Color-coded bins always available in the unit** | 63 (48.1) | 68 (51.9) |
| **Coworkers observed improperly disposing biomedical waste** | 40 (30.5) | 91 (69.5) |
| **Regular biomedical waste audits or checks conducted in unit** | 41 (31.3) | 90 (68.7) |
| **Additional biomedical waste management training requested** | 36 (27.5) | 95 (72.5) |

Self-reported practice and institutional safety indicators showed important gaps in biomedical waste management implementation. A previous needlestick or sharps injury was reported by 44 participants (33.6%), while 47 participants (35.9%) reported that an injury occurred during biomedical waste handling. Only 49 participants (37.4%) reported the injury, and 61 participants (46.6%) reported being offered post-exposure prophylaxis. Consistent use of personal protective equipment while handling biomedical waste was reported by 50 participants (38.2%), while 81 participants (61.8%) did not report consistent PPE use. Color-coded bins were always available in the units of 63 participants (48.1%), whereas 68 participants (51.9%) reported that such bins were not always available. Regular biomedical waste audits or checks were reported by only 41 participants (31.3%), indicating limited routine monitoring.

*Table 5. Descriptive Statistics for Knowledge, Risk Perception, and Practice Scores*

| Study variable | Minimum | Maximum | Mean ± SD | Interpreted level |
|---|---|---|---|---|
| **Knowledge score** | 19 | 39 | 27.00 ± 3.84 | Moderate |
| **Risk perception score** | 23 | 53 | 35.37 ± 6.03 | Moderate |
| **Practice score** | 1 | 13 | 7.63 ± 2.54 | Moderate |

The mean knowledge score was 27.00 ± 3.84, with observed scores ranging from 19 to 39, corresponding to a moderate level of biomedical waste management knowledge based on the predefined score categories. The mean risk perception score was 35.37 ± 6.03, with scores ranging from 23 to 53, indicating a moderate level of perceived risk. The mean practice score was 7.63 ± 2.54, with scores ranging from 1 to 13, also corresponding to a moderate level according to the stated scoring thresholds. Although the composite practice score was categorized as moderate, the item-level findings showed practical implementation gaps, particularly in consistent PPE use, availability of color-coded bins, injury reporting, post-exposure prophylaxis, and routine biomedical waste audits.

Overall, the results indicate that healthcare workers demonstrated moderate knowledge, moderate risk perception, and moderate composite practice scores regarding biomedical waste management. However,

several item-level findings suggest that biomedical waste management implementation was inconsistent. Only 37.4% of participants had received formal biomedical waste management training, 38.2% consistently used PPE while handling biomedical waste, 48.1% reported consistent availability of color-coded bins, and 31.3% reported regular biomedical waste audits or checks. These findings suggest a gap between general awareness and routine institutional practice.

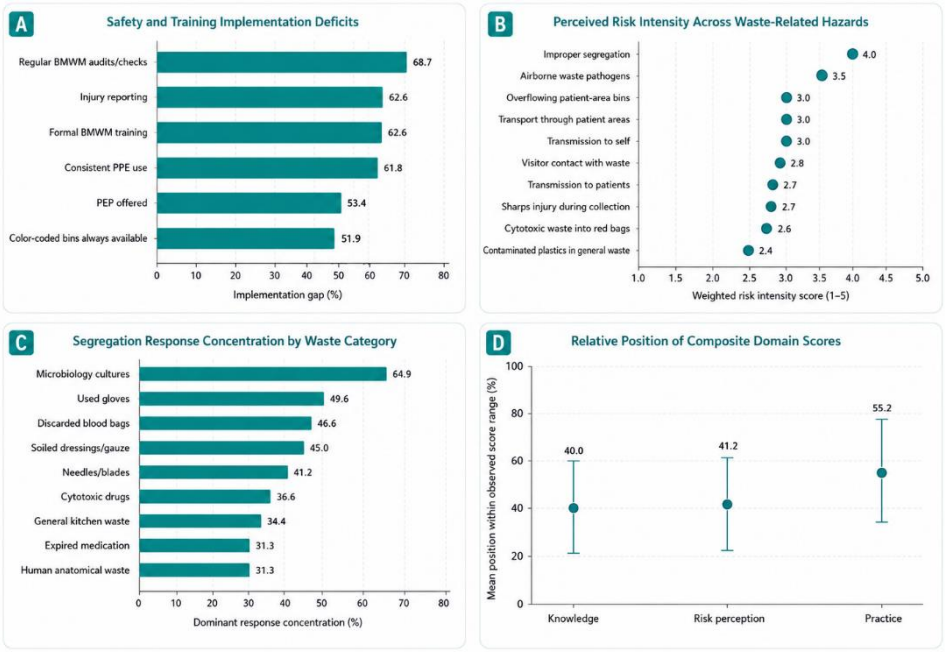


*Figure 1 Biomedical Waste Management Profile across Training, Risk Perception, Segregation Certainty, and Practice Indicators*

