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Biomedical Waste: Risk, Regulation and Responsible Management

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Abstract
Biomedical waste (BMW) refers to any solid or liquid waste generated during medical, laboratory, or research activities related to the diagnosis, treatment, or prevention of diseases. Unlike general waste, biomedical waste carries a high risk of infection and injury, posing serious threats to healthcare workers, patients, and the community. It includes human and animal body parts, laboratory cultures, used syringes and needles, expired medicines, soiled bandages, liquid waste, chemical residues and incineration ash. The primary sources of biomedical waste include hospitals, clinics, medical and veterinary colleges, blood banks, mortuaries, diagnostic laboratories, biotechnology institutions, and even home healthcare or funeral services. Hazardous chemicals and radioactive materials, although not infectious, also form an important part of biomedical waste and require proper disposal to prevent environmental contamination. According to the World Health Organization (WHO), approximately 10% of hospital waste is infectious, while around 5% is hazardous but non-infectious. WHO classifies biomedical waste into eight categories: general, pathological, radioactive, chemical, infectious, sharps, pharmaceutical and pressurized wastes. Proper classification is critical for safe handling, treatment, and disposal. In India, the management of biomedical waste is regulated under the Biomedical Waste (Management & Handling) Rules, 1998, with subsequent amendments. These rules specify waste categories, color-coded bins, labeling requirements, transportation procedures, treatment standards, and operational guidelines for systems like incinerators, autoclaves, and microwaves. Effective biomedical waste management involves segregation at the source, safe storage, transportation, treatment, and final disposal. Segregation is generally achieved using color-coded containers: yellow for infectious, pathological, chemical, and pharmaceutical waste; red for contaminated plastics; white for sharps; and blue for glassware or metallic waste. Treatment technologies include autoclaving, chemical disinfection, incineration, and microwaving, depending on the type of waste. Proper biomedical waste management is essential to protect public health, prevent environmental pollution, and ensure the safety of healthcare workers. With increasing healthcare activities, growing awareness, and technological advancements, effective management of biomedical waste remains a shared responsibility of governments, healthcare institutions, and individuals.

Keywords - Biomedical Waste, Color Coding, Autoclaving, Incineration, Sustainability, Waste Treatment, Hospital Waste, Safe Disposal.

Introduction

Biomedical waste refers to any waste that is generated during the diagnosis, treatment, or immunization of human beings or animals, as well as in related research activities or in the production and testing of biologicals. This type of waste can include sharps (like needles and scalpels), soiled bandages, disposable items, anatomical waste, body fluids, discarded medicines, and other chemical or microbiological waste.

Biomedical waste (BMW) is primarily produced in healthcare settings such as hospitals, clinics, research institutions, and laboratories. Due to its infectious nature, it poses a significant risk of infection to medical staff, support workers, patients, and the general environment if not managed properly.

Types of Occupational Hazards from BMW:

- Accidental cuts or punctures from contaminated sharps (e.g. needles, knives, scalpels).
- Contact with infectious materials such as used gloves, tubing, surgical waste, bedding, and dressings.
- Exposure to bodily fluids like blood, urine, stool, or pus—particularly during cleaning and waste-handling tasks.

Composition and Quantity of Waste:

- Approximately70–80% of hospital waste is general (non-hazardous).
- About20–30%ishazardousorinfectious, which requires special handling and disposal.
- Improper segregation can lead to contamination of the entire waste stream, increasing the risk of infection.
- According to NEERI (National Environmental Engineering Research Institute), healthcare facilities in India generate approximately 0.5–2.0 kg of biomedical waste per bed per day. Annually, this amounts to around 0.33 million tons of biomedical waste.

Typical Composition of Hospital Solid Waste:

- Infectious waste(including soiled dressings and tissues):30–35%
- Plastics:7–10%
- Disposablesyringes:0.3–0.5%
- Glasswaste:3–5%
- General waste(including food waste):40–45%

Categories of Infectious Waste from Hospitals

The following types of waste generated in hospitals are classified as infectious waste, due to their potential to spread infections:

1. Waste from Patients with Communicable Diseases (I)

   Any waste generated from the treatment of patients suffering from infectious diseases.

2. Laboratory Waste (I)

   Cultures and stocks of infectious agents from microbiology, pathology, and biotechnology labs. Associated biologicals used in diagnostic procedures.

3. Human Blood and Blood Products (I)

   Includes blood, serum, plasma, and other derivatives.

4. Pathological Waste (I)

   Tissues, organs, body parts, and body fluids from surgeries or autopsies.

5. Contaminated Sharps (I)

   Items such as hypodermic needles, syringes, Pasteur pipettes, scalpel blades, and broken glass.

