



BIOMEDICAL WASTE MANAGEMENT IN INDIA

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Abstract :It is both socially and legally responsible for everyone who supports and finances health-care operations to manage biological waste (BMW) in a safe and sustainable manner. For a cleaner environment and healthy people, effective BMW Management (BMWM) is essential. The main disadvantage of traditional methods, the most recent environmentally friendly ways for BMW disposal, the 2016 BMWM regulations, and practical issues for their successful application are all covered in this article. With the goal of reducing environmental pollution and improving transportation, disposal, and segregation practices, the new regulations aim to transform the dynamics of BMW disposal and treatment in India. A joint effort involving devoted government funding and infrastructure development, committed healthcare personnel and facilities, ongoing oversight of BMW procedures, and continual monitoring of healthcare practices is necessary for the effective disposal of BMWM. Waste minimization and source segregation are the cornerstones of BMWM. In addition, a great deal of research and development work has to be done in the areas of creating medical equipment that is environmentally friendly and BMW disposal methods that contribute to a cleaner and greener environment.

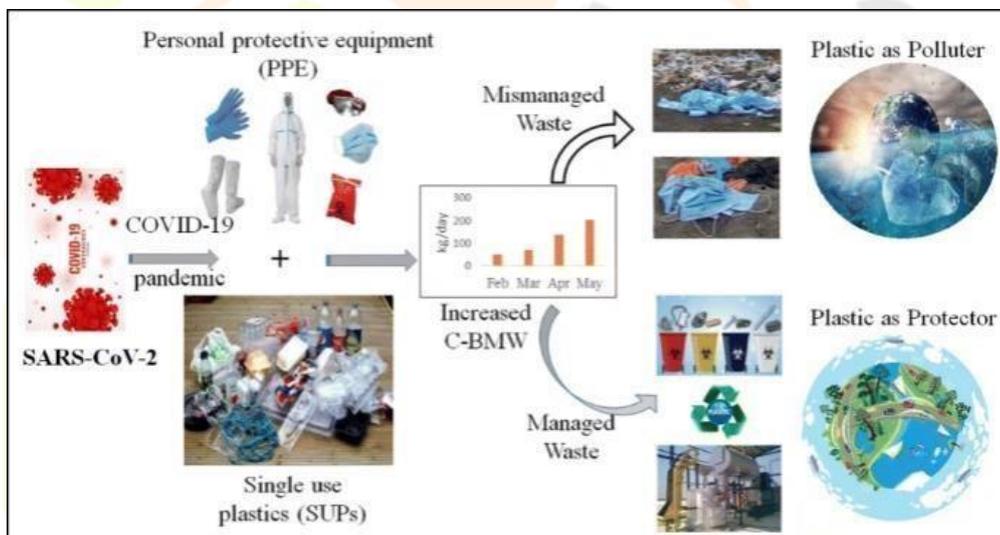


fig.1 graphical abstract of BMW during covid-19

KEY WORDS :- Biomedical waste, Hospital, Treatment, Waste Regulation and Management plan, Healthcare establishment.

INTRODUCTION

Biomedical waste includes any waste generated during diagnosis, treatment, or immunization of humans or animals, research activities, and production/testing of biological products. A hospital is a complicated organization that serves individuals of all ages, genders, races, and religions. This goes beyond the typical hospital population, including patients and staff. Scientific advancements are causing an increase in waste quantity and type, generating a significant impact.[1] Hospitals generate more and different types of waste throughout time. Hospital waste not only endangers patients and staff, but also harms public health and the environment. Biomedical waste (BMW) refers to waste generated during the diagnosis, treatment, or immunization of humans or animals in research activities. This includes activities related to biological production, testing, and health camps. BMW's sustainable practices revolve around the 3Rs principle: reduce, recycle, and reuse.[2] The growing number of treatments in healthcare facilities has resulted in significant waste generation. India generates approx. 2 kg/bed/day biological waste.

Biomedical waste, including anatomical waste, cytotoxic waste, and sharps, can lead to infectious diseases such as HIV, hepatitis C, and B, disrupt the environment, and negatively impact ecological balance if not properly segregated [3,4]. According to WHO,

15-25% of hospital waste poses a health risk to individuals. Contaminated sharps and syringes are estimated to cause 32% of new Hepatitis B infections, 40% of Hepatitis C Infections, and 5% of new HIV infections annually [5]. Hospital garbage contains hazardous tissues and fluids. According to WHO (1999), approximately 85% of hospital waste is nontoxic to health professionals, 10% is infectious, and 5% is hazardous to the flora [6].

