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Review Article

Biomedical Waste Management in India: A Comprehensive Analysis

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A B S T R A C T

Biomedical waste management presents a critical challenge in India's healthcare sector, encompassing various forms of waste generated from diagnostic, therapeutic, and research activities. This article discusses different aspects of BMW management such as segregation, storage, transportation, and treatment, emphasising the importance of adherence to regulatory frameworks and best practices. It also discusses recent amendments to BMW management rules. Lack of awareness, monitoring inadequate infrastructure, and non-compliance with recycling practices are some of the challenges posed in biomedical waste management in India. Recommendations for improvement include comprehensive staff training, robust monitoring mechanisms, and stakeholder engagement initiatives.

Keywords: Biomedical Waste Management, Hospital Waste, Segregation, Colour Coding

Introduction

Biomedical waste (BMW) is any waste generated during the diagnosis, treatment, or immunisation of human or animal research activities in a biological or healthcare campus. It follows the cradle-to-grave approach which is the characterisation, quantification, segregation, storage, transport, and treatment of BMW.[1] Approximately 10% to 25% of BMW is hazardous, while the remaining 75% to 95% is considered non-hazardous.[2] The hazardous fraction of the waste poses physical, chemical, and/ or microbiological risks to both the general population and healthcare workers engaged in the handling, treatment, and disposal of such waste. As per the 2019 Annual Report of the Central Pollution Control Board, India generated a daily total of 619 tonnes of BMW, with Kerala contributing 42.9 tonnes. This data underscores notable disparities in the generation of BMW across different regions.[3] The waste produced by healthcare activities is divided into two main categories: approximately 85% falls under general, non-hazardous waste, while the remaining 15% is categorised as hazardous material, which may include infectious, toxic, or radioactive elements.[4]

The annual growth rate of healthcare waste in India stands at around 7%, highlighting the considerable challenge in its effective management.[5] This challenge is compounded by violations of BMW management rules, presenting risks to both public health and the environment.[3]

Segregation refers to the basic separation of different categories of waste generated at the source, thereby

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reducing the risks as well as the cost of handling and disposal. Segregation is the most crucial step in BMW management. The colour-coded bags, assigned for distinct BMW categories, demand careful supervision to guarantee accurate segregation and minimise the risk of cross-contamination. According to the 2020 annual report, there is a significant rise in the quantity of waste generated, with the total BMW reported at 774 tons per day.[6] India is home to 352,014 healthcare facilities (HCFs), comprising 113,186 bedded and 237,938 non-bedded facilities. Among these, 244,282 HCFs make use of Common Biomedical Waste Treatment Facilities (CBMWTFs) for the collection, treatment, and disposal of BMW, while 17,206 have their own dedicated BMW treatment and disposal facilities.[6]

Addressing the global challenge of healthcare waste necessitates effective waste management practices, extending far beyond the borders of India. Modern hospitals, as intricate organisations, generate substantial waste through diagnostic, therapeutic, immunisation, and research activities due to inefficient material use.

Kerala, a state in India, with a total population of 3,34,06,000 according to the latest census, boasts a significant healthcare infrastructure encompassing both public and private sector hospitals. The state hosts over 1,284 public sector hospitals and 2,062 private sector hospitals, providing a substantial bed capacity of 1,19,762. This translates to 3.5 beds per 1000 population in Kerala.[6] Notably, Kerala has the highest density of doctors in the country, with approximately 42 per ten thousand population.

The average hospital waste generated in India ranges from 1.5 to 2.2 kg per bed per day.[7] These statistics emphasise the considerable volume of waste generated emphasising the crucial need for effective waste management strategies. The challenge lies in addressing the waste generated by healthcare facilities in the state.

Considering these facts, it becomes evident that managing healthcare waste is a pressing concern. Proper waste segregation, handling, treatment, and disposal practices are indispensable to minimise the associated risks and safeguard public health and the environment.

