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ORIGINAL RESEARCH ARTICLE

# Knowledge, attitude, and practices toward biomedical waste management among healthcare workers

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**Abstract:** Biomedical waste (BMW) refers to any solid or liquid waste, including its packaging and by-products, generated during the diagnosis, treatment, or immunization of humans or animals. Poor and inappropriate management of healthcare waste poses significant health risks and can cause substantial environmental damage. Given the enduring importance of BMW management, this study aims to assess healthcare workers' (HCWs) knowledge, attitudes, and practices regarding BMW management (BMWM) at various levels of hospitals and diagnostic services. This cross-sectional study included 163 participants and was carried out from April 2024 to June 2024 in the Nalgonda and Warangal districts of Telangana state, India. The findings revealed that a significant proportion of doctors (87.7%) and nurses (80%) demonstrated good to excellent knowledge of BMWM, whereas only 66.6% of other HCWs reached similar levels. A strong positive attitude toward BMWM was observed among 96.3% of participants. In terms of practices, 63.4% of doctors, 72% of nurses, and 76.3% of other HCWs exhibited excellent adherence to BMWM practices. The study also found knowledge regarding BMWM disparities based on workplace location. These findings provide critical insights for hospital executives, policymakers, and public health professionals to devise specialized training and awareness schemes to strengthen BMWM practices.

**Keywords:** Biomedical waste management; Healthcare workers; Knowledge; Attitude and practices

## 1. Introduction

"Biomedical waste" (BMW) refers to any waste generated during the diagnosis, treatment, or immunization of human beings or animals, or from related research activities, or from the production or testing of biologicals, including in health camps.[1-3] It is the social and legal responsibility of all individuals and institutions involved in funding or assisting healthcare activities to manage BMW safely and sustainably. For a healthier environment, effective BMW management (BMWM) is essential. Ministry of Environment and Forests, under the Environment (Protection) Act, 1986, established rules for the management and handling of BMW, which have been amended multiple times thereafter.[4] According to the Doctors Manual for Environmental Clearance (n.d.), the Bio-medical Waste (Management and Handling) Rules apply to all individuals and entities involved in the generation, collection, receipt, storage, transport, treatment,

disposal, or handling of BMW. This includes hospitals, nursing homes, clinics, dispensaries, veterinary institutions, animal houses, pathological laboratories, blood banks, traditional medicine hospitals, clinical establishments, research or educational institutions, health camps, medical or surgical camps, vaccination camps, blood donation camps, school first-aid rooms, forensic laboratories, and research labs.[4-6]

BMWM is a pressing issue, encompassing a multitude of practices and challenges across various healthcare settings. From the dynamic atmosphere of hospitals to the serene settings of home care, each context contributes uniquely to the escalating crisis of BMW. For instance, hospitals generate considerable quantities of hazardous waste, including used needles and contaminated dressings. Investigations at K.R. Hospital and J.S.S. Hospital in Mysore revealed considerable deficiencies in their waste disposal practices.[7]

BMW, a byproduct of healthcare endeavors, is categorized into various types, each with unique characteristics and ecological implications. These include infectious waste, radioactive waste, pharmaceutical waste, and non-infectious waste, such as sharps and general medical refuse.[8,9] Infectious waste, comprising discarded syringes and bodily fluids, harbors considerable health dangers due to the potential presence of harmful pathogens.[8] Radioactive waste, typically generated during diagnostic and therapeutic activities, can pose lasting environmental and health effects if not properly managed. Pharmaceutical waste, when inadequately handled, can lead to ecological degradation, ultimately impacting water systems and natural habitats.[8] Even non-infectious waste, though relatively less perilous, still necessitates diligent management to avert ecological pollution.[8]

Effective stewardship of medical waste is paramount, given its capacity to instigate environmental degradation and public health dilemmas. Conventional disposal techniques, such as incineration, although efficient in minimizing waste volume, can emit detrimental pollutants if not meticulously regulated.[7,10] Alternatives, such as autoclaving and microwaving are hailed as more eco-conscious options, yet may not be applicable for all waste types, particularly pathological or radioactive substances.[10] In resource-limited nations, inadequate infrastructure and weak regulatory enforcement exacerbate the environmental and health hazards associated with poor BMWM.[10,11] Proficient waste management strategies, encompassing accurate classification, labeling, and cutting-edge disposal technologies, are vital for alleviating these hazards.[12] Furthermore, adopting sustainable methodologies and promoting recycling can drastically diminish both environmental repercussions and the related expenses.[7,12] In conclusion, the holistic management of BMW is essential for safeguarding both human well-being and the ecosystem from the detrimental effects of improper disposal and treatment.[13]