According to the Government of India's 1998 announcement, Hospital Waste Management is part of hospital hygiene and maintenance tasks.

This entails managing many engineering functions, including collection, transportation, processing system functioning, and waste disposal.[7].

▪ Classification Of biomedical waste -

Approximately 75-90% of biomedical waste is nonhazardous and as safe as normal municipal waste. The remaining 10-25% is toxic, posing a risk to humans or animals as well as the environment. It is vital to understand that if both of these categories are mixed together, the entire trash becomes hazardous.

1. Non-hazardous Waste - This accounts for around 85% of the trash created in most healthcare settings. This comprises garbage such as food scraps, fruit peels, washing water, paper cartons, packing material, and so on.

2. Hazardous waste - Biohazard: Biological hazards, often known as biohazards, are biological compounds that are harmful to the health of living organisms, particularly humans.

2.1 Levels of biohazard - Quick removal of utilized needles into a Sharps holder is standard methodology. The US's habitats for Sickness Control and Counteraction (CDC) sorts different sicknesses in levels of biohazard, Level 1 being least gamble and Level 4 being outrageous gamble. Research centers and different offices are arranged as BSL (Biosafety Level) 1-4 or as P1 through P4 for short (Microbe or on the other hand Assurance Level).

- Biohazard Level 1- Microorganisms and infections including Bacillus, subtilis, canine Hepatitis, Escherichia coli, varicella (chicken pox), As well as some cell societies and non-irresistible microscopic organisms. At this level precautionary measures against the bio perilous materials being referred to are negligible, probably including gloves and a facial of some kind or another assurance. Generally, defiled materials are left in open (yet Independently showed) squander repositories. Purification methods for this level are comparable in many regards to present day precautionary measures against ordinary infections. In a lab climate, all materials utilized for cell and additionally Micro Organisms societies are purified through autoclave.

- Biohazard Level 2- Bacteria and viruses that cause only minor disease in humans or are difficult to spread via aerosol in a laboratory setting, such as hepatitis A, B, and C, influenza A, Lyme disease, salmonella, mumps, measles, scrapie, dengue fever, and HIV. Routine diagnostic work with clinical specimens can be completed safely at Biosafety Level 2 by following Biosafety Level 2 practices and procedures. Research (including co-cultivation, virus replication studies, or manipulations using concentrated virus) can be carried out in a BSL-2 (P2) facility using BSL-3 methods and procedures.

- Biohazard level 3 - It include anthrax, West Nile virus, Venezuelan equine Encephalitis, SARS virus, variola virus (smallpox), tuberculosis, typhus, Rift Valley fever, Rocky Mountain spotted fever, yellow fever, and malaria. This level includes Parasites such as Plasmodium falciparum (causing malaria) and Trypanosoma cruzi (causing trypanosomiasis).

- Biohazard Level 4 - It refers to viruses and bacteria that cause severe to fatal disease in humans and lack vaccines or treatments. Examples include Bolivian and Argentine Hemorrhagic fevers, H5N1 (bird flu), Dengue hemorrhagic fever, Marburg virus, Ebola virus, hantaviruses, and other hemorrhagic diseases. When dealing with biological threats at this level, a Hazmat suit and self-contained oxygen supply are required. A Level Four bio lab will have numerous showers, a vacuum room, an ultraviolet light room, an autonomous detection system, and other safety measures in place to eliminate any biohazards.

2.1.1. Potentially infectious waste - Infectious waste has been referred to by several terms in the scientific literature, regulations, guidance manuals, and standards. These include infectious, infective, medical, biomedical, hazardous, red bag, contaminated, medical infectious, and regulated medical waste. It accounts for 10% of the overall trash, which includes: Dressings and swabs contaminated with blood, pus, and bodily fluids. Laboratory waste, especially laboratory culture, stocks of infectious agents. Potentially infectious material includes excised tumor, and organs, placentas removed after surgery, and pulled teeth. Sharps include needles, syringes, and blades, blood and blood products.

2.1.2. Potentially toxic waste -

A Radioactive waste refers to waste polluted with radionuclides, which can be solid, liquid, or gaseous. These are obtained through in vitro study of body fluids and tissue, imaging, and therapeutic techniques.

B. Chemical waste consists of disinfectants (hypochlorite, Glutaraldehyde, iodophors, phenolic derivatives, and alcohol-based preparations), X-ray processing solutions, monomers and reagents, and base metal debris (e.g., amalgam from extracted teeth). c. pharmaceutical waste comprises anesthetics, sedatives, antibiotics, and analgesics.

