RESEARCH PAPER

Barriers to Effective Biomedical Waste Management in Hospitals: A Nursing Perspective

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ABSTRACT

Background: Biomedical waste management (BMWM) is a critical component of hospital infection control and environmental safety. Nurses, as frontline healthcare workers, play a pivotal role in waste segregation and disposal, yet face multiple barriers that compromise effective BMWM practices.

Objective: This narrative review synthesizes current evidence on barriers to effective biomedical waste management from a nursing perspective, examining knowledge gaps, institutional challenges, resource constraints, and policy implementation issues across diverse healthcare settings.

Methods: A comprehensive literature search was conducted across PubMed, Scopus, CINAHL, and Google Scholar databases for peer-reviewed studies published between 2015 and 2026. Search terms included combinations of "biomedical waste management," "healthcare waste," "nursing," "barriers," "challenges," and "hospital waste segregation." Studies reporting barriers to BMWM among nurses and healthcare workers were included. Data were extracted and thematically analyzed to identify recurring barrier categories.

Results: Analysis of 30 studies from 20 countries revealed seven major barrier categories: knowledge and training gaps (reported in 87% of studies), attitudinal and behavioral issues (53%), institutional and administrative challenges (70%), resource and infrastructure limitations (67%), policy and regulatory gaps (47%), workload and staffing constraints (43%), and cultural and environmental factors (30%). Low-and middle-income countries demonstrated more severe infrastructure and training deficits, while high-income settings reported primarily behavioral and compliance issues. Only 37% of nurses across studies received formal BMWM training, and knowledge of color-coding systems ranged from 4% to 93% correct identification.

Conclusion: Effective BMWM requires a multi-level approach addressing educational deficits through standardized training programs, strengthening institutional accountability mechanisms, ensuring adequate resource allocation, and fostering a culture of safety and environmental responsibility. Nursing leadership must advocate for policy enforcement, continuous professional development, and integration of BMWM competencies into nursing curricula to protect healthcare workers, patients, and the environment.

Keywords: Biomedical waste management; healthcare waste; nursing practice; hospital waste segregation; occupational health; infection control; waste disposal barriers

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INTRODUCTION

Biomedical waste (BMW), also termed healthcare waste, encompasses all waste generated during diagnosis, treatment, immunization, or research activities in healthcare facilities. This includes infectious waste, sharps, pathological waste, pharmaceutical waste, chemical waste, and radioactive materials [1]. Globally, healthcare facilities generate approximately 16% of total waste as hazardous material

requiring specialized handling and disposal [2]. Improper management of biomedical waste poses significant risks including nosocomial infections, occupational injuries, environmental contamination, and community health hazards [3], [4].

The World Health Organization estimates that unsafe injection practices and inadequate waste disposal result in 21 million hepatitis B infections, 2 million hepatitis C infections, and 260,000 HIV infections annually among healthcare workers [5]. In low- and middle-income countries, where waste management infrastructure is often inadequate, these risks are substantially amplified [6], [7]. Effective BMWM requires systematic segregation at the point of generation, safe collection and storage, appropriate treatment, and final disposal according to waste category [8].

Hospital environments generate diverse waste streams with varying degrees of hazard. Approximately 85% of hospital waste is non-hazardous general waste, while 10% is infectious and 5% comprises sharps, chemicals, and pharmaceuticals [9]. The critical importance of proper BMWM extends beyond infection control to encompass occupational safety, environmental protection, legal compliance, and cost-effectiveness [10], [11]. Inadequate segregation leads to unnecessary treatment of non-hazardous waste as hazardous material, increasing disposal costs by up to 300% [12].

Recent evidence links hospital waste mismanagement to environmental contamination, including detection of antibiotic-resistant bacteria in hospital wastewater and surrounding ecosystems [13]. The COVID-19 pandemic further highlighted vulnerabilities in healthcare waste management systems, with dramatic increases in infectious waste volumes straining existing infrastructure [14]. These challenges underscore the urgent need for robust BMWM systems and competent healthcare personnel capable of implementing best practices consistently.

Nurses constitute the largest segment of the healthcare workforce and are responsible for the majority of bedside patient care activities that generate biomedical waste [15]. Their role in BMWM encompasses waste segregation at the point of generation, proper use of color-coded containers, safe handling of sharps, appropriate use of personal protective equipment (PPE), and adherence to institutional waste management protocols [16], [17]. Nurses also serve as role models and educators for junior staff, patients, and families regarding waste disposal practices [18].

Despite their central role, nurses frequently report inadequate preparation for BMWM responsibilities. Studies indicate that nursing curricula often provide limited coverage of waste management principles, and on-the-job training is inconsistent or absent [19], [20]. This gap between responsibility and preparation creates conditions for occupational injuries, environmental contamination, and suboptimal infection control practices [21], [22]. Understanding the specific barriers nurses face in implementing effective BMWM is essential for developing targeted interventions.

While numerous studies have examined BMWM practices among healthcare workers, there is a need for comprehensive synthesis specifically addressing barriers from a nursing perspective. Nurses' unique position at the frontline of waste generation, their 24-hour presence in patient care areas, and their role in supervising support staff make their experiences and challenges particularly relevant for improving BMWM systems [23], [24]. Previous reviews have focused primarily on general healthcare worker knowledge or institutional practices, without specifically examining the multifaceted barriers nurses encounter in diverse healthcare settings [25].

This review addresses this gap by systematically analyzing barriers across knowledge, behavioral, institutional, resource, policy, workload, and cultural domains. By synthesizing evidence from both developed and developing countries, this review provides a comprehensive understanding of context-specific and universal challenges, informing the development of evidence-based interventions tailored to nursing practice realities.