6. Surgical and Autopsy Waste (I)

   Soiled dressings, sponges, surgical gloves, and lavage tubes.

7. Contaminated Laboratory Materials (I)

   Specimen containers, slides and cover slips, disposable gloves, dialysis units, and waste collected from floor sweepings in patient rooms (e.g., swabs, soil particles).

8. Radioactive Waste (R)

   Materials containing radionuclides used in diagnostics and therapeutic procedures.

Sources of generation:
Solid waste generated from different sources of the hospitals– Note- I: infectious disease
NI: non-infectious disease
R: radioactive waste
D:domestic waste

Major Sources of Health Care Waste
Healthcare waste is generated from a variety of medical and research settings, including:

1. Hospitals
2. Nursing Homes
3. Laboratories and Research Centers
4. Mortuaries and Autopsy Centers
5. Veterinary Hospitals and Animal Clinics
6. Animal Research and Testing Laboratories
7. Blood Banks and Blood Collection Services
8. Medical and Nursing Colleges

Importance of Waste Quantification

Quantitative estimation of infectious and non-infectious waste is crucial for proper biomedical waste management.

- Infectious waste is highly hazardous and can transmit diseases either directly or via vectors (like flies, rodents, etc.).
- Accurate data helps in planning safe collection, storage, treatment, and disposal systems.

➢ **Categories**

Part-1
SCHEDULEI[Seerules3(e),4(b),7(1),7(2),7(5),7(6)and8(2)]

Biomedical wastes categories and their segregation, collection, treatment, processing and disposal options

Category	Type of Waste	Type of Bag or Container to be used	Treatment and Disposal options
1	2	3	4
Yellow	a) Human Anatomical Waste: Human tissues, organs, body parts and fetus below the viability period (as per the Medical Termination of Pregnancy Act 1971, amended from time to time).	Yellow coloured non- chlorinated plastic bags	Incineration or Pla or deep burial*
	(b)Animal Anatomical Waste :Experimental animal carcasses, body parts, organs, tissues, including the waste generated from animals used in experiments or or testing in veterinary hospitals or colleges or animal houses.		
	(c)Soiled Waste: Items contaminated with blood, body fluids like dressings, plaster casts, cotton swabs and bags containing residual or discarded blood and blood components.		Incineration or Plasma Pyrolysis or deep burial* In absence waving/of facilities, autoclaving or micro above waving/ or micr -hydroclaving followed by shredding or mutilation or combination of sterilization and shredding. Treated waste to be sent for energy recovery.
	(d) Expired or Discarded Medicines: Pharmaceutical waste like antibiotics, cytotoxic drugs including all items contaminated with cytotoxic drugs along with glass or plastic ampoules, vials etc	Yellow coloured non- chlorinated plastic bags or containers	Expired `cytotoxic drugs and items contaminated with cytotoxic drugs to be returned back to the manufacturer or supplier for incineration at temperature >1200 0C or to common bio-medical waste treatment facility or hazardous waste treatment, storage and disposal facility for incineration at >12000C Or Encapsulation or Plasma Pyrolysis at >12000C All other discarded medicines shall be either sent back to manufacturer or disposed by incineration.

	(e) Chemical Waste: Chemicals used in production of biological and used or discarded disinfectants.	Yellow coloured containers or non-chlorinated plastic bags	Disposed of by incineration or Plasma Pyrolysis or Encapsulation in hazardous waste treatment, storage and disposal facility
	(f) Chemical Liquid Waste : Liquid waste generated due to use of chemicals in production of biological and used or discarded disinfectants, Silver X-ray film developing liquid, discarded Formalin, infected secretions, aspirated body fluids, liquid laboratories and floor washings, cleaning, house-keeping and disinfecting activities etc.from	Separate collection system leading to effluent treatment system	After resource recovery, the chemical liquid waste shall be pre-treated before mixing with other wastewater. The combined discharge shall conform to the discharge norms given in Schedule-III.
	(g) Discarded linen, mattresses, beddings contaminated with blood or body fluid.	Non- chlorinated yellow plastic bags or suitable packing material	Non- chlorinated chemical disinfection followed by incineration or Plazma Pyrolysis or for energy recovery. In absence of above facilities, shredding or mutilation or combination of sterilization and shredding. Treated waste to be sent for energy recovery or incineration or Plazma Pyrolysis.
	(h) Microbiology, Biotechnology and other clinical laboratory waste: Blood bags, Laboratory cultures, stocks or specimens of micro-organisms, live or attenuated vaccines, human and animal cell cultures used in research, industrial laboratories, production of biological, residual toxins, dishes and devices used for cultures.	Auto clave safe plastic bags or containers	Pre-treat to sterilize with non chlorinated chemicals on- site as per National AIDS Control Organisation or World Health Organisation guidelines there after for Incineration.
Red	**Contaminated Waste (Recyclable)** (a) Wastes generated from disposable items such as tubing, bottles, intravenous tubes and sets, catheters, urine bags, syringes (without needles and *fixed needle syringes*) and vaccutainers with their needles cut) and gloves.	Red coloured non-chlorinated plastic bags or containers	Autoclaving or micro-waving/ hydroclaving followed by shredding or mutilation or combination of sterilization and shredding. Treated waste to be sent to registered or authorized recyclers or for energy recovery or plastics to diesel or fuel oil or for road making, whichever is possible. Plastic waste should not be sent to landfill sites.

