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REVIEW ARTICLE

Healthcare Waste Management in Bangladesh: A Review of Environmental and Health Impacts

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ABSTRACT

Biomedical waste management has become a critical public health and environmental concern in Bangladesh due to rapid urbanization, growing healthcare infrastructure, and increasing patient flow. Improper handling, segregation, treatment, and disposal of BMW pose significant risks, including soil, water, and air contamination, occupational hazards for healthcare and waste management personnel, and broader public health implications. This review synthesizes current research, policy documents, and institutional reports from 2010 to 2024 to provide a comprehensive overview of biomedical waste generation patterns, management practices, environmental and health impacts, and regulatory frameworks in Bangladesh. Key challenges such as inadequate training, weak enforcement of regulations, insufficient infrastructure, and limited public awareness are highlighted. Recommendations for sustainable management include strict policy adherence, capacity-building programs, investment in modern treatment technologies, public-private partnerships, and environmental monitoring. This review underscores the urgent need for integrated, evidence-based strategies to ensure safe biomedical waste management and protect both human health and the environment in Bangladesh.

Keywords: Biomedical Waste; Waste Management; Environmental Safety; Public Health; Bangladesh

1. Introduction

Biomedical waste refers to all types of waste generated during the diagnosis, treatment, immunization, and research activities involving humans and animals in healthcare facilities such as hospitals, clinics, laboratories, blood banks, veterinary institutions, and research centers. This includes infectious materials, sharps, pathological tissues, pharmaceutical residues, chemical waste, and radioactive substances, all of which pose varying degrees of risk to human health and the environment. With the rapid advancement of modern healthcare systems, the volume and complexity of biomedical waste have increased significantly worldwide, making its proper management a critical environmental and public health issue[1].

Globally, approximately 10–25% of total healthcare waste is considered hazardous; however, in

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developing countries like Bangladesh, this proportion is often higher due to inadequate waste segregation, insufficient infrastructure, and limited awareness among healthcare workers. Improper handling, transportation, and disposal of biomedical waste can lead to severe health consequences, including the transmission of blood-borne diseases such as Human Immunodeficiency Virus (HIV), Hepatitis B virus (HBV), and Hepatitis C virus (HCV). In addition, chemical and pharmaceutical wastes contribute to toxic contamination of soil, water, and air, resulting in long-term ecological damage and increased human exposure to carcinogenic and hazardous substances[2].

In Bangladesh, biomedical waste generation has increased rapidly in recent decades due to the expansion of healthcare institutions, rising population density, urbanization, increased patient attendance, and the rapid growth of diagnostic laboratories and private clinics. The COVID-19 pandemic further intensified this situation by generating massive volumes of waste from personal protective equipment (PPE), testing materials, syringes, and disposable medical supplies. This unprecedented rise in medical waste has further strained the already limited waste management infrastructure in the country[3].

The World Health Organization (WHO)[4] has emphasized that unsafe disposal practices, such as open dumping and uncontrolled burning, release highly toxic pollutants including dioxins, furans, and heavy metals into the environment. These pollutants contaminate air, surface and groundwater, and agricultural soil, thereby endangering both ecosystem stability and human health. In the context of Bangladesh, where healthcare waste often ends up in municipal landfills or is handled by informal recycling sectors, the risk of environmental contamination and infection transmission becomes even more severe[5]. Therefore, effective biomedical waste management is not only essential for protecting public health but also crucial for ensuring long-term environmental sustainability in Bangladesh.

2. Methodology

This review adopted a qualitative, literature-based approach to evaluate the current status, challenges, and environmental and health implications of biomedical waste management (BMWM) in Bangladesh. The primary objective was to synthesize existing research, policy documents, and institutional reports to provide a comprehensive understanding of trends, gaps, and opportunities for sustainable waste management.

Relevant literature published between 2010 and 2024 was systematically collected from databases and sources including Google Scholar, PubMed, ResearchGate, and organizational reports from the World Health Organization (WHO), Department of Environment (DoE), Ministry of Health and Family Welfare, and Transparency International Bangladesh (TIB). Peer-reviewed journals in the fields of environmental science, public health, and waste management were prioritized. Search terms included “biomedical waste,” “hospital waste,” “waste management,” “environmental impact,” and “Bangladesh,” with Boolean operators and filters applied for relevance, language, and publication date.