The legal architecture for managing BMW in India is primarily shaped by the BMWM Rules of 2016, which superseded the earlier regulations set forth in 1998. These guidelines are comprehensive, intricately outlining the classification, separation, collection, transportation, and final disposal of BMW. They incorporate precise directives on color coding of waste containers, proper labeling, and standards governing treatment and disposal facilities, such as incinerators and autoclaves.[14,15] The regulations apply to all parties engaged in the creation and management of BMW, including hospitals, clinics, and laboratories.[16] However, in India, inadequate enforcement and insufficient waste segregation have led to environmental degradation and heightened public health risks.[17] Globally, the governance of BMW is determined by treaties, such as the Basel Convention, which oversees the movement of hazardous waste, and the Stockholm Convention, which aims to reduce the production and use of persistent pollutants.[18] The World Health Organization (WHO) categorizes medical waste into eight distinct groups, underlining the critical need for meticulous handling to avert infection and injury.[14] Nations, such as the United States and the United Kingdom have instituted rigorous regulations and practices for BMWM, acting as exemplary models for effective waste handling.[18] The international landscape highlights the need for robust legal frameworks and their effective enforcement to mitigate the risks associated with BMW. While India has established a solid legal foundation, the successful execution of these rules remains a pivotal hurdle, demanding amplified compliance mechanisms and enhanced public awareness initiatives.[17,19]

Although government bodies take immense responsibility in handling BMW – as seen in the state of Telangana, where 11 Common BMW Treatment Facilities are currently in operation[20] – BMWM should not be the sole responsibility of these facilities. Events, such as the COVID-19 pandemic have amplified global concern over BMW, underscoring the need for collective responsibility, particularly among frontline workers. In practice, all healthcare personnel, regardless of role or rank, are involved in the handling of BMW and are, therefore, key agents in its management.[21]

It is imperative that healthcare workers (HCWs) possess adequate knowledge of BMWM and adhere strictly to standard procedures. A lack of awareness or improper understanding can lead to environmental harm and pose significant health risks to all individuals involved in the waste management chain.

Effective BMWM requires sound knowledge, the right attitude, and a willingness to implement best practices. While ongoing research in this area is promising, periodic assessments across different institutions and geographical regions are needed to ensure adherence and identify gaps.

This distinctiveness of the present study lies in its detailed examination of knowledge, attitude, and practices (KAP) concerning BMWM among a diverse group of HCWs – including doctors, nurses, and support personnel – across both hospital and diagnostic settings. In contrast to previous investigations that predominantly concentrate on individual institutions or specific staff categories, this study presents a multi-tiered comparative examination, underscoring variations in awareness and practices based on professional role and workplace environment.

Furthermore, by conducting the study in the Nalgonda and Warangal districts of Telangana – regions characterized by a paucity of detailed data on the subject – this research addresses a significant geographical and contextual void in the existing literature. The outcomes furnish practical, location-specific insights that can be directly leveraged to enhance local BMWM protocols.

The incorporation of both quantitative metrics (e.g., percentages reflecting KAP levels) and visual representations (e.g., charts) substantially augments the study's utility by rendering the data more actionable for policy intervention. Consequently, this study establishes a data-driven framework for the formulation of targeted training programs, standardized operational policies, and monitoring systems designed to promote environmental safety and occupational health in healthcare environments.

The objectives of the present investigation are threefold. First, the study aims to evaluate the extent of knowledge possessed by HCWs concerning BMW, particularly their comprehension of waste categorization, segregation protocols, color coding systems, associated health and environmental hazards, and relevant regulatory frameworks. The study also aims to analyze the perspectives of HCWs on BMWM, focusing on their awareness of its significance, their sense of professional accountability, and their preparedness to comply with institutional protocols and guidelines. Finally, the study seeks to scrutinize the practices employed by HCWs in BMWM, concentrating on the specific methods utilized for waste segregation, handling, storage, transportation, and disposal, and the degree to which these practices correspond with their knowledge and attitudes.

## 2. Materials and methods

### 2.1. Study design and data collection

This study aims to assess the KAP concerning BMWM among HCWs. The study sample comprised doctors, nurses, and other HCWs – including pharmacists and lab technicians – from hospitals and diagnostic centers in the Nalgonda and Warangal districts of Telangana state, India.

Data were collected from 163 participants between April and June 2024 using a structured, closed-ended, self-administered questionnaire. A convenience sampling method was used, and respondent confidentiality was maintained through anonymous responses.

The questionnaire was divided into three sections. The "knowledge" section consisted of 10 dichotomous (yes/no) questions on BMWM. A correct response was assigned one point, while a wrong response received zero points. The total score ranged from 0 to 10. Knowledge levels were categorized as follows: 0 – 2: Very poor knowledge; 3 – 4: Poor knowledge; 5 – 6: "Average knowledge"; 7 – 8: Good knowledge; and 9 – 10: Excellent knowledge.

The attitude section included 10 questions on BMW and BMWM, rated using a five-point Likert scale: 1: Strongly disagree; 2: Disagree; 3: Neutral; 4: Agree; and 5: Strongly agree. The cumulative score was used to classify attitude into: 1 – 20: Negative attitude; 21 – 30: Neutral attitude; and 31 – 50: Positive attitude.

The practices section also comprised 10 dichotomous (yes/no) questions on BMWM. The total score ranged between 0 and 10 and was interpreted as: 0 – 2: Very poor practices; 3 – 4: Poor practices; 5 – 6: Average practices; 7 – 8: Good practices; and 9 – 10: Excellent practices.

Negatively framed questions were reverse-scored to maintain consistency. Specifically, items 5 and 7 in the knowledge section, and items 11 and 18 in the attitude section, were scored accordingly during analysis.