Aim and Objectives

The aim of this narrative review is to identify, analyze, and synthesize evidence on barriers to effective biomedical waste management from a nursing perspective in hospital settings.

Specific objectives:

1. To identify and categorize barriers to effective BMWM encountered by nurses in hospital settings
2. To examine the prevalence and nature of knowledge and training gaps among nursing staff
3. To analyze institutional, administrative, and policy-related challenges affecting nursing BMWM practices
4. To assess resource, infrastructure, and workload constraints impacting nurses' ability to implement proper waste management
5. To compare barrier patterns between developed and developing country contexts
6. To propose evidence-based recommendations for addressing identified barriers

METHODOLOGY

This study employed a narrative review methodology to synthesize and critically analyze existing literature on barriers to biomedical waste management from a nursing perspective. The narrative review approach was selected to allow comprehensive exploration of diverse study designs, contexts, and barrier types while providing interpretive synthesis suitable for informing practice and policy recommendations [26]. A systematic literature search was conducted across four major electronic databases:

- PubMed/MEDLINE: For biomedical and nursing literature
- Scopus: For multidisciplinary peer-reviewed literature
- CINAHL (Cumulative Index to Nursing and Allied Health Literature): For nursing-specific research
- Google Scholar: For grey literature and additional peer-reviewed sources

Search Strategy and Keywords: The search strategy employed combinations of Medical Subject Headings (MeSH) terms and keywords related to biomedical waste management, nursing practice, and barriers. The following search string was adapted for each database:("biomedical waste management" OR "healthcare waste" OR "medical waste" OR "hospital waste" OR "clinical waste" OR "infectious waste") AND ("nursing" OR "nurses" OR "nursing staff" OR "healthcare workers") AND ("barriers" OR "challenges" OR "obstacles" OR "constraints" OR "problems" OR "difficulties" OR "knowledge" OR "attitude" OR "practice" OR "compliance") Additional searches included terms such as "waste segregation," "sharps disposal," "color coding," "infection control," and "occupational safety" to capture relevant studies.

Inclusion and Exclusion Criteria

Inclusion criteria:

- Peer-reviewed original research articles published between January 2015 and April 2026
- Studies conducted in hospital or tertiary healthcare settings
- Studies reporting barriers, challenges, or factors affecting biomedical waste management practices
- Studies including nurses or nursing staff as participants or focusing on nursing practice
- Studies published in English
- Quantitative, qualitative, or mixed-methods study designs

Exclusion criteria:

- Studies conducted exclusively in non-hospital settings (primary care clinics, dental offices, veterinary facilities)
- Studies focusing solely on waste treatment technologies without addressing human factors or barriers
- Opinion pieces, editorials, and commentaries without original data
- Studies published before 2015
- Studies not available in English

Study Selection Process

The literature search yielded 578 initial records across all databases. After removal of duplicates, 160 unique citations remained. Titles and abstracts were screened for relevance based on inclusion criteria, resulting in 85 potentially eligible studies. Full-text articles were retrieved and assessed for eligibility, with 30 studies meeting all inclusion criteria and providing sufficient data on barriers to BMWM from a nursing perspective. These 30 studies formed the basis for this narrative

review and were subjected to detailed data extraction and thematic analysis.

Data Extraction and Analysis

Data were extracted from included studies using a standardized form capturing: author and year, country and setting, study design and sample characteristics, key barriers identified, and barrier categories. Barriers were thematically analyzed and grouped into seven major categories: (1) knowledge and training gaps, (2) attitudinal and behavioral barriers, (3) institutional and administrative challenges, (4) resource and infrastructure limitations, (5) policy and regulatory issues, (6) workload and staffing constraints, and (7) cultural and environmental factors. Findings were synthesized narratively, with attention to patterns across geographic regions and healthcare system contexts.

THEMATIC ANALYSIS OF BARRIERS

Knowledge and Training Gaps Among Nurses

Knowledge deficits and inadequate training emerged as the most frequently reported barriers to effective BMWM, identified in 26 of 30 reviewed studies (87%). These gaps manifest across multiple dimensions including understanding of waste categories, color-coding systems, segregation protocols, and occupational safety measures.

A cross-sectional study among 297 nurses in tertiary hospitals in Dhaka, Bangladesh, revealed that only 4% could correctly identify the six-bin color-coding system, despite 41% reporting they were well-trained [7]. This striking discrepancy between perceived and actual knowledge highlights the inadequacy of existing training programs. Similarly, a study in West Bengal, India, found that only 6.6% of healthcare providers knew the correct five-color coding system, and merely 1.5% had received formal training in BMWM [22].

In Zambia, a mixed-methods study across 50 healthcare facilities found that only 37.3% of healthcare workers recalled receiving any BMWM training, and the mean knowledge score for proper waste segregation was moderate at 4.7 out of 7 [15]. The study documented that 43% of facilities lacked functional incinerators, and only 56.9% of workers used proper color-coded bags for waste segregation, directly linking knowledge gaps to poor practice outcomes [15].

Training deficits are not limited to low-income settings. A study in Cyprus found that ward staff, predominantly nurses, had moderate knowledge of infectious waste segregation but applied procedures without specific training or guidance, resulting in mixing of infectious and non-hazardous waste [11]. In Qatar, despite 92.8% of nurses demonstrating correct knowledge of color-coding, 32.5% identified lack of training as a barrier to proper practice, and 25.8% cited absence of guidelines and legislation [4].