Inclusion criteria encompassed studies on biomedical waste generation, segregation, treatment, disposal, policy frameworks, and environmental and health impacts in Bangladesh, including original research, reviews, case studies, and government reports. Studies not relevant to Bangladesh, lacking empirical data, or opinion-based publications were excluded.

Data from the selected sources were extracted systematically, focusing on waste generation rates, management practices, environmental and health consequences, policy implementation, and institutional challenges. The information was synthesized qualitatively to identify patterns, recurring issues, and potential interventions. Limitations of the review include the scarcity of centralized national data and variability in reporting standards across studies, which may affect the comprehensiveness of findings.

3. Biomedical waste generation in Bangladesh

3.1. National scenario and growth trend

The generation of biomedical waste in Bangladesh has become an increasingly complex and critical environmental and public health issue due to the rapid expansion of the healthcare sector. Over the past two decades, the country has experienced a substantial increase in the number of government hospitals, private medical colleges, diagnostic centers, specialized clinics, and pharmaceutical institutions. This expansion has been driven by rising population density, urbanization, improved access to healthcare services, and increased health awareness among the public. As a consequence, the amount of waste generated from healthcare activities has increased significantly, particularly in major metropolitan areas such as Dhaka, Chattogram, Rajshahi, Khulna, and Sylhet, where large healthcare infrastructures serve millions of patients annually[6].

Several studies have estimated that biomedical waste generation in urban hospitals of Bangladesh ranges between **0.8 to 1.67 kg per bed per day**, depending on hospital size, service capacity, and patient occupancy rate. Although this figure is similar to other developing countries, the situation in Bangladesh is more alarming due to poor segregation practices and inadequate waste treatment infrastructure. According to Transparency International Bangladesh (TIB, 2022), the total biomedical waste produced in the country is approximately **7,440 tons per month**, of which around **20–25% is classified as hazardous**. The remaining portion is theoretically non-hazardous; however, due to improper segregation, much of it becomes contaminated, increasing both treatment costs and environmental risks[7].

The COVID-19 pandemic further intensified this problem. During the peak pandemic period, the volume of biomedical waste in Dhaka city reportedly increased more than threefold, largely due to extensive use of personal protective equipment (PPE), test kits, syringes, gloves, face masks, and disposable medical materials. The sudden surge overwhelmed existing waste management systems and highlighted critical weaknesses in national preparedness, policy implementation, and infrastructure capacity. This situation emphasized the urgent need for sustainable biomedical waste management planning and system reinforcement at the national level[8].

3.2. Factors influencing biomedical waste generation

The quantity and characteristics of biomedical waste generated in Bangladesh vary widely depending on several interrelated factors. These factors influence not only the volume but also the composition and hazardous nature of the waste produced by different healthcare facilities. Hospital size and bed capacity play a significant role in waste generation. Large tertiary care hospitals with multiple specialized departments—such as surgery, intensive care units (ICUs), oncology, dialysis, and emergency services—produce far higher volumes of waste compared to small clinics or primary healthcare centers. Similarly, institutions with higher bed occupancy rates and patient admissions produce more infectious and non-infectious waste on a daily basis[9]. Patient turnover rate is another crucial factor. Government hospitals, which often serve a large low-income population, experience extremely high patient turnover. Continuous patient inflow and outflow, especially in emergency departments and outpatient services, lead to higher generation of disposable medical supplies such as syringes, saline sets, gloves, and sample collection materials.

The type of medical services provided also significantly affects waste composition. Diagnostic laboratories produce large volumes of infectious waste, including blood-contaminated materials, test kits, culture plates, pipette tips, and chemical reagents. Surgical departments generate pathological waste, sharps, and chemically contaminated items. Maternity wards generate biological waste, including placental tissues, cotton swabs, and disposable delivery kits. Vaccination centers and blood banks contribute large quantities

of syringes, needles, and blood-contaminated materials. Furthermore, the increased preference for single-use disposable medical items due to infection control requirements has substantially increased waste production. Although this practice reduces cross-contamination risks, it contributes heavily to plastic waste accumulation, posing long-term environmental challenges[10].