### 2.2. Statistical analysis

The data collected through the administered questionnaires were systematically entered into Microsoft Excel and subsequently exported to Statistical Package for the Social Sciences version 23

for comprehensive data analysis. Descriptive statistics were used to summarize the data, with results presented as frequencies and percentages. The chi-square test was applied to determine the association between categorical variables.

## 3. Results

This study involved a total of 163 participants, and their characteristics are shown in Table 1. The majority were aged between 30 and 40 years (37.4%), followed by those aged 40 – 50 years (29.4%), 20 – 30 years (17.8%), and above 50 years (15.3%). As per gender classification, there were 100 females (61.3%) and 63 males (38.7%). Regarding the professional roles, 41participants (25.2%) were doctors, 50 (30.7%) were nurses, and 72 (44.2%) were other HCWs, including lab technicians and pharmacists. Most participants – 139 (85.3%) – were employed in government hospitals. The professional settings included village-level facilities (37.4%), town or mandal headquarters (31.3%), and municipal or municipal corporation areas (31.3%).

### 3.1. Knowledge assessment

The study revealed that only 65% of the participants have undergone training in BMWM (Table 2). About 11% of the survey participants did not recognize the biohazard symbol. All doctors (100%) and more than 95% of nurses and other HCWs accepted that waste separation is the most critical phase of BMWM and agreed that wearing personal protective equipment (PPE) reduces the risk of infection. However, 19% of the participants were not aware that waste collected in the yellow bags must be treated through incineration.

In this study, 76% of doctors, nurses, and other HCWs demonstrated good to excellent knowledge on BMWM, while only 2% exhibited poor knowledge (Table 3). An analysis was done to determine whether knowledge levels were influenced by the profession, revealing no statistically significant association ($p>0.05$).

Given that 24% of respondents fell into the average to poor knowledge category, a further analysis was carried out to examine the relationship between workplace location and knowledge level (Table 4). Among those working in village areas (37.4%), only 13.1% had excellent knowledge. In comparison, 15.6% of HCWs based in town or mandal headquarters and 45% of those in municipality or municipal corporation areas demonstrated excellent knowledge of BMWM. This analysis revealed a statistically significant relationship between workplace location and knowledge level ($p<0.05$).

**Table 1. Demographic characteristics of the participants**

| Characteristics | *n* (total=163) | Percentage |
|---|---|---|
| Age (years) | | |
| 20 – 30 | 29 | 17.8 |
| 30 – 40 | 61 | 37.4 |
| 40 – 50 | 48 | 29.4 |
| >50 | 25 | 15.3 |
| Gender | | |
| Male | 63 | 38.7 |
| Female | 100 | 61.3 |
| Profession | | |
| Doctors | 41 | 25.2 |
| Nurses | 50 | 30.7 |
| Other healthcare workers | 72 | 44.2 |
| Working experience in healthcare (years) | | |
| <5 | 40 | 24.5 |
| 6 – 10 | 25 | 15.3 |
| 11 – 20 | 61 | 37.4 |
| 21 – 30 | 30 | 18.4 |
| >31 | 7 | 4.3 |
| Organization | | |
| Corporate hospital | 5 | 3.1 |
| Government hospital | 139 | 85.3 |
| Medical college | 6 | 3.7 |
| Own clinic/private hospital/ diagnostic center | 13 | 8 |
| Place of work | | |
| Village | 61 | 37.4 |
| Town/mandal headquarters | 51 | 31.3 |
| Municipal/municipal corporation | 51 | 31.3 |

### 3.2. Attitude assessment

The analysis of the attitude of HCWs revealed that around 90% agreed that safe BMWM management requires teamwork (Table 5). The majority of respondents strongly believed that infection transmission can be prevented with proper disposal of BMW (mean score = 4.46). Most respondents also expressed concern for occupational safety, emphasizing its importance for individuals handling BMW (mean score = 4.45). However, around 20% of the respondents did not

**Table 2. Knowledge of the participants in BMWM**

| No. | Knowledge item | *n* (%) | | | | *p*-value |
|---|---|---|---|---|---|---|
| | | Doctors (total=41) | Nurses (total=50) | Others (total=72) | Subtotal (total=163) | |
| 1 | Have you received any training for BMWM? | 27 (65.9) | 32 (64.0) | 47 (65.3) | 106 (65.0) | 0.981 |
| 2 | Is there any hazard related to BMWM? | 34 (82.9) | 38 (76.0) | 49 (68.1) | 121 (74.2) | 0.208 |
| 3 | Do you know the symbol for biohazard? | 40 (97.6) | 46 (92.0) | 60 (83.3) | 146 (89.6) | 0.047 |
| 4 | The most important aspect of BMWM is segregation. | 41 (100) | 49 (98.0) | 69 (95.8) | 159 (97.5) | 0.376 |
| 5 | PEP can be taken at any time. | 20 (48.8) | 22 (44.0) | 35 (48.6) | 77 (47.2) | 0.859 |
| 6 | Do you know about segregation based on the color-coding system? | 38 (92.7) | 44 (88.0) | 64 (88.9) | 146 (89.6) | 0.743 |
| 7 | Do you know that the general waste is to be collected in a yellow bin? | 15 (36.6) | 16 (32.0) | 12 (16.7) | 43 (26.4) | 0.039 |
| 8 | Wearing PPE reduces the risk of infection. | 41 (100) | 47 (94.0) | 69 (95.8) | 157 (96.3) | 0.305 |
| 9 | Do you know that the maximum storage time for untreated waste is 2 days or 48 h? | 35 (85.4) | 42 (84.0) | 63 (87.5) | 140 (85.9) | 0.856 |
| 10 | Yellow bags are treated by incineration. | 31 (75.6) | 38 (76.0) | 62 (86.1) | 128 (78.5) | 0.259 |

Abbreviations: BMWM: Biomedical waste management; HCWs: Healthcare workers; PEP: Post-exposure prophylaxis; PPE: Personal protective equipment.