2.1.3. Micro- Organisms - The medical establishment should form a team consisting of experts, people, and workers, including doctors, chemists, laboratory technicians, hospital engineers, nurses, cleaning supervisors/inspectors, and cleaning staff. If the necessary expertise is not available, external specialists in the subject can assist with the survey. A third option is to hire competent agencies to complete the work as a bundle under a contract.

The World Health Organization (WHO) categorizes medical waste into eight categories,

Including : A. General waste

- b. Pathological waste.
- c. Radioactive
- d. Chemicals
- e. Infectious or potentially infectious waste
- f. Sharps
- g. Pharmaceuticals
- h. Pressurized Containers

Major Sources of bio-medical waste

- Primary health centers
- Medical colleges and research centers
- Veterinary colleges and animal research centers
- Laboratories and research centers
- Mortuaries and autopsy centers
- Blood banks and collection services
- Nursing homes for the elderly
- Biotechnology institutions & Production units.

Minor Sources of bio-medical waste.

- Medical/dental clinics.
- Animal houses/slaughterhouses.
- Blood donation camps.
- Vaccination centers.
- Acupuncture, psychiatric clinics, and cosmetic piercings.
- Funeral services.
- Institutions for impaired people.

▪ Hospitals require effective biomedical waste Management.

Hospital waste management is necessary for several reasons, including:

1. Sharps injuries can cause infections among medical personnel and waste handlers.
2. Patients may contract nosocomial illnesses due to inadequate infection control and waste management measures.
3. Infection risk for waste workers, scavengers, and the general population living near hospitals.
4. Hazardous chemicals and pharmaceuticals pose a risk to waste handlers at any level.
5. Unscrupulous individuals repack and sell disposable items without proper cleaning.
6. Discarded drugs are repackaged and sold to unsuspecting purchasers.
7. Pollution of air, water, and soil can be caused by waste or defective incineration emissions and ash.[8]

▪ Benefits of Biomedical Waste Management:

1. Cleaner, healthier environments.
2. Lower incidence of hospital-acquired and general infections.
3. Lower cost of infection management in the hospital.
4. Reduced risk of sickness and mortality by reusing and repackaging infectious disposables.
5. Low risk of community and occupational health hazards.
6. Reduce waste management costs and generate cash by treating and disposing of garbage properly.
7. Enhances the image of healthcare and improves quality of life.

□ Biomedical Waste Management Process

Mismanagement of hospital waste refers to the poor handling of waste during generation, collection, storage, transportation, and treatment. Improper handling includes a variety of dangerous actions, such as handling without personal protective equipment (PPE), poor storage (e.g., high temperature conditions combined with extended storage times before treatment), manual transport over longer distances, the use of uncovered containers instead of closed plastic bags, etc. Other instances include exceeding permitted exposure limits, a lack of worker and equipment disinfection processes, and so on, all of which have varying effects on hospital workers. There is a large network of healthcare institutions in India. To prevent nosocomial or hospital-acquired infection, hospital waste such as body parts, organs, tissues, blood and body fluids, as well as soiled linen, cotton, bandages, and plaster casts from infected and contaminated areas, must be properly collected, segregated, stored, transported, treated, and disposed of in a safe manner.

Six Steps of Biomedical Waste Management

1. Waste collection
2. Separation
3. Transportation and storage
4. Treatment and Disposal
5. Transport to the final disposal site
6. Final disposal

To protect healthcare workers from occupational health risks associated with hospital waste management, efficient infectious waste control methods are necessary. In addition to safeguarding workers' health, such controls protect public health and the environment from the risks posed by hospital waste.

1.WASTE COLLECTION

Biomedical Waste Collection is an important phase in India's Biomedical Waste Management (BMWM) process. Proper collection ensures that hazardous waste is safely transported from healthcare institutions to treatment facilities, avoiding contamination and exposure to infectious pathogens. The biomedical waste collection process is regulated to protect human health and the environment.

2.3. Tracking and Barcode Systems - Biomedical waste bags and containers are barcoded in accordance with the 2016 BMW Management Rules to facilitate tracing from the point of generation to the disposal location.

2.4. Storage in Specific Short-Term Locations Waste is temporarily held in specified areas within healthcare institutions after it has been segregated. To avoid unwanted access, these spaces are usually well-ventilated, remote, and have restricted access. Regulations dictate that waste must only be held for a certain amount of time in order to avoid contamination or decomposition, especially in hot and muggy climates.

2.5. Programs for Employee Awareness and Training Healthcare personnel, support staff, and trash handlers receive training and frequent refresher courses on BMW rules to guarantee that waste is properly segregated at the source. Employees receive training on safety practices, how to handle garbage in accordance with rules, and the dangers of improper segregation.