3.3. Central vs Peripheral healthcare facilities

A clear disparity exists between biomedical waste generation patterns in urban tertiary hospitals and peripheral healthcare facilities in rural areas. Large government hospitals located in metropolitan cities serve thousands of patients daily and often operate beyond their intended capacity. This leads to continuous generation of huge volumes of waste, including both hazardous and non-hazardous categories. Private hospitals, although they generally serve fewer patients than government hospitals, tend to generate a higher proportion of disposable waste due to their extensive use of modern medical technology and single-use instruments[2]. However, documentation and reporting of waste generation in private facilities remain largely inconsistent. Many private healthcare institutions do not maintain proper waste records, making it difficult to obtain a comprehensive national estimate. On the other hand, rural and sub-district level healthcare centers generate relatively smaller amounts of waste; however, they face more severe problems in terms of disposal. These facilities often lack proper waste segregation bins, collection services, treatment facilities, and trained personnel. Consequently, biomedical waste from rural areas is frequently dumped in open spaces, roadside areas, or unlined pits, posing severe risks to local populations, scavengers, and the surrounding environment[11].

3.4. Waste composition and classification

Biomedical waste in Bangladesh comprises a diverse mixture of hazardous and non-hazardous materials. Hazardous waste includes infectious waste, pathological tissues, sharps (needles, blades), chemical disinfectants, pharmaceutical residues, and laboratory chemical waste. Non-hazardous waste mainly consists of paper, plastic packaging, food waste, and general office waste generated in healthcare institutions. Although globally only about one-fifth of healthcare waste is hazardous, in Bangladesh poor segregation practices significantly increase this proportion[3]. In many healthcare facilities, color-coded bins are either not available or not used correctly, resulting in the mixing of infectious waste with general waste. This increases the volume of waste requiring special treatment and raises serious environmental and occupational health concerns. Plastic materials constitute a major fraction of biomedical waste in Bangladesh, especially from disposable syringes, saline bags, IV tubes, gloves, PPE kits, and diagnostic components. When not properly treated, these plastics are dumped into landfills or water bodies where they eventually degrade into microplastics. These microplastics enter aquatic food chains and pose serious long-term ecological and health threats[12].

3.5. Impact of seasonal and epidemic outbreaks

Seasonal disease outbreaks significantly affect biomedical waste generation patterns in Bangladesh. During dengue outbreaks, hospitals experience a massive increase in patient admissions, resulting in higher use of disposable syringes, IV sets, test kits, and medications. Similarly, during diarrheal disease outbreaks, large volumes of saline bags and medical consumables are used, contributing to increased waste load. The COVID-19 pandemic represents the most significant example of crisis-driven waste generation. Large-scale PCR and antigen testing, mass vaccination programs, and the widespread use of PPE generated unprecedented quantities of biomedical waste[4]. This sudden escalation in waste volume exposed the fragility of the existing waste management system and underscored the necessity of emergency waste management planning and infrastructure strengthening.

3.6. Institutional recording and data gaps

One of the major limitations in assessing biomedical waste generation in Bangladesh is the lack of reliable and standardized data collection systems. Most healthcare institutions do not maintain regular and categorized records of waste generation. There is no centralized national digital database for biomedical waste reporting, which makes it difficult to monitor trends, enforce policies, and evaluate system improvements. Most available data are based on isolated research studies, NGO reports, and international organization publications. This fragmented data system limits effective policymaking and resource allocation. Furthermore, inter-departmental waste recording within hospitals is rarely practiced, which weakens internal monitoring and quality control[6]. Without accurate data, it remains challenging to measure compliance with national biomedical waste management guidelines or evaluate the effectiveness of interventions implemented over time.

3.7. Sector-wise differences in waste generation

Government hospitals remain the largest contributors to biomedical waste in Bangladesh due to their high patient loads and extensive service coverage. However, these institutions often suffer from poor segregation efficiency, limited storage facilities, and inadequate treatment infrastructure. Private hospitals and diagnostic centers demonstrate mixed performance. Some internationally accredited facilities maintain better waste management practices, including segregation and outsourcing treatment services. However, many smaller private clinics and diagnostic centers prioritize cost reduction, leading to poor waste handling practices and illegal disposal. Community clinics and rural health centers generate lower quantities of waste but face severe challenges due to lack of waste treatment facilities, transportation services, and trained manpower. As a result, waste is frequently burned in open areas or buried without any protective measures, exposing healthcare workers and local populations to serious health hazards[13].