**Table3. Knowledge of HCWs among different occupations of health care professionals in BMWM**

| Occupation (*n*) | Knowledge about BMWM, *n* (%) | | | | | *p*-value |
|---|---|---|---|---|---|---|
| | Very poor | Poor | Average | Good | Excellent | |
| Doctors (41) | 0 (0) | 0 (0) | 5 (12.1) | 25 (60.9) | 11 (26.8) | 0.131 |
| Nurses (50) | 0 (0) | 2 (4.0) | 8 (16.0) | 30 (60.0) | 10 (20.0) | |
| Others (72) | 0 (0) | 2 (2.7) | 22 (30.5) | 30 (41.6) | 18 (25.0) | |
| Total | 0 (0) | 4 (2.5) | 35 (21.5) | 85 (52.1) | 39 (23.9) | |

Abbreviation: BMWM: Biomedical waste management; HCWs: Healthcare workers.

**Table 4. Association between place of work and knowledge of BMWM**

| Place of work | Knowledge about BMWM (*n*) | | | | | Total, *n* (%) | Chi-square | *p*-value |
|---|---|---|---|---|---|---|---|---|
| | Very poor | Poor | Average | Good | Excellent | | | |
| Village | 0 | 3 | 21 | 29 | 8 | 61 (37.4) | 27.41 | 0.001 |
| Town/mandal headquarters | 0 | 1 | 9 | 33 | 8 | 51 (31.3) | | |
| Municipal/municipal corporation | 0 | 0 | 5 | 23 | 23 | 51 (31.3) | | |

Abbreviations: BMWM: Biomedical waste management.

express concern about the adverse effects of BMW on public health (mean score = 3.87). Overall, the study found that HCWs showed a generally positive attitude toward BMWM (Table 6).

### 3.3. Practice assessment

Regarding actual practices, 80% to 90% of doctors, nurses, and other HCWs reported adherence to best practices in BMWM (Table 7). However, 17% of respondents indicated the absence of a formal system for reporting injuries and accidents. A large majority (83%) reported maintaining BMW records at the point of generation. In addition, 94% of participants followed proper color-coding practices for waste segregation, and 87% reported using PPE while handling BMW. A point of concern is that 18% of HCWs reported not following post-exposure prophylaxis protocols after experiencing needle-stick or percutaneous injuries. Most participants (85%) disposed of non-infectious waste in black containers, consistent with standard guidelines.

**Table 5. HCWs' attitude toward BMWM**

| No. | Attitude item | *n* (%) | | | | | Mean±SD |
|---|---|---|---|---|---|---|---|
| | | Strongly disagree | Disagree | Neutral | Agree | Strongly agree | |
| 1 | Proper BMWM is an issue. | 23 (14.1) | 71 (43.6) | 14 (8.6) | 29 (17.8) | 26 (16) | 2.78±1.33 |
| 2 | Safe BMWM requires teamwork. | 9 (5.5) | 4 (2.5) | 4 (2.5) | 67 (41.1) | 79 (48.5) | 4.24±1.02 |
| 3 | General public health can be negatively affected by BMW. | 7 (4.3) | 21 (12.9) | 5 (3.1) | 82 (50.3) | 48 (29.4) | 3.88±1.10 |
| 4 | Needle-stick or sharp injury is a concern. | 3 (1.8) | 6 (3.7) | 11 (6.7) | 94 (57.7) | 49 (30.1) | 4.10±0.82 |
| 5 | BMW has to be separated at the point of origin. | 3 (1.8) | 1 (0.6) | 5 (3.1) | 101 (62.0) | 53 (32.5) | 4.23±0.70 |
| 6 | BMWM practices and administration should be an essential component of the academic curriculum. | 3 (1.8) | 4 (2.5) | 8 (4.9) | 88 (54.0) | 60 (36.8) | 4.2±0.80 |
| 7 | Proper BMW disposal can prevent infection transmission. | 3 (1.8) | 1 (0.6) | 1 (0.6) | 71 (43.6) | 87 (53.4) | 4.46±0.722 |
| 8 | Reporting of needle-stick injury is an extra burden. | 19 (11.7) | 42 (25.8) | 12 (7.4) | 50 (30.7) | 40 (24.5) | 3.31±1.38 |
| 9 | Use of color-coded bags is a must for waste segregation. | 3 (1.8) | 0 (0) | 6 (3.7) | 91 (55.8) | 63 (38.7) | 4.29±0.711 |
| 10 | Occupational safety is essential for individuals handling BMW. | 3 (1.8) | 0 (0) | 3 (1.8) | 71 (43.6) | 86 (52.8) | 4.45±0.7132 |

Abbreviations: BMW: Biomedical waste; BMWM: Biomedical waste management; HCWs: Healthcare workers; SD: Standard deviation.