2.6. Monitoring and Compliance with Regulations To make sure that the segregation rules are being followed, healthcare facilities must perform internal audits and inspections.

3. TRANSPORTATION AND STORAGE

3.1 India's Biomedical Waste Management (BMW) process, transportation and storage are crucial steps because they guarantee that BMW is handled securely from the point of generation to the facility for treatment and disposal. BMW should be stored and transported carefully to reduce the possibility of infection transmission, public exposure, and environmental pollution. This is a summary of the laws and procedures governing the movement and storage of biological waste in India. Storage on-site at medical facilities Specific Storage Spaces - Before being picked up by approved garbage haulers, waste produced at healthcare facilities is initially kept in certain, remote locations on the premises. To stop unwanted access, these places need to be well-ventilated, have warning signs posted, and have limited access.

Color-Coded Bag Storage: Depending on the type of trash, it is kept separate even in temporary storage spaces by being stored in bags that are colored yellow, red, white, and blue. Time Limits: In order to prevent decomposition, particularly in warm or humid conditions that could raise the danger of contamination, regulations state that biological waste cannot be kept on-site for longer than 48 hours. Healthcare establishments are required to notify local authorities and take extra precautions if trash cannot be delivered within this time frame.

3.2 Interim Storage at Regional Collection and Treatment Centers and Common Biomedical.

Waste Treatment Facilities (CBWTFs): India has set up CBWTFs in a number of areas, particularly to serve small clinics, laboratories, and medical facilities without internal waste management systems.

Waste Sorting and Temporary Storage: When waste arrives at a CBWTF, it is sorted and kept in separate areas of the building for a short time. This guarantees that the garbage will remain segregated until it is processed. CBWTFs can manage waste securely for brief periods of time thanks to their safe, climate-controlled storage spaces. Daily or Frequent Collection plans: To control the amount of waste produced in densely populated regions, CBWTFs frequently implement daily collection plans. Depending on facility capacity and demand, collection in rural regions may occur twice or three times per week.

3.3 Transportation of Licensed Transporters: Only organizations that have received certification and licensing are permitted to transport biological waste. To guarantee that biomedical waste reaches treatment facilities safely, these organizations handle, load, and unload it according to stringent guidelines.

Designated Vehicles: Closed, specially made vehicles with the following characteristics are used to carry biomedical waste.

Leak-Proof Compartment: To stop infectious waste from spilling or leaking, vehicles must have leak-proof compartments.

Color Coding and Labeling: To identify that they are transporting biomedical waste, vehicles should have unambiguous labeling and the biohazard emblem displayed.

Compartmentalization: To avoid mixing while being transported, various waste kinds are frequently kept in distinct compartments within the vehicle.

Training for Drivers and Staff: Transportation-related drivers and waste handlers need to get instruction in safe handling procedures, including emergency procedures for spills and mishaps. Additionally, they make use of personal protective equipment (PPE) such as masks, gloves, and protective clothes.

Barcode Tracking and Documentation: To guarantee traceability, waste bags and containers are labelled or barcoded. Each shipment is accompanied by a manifest or logbook that lists the waste's kind, quantity, and source along with the treatment facility where it will be treated.

4. TREATMENT AND DISPOSAL

In India, the biomedical waste management (BMW) process, which aims to reduce the hazards associated with infectious and hazardous materials produced by healthcare facilities, includes the treatment and disposal of biomedical waste (BMW). The Biomedical waste

Management Rules, 2016, which specify safe handling, treatment, and disposal procedures, regulate the treatment and disposal of BMW in India. • Techniques for Treating Biomedical Waste India employs a range of treatment techniques based on the waste's kind and degree of hazard. Among the important therapy technologies are:

○ Incineration: Waste that cannot be properly disposed of in any other way is burned. This includes contaminated medications, objects soiled with blood or biological fluids, and pathological waste (such as tissues or body parts).

- Procedure: Waste is burned at high temperatures (usually between 850 and 1,100°C) during incineration, producing heat, gas, and ash. To reduce dangerous emissions, the gases are filtered using pollution control equipment.

- Benefits: include lowering the volume of waste, eliminating pathogens, and lowering the risk of infectious transmission.

- Cons: Incineration uses a lot of energy and might create dioxins and other gasses if not controlled. [14]

○ Autoclaving: This steam-based sterilizing technique is mostly utilized for infectious waste, including lab waste and microbiological cultures. - Procedure: To eliminate germs, waste is exposed to high-pressure steam at 121–134°C for a predetermined amount of time.