4. Current biomedical waste disposal practices in Bangladesh

Biomedical waste management is a multidimensional process involving several interconnected stages, including segregation, collection, transportation, treatment, and final disposal. The effectiveness of these steps largely determines the level of risk posed to healthcare workers, the general public, and the environment. Although national guidelines for biomedical waste management exist in Bangladesh, their practical implementation remains inadequate and inconsistent across healthcare facilities.

4.1. Segregation practices

Segregation is the most critical step in biomedical waste management, as it determines the safety, treatment method, and final disposal route of different types of waste. Proper segregation ensures that hazardous waste is separated from non-hazardous waste at the point of generation, minimizing contamination and reducing treatment costs. The World Health Organization (WHO) recommends the use of standardized color-coded bins and clearly labeled containers for different waste categories such as infectious waste, sharps, pharmaceutical waste, and general waste. In Bangladesh, however, segregation practices remain weak and poorly implemented, particularly in government hospitals and small private healthcare facilities[7]. Although some large hospitals have introduced color-coded bin systems, these are often inconsistently used or poorly maintained. In many cases, hazardous and non-hazardous wastes are mixed together due to lack of staff training, negligence, time constraints, or absence of strict supervision. Sharps such as needles and blades are frequently disposed of in ordinary waste containers, increasing the risk of needle-stick injuries for waste handlers and cleaners. Another important challenge is the lack of awareness among healthcare staff regarding proper segregation. Nurses, ward attendants, and cleaners often receive minimal training on biomedical waste handling. As a result, even facilities with available segregation infrastructure often fail to utilize it

correctly. This poor segregation practice not only increases occupational health risks but also leads to unnecessary contamination of non-hazardous waste, increasing the overall volume of waste that requires special treatment[14].

4.2. Collection and transportation systems

After segregation, biomedical waste must be collected from healthcare facilities and transported to designated treatment or disposal sites. In Dhaka city, both the North and South City Corporations have collaborated with NGOs and private waste management companies for biomedical waste collection and transportation. These organizations are responsible for daily or periodic waste pickup from major hospitals, diagnostic centers, and clinics. However, the collection system suffers from several limitations. One of the major issues is the **irregularity of collection schedules**, particularly in smaller healthcare facilities and peripheral areas. Many clinics and diagnostic centers report that waste is not collected consistently, forcing them to store waste for extended periods under unsafe conditions[8]. This increases the risk of the proliferation of pathogens, unpleasant odors, and attraction of disease-carrying insects and rodents. Additionally, transportation vehicles used for biomedical waste are often not designed specifically for this purpose. In many cases, waste is transported in open or poorly sealed vehicles, increasing the risk of spillage and environmental contamination during transit. There is also a lack of strict monitoring to ensure that transportation protocols are followed properly. A serious concern is the inadequate use of personal protective equipment (PPE) by waste handlers. Many waste collectors are not provided with proper gloves, masks, boots, or protective clothing. Even when PPE is available, its proper use is often neglected due to insufficient training and supervision[15]. As a result, waste handlers remain highly vulnerable to infections, injuries, and exposure to toxic substances.

4.3. Treatment technologies in bangladesh

The treatment of biomedical waste aims to reduce its hazardous nature and make it safe for final disposal. Several treatment technologies are used worldwide, including high-temperature incineration, autoclaving, microwave treatment, and chemical disinfection. In Bangladesh, however, the availability and use of advanced treatment technologies remain very limited. Small-scale incinerators are one of the most commonly used treatment methods in Bangladesh. These incinerators are often installed in large hospitals or operated by private waste management agencies. However, many of these incinerators are outdated and do not meet modern environmental standards[16]. Poor combustion efficiency leads to the release of highly toxic air pollutants such as dioxins, furans, and particulate matter, which contribute to air pollution and pose severe health hazards to nearby communities. In rural areas and small healthcare facilities, the most common treatment method is open burning or burial in shallow pits. Open burning, in particular, is extremely harmful as it releases toxic chemicals into the air and leaves behind partially burned residues that contaminate soil and water sources. Burial pits, when not properly designed, can also lead to groundwater contamination, especially during the monsoon season when water levels rise. Modern treatment methods such as autoclaving and chemical disinfection are still rarely used in Bangladesh. Only a few institutions and specialized waste treatment centers in major cities have access to autoclave facilities[9]. The lack of investment in advanced treatment technologies and technical expertise remains a significant barrier to sustainable biomedical waste management.