White (Translucent)	**Waste sharps including Metals:** Needles, syringes with fixed needles, needles from needle tip cutter or burner, scalpels, blades, or any other contaminated sharp object that may cause puncture and cuts. This includes both used, discarded and contaminated metal sharps	Puncture proof,Leak proof, tamper proof containers	Autoclaving or Dry Heat Sterilization followed by shredding or mutilation or encapsulation in metal container or cement concrete; combination of shredding cum autoclaving; and sent for final disposal to iron foundries (having consent to operate from the State Pollution Control Boards or Pollution Control Committees) or sanitary landfill or designated concrete waste sharp pit.
Blue	**(a) Glassware:** Broken or discarded and contaminated glass including medicine vials and ampoules except those contaminated with cytotoxic wastes. **(b) Metallic Body Implants**	Cardboard boxes with blue colored marking Cardboard boxes with blue colored marking	Disinfection (by soaking the washed glass waste after cleaning with detergent and Sodium Hypochlorite treatment) or through autoclaving or microwaving or hydroclaving and then sent for recycling.

Segregation, Handling, Storage, Transportation Of Bio- Medical Waste

Handling :

- Proper handling of biomedical waste is essential for safety and infection control.
- Waste should be segregated immediately after generation into specific color-coded containers or bags, as per the type of waste.
- Containers should be emptied when they are three-quarters (¾) full to avoid spillage or overfilling.
- Special care must be taken to prevent needle-stick injuries and reduce the risk of infection.
- Biomedical waste must not be mixed with any other types of waste.
- During transportation, the waste should be handled carefully and not overloaded to ensure safe and hygienic disposal.

Storage :

- Every hospital or healthcare facility should designate a specific area within its premises for storing biomedical waste.
- The storage area must have an impermeable, hard-standing floor with proper drainage, making it easy to clean and disinfect.
- A water supply should be available nearby for cleaning purposes.
- The area should be easily accessible to the staff responsible for waste handling.
- The storage space must be lockable to prevent entry by unauthorized individuals.
- It should allow easy access for waste collection vehicles.
- The storage location should provide protection from direct sunlight.
- It must be inaccessible to animals, insects, and birds to avoid contamination.
- The area should be well-lit and have at least passive ventilation.
- It must not be located near food storage or preparation areas to prevent contamination risks.
- A supply of cleaning equipment, protective clothing, and waste bags or containers should be kept close to the storage area.
- Cytotoxic waste (e.g., chemotherapy waste) must be stored separately in a secure, designated location.

Transportation :

- Designated internal routes should be used for moving waste within the hospital to avoid passing through patient care areas.
- Waste should be transported at pre-scheduled times to prevent mixing with general waste.
- Dedicated, wheeled containers, trolleys, or carts must be used for transporting waste bags or bins to the storage or treatment site.
- These trolleys/carts should be cleaned and disinfected thoroughly, especially after any spillage.

- Containers must be designed to:
- Allow easy loading and unloading
- Secure the waste during movement
- Be free of sharp edges
- Be easy to clean
- Hazardous biomedical waste meant for long-distance transport should be placed in proper containers, clearly labeled for identification and safety.
- Biomedical waste should be transported using dedicated vehicles that are specially designed for this purpose.
- These vehicles must have a fully enclosed body, internally lined with stainless steel or aluminium to ensure a smooth, impervious surface that is easy to clean and disinfect.
- The driver's compartment must be separated from the waste-carrying compartment by a secure bulkhead to ensure safety.
- The waste compartment should be equipped with roof vents to allow proper ventilation during transport.

Need for Biomedical Waste Management

Improper management of biomedical waste poses serious environmental and health hazards to both humans and animals. It can lead to pollution and increased risk of disease transmission.

Healthcare professionals can play a major role in reducing these risks by:

- Properly segregating and disposing of waste in clearly labeled and designated bins.
- Ensuring the facility partners with a reliable and authorized biomedical waste disposal service.