- Benefits include being safe for the environment because it doesn't produce harmful emissions and effectively sterilizing garbage so that it may be dumped in landfills.

- Cons: Does not lessen the physical volume of garbage and is only appropriate for certain types of waste. [15] ○ Microwave Treatment: Pathogens in garbage are heated and destroyed by microwaves using electromagnetic waves. - Procedure: After being shred, waste is sterilized for safe disposal by heating it to high temperatures in microwaves. - Benefits include decreased waste volume, low pollution risk, and effective pathogen killing.
- Cons: Expensive initial outlay and ongoing upkeep; not appropriate for all waste kinds.[16]
- Chemical Disinfection: Certain pathogenic and hazardous wastes, especially liquid waste from labs, blood, and bodily fluids, are treated chemically.
 - Procedure: Pathogens are neutralized by chemical disinfectants (such as chlorine compounds), enabling the waste to be handled or disposed of as non-infectious trash.
 - Benefits: Easy procedure that works well for liquid waste.
 - Cons: It is not appropriate for huge volumes of waste and chemical leftovers can damage the environment if improperly managed. [17] ○ Mutilation and Shredding: Shredding is frequently used in conjunction with chemical disinfection or autoclaving to stop the reuse of objects like plastics, syringes, and needles.
 - Process: To render waste unidentifiable and worthless, it is torn into smaller bits.
 - Benefits: include improved waste safety, reduced reuse risk, and assistance with landfill disposal. - Cons: Only a supplemental treatment; more steps are needed to destroy the pathogen.
- Facilities for the Common Biomedical Waste Treatment (CBWTFs): In order to centralize the treatment of biomedical waste, especially for small healthcare facilities without internal waste treatment infrastructure, India established CBWTFs. For some facilities in a given area, CBWTFs are permitted to collect, handle, and dispose of BMW. Among the services offered by CBWTFs are:
 - Collection and Transportation: Usually, CBWTFs oversee the collection of waste from medical facilities and drive it in specially designated vehicles with labels.
 - On-site Treatment: CBWTFs have capabilities for chemical disinfection, shredding, autoclaving, and burning. Waste is sorted and handled based on its type.
 - Environmental Compliance: CBWTFs must have pollution control systems and are subject to oversight by the State Pollution Control Boards (SPCBs) to guarantee adherence to environmental regulations.

table 1- comparison of treatment technologies for medical wastes [18]

Systems	for autoclave	Microwave	Hydro clave	Incinerator	Chemicals treatment
Description	Sterilization by steam (direct heating)	Heating garbage in microwave	Pressed in a steam sterilization, concurrent shredding, dehydration, and indirect heating	High temperature incineration of rubbish	Mixing chemicals like chlorine with Pre ground trash
Effectiveness of sterilization	Moderate	Moderate	Moderate	High	Depending on the strength of the chlorine and how it spreads throughout the waste
Maintenance abilities of operators	Low degree of expertise needed	Automated, but requiring a high degree of complexity and maintenance expertise	Low degree of expertise needed	Superior operator and maintenance abilities are necessary	Grinding and chemical control require a high level
Capital cost	Minimal	High cost	Minimal	High cost	Moderate
Operating cost	Minimal	High cost	Minimal	High cost	Minimal
Air emissions	Not harmful yet odorous	Odorous to some extent, but not harmful	Odorous to some extent, but not harmful	May be extremely harmful	A few emissions of chlorine
Water emissions	Smelly and maybe containing live microbes	Inconsiderate	Sterilized but odorous	No	No

Features of treated waste	Wet garbage with identifiable materials	Wet garbage that has been shred	Shredded garbage, dehydrated, and unidentifiable stuff	Mostly ash, but it could also include harmful materials	Shredded wet trash that contains disinfecting chemicals
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● Methods of Disposal

Waste is recycled, dumped in a landfill, or disposed of in an environmentally responsible way after it has been handled.

- Sanitary Landfills: Sanitary landfills are lined and outfitted to prevent contamination of soil and groundwater and are used to dispose of non-hazardous, treated waste (such as incinerated ash or autoclaved trash).
- Encapsulation: To avoid reuse and landfill disposal, sharp trash, including needles and blades, is frequently enclosed in concrete or plastic containers.
- Deep Burial: In isolated and rural locations without access to burning facilities, anatomical waste and other highly contagious items are interred in deep burial pits while adhering to stringent regulations to avoid contaminating the environment.