**Table 6. Attitude of the HCWs on BMWM**

| Attitude | *n* | Percentage |
|---|---|---|
| Negative | 2 | 1.2 |
| Neutral | 4 | 2.5 |
| Positive | 157 | 96.3 |

Abbreviations: BMWM: Biomedical waste management; HCWs: Healthcare workers.

Overall, 71.8 % of HCWs were following excellent practices of BMWM. Notably, none of the doctors fell under the very poor category, though a small proportion (2.5%) of nurses and other HCWs were identified as having very poor practices (Figure 1).

## 4. Discussion

The proper disposal of BMW, comprising hazardous materials, such as contaminated medical instruments and sharp needles, is very crucial to protect public health and ensure environmental safety. This study aimed to assess the KAP related to BMWM among the frontline HCWs, including doctors, nurses, laboratory technicians, and pharmacists, working in hospitals across the Nalgonda and Warangal districts of Telangana.

The Covid-19 pandemic has led to a significant increase BMW generated worldwide, placing immense pressure on waste management systems.[1] In India, and particularly in states, such as Telangana, medical establishments generate a substantial volume of BMW, exacerbating the broader challenges of waste disposal in the region. Across the nation, India generates approximately 710 tons of BMW daily, with waste linked to COVID-19 accounting for 126 tons per day during the initial wave of the pandemic.[22] According to the WHO reports, nearly 10% of hospital waste is classified as infectious, underscoring the widespread and critical nature of proper waste management.[14] According to the Central Pollution Control Board (CPCB) annual report on BMWM for the year 2022, Telangana state has 9346 healthcare facilities.[4] The total BMW in Telangana has generated 25 tons of BMW per day, positioning it as the ninth-highest state in terms of BMW generation. In comparison, Uttar Pradesh is ranked at the top of the list, generating 89 tons per day, while Arunachal Pradesh generates the least, at 0.5 tons per day. These figures reflect factors, such as population density and the type of healthcare facility. Telangana currently utilizes 11 CBWTF to manage waste.

Captive treatment facilities (CTFs) are established to ensure proper treatment and disposal of generated BM.[4] The number of CTFs operational in India is presented in Figure 2. CTFs are not currently in use in Telangana,

**Table 7. BMWM practices of HCWs**

| No. | Practices | *n* (%) | | | Chi-square | *p*-value |
|---|---|---|---|---|---|---|
| | | Doctors (total=41) | Nurses (total=50) | Others (total=72) | | |
| 1 | Is PEP utilized during the handling of BMW? | 31 (75.6) | 43 (86.0) | 68 (94.4) | 8.337 | 0.015 |
| 2 | Do you divide BMW into different categories? | 36 (87.8) | 46 (92.0) | 67 (93.1) | 0.949 | 0.622 |
| 3 | Do you collect waste sharps using puncture-proof plastic containers? | 37 (90.2) | 45 (90.0) | 64 (88.9) | 0.66 | 0.968 |
| 4 | Do you follow color coding system for waste segregation? | 39 (95.1) | 46 (92.0) | 68 (94.4) | 0.456 | 0.796 |
| 5 | At the point of origin, do you maintain a record for BMW? | 34 (82.9) | 39 (78.0) | 62 (86.1) | 1.365 | 0.505 |
| 6 | Do you have a system to report injuries and accidents? | 33 (80.5) | 44 (88.0) | 58 (80.1) | 1.359 | 0.507 |
| 7 | Have you been immunized against Hepatitis B? | 37 (90.2) | 45 (90.0) | 59 (81.9) | 2.297 | 0.317 |
| 8 | After a needle stick injury or percutaneous injury, do you follow PEP protocol? | 35 (85.4) | 38 (76.0) | 61 (84.7) | 1.908 | 0.385 |
| 9 | Do you put non-infectious wastes in a black container? | 35 (85.4) | 42 (84.0) | 62 (86.1) | 0.105 | 0.949 |
| 10 | Do you know the method to prepare 1 L of 1% sodium hypochlorite from a stock of 5% concentration? | 34 (82.9) | 44 (88.0) | 64 (88.9) | 0.878 | 0.645 |

Abbreviations: BMW: Biomedical waste; BMWM: Biomedical waste management; HCWs: Healthcare workers; PEP: Post-exposure prophylaxis; PPE: Personal protective equipment.