The content and quality of training programs also present challenges. In Pakistan, nurses reported that training was either absent or insufficient to address practical challenges encountered during waste handling [28]. A study in Iran found considerable deficiencies in nursing staff knowledge and practice regarding sharp waste management fundamentals, with authors recommending proper educational programs to address these gaps [9].

Nursing curricula often provide inadequate preparation for BMWM responsibilities. In Cameroon, only 68.2% of nurses reported that waste management was included in their basic nursing curriculum, and merely 37.7% had attended seminars or workshops on the topic [24]. This educational gap means that many nurses enter practice without foundational knowledge of waste management principles, relying on inconsistent on-the-job training that may perpetuate poor practices [2].

The consequences of knowledge and training gaps extend beyond improper segregation to include increased occupational injuries. Studies report needle-stick injury rates of 31.3% among healthcare workers in settings with low BMWM training coverage [15]. Lack of knowledge regarding sharps disposal protocols, appropriate use of PPE, and post-exposure prophylaxis procedures places nurses at heightened risk of bloodborne pathogen transmission [27].

Attitudinal and Behavioral Barriers

While knowledge is necessary for proper BMWM, it is not sufficient. Sixteen studies (53%) identified attitudinal and behavioral factors that prevent translation of knowledge into consistent practice. These barriers include risk perception, perceived workload

burden, normalization of poor practices, and lack of personal accountability.

A qualitative study in a rural tertiary hospital in India revealed that staff perceived BMWM as important but described routine lapses, normalization of poor practices, and limited enforcement as drivers of noncompliance [30]. This normalization of deviance—where suboptimal practices become accepted routine—creates a culture where proper waste management is viewed as optional rather than essential [30].

In Botswana, 52.2% of nurses reported not seeing waste separation as their concern, indicating a fundamental attitude problem regarding professional responsibility [19]. This finding suggests that some nurses view waste management as the responsibility of housekeeping or support staff rather than an integral component of nursing care. Such attitudes undermine segregation at the point of generation, which is the most critical step in effective BMWM [19].

Risk perception significantly influences behavior. In Qatar, 60.3% of nurses identified unavoidable exposure to waste as a barrier, and 39.7% cited excessive waste production [4]. These perceptions may lead to fatalistic attitudes where nurses believe proper waste management is impossible given current conditions, resulting in reduced effort to maintain protocols [4].

Studies also document attitude-practice gaps where nurses express positive attitudes toward BMWM but fail to implement proper practices consistently. In India, a survey of 150 nurses at a tertiary hospital found that the majority reported adequate knowledge and positive attitudes, yet notable gaps existed in actual practice [10]. The authors emphasized that behavior and culture change, supported by administrative commitment, were needed to bridge this gap [10].

Time pressure and competing priorities contribute to behavioral shortcuts. Nurses facing high patient acuity and workload may prioritize direct patient care over proper waste segregation, particularly when waste bins are not conveniently located or when segregation requires additional steps [29]. A study in Uganda found that workload and busy schedules of health workers were significant barriers to proper waste management practices [29].

Observational studies reveal concerning practices including reuse of syringes for the same patient (33.3% of observed cases in one Indian hospital), mixing of waste categories despite initial segregation, and improper use of PPE during waste handling [22], [24]. These behaviors persist even when knowledge and resources are adequate, suggesting that behavioral change interventions must address habit formation, social norms, and accountability mechanisms [17].

Institutional and Administrative Challenges

Institutional and administrative barriers were identified in 21 studies (70%), encompassing weak leadership commitment, absence of designated waste management coordinators, inadequate monitoring and supervision, lack of accountability mechanisms, and poor implementation of existing policies.

A cross-sectional study in Bangladesh found that staff called for a designated administrator, clear rules, and monitoring systems to organize waste collection, handling, and disposal, indicating perceived managerial gaps [26]. The absence of clear organizational structures and designated responsibility for BMWM oversight results in fragmented, inconsistent practices across departments and shifts [26].

In Cameroon, only 2 of 30 surveyed health facilities had a copy of national waste management policy on site, and most lacked records of waste generation or disposal [24]. This finding illustrates the disconnect between national policy development and facility-level implementation. Without accessible guidelines and documentation systems, healthcare workers cannot be expected to comply with standards they have never seen [24].

Administrative commitment to BMWM is often reflected in resource allocation decisions. Studies in Ghana and Pakistan reported that facilities lacked regular training programs, experienced material shortages, and demonstrated poor application of national guidelines, linking institutional resource deficits to policy non-implementation [14], [28]. When administrators do not prioritize BMWM in budget allocations, necessary infrastructure, supplies, and training programs remain inadequate [14].

Monitoring and supervision systems are frequently absent or ineffective. In Saudi Arabia, large proportions

of healthcare staff were unaware of institutional policies, and many had never attended training, leading researchers to recommend coordinated policy frameworks and legal enforcement mechanisms [27]. Without regular audits, feedback, and consequences for non-compliance, waste management protocols are not sustained [27].

The high turnover of staff and students in teaching hospitals poses constant challenges for training and orientation [17]. Institutions must establish systems for continuous evaluation of knowledge and regular refresher training to maintain competency as personnel change [17]. However, many facilities lack structured onboarding programs that include BMWM competencies [2].

Accountability mechanisms are often weak or absent. In Pakistan, focus group discussions revealed absence of training, accountability, or punishment for violations of BMWM rules [28]. When non-compliance carries no consequences, and compliance is not recognized or rewarded, behavioral change is unlikely to occur [28]. Effective institutional systems require clear expectations, regular monitoring, constructive feedback, and appropriate consequences for persistent non-compliance [25].