4.4. Final disposal practices

Final disposal refers to the last stage of the biomedical waste management process after the waste has been treated. Ideally, treated waste should be disposed of in specially designed sanitary landfills or hazardous waste disposal sites. However, in Bangladesh, most biomedical waste eventually ends up in regular

municipal landfills or open dumping sites. Very few cities in Bangladesh have dedicated landfill sites for hazardous or biomedical waste. As a result, treated and untreated medical waste often gets mixed with general municipal waste, increasing the risk of environmental contamination. The absence of engineered sanitary landfills with protective liners and leachate treatment systems contributes to groundwater and soil pollution, which can have long-term ecological and public health consequences[17]. A particularly alarming issue is informal recycling and scavenging. In many urban areas, waste pickers collect used syringes, saline bags, plastic bottles, and other medical materials from dumping sites. These materials are often illegally recycled and resold in the market without proper sterilization. This not only poses a direct threat to public health by spreading infectious diseases but also reflects the failure of monitoring and regulatory enforcement in the biomedical waste sector. Furthermore, poor security around dumping and treatment sites allows unauthorized persons to access hazardous waste. The absence of surveillance systems and weak enforcement of waste management laws contribute to the persistence of unsafe disposal practices across the country[10].

4.5. Key challenges in current practices

Despite the presence of national guidelines and regulatory frameworks, biomedical waste disposal practices in Bangladesh continue to face several challenges. These include lack of awareness, insufficient infrastructure, weak enforcement of laws, limited funding, and lack of skilled manpower. Many healthcare institutions consider waste management as a secondary issue rather than an integral part of patient safety and environmental protection. The coordination between healthcare institutions, municipal authorities, and private waste management agencies is also often weak, leading to fragmented and inefficient waste handling systems. Without strong governance, regular monitoring, and proper accountability, achieving sustainable biomedical waste disposal remains a significant challenge.

5. Environmental and health implications of biomedical waste in Bangladesh

Biomedical waste (BMW) poses significant environmental and health risks when not properly managed. In Bangladesh, where segregation, collection, treatment, and final disposal are often inconsistent, these risks are magnified. Beyond healthcare facilities, improper handling and disposal of BMW can have far-reaching consequences, directly affecting surrounding communities, ecosystems, and waste-handling personnel. The increasing volume of biomedical waste in urban centers and the rapid expansion of healthcare services have made understanding its impacts a critical public health concern.

5.1. Environmental impacts

The environmental consequences of mismanaged biomedical waste are complex and multi-dimensional, affecting air, water, soil, and ecosystems.

Soil Contamination: Hazardous components of biomedical waste, including heavy metals (mercury, lead, cadmium), chemical reagents, and pathogenic microorganisms, often leach into the soil when waste is disposed of in unlined pits or open dumping areas. Contaminated soil may reduce agricultural productivity and accumulate toxins in food crops. Studies indicate that improper disposal of sharps, laboratory reagents, and pharmaceuticals increases the microbial load in soil, creating reservoirs for infectious agents. Continuous accumulation of heavy metals can lead to long-term environmental toxicity, affecting both flora and fauna[11].

Water Contamination: Groundwater and surface water contamination is a significant problem in Bangladesh, especially in densely populated urban areas. Biomedical waste leachate from open dumps, burial pits, and landfills introduces pathogens, chemicals, pharmaceuticals, and microplastics into rivers, ponds, and aquifers. Toxic chemicals, including disinfectants and laboratory reagents, may alter water pH

and nutrient balance, affecting aquatic organisms. Heavy metals and persistent microplastics accumulate in water bodies, entering the food chain via fish and other aquatic species, ultimately posing health risks to humans. During the monsoon season, leachate runoff increases, exacerbating contamination and creating hotspots for waterborne diseases[12].

Air Pollution: Incineration of biomedical waste, especially in low-efficiency or outdated incinerators, releases highly toxic pollutants, including dioxins, furans, particulate matter, carbon monoxide, and volatile organic compounds (VOCs). Open burning, a common practice in rural and peri-urban areas, worsens air quality, releasing smoke laden with chemical toxins and microbial aerosols. Continuous inhalation of these pollutants is linked to respiratory disorders, including chronic bronchitis, asthma, and increased susceptibility to pulmonary infections. Furthermore, dioxins and furans are persistent organic pollutants (POPs) that can bioaccumulate in the food chain, causing long-term ecological and human health effects[18].