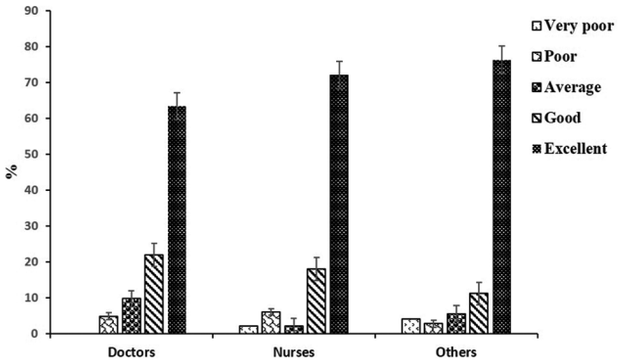


**Figure 1. Practices of biomedical waste management among healthcare workers with different professional roles**

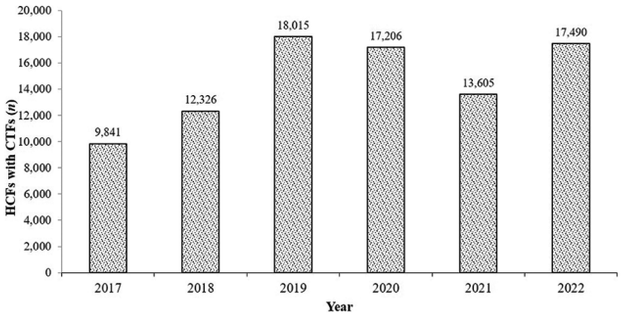


**Figure 2. Number of healthcare facilities with captive treatment facilities in year 2017 – 2022. Adapted from Central Pollution Control Board annual report on biomedical waste management (2022) as per 2016 rules.**

as there is no operational necessity for them at this time. Further details on the BMWM status in Telangana, as per the 2022 CPCB report, are presented in Table 8.

Many studies on BMWM in different Indian states have contributed data on the importance of the HCWs' KAP regarding BMW.[2,7,8,10,21,23] In the post-pandemic context, the issue of BMW has gained a new attention, introducing an added burden to the existing waste management systems. BMW increases the risk of infection transmission and contributes to air, water, and soil pollution.[9,24,25] The present study indicates that while the overall knowledge regarding BMWM among HCWs is adequate, gaps remain in formal training. Although over 95% of participants displayed a positive attitude toward BMWM, disparities in knowledge levels were observed based on workplace location. HCWs stationed in villages and towns or mandal headquarters demonstrated lower knowledge levels compared to their counterparts in municipal or urban healthcare settings. This suggests a need for targeted training efforts to enhance awareness and capacity in rural and semi-urban areas. Moreover, despite adequate knowledge, a small but important deficiency persists in the translation of knowledge into practice. This underscores the need for consistent guidance, motivation, and oversight. Previous investigations have shown that nurses often possess stronger BMWM

**Table 8. BMWM status of Telangana state**

| Parameter | Value |
|---|---|
| Total number of HCFs | 9346 |
| Number of bedded HCFs | 4830 |
| Number of non-bedded HCFs | 4516 |
| Total number of hospital beds | 132332 |
| Number of CBWTFs | 11 |
| Number of HCFs granted authorization | 5036 |
| Number of HCFs utilizing CBWTFs | 9346 |
| Number of HCFs with CTF | 0 |
| Number of captive incinerators operated by HCFs | 0 |
| Quantity of BMW generated (kg/day) | 25306 |
| Quantity of BMW treated (kg/day) | 25306 |
| Number of HCFs/CBWTFs that violated BMW rules | 188 |
| Number of show-cause notices/directions issued to defaulting HCFs/CBWTFs | 188 |

Note: Adapted from Central Pollution Control Board (CPCB) annual report on BMWM (2022).
Abbreviations: BMW: Biomedical waste; BMWM: Biomedical waste management; CBWTFs: Common biomedical waste treatment facilities; CTF: Captive treatment facilities; HCFs: Healthcare facilities; PEP: Post-exposure prophylaxis; PPE: Personal protective equipment.

competencies than other HCWs; however, significant gaps remain among sanitation workers and paramedical aides – a finding supported by the present study.[26-30] The implementation of training and continuous education is crucial to enhance the knowledge and practices of all HCWs involved in BMW stewardship. Well-structured training programs, featuring engaging workshops and hands-on sessions, have proven to significantly elevate the understanding and practices of healthcare staff, even among those with minimal prior exposure, such as class IV workers.[23,31-32] Moreover, the introduction of systematic training interventions has shown remarkable effectiveness in boosting awareness and compliance with BMWM protocols across various healthcare settings.[33,34] The urgency for such educational initiatives is underscored by the dangers linked to improper BMW handling, such as needlestick injuries and exposure to infectious agents, which can have dire consequences for both HCWs and the wider community.[35-37] Thus, it is imperative for healthcare institutions to prioritize regular and thorough training programs to ensure that all front-line personnel are armed with the essential knowledge and skills to safely and effectively manage BMW.[23]

This study evaluated the understanding, perceptions, and actions regarding BMWM among HCWs in the state of Telangana, India. Nonetheless, certain limitations must be acknowledged. The study focused on a specific geographic region with a relatively modest sample size, which may limit the generalizability of its findings. Future research should expand to include broader geographic areas and larger, more diverse samples. Such studies could also explore the long-term impact of training programs on knowledge retention and practice improvement.

Overall, this investigation emphasizes the vital role of continuous education, institutional commitment, and policy-level engagement in advancing BMWM practices. Bridging the existing knowledge-practice gap among HCWs – especially in under-resourced settings – requires a coordinated, multidisciplinary effort to foster long-term improvements in public health and environmental safety.

## 5. Conclusion

The proper disposal of BMW is essential for protecting public health and safeguarding the environment – an imperative that has become even more pronounced in the wake of the COVID-19 pandemic and the ongoing increase in medical waste generation. This study, conducted in the Nalgonda and Warangal districts of Telangana, reveals that while HCWs generally possess adequate knowledge of BMWM, notable gaps persist in training and practice. Although the majority of HCWs showed a positive attitude toward BMWM, the findings highlight the need for enhanced guidance and motivation to ensure consistent and effective implementation. Addressing these deficiencies through proper training and support is essential for minimizing the risks associated with BMW and enhancing overall waste management practices.