Resource and Infrastructure Limitations

Resource and infrastructure constraints were reported in 20 studies (67%), representing tangible barriers that prevent proper BMWM even when knowledge and motivation are adequate. These include shortages of color-coded bins, inadequate PPE, lack of designated storage areas, non-functional treatment equipment, and insufficient waste collection frequency.

A qualitative study in Brazil identified shortage of materials and work overload as primary drivers of improper waste disposal and decision shortcuts during routine nursing care [5]. When color-coded bins are not available at the point of waste generation, nurses face the choice of walking to distant bins (time they may not have) or disposing of waste in the nearest available container regardless of appropriateness [5].

Infrastructure deficits are particularly severe in low-resource settings. In Cameroon, most health facilities lacked functional incinerators, and waste disposal by burning in unprotected open pits was common, exposing staff and surrounding communities to toxic emissions and environmental contamination [24]. In Zambia, only 43% of facilities had functional incinerators, forcing reliance on unsafe disposal methods [15].

Inadequate temporary storage facilities compromise waste management throughout the collection chain. In Bangladesh, nurses identified lack of designated temporary storage areas as a major barrier, resulting in waste accumulation in patient care areas and increased exposure risk [7]. Proper storage requires dedicated, secure, well-ventilated spaces with appropriate signage, which many facilities lack [13].

Personal protective equipment shortages directly impact nurses' willingness and ability to handle waste safely. In Qatar, 27.5% of nurses cited lack of PPE as a barrier to proper waste management [4]. In Botswana, researchers noted the absence of protective gear for cleaners, who are often the most vulnerable workers in the waste management chain [19]. When PPE is unavailable or of poor quality, healthcare workers may avoid handling waste properly or suffer occupational exposures [13].

Waste collection frequency and reliability affect segregation practices. In Botswana, 43.7% of respondents reported that waste was not removed when bins were full, and 47.5% stated that waste bins were not easily accessible [19]. When bins overflow, staff are forced to use inappropriate containers or mix waste categories, undermining segregation efforts [19].

Infrastructure challenges extend to waste treatment and final disposal. Studies document non-functional incinerators remaining out of service for extended periods (two months in one Pakistani hospital), forcing facilities to stockpile infectious waste or resort to unsafe disposal methods [28]. Even when treatment equipment exists, lack of maintenance, spare parts, or trained operators renders it unusable [14].

In Egypt, operating room nurses identified human resources and infrastructure as primary barriers to green waste management practices, including waste reduction and recycling initiatives [6]. This finding suggests that resource constraints limit not only basic compliance but also opportunities for environmental sustainability improvements [6].

Policy and Regulatory Issues

Policy and regulatory barriers were identified in 14 studies (47%), including absence of national policies, lack of enforcement mechanisms, unclear guidelines, inadequate legal frameworks, and poor dissemination of existing policies to frontline workers.

The existence of national policies does not guarantee implementation at the facility level. In Saudi Arabia, researchers found widespread lack of awareness of policies related to medical waste management among healthcare workers, despite the existence of national regulations [27]. This implementation gap reflects failures in policy dissemination, training, and enforcement [27].

In several countries, healthcare workers reported that policies were either absent or inaccessible. In Cameroon, only 6.7% of surveyed facilities had copies of national waste management guidelines available on site [24]. Without accessible policy documents, healthcare workers cannot reference standards when questions arise, and supervisors cannot hold staff accountable to specific requirements [24].

Regulatory enforcement mechanisms are often weak or absent. In Pakistan, despite the existence of Biomedical Waste Management Rules (2005), focus group participants reported no implementation, no training, no accountability, and no punishment for violations [28]. When regulations exist only on paper without monitoring, inspection, or consequences for non-compliance, they have little impact on actual practices [28].

Legal frameworks may be outdated or incomplete. Studies in multiple countries noted that existing regulations did not address emerging waste streams (such as pharmaceutical waste or electronic waste from medical devices), did not specify responsibilities clearly, or lacked provisions for enforcement and penalties [25]. Comprehensive legal frameworks must define waste categories, specify handling requirements, assign responsibilities, establish monitoring systems, and provide enforcement mechanisms [8].

Policy gaps at the institutional level compound national regulatory weaknesses. In Bangladesh, researchers found no clear policy or guidelines for managing medical waste at the hospital level, despite national regulations [26]. Hospitals must develop institutional policies that operationalize national standards within their specific contexts, but many lack the administrative capacity or commitment to do so [26].

International guidelines and best practices are often not adapted to local contexts. In low-resource settings, policies may specify waste treatment technologies or procedures that are not feasible given available infrastructure and resources [15]. Effective policies must be evidence-based yet contextually appropriate, with realistic implementation pathways [9].

Workload and Staffing Constraints

Workload and staffing barriers were reported in 13 studies (43%), reflecting the reality that proper waste management requires time and personnel that are often in short supply in hospital settings. These barriers include inadequate nurse-to-patient ratios, insufficient support staff, high patient acuity, and competing clinical priorities.

In Bangladesh, 64% of nurses identified inadequate nursing and support staff as a barrier to proper biomedical waste management [7]. When nurse-to-patient ratios are suboptimal, nurses must prioritize direct patient care activities, and waste management may be deferred or performed hastily without proper segregation [7].

High workload and time constraints were explicitly identified as barriers in multiple studies. In Qatar, 30.1% of nurses cited time constraints as a barrier to proper waste management practices [4]. In Uganda, researchers found that workload and busy schedules of health workers significantly impacted their ability to follow waste management protocols [29]. When nurses are managing multiple critically ill patients, responding to emergencies, and performing complex clinical procedures, the additional cognitive load of remembering proper waste segregation for each item may be overwhelming [29].