5. TRANSPORTATION TO FINAL DISPOSAL SITE

5.1 Approved Transportation Organizations and Automobiles

- Licensed Transporters: Biomedical waste can only be transported by recognized organizations and individuals. SPCBs grant these agencies licenses, guaranteeing that they adhere to operational and safety norms.
- Dedicated trucks: To reduce the possibility of cross-contamination with regular waste, biomedical waste needs to be transported in specially built, dedicated trucks. These cars have special qualities:
 - Leak-proof compartments: guarantee waste containment and stop leaks while in transit.
 - Segregated Sections: Various sections aid in the separation of waste kinds and prevent the mixing of dangerous, sharp, and infectious wastes.
 - Biohazard emblem: To notify the public and waste handlers of the possible risks, vehicles display the biohazard emblem in addition to warning labels.

5.2 Waste Tracking with Color-Coded Bagging and Labelling.

5.3Barcode Monitoring: Bags and containers frequently have barcodes to increase accountability and traceability. This enables authorities to track garbage from the site of generation to the Common Biomedical garbage Treatment Facility (CBWTF), where it is eventually disposed of.

5.4Instruction for Drivers and Handlers: The safe handling of biomedical waste is taught to drivers and other transportation-related staff. Protocols for handling, emergency response, spill control, the use of personal protective equipment (PPE), and documentation requirements are all included in training.

- Personal protective equipment (PPE): To lessen exposure to hazardous materials, all employees handling trash must wear the proper PPE, such as gloves, masks, goggles, and protective clothes.

5.5 GPS tracking and monitoring in real time BMW freight vehicles are now subject to GPS tracking in numerous states. By using GPS tracking, the location of the truck can be tracked in real time, preventing unlawful dumping or unapproved detours and guaranteeing that the waste reaches the designated CBWTF.

- Record-keeping: Transporters must keep a logbook that contains comprehensive details about every shipment, such as the origin, destination, time of collection, and amount of waste. This paperwork acts as a record for inspections and aids in upholding accountability.

5.6 Emergency Preparedness and Safety Procedures Emergency Equipment and Spill Kits: To handle any unintentional spills or leaks during transit, vehicles are equipped with disinfectants, first aid materials, and spill containment kits.

- Emergency contact information: It is displayed on vehicles so that in the event of an accident or spill while in transit, the public or authorities can get in touch with the appropriate parties.

5.7 Transfer Points: In certain situations, trash may be moved to larger vehicles for delivery to a CBWTF if distances are great, or it may be temporarily held at certain locations. Vehicles and transfer points are built to maintain safety and avoid contamination.

- Transportation to CBWTFs: Usually, biomedical waste is taken to CBWTFs for disposal and final treatment. To prepare the waste for ultimate disposal, CBWTFs are outfitted with treatment technologies like shredders, autoclaves, and incinerators.
- Final Disposal Location: Following treatment, residual and non-infectious waste (such as incinerated ash or sterilized garbage) is dumped in approved sanitary landfills.

5.8 Regulatory Authorities' Compliance and Monitoring: Compliance with garbage transportation is regularly monitored by the CPCB and SPCBs. Checks of the vehicle's condition, records, and safety procedures may be part of an inspection.

- Reporting Requirements: SPCBs must receive periodic reports from healthcare facilities and carriers that include information on the quantity of waste produced, moved, and handled. This helps authorities resolve any disparities in waste management and promotes regulatory compliance.[25]

6. FINAL DISPOSAL

table.3: general techniques used in different nations to dispose of biological waste table 3 lists the many methods of disposal that different nations employ to handle their biological waste.

Sr. No	Name Of Country	Common Techniques Used to Get Rid of Biomedical Waste	References
1.	Mongolia	Incineration, autoclaving, and open dumping or burning	Shineet al. (2008)
2.	Iran	Sewers, landfills, and incineration	M. H. Dehghani et al. (2008)
3.	India	Autoclaving, landfilling, incineration, and recycling/reuse	Yashasvi et al. (2012)
4.	Bangladesh	Dumping	Hassan et al. (2008)
5.	Malaysia	Recycling, Incineration, and Landfill	Hossain et al. (2011)
6.	Libya	Incineration and Dumping	Sawalem et al. (2009)
7.	Greece	Landfill, pyrolytic combustion, and recycling	Tsakona et al. (2007)