Plastic and Microplastic Pollution: The widespread use of single-use plastics in healthcare—such as gloves, PPE kits, syringes, infusion bags, and disposable diagnostic tools—significantly contributes to biomedical waste. Improper disposal leads to fragmentation of plastics into microplastics, which contaminate soil, freshwater, and coastal ecosystems. Microplastics act as carriers for other toxic chemicals, including heavy metals and persistent organic pollutants, and are ingested by aquatic organisms, eventually entering the human food chain. This presents emerging environmental and health challenges that require urgent attention[6].

Ecological Disruption: Beyond pollution, biomedical waste adversely affects biodiversity. Pathogens and chemical pollutants from improperly disposed medical waste can disrupt soil microbiota, freshwater ecosystems, and terrestrial habitats. Accumulation of medical plastics, sharps, and chemical residues in rivers and wetlands harms aquatic life, including fish, amphibians, and invertebrates, threatening ecological balance.

5.2. Health impacts

Improperly managed biomedical waste presents serious direct and indirect health risks, particularly for hospital staff, municipal waste workers, informal scavengers, and nearby communities.

Occupational Hazards: Healthcare personnel and waste handlers face high exposure to sharps, infectious materials, and hazardous chemicals. Needlestick injuries are common, placing workers at risk of contracting blood-borne infections such as HIV, Hepatitis B, and Hepatitis C. Chemical exposure from disinfectants, laboratory reagents, and pharmaceutical residues can cause acute and chronic toxicity, skin irritation, and allergic reactions. Insufficient training and inadequate use of personal protective equipment (PPE) further increase the vulnerability of these occupational groups[19].

Blood-borne and Infectious Disease Transmission: Direct contact with improperly segregated waste, contaminated syringes, laboratory samples, and used PPE contributes to the spread of infectious diseases. Informal waste pickers who salvage and recycle medical materials are particularly at risk. In densely populated urban areas, improper disposal increases human exposure to pathogens, creating a broader public health risk[14].

Respiratory and Dermatological Disorders: Inhalation of smoke and airborne pathogens from incineration and open burning of biomedical waste can trigger respiratory illnesses, including asthma, bronchitis, and chronic obstructive pulmonary disease (COPD). Skin contact with contaminated materials can lead to dermatitis, fungal infections, and other dermatological issues, particularly among hospital cleaners and waste handlers[13].

Community Health Risks: Communities residing near dumping sites and hospitals often face heightened exposure to biomedical waste. Informal scavenging of medical plastics, needles, and discarded pharmaceutical items increases disease transmission and chemical exposure. This practice is widespread in urban slums, where economic necessity drives the collection of medical waste for resale or recycling without sterilization. Consequently, residents experience higher incidences of infections, chemical poisoning, and long-term chronic diseases[1].

Psychosocial and Socioeconomic Impacts: Beyond physical health, exposure to biomedical waste creates psychosocial stress and anxiety among waste workers and residents near dumping sites. The stigma associated with waste handling, coupled with fear of infection, affects mental well-being. Communities may also face socioeconomic challenges, as polluted environments reduce agricultural productivity, contaminate water supplies, and increase healthcare costs[11].

5.3. Cumulative environmental-health interactions

The environmental and health consequences of biomedical waste are deeply interconnected, creating a feedback loop that amplifies risk. Contaminated soil and water support the proliferation of disease vectors, including mosquitoes, flies, and rodents, increasing the incidence of vector-borne diseases such as dengue, chikungunya, and leptospirosis. Airborne pollutants from incineration or open burning exacerbate respiratory illnesses while carrying chemical toxins into nearby ecosystems. Moreover, the widespread informal handling and scavenging of biomedical waste further elevate the likelihood of infections and chemical exposure in humans. This cumulative effect underscores the urgent need for integrated biomedical waste management strategies in Bangladesh. Sustainable solutions should focus not only on infrastructure and technology but also on public health education, regulatory enforcement, and community engagement. Without comprehensive intervention, the growing volume of biomedical waste will continue to pose severe environmental and health challenges for decades to come[20].