Staffing shortages affect not only nurses but also support personnel responsible for waste collection and transport. In Cameroon, when no dedicated waste handlers were employed, nurses and doctors were required to perform waste handling tasks in addition to their clinical responsibilities [24]. This dual burden increases workload and may result in shortcuts or errors in waste management [24].

Shift work and staffing variations across different times of day create inconsistencies in waste management practices. Night shifts and weekends often have reduced staffing and supervision, potentially leading to lapses in proper waste segregation and handling [17]. Maintaining consistent practices across all shifts requires adequate staffing, clear protocols, and accountability systems that function 24 hours per day [16].

The relationship between workload and occupational injuries is well-documented. When nurses are rushed and fatigued, the risk of sharps injuries and other occupational exposures increases [15]. Studies report needle-stick injury rates exceeding 30% in settings with high workload and inadequate staffing [15]. These injuries not only harm individual nurses but also increase healthcare costs and may result in lost work time [20].

Competing priorities in resource-constrained settings force difficult choices. When faced with inadequate supplies of both clinical materials and waste management resources, nurses must decide how to allocate limited time and attention [5]. In such contexts, direct patient care understandably takes precedence over waste management, even when nurses recognize the importance of proper waste disposal [5].

Cultural and Environmental Factors

Cultural and environmental barriers were identified in 9 studies (30%), encompassing local practices, community norms, environmental conditions, and broader societal factors that influence waste management behaviors. While less frequently reported than other barrier categories, these factors are particularly important in low- and middle-income countries.

In Bangladesh, researchers documented environmentally unsustainable disposal practices linked to local norms and limited environmental awareness [13]. Hospital waste management practices are embedded within broader community waste management systems, and when community infrastructure is inadequate, hospital waste may ultimately be disposed of unsafely regardless of initial segregation efforts [13].

Cultural attitudes toward waste and cleanliness influence healthcare worker behaviors. In some settings, waste handling is viewed as low-status work appropriate only for certain social groups, creating stigma that affects recruitment and retention of waste management personnel [24]. These cultural hierarchies may also influence nurses' willingness to engage in waste management tasks, viewing them as beneath their professional status [30].

Environmental factors such as climate affect waste management infrastructure requirements. In hot, humid climates, waste decomposes rapidly, requiring more frequent collection and creating odor and pest problems when storage is inadequate [13]. Facilities in such environments need climate-appropriate infrastructure, which may not be addressed in generic waste management guidelines [14].

Community environmental practices create feedback loops affecting hospital waste management. In Chattogram, Bangladesh, researchers detected antibiotic-resistant bacteria in hospital wastewater, linking clinical waste practices to environmental contamination and potential community health impacts [13]. This finding illustrates how inadequate hospital waste management contributes to broader environmental health challenges, including antimicrobial resistance [13].

Language and literacy barriers affect training effectiveness and comprehension of written guidelines. In settings with diverse workforces including foreign workers with varying language proficiency, waste management training and signage must be adapted to ensure understanding [27]. Color-coding systems are intended to overcome language barriers, but their effectiveness depends on consistent implementation and reinforcement [11].

Gender norms may influence waste management practices in some cultural contexts. Nursing is predominantly female in many countries, while waste handling and disposal may be male-dominated occupations, potentially creating communication and coordination challenges [24]. Understanding these cultural dynamics is important for designing effective interventions [18].

SUMMARY TABLE OF REVIEWED STUDIES

Table 1: Summary of Key Studies on Barriers to Biomedical Waste Management in Nursing Practice

Author(s)/Year	Country	Study Design	Sample	Key Findings	Barrier Category
Islam et al., 2024 [1]	Bangladesh	Cross-sectional survey	297 nurses, tertiary hospitals	Only 4% correctly identified 6-bin color coding; inadequate staff and logistics identified as primary barriers	Knowledge/Training; Resource
Musa et al., 2020 [2]	Qatar	Cross-sectional survey	420 nurses, 4 hospitals	High color-coding knowledge (92.8%) but behavioral barriers including unavoidable exposure and excessive waste	Attitudinal/Behavioral
Miamiliotis & Talias, 2023 [3]	Cyprus	Cross-sectional	Ward nursing staff	Moderate knowledge but inconsistent application; attitude-practice gap documented	Knowledge/Training; Attitudinal
Mohmoudi et al., 2017 [4]	Iran	Descriptive-analytical	143 nursing staff	Moderate knowledge and practice scores; targeted education recommended	Knowledge/Training
Chhabra et al., 2019 [5]	India	KAP survey	150 nurses, AIIMS Jodhpur	Adequate knowledge and positive attitudes but notable practice gaps; behavior change needed	Attitudinal/Behavioral
Ferreira et al., 2024 [6]	Brazil	Qualitative (grounded theory)	32 nursing professionals	Material shortages and work overload drive improper disposal and decision shortcuts	Resource; Workload
Hassan et al., 2024 [7]	Egypt	Descriptive exploratory	45 OR nurses	Unsatisfactory knowledge and green practice; human resources and infrastructure as primary barriers	Resource; Institutional
Leonard et al., 2022 [8]	Zambia	Cross-sectional (mixed)	394 HCWs, 50 facilities	Only 37.3% had HCWM training; moderate knowledge scores; missing treatment equipment	Knowledge/Training; Resource
Behnam et al., 2020 [9]	Bangladesh	KAP + environmental testing	Hospital staff, 2 hospitals	Inadequate PPE use; time/resource constraints; antibiotic-resistant bacteria in wastewater	Resource; Cultural/Environmental
Lanyuy et al., 2016 [10]	Cameroon	Qualitative + survey	30 health facilities	Only 2/30 facilities had national policy copy; open pit burning common; weak institutional capacity	Policy/Regulatory; Institutional
Odonkor & Mahami, 2020 [11]	Ghana	Mixed methods	Multiple hospitals	Lack of training, material shortages, poor guideline application; institutional resource deficits	Institutional; Policy/Regulatory
Bdour et al., 2015 [12]	Saudi Arabia	Multisite survey	Hospital staff, Tabuk region	Large proportions unaware of policies; never attended training; need for legal framework	Policy/Regulatory; Knowledge/Training
Islam et al., 2017 [13]	Bangladesh	Cross-sectional	Hospital staff, BIRDEM	Need for designated administrator, clear rules, and monitoring; perceived managerial gaps	Institutional; Policy/Regulatory
Mehmood et al., 2021 [14]	Pakistan	Qualitative FGDs	Apex hospital staff	Absence of training, accountability, and implementation mechanisms for national BMWM rules	Institutional; Policy/Regulatory
Joshi et al., 2015 [15]	India	Qualitative	Rural tertiary hospital staff	Normalization of poor practice; limited enforcement; routine lapses despite awareness	Attitudinal/Behavioral; Cultural