The panelled figure demonstrates that biomedical waste management performance was constrained primarily by implementation gaps rather than absence of general awareness. The largest deficits were observed in regular biomedical waste audits or checks, with 68.7% reporting no routine monitoring, followed by lack of formal BMWM training in 62.6% and inconsistent PPE use in 61.8%. Weighted risk intensity was highest for improper waste segregation and exposure to airborne waste pathogens, indicating that respondents perceived visibly hazardous and infection-related exposures as more serious than system-level disposal errors. Segregation response concentration was strongest for microbiology laboratory cultures, where 64.9% selected the dominant disposal category, but was weaker for several routine waste categories, indicating uncertainty in practical color-coded segregation. Composite score profiling placed knowledge, risk perception, and practice in the moderate range, with practice showing a relatively higher position within its observed score range; however, this moderate composite score should be interpreted alongside the item-level deficits in training, PPE use, bin availability, and audit systems.

## DISCUSSION

The present study assessed knowledge, risk perception, and practices regarding biomedical waste management among healthcare workers at a tertiary care hospital in Jamshoro. The findings showed that participants had moderate knowledge, moderate risk perception, and moderate composite practice scores; however, several item-level indicators demonstrated important implementation gaps. The mean knowledge score was 27.00 ± 3.84, with scores ranging from 19 to 39, suggesting that healthcare workers possessed a basic understanding of biomedical waste management but had incomplete or inconsistent knowledge of correct waste segregation. This finding is clinically relevant because segregation errors at the point of generation can affect all subsequent stages of biomedical waste handling, including collection, transport, treatment, and disposal. Similar knowledge gaps have been reported in regional and international studies, where healthcare workers often demonstrated general awareness of biomedical waste hazards but variable understanding of specific segregation categories, treatment pathways, and disposal requirements (15–17).

The distribution of responses in the segregation domain further supports the presence of practical uncertainty. Although microbiology laboratory cultures showed the strongest concentration of responses, with 64.9% of participants selecting the dominant disposal category, several other waste categories had dispersed responses across multiple color-coded bins. For example, used gloves, soiled dressings and gauze, cytotoxic drugs, expired medications, and human anatomical waste showed considerable variability in selected disposal categories. This pattern suggests that participants may recognize biomedical waste as hazardous in general but may not consistently differentiate between specific waste streams. Such uncertainty is important because incorrect segregation can lead to mixing of infectious, hazardous, recyclable, and general waste, thereby increasing occupational exposure, treatment burden, and environmental risk. Previous studies have similarly emphasized that biomedical waste management performance depends not only on awareness but also on clear operational knowledge of color-coded segregation systems and repeated practical training (18–20).

Risk perception was also moderate, with a mean score of 35.37 ± 6.03. Participants perceived certain hazards, particularly improper segregation and exposure to airborne waste pathogens, as relatively high-risk. Improper segregation was rated as very high risk by 35.9% of participants and high risk by 26.7%, while exposure to airborne waste pathogens was rated as very high risk by 35.1%. These findings indicate that many healthcare workers recognized visibly hazardous or infection-related risks. However, risk perception was lower or more variable for some system-level hazards, including disposal of cytotoxic waste into red bags, visitor contact with waste, contaminated plastics discarded with general waste, and cross-contamination through reusable bins. This variation is important because biomedical waste hazards are not limited to direct sharps injuries or visible contamination; they also arise from routine procedural failures, inadequate bin systems, unsafe transport pathways, and weak institutional monitoring. Studies from different healthcare settings have shown that risk perception is influenced by training, experience, workload, supervision, and availability of safety resources, and that incomplete risk perception may reduce compliance with standard precautions (21–23).

The composite practice score was 7.63 ± 2.54, which fell within the moderate category according to the predefined scoring thresholds. However, item-level practice findings suggest that actual implementation was suboptimal in several key areas. Only 38.2% of participants reported consistent use of personal protective equipment while handling biomedical waste, and only 48.1% reported that color-coded bins were always available in their units. Regular biomedical waste audits or checks were reported by only 31.3% of participants, while 62.6% had not received formal biomedical waste management training. These findings indicate that moderate composite scores should be interpreted cautiously because summary scores may mask deficiencies in specific safety behaviors and institutional support systems. In biomedical waste management, even isolated gaps in PPE use, segregation resources, injury reporting, or monitoring can compromise infection prevention and occupational safety. Comparable studies have reported that healthcare workers may demonstrate acceptable awareness while still showing inconsistent practice due to inadequate infrastructure, limited refresher training, weak enforcement, and insufficient supervision (24–26).