Health and sustainability are inherently interconnected. Sustainable practices in healthcare and other sectors play a pivotal role in reducing the risks associated with environmental pollution and waste mismanagement. By adopting sustainable methods, healthcare systems can mitigate health hazards, enhance public well-being, and strengthen resilience against environmental challenges. Moreover, sustainable waste management not only protects human health but also conserves ecosystems – ensuring a safe and healthy environment for future generations.

The United Nations' Sustainable Development Goals, established in 2015 as part of the 2030 Agenda

for Sustainable Development, consist of 17 interlinked objectives among these; environmental protection and public health are central themes. BMWs, if improperly managed, contributes significantly to environmental degradation by contaminating land and water sources. Therefore, the safe disposal of BMW and adherence to sanitation standards are essential for preventing infections, controlling disease outbreaks, and promoting overall health and well-being.

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## Conflict of interest

The authors declare no competing interests.

## Author contributions

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## Availability of data

Data areavailable from the corresponding author upon reasonable request.

## References

1. Arora R, Aggarwal P. Biomedical waste management: An emerging concern in COVID-19 pandemic. *Indian J Public Health*. 2021;65(6):65-67. doi: 10.4103/ijph.ijph_1242_21
2. Basavaraj TJ, Shashibhushan BL, Sreedevi A. To assess the knowledge, attitude and practices in biomedical waste management among health care workers in dedicated COVID hospital in Bangalore. *Egypt J Intern Med*. 2021;33:37. doi: 10.1186/s43162-021-00045-8
3. Datta P, Mohi G, Chander J. Biomedical waste management in India: Critical appraisal. *J Lab Physicians*. 2018;10(1):6-14. doi: 10.4103/jlp.jlp_89_17
4. Central Pollution Control Board. *Bio-Medical Waste Rules*. Available from: https://cpcb.nic.in/bio-medical-waste-rules [Last accessed on 2024 Jun 21].
5. Central Pollution Control Board. *Bio-Medical Waste Management Rules, 2016*; 2016. Available from: from: https://cpcb.nic.in/uploads/projects/bio-medical-waste/bio-medical_waste_management_rules_2016.pdf [Last accessed on 2024 Jun 21].
6. Central Pollution Control Board. *Annual Report on Biomedical Waste Management for the Year 2022 as per Biomedical Waste Management Rules, 2016*. New Delhi: Central Pollution Control Board; 2022.
7. Omo QG, Hassan NE. Biomedical waste management and their effects on the environment: A review. *World J Adv Eng Technol Sci*. 2024;11(1):86-95. doi: 10.30574/wjaets.2024.11.1.0020
8. Bhardwaj R. Reduction of Both Health and Environmental Risk from the Med-Waste Technology of COVID-19. In: *2023 3rd Asian Conference on Innovation in Technology (ASIANCON)*. IEEE; 2023. p. 1-7. doi: 10.1109/asiancon58793.2023.10270178
9. Kim V, Saunders G, Tahir M. A review of current and novel methods of medical waste management. *J Student Res*. 2022;11(4):1-12. doi: 10.47611/jsrhs.v11i4.3477
10. Ghali H, Cheikh AB, Bhiri S, *et al*. Health and environmental impact of hospital wastes: Systematic review. *Dubai Med J*. 2023;6(2):103-116. doi: 10.1159/000529432
11. Jang YC. Infectious/medical/hospital waste: General characteristics. In: *Solid Waste Management and Recycling*. Amsterdam: Elsevier; 2024. p. 805-810. doi: 10.1016/B978-0-444-52272-6.00508-0
12. Singh N, Shreshtha I, Nigam VK. Integrated biomedical waste degradation and detoxification. In: Sharma YC, editor. *Integrated Environmental Technologies for Wastewater Treatment and Sustainable Development*. Amsterdam: Elsevier; 2022. p. 481-508.
13. Seilkassymova R, Nurmukhankyzy D, Rzabay A, Baktykhozhaye Z, Nessipbayeva I. Environmental safety and legal regulation of medical waste management: International experience. *J Environ Manag Tour*. 2022;13(7):1853-1860. doi: 10.14505/jemt.v13.7(63).01
14. Kanyal D, Butola LK, Ambad R. Biomedical waste management in India-a review. *J Forensic Med*. 2021;15(2):108-113. doi: 10.37506/ijfmt.v15i2.14285
15. Sheth JK. Salient features of bio-medical waste management rules, 2016. *Indian J Community Health*. 2017;29(1):5-9.
16. Shah C. Biomedical waste management: A move towards green environment. *Asia Pacific J Manag*