□ Key Elements of the 2016 Biomedical Waste Regulations

- The regulations now include a wider range of health camps, including those for blood donation, vaccination, and surgery. [9]
 - The occupant of HCFs now has updated duties. The individual with administrative authority over the HCF that is producing BMW is known as the occupier.[10]
 - Laboratory, microbiological waste, and blood bags must be pre-treated on-site before being disposed of at CBMWTF or on site. The National AIDS Control Organization (NACO) or WHO guidelines should be followed while sterilizing or disinfecting.
 - Within two years of these regulations being announced, the use of gloves, blood bags, chlorinated plastic bags, and other items should be phased out.
 - To train all of its healthcare workers and vaccinate them against tetanus and hepatitis B.
 - Before combining with other liquid waste, liquid waste must be pre-treated to separate it at the source.
 - To install a barcode system for BMW that will allow items to be sent outside for disposal and treatment.
 - All significant incidents, including those brought on by blasts, fire dangers, handling BMWs, and corrective measures implemented by the designated authority, must be notified.
 - Within two years of the date of this notification, the current incinerator must be improved or modified to meet the new requirement.
 - The website's BMW disposal registry must be updated every month and kept up to date every day.
 - A common biomedical waste treatment and disposal facility (CBMWTF) operator now has more responsibilities. They ought to help train the HCW from the location where the garbage is picked up. Additionally, a global positioning system and barcoding should be set up within a year to handle BMW. Keep any documentation related to the incineration and autoclaving processes for a duration of five years.
 - BMW has been better segregated, packaged, transported, and stored. Based on color coding, waste kind, and available treatment options, biomedical waste has been divided into four groups. Furthermore, untreated animal and human anatomic waste, dirty trash, and biotechnological waste shouldn't be kept in storage for longer than 48 hours.
 - If there are CBMWTF facilities within 75 Km, no HCF is allowed to build an onsite BMW treatment and disposal plant. In the event that no CBMWTF is accessible, the occupier must first obtain permission from the appropriate authority before setting up the necessary BMW treatment facilities, such as an autoclave, microwave, shredder, or incineration. These recyclables should be delivered to approved recyclers once the autoclaving or microwaving of plastics and glassware has been verified, followed by mutilation or shredding.
 - The occupier is only given permission to dispose of BMWs for Non bedded HCFs once. For bedded HCFs, the authorization's validity and the consent orders' validity must coincide.
 - Incinerator emission standards have been changed to be more ecologically friendly. The acceptable limit for SPM is 50 mg/nm³, the residence period in the incinerator's secondary chamber is two seconds, and the standard for dioxin and furans is 0.1 ng TEQ/Nm³.
- Every year, the Ministry of Environment, Forests, and Climate Change will oversee how the regulations are being applied. Each state will be responsible for ensuring compliance by establishing a district-level committee headed by a district collector, district magistrate, or additional district magistrate. Additionally, this group will report to the state Pollution Control Board every six months.

□ **Biomedical Waste Management Rule**

The 'Bio-medical Waste (Management and Handling) Rules, 1998,' which were notified on July 20, 1998, and were formulated by the Ministry of Environment and Forests (MOEF), Government of India, offer consistent guidelines and a code of practice for the entire country. The

'occupier' (a person who has control over the concerned institution / premises) of an institution generating biomedical waste (e.g., hospital, nursing home, clinic, dispensary, veterinary institution, animal house, pathological laboratory, blood bank, etc.) is explicitly stated in this rule as being responsible for taking the necessary actions to ensure that such waste is handled without any negative impact on human health and the environment. In accordance with the Environment Protection Act of 1986, the Biomedical Waste Management Rules were published on July 20, 1998. This regulation requires all operators of facilities that produce biomedical waste, such as clinics, hospitals, nursing homes, dispensaries, veterinary clinics, animal houses, pathological labs, and blood banks, to take all reasonable precautions to handle such waste without endangering the environment or public health. A Form 1 application must be submitted to the designated authority for authorization by any occupier of an institution that generates, collects, receives, stores, transports, treats, disposes of, and/or handles biomedical waste in any other way, with the exception of clinics, dispensaries, pathological laboratories, and blood banks that treat or serve fewer than 1000 (one thousand) patients per month.

Each biomedical waste facility operator must submit an application in Form 1 to the designated authority in order to be granted authorization. Each Form 1 application for authorization must be submitted with a fee that the State or Union Territory government may specify. Both Schedule I and Schedule V requirements must be followed when treating and disposing of biomedical waste. Every occupier must, if necessary, set up the necessary biomedical waste treatment facilities, such as an autoclave, microwave system, or incinerator, in accordance with the schedule in Schedule VI, or guarantee that the necessary treatment is provided. Every State and Union Territory (UT) government must set up a designated authority for this purpose.