6. Challenges and gaps in biomedical waste management in Bangladesh

Despite the establishment of regulatory frameworks such as the Medical Waste (Management and Handling) Rules 2008, biomedical waste management (BMWM) in Bangladesh faces multiple challenges and systemic gaps that hinder effective implementation. These challenges are multidimensional, encompassing regulatory, institutional, infrastructural, financial, and social aspects.

6.1. Weak enforcement of existing laws

Although national guidelines and laws exist for biomedical waste management, their enforcement is inconsistent. Hospitals and healthcare facilities often operate without strict oversight due to limited regulatory capacity at both central and municipal levels. Penalties for non-compliance are rarely applied, and monitoring mechanisms are weak. As a result, many facilities neglect proper segregation, treatment, and disposal practices, undermining national policy objectives. A lack of coordination between the Ministry of Health, local city corporations, and environmental authorities further exacerbates regulatory gaps.

6.2. Inadequate training and awareness among healthcare staff

Healthcare personnel, including doctors, nurses, laboratory technicians, and cleaning staff, often lack formal training in biomedical waste management. Many are unaware of proper segregation protocols, color-coded bin systems, and safe handling practices. For example, a Dhaka-based study reported that although 96% of hospital wards had a waste segregation policy, only 29% of private hospital staff and 63% of government hospital staff received formal training. This training deficit directly contributes to improper

handling of sharps, infectious waste, and chemical residues, increasing occupational hazards and public health risks.

6.3. Poor waste segregation practices

Segregation of biomedical waste at the point of generation is critical for safe management. In Bangladesh, this step is often poorly implemented. Hazardous and non-hazardous waste is frequently mixed, sharps are discarded improperly, and color-coded bins are either unavailable or not maintained. Non-compliance is more pronounced in smaller clinics, rural health facilities, and private diagnostic centers, where the perceived cost of segregation is considered high. This practice increases the volume of hazardous waste and complicates downstream treatment and disposal processes.

6.4. Lack of modern treatment and disposal facilities

The treatment infrastructure for biomedical waste in Bangladesh remains underdeveloped. Most hospitals rely on small-scale incinerators, burial pits, or open burning, which are inefficient and environmentally hazardous. Modern treatment technologies such as autoclaves, chemical disinfection, and centralized waste treatment facilities are limited and often restricted to large urban hospitals. Rural healthcare facilities and peripheral clinics usually lack any treatment capacity, resulting in the unsafe disposal of infectious and chemical waste. The absence of dedicated sanitary landfills for hazardous medical waste further exacerbates environmental contamination.

6.5. Insufficient funding and policy monitoring

Financial constraints are a major barrier to effective BMW management. Many hospitals, particularly in the public sector, operate with limited budgets, restricting their ability to invest in training, equipment, and modern treatment technologies. Policy monitoring mechanisms are weak, with no centralized national database to track waste generation, segregation, treatment, or disposal. Without robust data, policymakers cannot identify priority areas, allocate resources effectively, or measure compliance with regulations.

6.6. Limited public awareness and community engagement

Public awareness regarding the risks associated with biomedical waste is generally low in Bangladesh. Informal scavenging, recycling of medical plastics, and use of contaminated syringes are widespread in urban and peri-urban areas, reflecting a lack of knowledge about associated health hazards. Community engagement programs to raise awareness about safe disposal practices, disease prevention, and environmental protection are limited in scope and coverage. This gap increases the risk of disease transmission and environmental pollution, particularly in densely populated areas.

6.7. Data gaps and lack of standardized reporting

One of the most critical challenges is the absence of standardized and reliable data on biomedical waste generation and management. Hospitals and clinics do not consistently record waste volumes by type or department, and no national centralized system exists to collect this information. Existing data are often fragmented, collected through isolated studies or NGO reports. The lack of accurate, real-time data makes it difficult to evaluate compliance, track improvements, or plan for future expansion of treatment infrastructure.

6.8. Sectoral and geographical disparities

There is a clear disparity between urban and rural healthcare facilities in terms of waste management capacity. Urban tertiary hospitals generally have better resources, equipment, and trained staff, but still struggle with consistent enforcement. Rural health centers, upazila hospitals, and community clinics lack infrastructure, technical expertise, and access to treatment facilities. Private hospitals may have modern

equipment but often prioritize cost-saving over compliance, while public hospitals face bureaucratic delays and funding shortages. These disparities create unequal environmental and health risks across regions.