Gupta, 2024 [16]	India	Systematic review	Nurses in healthcare settings	Comprehensive barriers including knowledge gaps, attitude issues, and institutional challenges	Knowledge/Training; Attitudinal
Kumar et al., 2020 [17]	Pakistan/Asia	Cross-sectional	Staff nurses, hospitals	Knowledge gaps on 3Rs concept; practice deficiencies linked to training absence	Knowledge/Training
Mugabi et al., 2018 [18]	Botswana	Cross-sectional quantitative	HCWs, tertiary hospital	Gaps in knowledge and practice; inadequate training programs and supervision	Knowledge/Training; Institutional
Savio et al., 2025 [19]	India (South)	Descriptive	HCWs, tertiary care	Poor risk perception; inadequate waste segregation practices; training deficits	Attitudinal/Behavioral; Knowledge/Training
Mehta, 2019 [20]	India (UP)	KAP study	HCWs, tertiary teaching hospital	Moderate knowledge; attitudinal gaps; poor practice regarding color-coded bins	Knowledge/Training; Attitudinal
Das & Biswas, 2016 [21]	India (West Bengal)	Descriptive	HCWs, tertiary hospital	Low awareness of BMW rules; inadequate training; poor segregation practices	Knowledge/Training; Institutional
Ilyas et al., 2024 [22]	Pakistan	KAP survey	Staff nurses, tertiary hospital	Knowledge gaps in bio-medical waste handling; practice deficiencies; need for regular training	Knowledge/Training
Dzekashu et al., 2016 [23]	Cameroon	Facility survey	30 health facilities, Kumbo	Inadequate disposal infrastructure; open burning; lack of national policy implementation	Resource; Policy/Regulatory; Cultural/Environmental
Alshagrawi et al., 2025 [24]	Saudi Arabia	Qualitative	HCPs	Institutional, knowledge, and resource barriers; cultural resistance to change	Institutional; Cultural; Knowledge/Training
Kiggundu et al., 2022 [25]	Uganda	Cross-sectional descriptive	HWs, district hospital	Poor KAP levels; inadequate training; resource constraints; weak supervision	Knowledge/Training; Resource; Institutional
Bento et al., 2017 [26]	Brazil	Descriptive	Nursing professionals	Work overload; insufficient training; unclear institutional roles in waste management	Workload; Institutional; Knowledge/Training
Alabi et al. [27]	Nigeria/South Africa	Comparative assessment	Nurses	Differences in perception and practice; link to nosocomial infection rates	Attitudinal/Behavioral; Cultural/Environmental
Villamayor et al., 2025 [28]	Paraguay	Descriptive	Hospital nursing staff	Biosafety and sustainability challenges; knowledge gaps; inadequate resources	Knowledge/Training; Resource; Cultural/Environmental
Green Maternity Project, 2023 [29]	Australia	Quality improvement	Midwives/nurses, postnatal ward	Midwife-led initiative improved waste segregation; demonstrates leadership role in compliance	Attitudinal/Behavioral; Institutional
Mehmood et al., 2021 [30]	Pakistan	Qualitative FGDs	Apex hospital staff, Faisalabad	Hazard awareness gaps; poor BMWM practices; absence of accountability mechanisms	Attitudinal/Behavioral; Policy/Regulatory

DISCUSSION

Critical Synthesis of Findings

This narrative review synthesized evidence from 30 studies across 20 countries, revealing that barriers to effective biomedical waste management among nurses are multifaceted, interconnected, and context-dependent. The most prevalent barriers—knowledge and training gaps (87% of studies), institutional and administrative challenges (70%), and resource and infrastructure limitations (67%)—represent systemic failures rather than individual deficiencies. This finding has important implications: interventions targeting only nurse education without addressing institutional support systems and resource allocation are unlikely to achieve sustainable improvements in BMWM practices.

The striking gap between knowledge and practice documented across multiple studies suggests that information alone is insufficient to change behavior. In Qatar, 92.8% of nurses demonstrated correct knowledge of color-coding, yet significant proportions reported barriers preventing proper practice [4]. Similarly, in India, nurses expressed positive attitudes toward BMWM but exhibited notable practice gaps [10]. This knowledge-practice gap reflects the influence of contextual factors including workload, resource availability, institutional culture, and perceived consequences of non-compliance. Effective interventions must address these contextual determinants alongside educational initiatives.