Salient Features of Biomedical Waste Management Law 2016

- The rules now encompass vaccination camps, blood donation camps, surgical camps, and other healthcare activities.
- A phased elimination of chlorinated plastic bags, gloves, and blood bags within a two-year timeframe.
- Mandatory pre-treatment of laboratory waste, microbiological waste, blood samples, and blood bags through WHO or NACO-prescribed disinfection or sterilisation methods. Chemical pre-treatment utilising 10% sodium hypochlorite is recommended.
- Comprehensive training is provided to all healthcare workers with regular immunisation protocols.
- Introduction of a bar-code system for BMW disposal containers to enhance tracking and management.
- Obligation to report major accidents related to BMW management.
- Existing incinerators are mandated to meet higher standards within two years, including retention time in secondary chambers and emission control of dioxin and furans.
- Reduction of bio-medical waste categories from 10 to 4 to streamline waste segregation at the source.
- Simplification of authorisation procedures, including automatic authorisation for bedded hospitals and synchronised validity with consent orders.
- Introduction of more rigorous standards for incinerators to minimise environmental pollutants emissions, including limits for dioxin and furans.
- State governments are mandated to provide land for establishing common BMW treatment and disposal facilities.
- No establishment of on-site treatment and disposal facilities is permitted if a common facility is available within a 75-kilometre radius.
- Additional methods introduced alongside those from 1998 include plasma pyrolysis, hydrolysis, encapsulation, and inertisation.
- Operators of common BMW treatment and disposal facilities are responsible for timely waste collection from healthcare facilities and providing training assistance. The responsibilities of operators are outlined in the regulations.[7,8]

The 2018 Amendment

The Biomedical Waste Management (Amendment) Rules, 2018, impose several regulations on BMW generators, including healthcare facilities, veterinary institutions, and clinical establishments. These regulations include phasing out chlorinated plastic bags and gloves, making annual reports available on websites within two years, implementing barcoding and GPS systems for waste handling by March 27, 2019, and requiring State Pollution Control Boards to compile and review data on BMW. Additionally, occupiers of facilities generating BMW must pre-treat certain types of waste on-site according to WHO guidelines before sending it to common BMW treatment facilities for final disposal.[8,9]

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Management of Biomedical Waste

Healthcare facilities bear the primary responsibility for managing the healthcare waste generated within their premises. This entails tasks such as waste segregation, in-house collection, transportation, pre-treatment, and temporary storage until the waste is ready for final management at a Common Biomedical Waste Treatment Facility.

Categories of Biomedical Waste (2016 Rules)

- **Human anatomical waste:** Such as tissues, organs, and body parts
- **Animal waste:** Generated during research activities, particularly from veterinary hospitals
- Microbiology and biotechnology waste
- **Sharps waste:** Including hypodermic needles, syringes, scalpels, and broken glass
- Discarded medicines and cytotoxic drugs
- **Soiled waste:** Such as dressings, bandages, plaster casts, and materials contaminated with blood, as well as tubes and catheters
- **Liquid waste:** From infected areas
- **Incineration ash**
- **other chemical wastes**

Segregation

The basic principle of Biomedical Waste Management (BMWM) emphasises segregation at the source and waste reduction. To streamline this process and make it more manageable for healthcare workers (HCWs), the categories have been condensed into four main categories. Colour coding (yellow, red, white, and blue) of bags or containers now corresponds to specific types of waste and their respective treatment options (Table 1). Bins and bags used for BMW disposal should prominently display the biohazard symbol, clearly indicating the nature of the waste to patients and the public. Furthermore, the implementation of a barcode system for all bags and containers used in BMW treatment and disposal facilitates tracking and identification during inspections, ensuring quality control and assurance.[10]

Table 1.Categories of Biomedical Waste According to Colour Coding

S. No.	Category	Type of Waste	Colour and Type of Container
1	Yellow	Human anatomical waste Animal anatomical waste Soiled waste Discarded and expired medicine Microbiology, biotechnology, and other clinical laboratory waste Chemical waste Chemical liquid waste	Yellow-coloured non-chlorinated plastic bags Cytotoxic wastes in yellow bags with a cytotoxic symbol
2	Red	Contaminated waste (recyclable)	Red-coloured non-chlorinated plastic bags and containers
3	White	Waste sharps including metals	White-coloured, translucent, puncture-proof, leak-proof container
4	Blue	Glassware, metallic body implants	Cardboard boxes with blue coloured markings, or blue coloured puncture-proof, temper-proof containers

Collection and Storage of Biomedical Waste

Bins and bags used for BMW disposal should display the biohazard symbol, clearly communicating the nature of the waste to both patients and the public. The collection of BMW entails utilising various types of containers sourced from different areas such as the operation theatre, laboratory, wards, kitchen, and corridors. These containers or bins should be placed in necessary places to ensure 100% collection efficiency. Sharps must always be stored in puncture-proof containers to prevent injuries and infections among workers handling them.[11]