7. Recommendations for sustainable biomedical waste management in Bangladesh

Effective management of biomedical waste (BMW) in Bangladesh requires a multi-dimensional strategy that addresses regulatory, technological, institutional, and community-related gaps. Based on the findings from existing literature, current practices, and environmental and health implications, the following recommendations are proposed to improve biomedical waste management across the country:

7.1. Strengthening regulatory compliance

Strict enforcement of existing biomedical waste management laws and policies is essential. Healthcare institutions must comply fully with the Medical Waste (Management and Handling) Rules 2008 and any subsequent updates. Regular audits, inspections, and penalties for non-compliance should be implemented to ensure adherence. Regulatory agencies should develop performance indicators and compliance benchmarks for hospitals, clinics, and laboratories to encourage accountability. Integration of BMW management into hospital accreditation and licensing processes could further promote systematic compliance.

7.2. Standardized segregation systems

Uniform segregation of waste at the point of generation is crucial for safe handling and treatment. All healthcare facilities should implement standardized color-coded bin systems for different types of biomedical waste, including infectious, sharps, chemical, pharmaceutical, and general waste. Clear labeling, instructions, and visual aids should be provided in local languages to ensure understanding by all staff members. Regular monitoring and supervision should reinforce proper segregation practices and prevent cross-contamination of hazardous and non-hazardous waste.

7.3. Capacity building and training programs

Healthcare personnel, including doctors, nurses, laboratory staff, cleaners, and waste handlers, should undergo continuous training on safe biomedical waste management practices. Training modules should cover proper segregation, handling of sharps and infectious materials, use of personal protective equipment (PPE), emergency response to exposure incidents, and environmental awareness. Specialized training programs can be tailored for supervisory staff to monitor compliance and provide ongoing support to waste-handling teams. Collaboration with NGOs, international organizations, and academic institutions can enhance the quality and reach of these programs.

7.4. Adoption of modern treatment technologies

Investment in modern biomedical waste treatment infrastructure is imperative. Hospitals and laboratories should prioritize the acquisition of emission-controlled incinerators, autoclaves, shredders, chemical disinfection units, and other environmentally safe treatment technologies. Centralized treatment facilities, particularly in urban areas, can improve efficiency and reduce environmental contamination. Emphasis should also be placed on technologies that minimize the generation of toxic emissions, leachate, and microplastics. For rural and peripheral facilities, mobile treatment units and regional collection centers can provide practical solutions for safe disposal.

7.5. Public-private partnerships and infrastructure development

Collaboration between government agencies, private healthcare providers, NGOs, and waste management companies can strengthen BMW infrastructure. Partnerships can facilitate centralized collection

systems, transportation logistics, treatment facilities, and landfill management. Incentives such as tax breaks, funding assistance, or technical support can encourage private-sector participation. Coordination among stakeholders will also improve standardization, reduce operational gaps, and ensure environmental safety across regions.

7.6. Data management and environmental monitoring

Robust data collection and monitoring systems are necessary to track biomedical waste generation, treatment, and disposal. Hospitals should maintain detailed records of waste volumes, types, and disposal methods. A centralized national database, accessible to policymakers and regulatory authorities, can facilitate real-time monitoring, trend analysis, and policy planning. Environmental monitoring, including soil, water, and air quality assessments near healthcare facilities, should be conducted periodically to detect contamination and guide mitigation measures.

7.7. Public awareness and community engagement

Raising public awareness about the health and environmental hazards of biomedical waste is critical. Community education campaigns, workshops, and media outreach programs can inform the public about the risks of informal scavenging, improper disposal, and recycling of medical materials. Encouraging community participation in proper disposal practices, safe handling of household medical waste, and reporting of illegal dumping sites can complement institutional efforts. Engaging local leaders, schools, and community organizations can strengthen the social and behavioral impact of these initiatives.

7.8. Integrated and sustainable policy approach

An integrated policy framework that combines regulation, training, infrastructure development, public awareness, and technological innovation is essential for sustainable biomedical waste management in Bangladesh. Policymakers should prioritize investments in modern treatment facilities, incentivize best practices in healthcare institutions, and ensure continuous monitoring and evaluation. Incorporating environmental safety and public health metrics into national health strategies will help align biomedical waste management with broader sustainable development goals.

Conflict of interest

The authors declare no conflict of interest

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