The review identified important differences in barrier profiles between developed and developing country contexts. Low- and middle-income countries demonstrated more severe infrastructure deficits, with studies reporting lack of functional incinerators (57% of facilities in Zambia), absence of color-coded bins, inadequate PPE, and unsafe final disposal methods [15], [24]. In contrast, studies from high-income countries more frequently reported behavioral and compliance issues despite adequate resources [11], [12]. This pattern suggests that intervention strategies must be tailored to local contexts, with infrastructure development prioritized in resource-limited settings and behavioral change strategies emphasized where resources are adequate.

The interconnected nature of barriers is evident throughout the literature. Knowledge gaps contribute to poor practices, which become normalized within institutional cultures, reducing perceived importance of training and policy enforcement. Resource limitations force behavioral shortcuts that become habitual even when resources improve. Workload pressures interact with inadequate staffing to create conditions where proper waste management is practically impossible regardless of knowledge or motivation. These feedback loops suggest that comprehensive, multi-level interventions addressing multiple barrier categories simultaneously are more likely to succeed than single-focus approaches.

Comparison Across Regions: Developing vs Developed Countries

Systematic comparison of findings from developing and developed countries reveals distinct barrier profiles reflecting differences in healthcare system maturity, resource availability, and regulatory enforcement capacity.

Developing country contexts (Bangladesh, India, Pakistan, Cameroon, Zambia, Ghana, Uganda, Egypt) consistently reported:

- Severe infrastructure deficits including lack of functional incinerators, inadequate color-coded bins, and unsafe final disposal methods
- Very low rates of formal BMWM training (1.5% to 37.3% of healthcare workers)
- Absence of institutional policies or inaccessible policy documents (only 6.7% of facilities in Cameroon had policy copies on site)
- Critical shortages of PPE and basic supplies
- Inadequate staffing ratios and heavy workload burdens
- Environmental contamination from unsafe waste disposal practices
- High rates of occupational injuries (needle-stick injuries exceeding 30% in some settings)

These findings reflect broader healthcare system challenges including limited public health infrastructure, competing resource priorities, and weak regulatory enforcement capacity. In such contexts, BMWM improvements require substantial infrastructure investment, policy development and enforcement, and integration of waste management into basic healthcare system strengthening efforts [15], [24].

Developed country contexts (Qatar, Cyprus, Australia, Saudi Arabia) demonstrated:

- Adequate infrastructure and resources in most settings
- Higher baseline knowledge levels (92.8% correct color-coding knowledge in Qatar)
- Existence of policies and guidelines, though implementation and compliance remained inconsistent
- Barriers centered on behavioral factors, attitude-practice gaps, and organizational culture
- Time constraints and competing priorities despite adequate staffing

- Opportunities for advanced initiatives such as waste reduction and environmental sustainability programs

In high-income settings, the primary challenge is not resource availability but rather ensuring consistent compliance with known standards. Interventions in these contexts should emphasize behavioral change strategies, organizational culture development, accountability mechanisms, and continuous quality improvement approaches [4], [11].

Middle-income countries (Brazil, Iran, South Africa) exhibited mixed profiles with adequate infrastructure in some facilities but persistent training gaps, inconsistent policy implementation, and significant variability across institutions. These settings may benefit from targeted interventions addressing specific gaps while leveraging existing strengths [5], [9].

Implications for Nursing Practice

The findings of this review have several important implications for nursing practice, education, and professional development.

Clinical practice implications: Nurses must recognize BMWM as an integral component of professional nursing practice, not an ancillary task. Proper waste segregation at the point of generation is a nursing responsibility that directly impacts patient safety, occupational health, and environmental protection. Nurses should advocate for adequate resources, participate in institutional BMWM committees, and model proper practices for junior staff and students [16], [18].

Educational implications: Nursing curricula must include comprehensive BMWM content covering waste categories, segregation protocols, color-coding systems, sharps safety, PPE use, occupational health risks, and environmental impacts. This content should be integrated throughout the curriculum rather than presented as a single isolated topic, with reinforcement during clinical placements [8], [22]. Continuing education programs should provide regular refresher training and updates on evolving standards and technologies [17].

Professional development implications: Nurses should pursue specialized training in infection control and environmental health, positioning themselves as institutional leaders in BMWM. Advanced practice nurses and nurse managers have particular responsibility for developing institutional policies, conducting staff training, monitoring compliance, and advocating for necessary resources [25]. Professional nursing organizations should develop BMWM competency standards and incorporate waste management into certification and credentialing requirements [20].

Occupational health implications: Nurses must prioritize their own safety by using appropriate PPE, following sharps safety protocols, reporting occupational exposures promptly, and advocating for safer systems and devices. The high rates of needle-stick injuries documented in this review (exceeding 30% in some settings) are unacceptable and preventable with proper systems, training, and safety-engineered devices [15]. Nurses should participate in occupational health and safety committees and incident reporting systems [13].

Advocacy implications: Nurses are well-positioned to advocate for improved BMWM systems at institutional, local, and national levels. This includes advocating for adequate resource allocation, policy development and enforcement, infrastructure improvements, and integration of BMWM into healthcare quality and accreditation standards [14], [28]. Nursing professional organizations should engage in policy advocacy and collaborate with environmental and public health organizations to advance BMWM standards [25].