Advisory committees would be established by the respective governments to provide guidance on the application of these regulations. If the occupier or operator feels wronged by any of the authority's orders, they may also file an appeal with any other authority that the State or UT government deems appropriate. Schedule VI of the "Bio-Medical (Management & Handling) Rules, 1998" specifies the time limit and a list of prescribed authorities that have been created thus far by different State Governments can be found in Annexure 7.3 Disposal of garbage in any waste treatment plant, including a common one. Schedule I, Schedule II, Schedule III, Schedule IV, Schedule V, and Schedule VI are the primary components of the Biomedical Waste Management Rule of 1998.[13]

□ **Current status of medical waste disposal in India**

Despite having a total treatment capacity of 1,590 TPD, India produces roughly 700 TPD of biomedical waste annually, of which 640 TPD is processed. According to reports, the installed autoclaving and incineration capacities are 752 and 857 TPD, respectively.[26]

□ **CHALLENGES**

India's biomedical waste management industry has many obstacles that affect human health and the environment. Here are a few of the main concerns:

1. **Inadequate Segregation Practices:** One of the fundamental problems is that biological waste is not properly separated at the source. Because of inadequate training or a lack of resources, biomedical waste is frequently combined with general waste, raising the risk of contamination and making safe disposal challenging.
2. **Limited Treatment Facilities:** Licensed biological waste treatment facilities are hard to come by, especially in smaller towns and rural locations. Waste may be burned or illegally disposed of.
3. **Lack of Knowledge and Training:** A large number of trash handlers, healthcare professionals, and other employees are not properly trained in the safe handling of biomedical waste.
4. **Lax Enforcement of Regulations:** India has the Biomedical Waste Management Rules (2016) for the safe management of waste however enforcement is still uneven. This is frequently brought about by a lack of cooperation between regulatory agencies, a lack of resources, and problems keeping an eye on compliance in both public and private healthcare facilities.
5. **Increasing biological Waste Volume:** As healthcare facilities and medical procedures have grown, so too has the amount of biological waste. This was made worse by the COVID-19 epidemic, which brought in new kinds of hazardous trash, including testing kits, syringes, and personal protective equipment.
6. **Difficulties in Rural and Remote Areas:** Because biomedical waste management infrastructure is frequently centralized in urban areas, safe waste treatment facilities are either scarce or nonexistent in rural and remote places. This puts communities and the environment at greater risk by forcing healthcare providers to use inferior disposal techniques.[25]

□ **FUTURE DIRECTIONS**

An all-encompassing strategy incorporating regulatory changes, technology breakthroughs, more public awareness, and better infrastructure is needed for India's biological waste management in the future. The following are some important avenues for future development to enhance the biomedical waste management system:

1. **Strengthening Regulations and Compliance:** Biomedical waste management regulations must be updated and strictly enforced. Healthcare facilities can adhere to safe waste disposal procedures with the support of more transparency, harsher sanctions for noncompliance, and routine monitoring.
2. **Investing in Waste Treatment Infrastructure:** It is crucial to construct additional waste treatment facilities nationwide, especially in rural and neglected areas.
3. **Promotion of Eco-Friendly and Sustainable Practices:** The amount of biomedical waste produced can be decreased by promoting healthcare institutions to employ eco-friendly alternatives and reduce single-use plastic.

4. Using Advanced Waste Treatment Technologies: Older incineration techniques that emit harmful emissions may be replaced with cutting-edge technologies including chemical disinfection, plasma pyrolysis, and microwave-based disinfection. Investing in these technologies development and research could greatly lessen the environmentally harmful effects of biomedical waste.
 5. Decentralized Waste Management Systems: In distant locations, setting up tiny, decentralized waste treatment facilities can assist control garbage closer to its source. Decentralized systems enable facilities handle trash more efficiently on-site, lower transportation costs, and lower the chance of waste exposure.
 6. Strengthening Training and Awareness Programs: Healthcare personnel and support staff should be required to complete extensive training programs on handling biological waste.
 7. Digital Tracking and Monitoring: Accountability in the disposal of biological waste can be guaranteed by putting in place a digital tracking system.
 8. More Public Awareness initiatives: By teaching communities about the dangers of biological waste and how to properly dispose of it, public awareness initiatives can help prevent the general public from handling it improperly. Community-driven solutions can also be developed by involving communities and teaching them about the dangers of improper biomedical waste management, particularly in places with high population densities.
 9. Emphasis on Recyclable and Reusable Materials: Reducing waste can be achieved by promoting the use of materials that can be sterilized and reused, where practical and safe. Innovation and research in sterilization techniques that allow for the safe reuse of PPE and other equipment may also be beneficial.
- If successfully carried out, these programs have the potential to improve India's biomedical waste management system and lower hazards to the environment and public health by making it safer, more sustainable, and more effective.[25]

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