*Entrepreneurship Res*. 2012;1(3):136-140.
17. Iyengar V, Islam R. Biomedical, sharps and general waste disposal in India: Potential for the spread of contagious diseases and serious environmental contamination. *Univ J Public Health*. 2017;5(5):236-242. doi: 10.13189/ujph.2017.050509
18. Singh DK, Singh AK. An overview of the new legal regime of bio medical waste management in India. *Asian J Multidimens Res (AJMR)*. 2018;7(7):32-45.
19. Babu BR, Parande AK, Rajalakshmi R, Suriyakala P, Volga M. Management of biomedical waste in India and other countries: A review. *J Int Environ Appl Sci*. 2009;4(1):65-78.
20. National Mission for Clean Ganga. *Telangana - October 2022 to March 2023 MPR*. Ministry of Jal Shakti, Government of India; 2023. Available from: https://nmcg.nic.in/writereaddata/fileupload/ngtmpr/51_telangana%20-%20october%202022%20to%20march%202023%20mpr.pdf [Last accessed on 2024 Jun 21].
21. Palaneswamy S, Srikumar A, Kannan I, Rathinam TP. Assessment of knowledge, attitude, and practices of biomedical waste management among health care workers in a tertiary care hospital, Chengalpattu, Tamilnadu, India. *Int J Occup Saf Health*. 2024;14(1):124-133. doi: 10.3126/ijosh.v14i1.52697
22. Manekar SS, Bakal RL, Jawarkar RD, Charde MS. Challenges and measures during management of mounting biomedical waste in COVID-19 pandemic: An Indian approach. *Bull Natl Res Cent*. 2022;46(1):159. doi: 10.1186/s42269-022-00845-8
23. Thirunavukkarasu A, Al-Hazmi AH, Dar UF, *et al*. Knowledge, attitude and practice towards bio-medical waste management among healthcare workers: A Northern Saudi study. *PeerJ*. 2022;10:e13773. doi: 10.7717/peerj.13773
24. Agarwal AK, Yadav A, Yadav C, Mahore R, Singh AP. A study of awareness about biomedical waste management among health care personnel. *Asian J Manag*. 2022;13(1):31-34. doi: 10.52711/2321-5763.2022.00031
25. Bagali SS, Gowrishankar BS, Bagali SS. A review on biomedical waste management. *Waste Technol*. 2021;9(2):29-33. doi: 10.12962/j23386956.v9i2.10118
26. Balamurugan SS, Priyadarsini SP, Justin R, Sonai RP, Rajeswari B. A descriptive study on knowledge regarding biomedical waste management among health care personnel in a tertiary care hospital. *Natl J Res Community Med*. 2014;3(2):186-191.
27. Bhandari K, Yadav R, Pradhan SR, Singh R, Kushwaha NK. Knowledge regarding biomedical waste management among nursing staffs of teaching hospital at Birgunj, Parsa, Nepal. *Int J Adv Nurs Manag*. 2024;12(1):1-6. doi: 10.52711/2454-2652.2024.00001
28. Mathur V, Dwivedi S, Hassan MA, Misra RP. Knowledge, attitude, and practices about biomedical waste management among healthcare personnel: A cross-sectional study. *Indian J Community Med*. 2011;36(2):143-145. doi: 10.4103/0970-0218.84122
29. Sindhu RK, Kaur H, Sharma K, Dora CP, Batiha GE. Green technologies for handling and management of biomedical waste. In: *Green Technological Innovation for Sustainable Smart Societies: Post Pandemic Era*. Berlin: Springer; 2021. p. 169-189. doi: 10.1007/978-981-16-2435-7_9
30. Singh H, Rehman R, Bumb SS. Management of biomedical waste: A review. *Int J Dent Med Res*. 2014;1(1):14-20.
31. Soni L, Soni P, Soni A. Pre- and post-training study of awareness about biomedical waste management among healthcare personnel in medical college hospital in Western Rajasthan. *IP Int J Med Microbiol Trop Dis*. 2020;6(3):175-178. doi: 10.18231/j.ijmmtd.2020.038
32. Sonkar GK, Singh S, Sonkar SK. Biomedical Waste: Impact on Environment and Its Management in Health Care Facilities. In: *Current Research Trends and Applications in Waste Management*. Singapore: Springer Nature Singapore; 2023. p. 139-159.
33. Twinkle T, Mehta M, Jatesh JK. Safe hands, safe earth: Prioritizing security and sustainability in medical waste management. *Adv Res*. 2024;25(4):10-18. doi: 10.9734/air/2024/v25i41090
34. Dalui A, Banerjee S, Roy R. Assessment of knowledge, attitude, and practice about biomedical waste management among healthcare workers during COVID-19 pandemic in a health district of West Bengal. *Indian J Public Health*. 2021;65(4):345-351. doi: 10.4103/ijph.ijph_1586_20
35. Dutta R, Prashanth R, Parasuraman G, *et al*. Knowledge, attitude and practice of bio-medical waste management among private practitioners in Poonamallee taluk, Chennai. *Int J Community Med Public Health*. 2017;4(8):2930. doi: 10.18203/2394-6040.ijcmph20173363
36. Kapoor D, Nirola A, Kapoor V, Gambhir RS. Knowledge and awareness regarding biomedical waste management in dental teaching institutions in India: A systematic review. *J Clin Exp Dent*. 2014;6(4):e419-e424. doi: 10.4317/jced.51644
37. Ministry of Environment, Forest and Climate Change, India. *Doctors Manual for Environmental Clearance*. Available from: https://moef.gov.in/wp-content/uploads/2019/05/4.-doctorss-manual.pdf [Last accessed on 2024 Jun 21].