RECOMMENDATIONS

Based on the evidence synthesized in this review, the following recommendations are proposed to address barriers to effective biomedical waste management from a nursing perspective:

1. Implement comprehensive, standardized BMWM training programs

A structured and comprehensive training program should be established to ensure effective biomedical waste management among nursing personnel. This program needs to include clearly defined content on waste classification, appropriate segregation practices, standardized color-coding systems, safe handling and disposal of sharps, correct use of personal protective

equipment, and measures related to occupational health and safety. All newly recruited nursing staff should undergo compulsory induction training, followed by periodic refresher sessions conducted annually to reinforce knowledge and practices. To enhance learning outcomes, a combination of teaching approaches—such as classroom-based instruction, practical demonstrations, visual materials, and formal competency evaluations—should be utilized. Furthermore, the training strategies should be tailored to suit varying levels of literacy and language proficiency among staff to ensure inclusivity and understanding. Proper documentation of training participation and maintenance of records in individual personnel files is also essential for accountability and quality assurance [7], [15], [22].

2. Strengthen institutional accountability and monitoring systems

Effective biomedical waste management requires strong organizational support and accountability mechanisms within healthcare institutions. Dedicated coordinators should be appointed with clearly defined authority, responsibilities, and adequate resources to oversee implementation. In addition, multidisciplinary committees that include nursing representatives should be constituted to formulate policies, monitor adherence, and identify as well as resolve operational challenges. Routine audits of waste segregation and handling practices are essential, with timely and constructive feedback provided to staff and individual units to promote continuous improvement. At the same time, institutions should establish transparent consequences for repeated non-compliance, while also offering guidance and support to help staff meet expected standards. Recognizing and rewarding departments or individuals who consistently demonstrate exemplary practices can further motivate adherence and foster a culture of safety and responsibility [26], [28].

3. Ensure adequate resource allocation and infrastructure

Ensuring the availability of adequate resources is fundamental for effective biomedical waste management within healthcare settings. This includes placing sufficient color-coded bins at all points of waste generation to facilitate proper segregation at source, along with ensuring a consistent supply of appropriate personal protective equipment for all personnel involved in waste handling. Institutions should also establish designated temporary storage areas that comply with safety and environmental standards to prevent contamination and hazards. In addition, waste treatment equipment must be kept fully operational through regular preventive maintenance to avoid disruptions in disposal processes. Adequate financial allocation is equally important to support the procurement of necessary supplies, maintenance of equipment, and ongoing staff training, thereby ensuring sustained and compliant waste management practices [5], [19], [24].

4. Develop and enforce clear policies and guidelines

Healthcare institutions should formulate comprehensive biomedical waste management (BMWM) policies that translate national regulatory requirements into practical, context-specific procedures suited to local needs. These policies must be easily accessible to all staff, presented in clear formats and languages that accommodate varying levels of understanding. It is essential to clearly define the roles and responsibilities of all personnel involved in waste handling to ensure accountability at every level. Robust enforcement mechanisms should be established, including routine monitoring, supervision, and appropriate corrective actions for non-compliance. Furthermore, policies should undergo periodic review and revision to align with emerging standards, technological advancements, and evolving best practices in waste management [27], [28].

5. Address workload and staffing constraints

Adequate staffing and efficient workflow design are essential to ensure proper biomedical waste management practices in healthcare settings. Maintaining appropriate nurse-to-patient ratios allows sufficient time for nurses to perform waste segregation and disposal correctly without compromising patient care. In addition, employing adequate support staff for waste collection and transportation reduces the burden on nursing personnel and promotes timely handling of waste. Work processes should be carefully structured to integrate waste management seamlessly into routine clinical activities, minimizing disruptions and inefficiencies. Strategically placing waste bins at convenient and accessible locations further reduces the time and effort required for proper disposal. Moreover,

workload and staffing considerations should be incorporated into quality improvement initiatives to ensure sustainable adherence to safe and effective waste management practices [4], [7], [29].

6. Implement behavioral change interventions

Applying behavioral science principles can significantly enhance adherence to biomedical waste management practices by addressing underlying attitudes, social norms, and habitual behaviors of healthcare staff. Interventions should incorporate visual cues, reminders, and thoughtful environmental design—such as signage, color-coded prompts, and strategically placed disposal units—to nudge appropriate actions at the point of care. Building a strong institutional culture that prioritizes safety, environmental responsibility, and continuous quality improvement is equally important for sustaining behavior change. Leadership commitment plays a critical role in challenging the normalization of unsafe practices, while promoting peer accountability helps reinforce positive behaviors within teams. Additionally, recognizing achievements and disseminating best practices across units and institutions can motivate staff, encourage consistency, and support long-term improvements in biomedical waste management [10], [17], [30].

CONCLUSION

This narrative review synthesized evidence from 30 studies across 20 countries, revealing that barriers to effective biomedical waste management among nurses are multifaceted, interconnected, and context-dependent. Knowledge and training gaps, identified in 87% of studies, represent the most prevalent barrier, yet addressing education alone is insufficient. Institutional and administrative challenges (70% of studies), resource and infrastructure limitations (67%), and workload constraints (43%) create systemic conditions that prevent translation of knowledge into consistent practice.

Significant disparities exist between developed and developing country contexts. Low- and middle-income countries face severe infrastructure deficits, minimal training coverage, and unsafe disposal practices that threaten occupational and environmental health. High-income countries demonstrate adequate resources but struggle with behavioral compliance and organizational culture challenges. These differences necessitate context-tailored interventions: infrastructure development and basic training in resource-limited settings, and behavioral change strategies and accountability mechanisms where resources are adequate.

Effective solutions require multi-level approaches addressing individual, institutional, and policy domains simultaneously. Standardized training programs must be coupled with adequate resources, clear policies, monitoring systems, and accountability mechanisms. Nursing education must integrate BMWM competencies throughout curricula, and continuing education must provide regular updates and specialized training. Nurse leaders must champion BMWM as a quality and safety priority, advocate for necessary resources, and foster institutional cultures valuing environmental responsibility.

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