In this plant proper treatment and disposal methods are carried out regarding to waste. Following Steps are:

[a] Collection and Transportation of waste:

The collection of Biomedical Waste in plant involves use of different types of container from various source of biomedical waste. It includes color codding bags and transporting vehicle as per government laws.

[b| Segregation of Waste:

Segregation refers to the basic separation of the different categories of waste generated at source or at a plant. Prevents illegally reuse of certain components of medical waste like used syringes, needles and other plastics are segregated in plant.

[c] Incineration:

Incineration is carried out in plant done at high temperature, which reduces organic and compostable and inorganic compostable matter. Anatomical waste is treated.

[d] Autoclaving:

In plant Autoclaving is done at low heat thermal process and its uses steam for disinfection of waste. Wastes form laboratory cultures, stocks, tubing, catheters and intravenous sets are autoclaved.

Le/Shredder:

In plant Shredder are used to destroy plastic and paper Waste to prevent their reuse. It requires maintenance after specific time interval.

[e]Chemical methods:

In plant chemical methods are used for disinfection of waste such as syringes, needles, drug bottles etc. chemical such as hypochloride is used.

[f] Safety Measures:

In plant during the collection of biomedical waste segregation and treatment processes of biomedical waste have adopted universal precautions and appropriate safety measures are provided while handling the Biomedical Waste, such as mask, goggles, hand gloves, safety shoes etc. to the workers.

Treatment for Biomedical waste management in Kolhapur City:

Incineration -

Incineration of waste converts the biomedical waste into ash, flue gas, and heat. Incinerator has 2 chambers; primary and secondary chamber. Primary chamber has 850 degrees temp. And in secondary chamber 1050 degrees temp.

- Incineration decreases quantity of waste.
- It reduction of pollution.
- Production of heat and power.
- Incinerators have filters for trapping pollutants.
- Saves on transportation of waste.
- Provides better control over noise and odour.
- Prevent the production of methane gas.
- Eliminates harmful germs and chemicals.

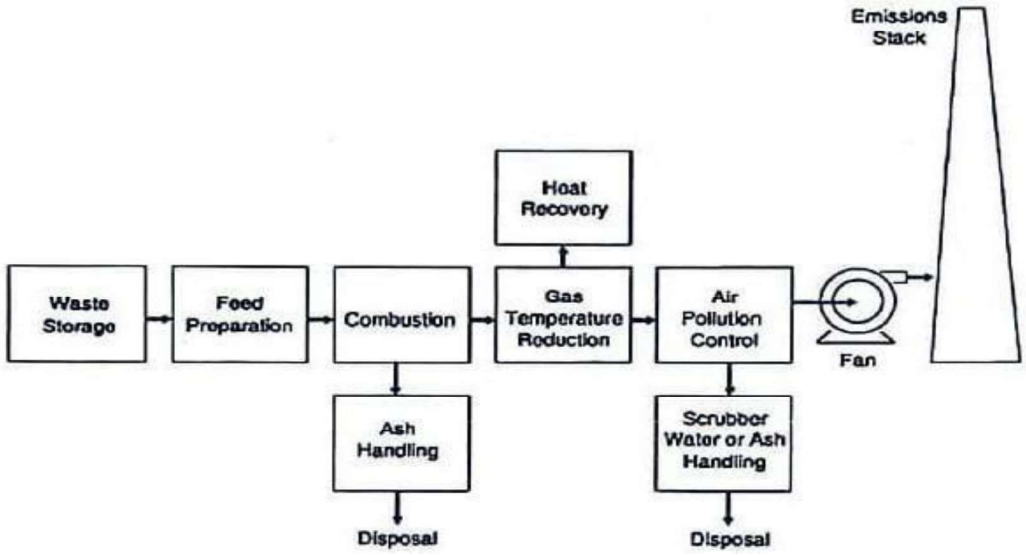

Figure 1 - Incineration Process

Conclusion

Biomedical waste is not just leftover material from hospitals but a hidden danger to people and the environment if it is not handled properly. Every hospital, clinic, lab, or diagnostic center produces this waste every day. Even though the amount may seem small, the harm it can cause is much bigger. Used syringes, blood-stained bandages, and lab samples can spread serious diseases like HIV, Hepatitis B, and Hepatitis C if thrown away carelessly.

In the same way, harmful chemicals, expired medicines, and radioactive waste can pollute soil, water, and air for a long time, damaging nature and risking human and animal health. That is why managing biomedical waste safely is very important—not just for doctors and nurses who handle it directly, but also for protecting the community and keeping the environment safe. The duty of proper waste management is not only on hospitals but also on all healthcare institutions and individuals connected to medical care.

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