The training gap observed in this study is particularly important. Only 37.4% of participants had received formal training in biomedical waste management, despite the fact that healthcare workers from different professional categories are directly or indirectly involved in waste generation, segregation, handling, or disposal. Training is essential because biomedical waste management protocols require correct interpretation of waste categories, color-coded disposal, safe sharps handling, use of PPE, injury reporting, and post-exposure procedures. The observed gaps in PPE use, availability of color-coded bins, and routine audits suggest that improving knowledge alone may not be sufficient unless institutions also ensure regular skill-based training, visible disposal instructions, adequate supplies, supervisory accountability, and periodic compliance assessment. Evidence from recent literature supports the role of structured training and continuous education in improving healthcare workers' knowledge, attitudes, and compliance with biomedical waste management standards (27,28).

The findings also highlight concerns related to sharps injury and post-exposure response. A previous needlestick or sharps injury was reported by 33.6% of participants, while 35.9% reported that an injury occurred during biomedical waste handling. Only 37.4% reported injury reporting, and 46.6% reported being offered post-exposure prophylaxis. These results should be interpreted carefully because the questionnaire items appear to measure related but not necessarily conditional events; for example, the number reporting injury during biomedical waste handling was slightly higher than the number reporting any previous sharps injury, suggesting that item wording or response interpretation may need refinement. Nevertheless, the findings point toward possible weaknesses in occupational injury reporting and post-exposure response systems. Safe biomedical waste management requires not only prevention of sharps injuries but also immediate reporting, risk assessment, documentation, and timely post-exposure prophylaxis where indicated. Under-reporting of sharps injuries has been widely described in healthcare settings and may be influenced by lack of awareness, fear of blame, time constraints, perceived low risk, or uncertainty about reporting pathways.

This study contributes useful descriptive evidence from a tertiary care hospital in Jamshoro by showing that biomedical waste management challenges are multidimensional. The central problem was not limited to knowledge deficiency; rather, the findings suggest an interaction between moderate knowledge, incomplete risk perception, inconsistent safety behaviors, and institutional limitations such as inadequate training, inconsistent bin availability, and limited audits. These findings are important for hospital administrators, nursing managers, infection prevention committees, and occupational health teams because they indicate where corrective action should be prioritized. Practical interventions should include mandatory induction and refresher training for all healthcare worker categories, department-level display of color-coded segregation protocols, continuous availability of bins and PPE, routine biomedical waste audits, documentation of sharps injuries, reinforcement of post-exposure prophylaxis pathways, and feedback-based monitoring systems.

The study has several limitations. The cross-sectional design limits temporal interpretation and does not allow causal conclusions about the relationship between training, risk perception, and practice. The use of convenience sampling may limit representativeness, and the single-center setting restricts generalizability to other tertiary care hospitals. Data were collected through self-reported questionnaires, which may be affected by recall bias and social desirability bias, particularly for PPE use, injury reporting, and disposal practices. Direct observational assessment of biomedical waste handling was not performed, so reported practices may not fully reflect actual behavior. The study also did not conduct inferential analysis to identify predictors of better knowledge, risk perception, or practice, and some item-level inconsistencies suggest that questionnaire coding and data verification should be strengthened in future work. Despite these limitations, the study provides institutionally relevant evidence for improving biomedical waste management practices through training, supervision, resource provision, and regular monitoring.

## CONCLUSION

Healthcare workers at the tertiary care hospital demonstrated moderate knowledge, moderate risk perception, and moderate composite practice scores regarding biomedical waste management; however, item-level findings revealed important gaps in formal training, consistent PPE use, availability of color-coded bins, injury reporting, post-exposure response, and routine biomedical waste audits. These findings indicate that biomedical waste management improvement requires more than general awareness and should focus on structured training, practical demonstrations of color-coded segregation, adequate provision of PPE and disposal resources, clear reporting pathways for sharps injuries, and continuous departmental monitoring. Strengthening these institutional measures can improve compliance with biomedical waste management standards, reduce occupational exposure risks, and support a safer healthcare environment for healthcare workers, patients, attendants, waste handlers, and the surrounding community.

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