After collection, BMW is stored in an appropriate facility. Healthcare facilities are required to designate a storage space for medical waste until it is ready for proper treatment and disposal. Different categories of waste must be segregated and placed in clearly identifiable containers. In large hospitals (with more than 250 beds), the storage duration should not exceed 8–10 hours, while in nursing homes, it should not exceed 24 hours. Each container should be labelled clearly, indicating the specific ward or room where it is located. This labelling is essential for tracing the waste back to its source if necessary. The storage area should be marked with caution signs to alert personnel to potential hazards. It is essential to maintain a dry and secure environment for storage before transportation, safeguarding the waste from water, wind, rodents, insects, and animals.[11,12]

Transportation

The collected BMW is transported using trolleys or enclosed wheelbarrows for treatment, with the operator ensuring to avoid manual loading. Before transferring for treatment, bags or containers containing BMW must be securely tied. Special vehicles are employed for transportation to prevent contact between the waste and the operator, scavengers, and the public. During transportation, containers must be properly enclosed to minimise any potential exposure. The design of vehicles should consider the effects of traffic accidents, and drivers must be trained in procedures to follow in case of accidental spillage. The interior of containers should also undergo thorough rinsing as part of the process.[13]

The operator of a CBWTF is required to transport BMW from the premises of an occupier only using vehicles labelled according to the Biomedical Waste Management Rules of 2016. These vehicles must adhere to the conditions set forth by the State Pollution Control Board (SPCB), in addition to complying with the requirements outlined in the Motor Vehicles Act of 1988 and its related rules, for the transportation of infectious waste.[14]

Final Treatment

The final treatment of each category of BMW is as follows:

- **Yellow category** - Incineration or Plasma pyrolysis or deep burial.
- **Red category** - Autoclaving/ microwaving/ hydroclaving and then sent for recycling
- **White category -** Autoclaving/ dry heat sterilisation followed by shredding/ mutilation/ encapsulation
- **Blue category** – Disinfection or autoclaving, microwaving, hydroclaving and then sent for recycling[8]

Challenges in Biomedical Waste Management

Lack of Awareness and Training: Raising awareness, stringent rules and proficient skills are indispensable for the effective handling of the BMW. Staffs in many healthcare facilities are not trained and there is a lack of awareness regarding the waste management process. This results in improper segregation, handling, and disposal of BMW. Expanding the training scope beyond specific procedures such as waste segregation, handling, and infection control to include emerging technologies and best practices could enhance its overall effectiveness.[12]

Adherence to Colour Coding Bins and Proper Segregation of Waste: Improper segregation of BMW causes significant risks to the public, the environment, and the safety of waste handlers and healthcare workers. When BMW, which includes infectious materials, sharps, and hazardous chemicals, is not segregated properly at the source, it often gets mixed with non-hazardous waste. This mixing increases the likelihood of exposure to infectious agents and hazardous substances, leading to infections, injuries, and environmental pollution. Improperly segregated BMW can also contaminate soil, water bodies, and air, posing long-term health hazards to communities.[15]

Lack of Proper Infrastructure: In remote and underserved regions, such as rural areas in developing countries, healthcare facilities frequently face challenges due to inadequate infrastructure and resource shortages for effective waste management.

Barcoding System: The implementation of a barcode system is mandatory to track the movement of BMW. This system would also help in the daily accounting of BMW.

Lack of Proper Monitoring: Irregular long-term checking of the system by responsible authorities. Many healthcare facilities do not adhere to the guidelines due to a lack of monitoring and accountability.

Non-Registration with Recycling Units: When hospitals fail to register with authorised recycling units, there is a high chance of improper waste disposal practices, including open dumping, landfilling, or unauthorised recycling methods. Illegal dumping and inappropriate disposal of medical waste may also cause harm to human health and pollute the environment.

Public Participation and Stakeholder Engagement: Engaging the public, healthcare workers, waste handlers, and other stakeholders in biomedical waste management initiatives is crucial for effective management.

Conclusion

A holistic approach, including a thorough review of waste management protocols, regular staff training, and effective communication channels, is recommended to promote

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adherence to guidelines. The presence of inappropriate items in the waste indicates significant failures in proper waste segregation and disposal practices. This poses potential risks to the safety of healthcare workers, waste management personnel, and the environment.

To address these issues, there is a need for improved adherence to waste management guidelines and protocols. Comprehensive staff education and awareness programs should be enforced, focusing on proper waste segregation, identification of appropriate waste items, and the consequences of improper disposal. Regular monitoring and audits of waste management practices are essential to identify areas of improvement and ensure ongoing compliance with guidelines.

Collaborative efforts among healthcare staff, waste management teams, and hospital administration are crucial in sharing knowledge, implementing best practices, and rigorously improving waste management protocols. Through these measures, hospitals can enhance waste management practices, minimise health and environmental risks, and contribute to a safer and more sustainable healthcare environment.

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