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# Biomedical waste management for risk pathogens

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## Abstract
Biomedical waste is a potent risk or hazard to human and animal health, there is a vital need for its efficient management. This article is an examination of various guidelines and efficient measures to deal with the biomedical waste particularly with biomedical waste management and risk pathogens associated with the waste. Classification of biomedical waste as given by concerned authorities along with the guidelines covering all rules and regulations for biomedical waste management minimizing the risk from pathogens, this article also covers the categories of biomedical waste, basic outline of steps in managing biomedical waste. Emphasis on biosafety levels hazard control and separate management of hazardous pathogens according to four different biosafety level laboratories. Different techniques and processes involved in biomedical waste management were also discussed along with their demerits and possible alternative measures to avoid risk to environment and animal health. Finally, some basic cautions to deal with the biomedical waste especially in microbiological laboratories as this was the major concern recently during COVID-19 pandemic. This article is an overview of several basic aspects of management and risk associated with biomedical waste.

**Keywords:** Biomedical waste, biosafety levels, environment, hazard, pathogens

## Introduction
WHO defines biomedical waste as waste generated by healthcare activities such as diagnosis, treatment or immunization of animals or human beings or through research activities that include a wide range of materials from used syringes and needles to diagnostic samples, medical devices, pharmaceuticals, chemicals, blood, body parts, solid dressings and radioactive materials. According to the World Health Organization (WHO, 2000) [22], the composition of bio-medical waste are Non-hazardous waste (85%), Hazardous waste (15%). Infectious waste accounting for 10 percent and radioactive or chemical waste accounting for 5 percent, every year (WHO, 2000) [22]. It was estimated that more than 5.2 million people, including 4 million children, die as a result of diseases caused by medical waste throughout the world (Rahman *et al*., 2020) [13]. Bio-medical waste means any waste, which is generated during the diagnosis, treatment or immunization of human beings or animals or research activities pertaining thereto or in the production or testing of biological or in health camps. Bio-Medical waste includes all the waste generated from the Health Care Facility which can have any adverse effect to the health of a person or to the environment in general if not disposed properly. It constitutes about 15% of the total waste. All such waste which can adversely harm the environment or health of a person is considered as infectious and such waste has to be managed as per BMWM Rules, 2016.

## Classification of biomedical waste
The World Health Organization has categorized biomedical waste into eight categories. These are waste and by-products covering a diverse range of materials:

**Infectious waste:** Waste contaminated with blood and other bodily fluids (e.g., from discarded diagnostic samples), cultures and stocks of infectious agents from laboratory work (e.g., waste from autopsies and infected animals from laboratories), or waste from patients in isolation wards and equipment (e.g., swabs, bandages and disposable medical devices); Pathological wastes including tissues, organs or fluids, body parts and contaminated animal carcasses. This includes anatomical waste from human and animals usually generated from hospitals and veterinary hospitals. Examples include blood, body parts such as amputated legs or arms, placenta and tissues. They are potentially dangerous with a high risk of disease and infection in a susceptible individual who has direct contact with them; Sharps such as Syringes, needles, disposable scalpels and blades, etc.;

**Chemicals:** For example, solvents used for laboratory preparations, disinfectants and heavy metals contained in medical devices (e.g., mercury in broken thermometers) and batteries.

**Pharmaceuticals:** (Expired, unused, and contaminated drugs and vaccines).

**Genotoxic waste:** Highly hazardous, mutagenic, teratogenic or carcinogenic, such as cytotoxic drugs used in cancer treatment and their metabolites.

**Radioactive waste:** Such as products contaminated by radionuclides including radioactive diagnostic material or radiotherapeutic materials.

**Nonhazardous or general waste:** Waste that does not pose any particular biological, chemical, radioactive, or physical hazard.

**Categories of biomedical wastes**

Bio Medical Waste Management Rules, 2016 categorizes the bio-medical waste generated from the health care facility into four categories based on the segregation pathway and colour code. Various types of bio medical waste are further assigned to each one of the categories, as detailed below:

**Yellow category:** This constitutes Human anatomical waste, solid wastes, Discarded or Expired Medicine (Pharmaceutical waste like antibiotics, cytotoxic drugs including all items contaminated with cytotoxic drugs along with glass or plastic ampoules, vials etc.); Chemical wastes (Microbiology, Biotechnology and other clinical laboratory waste).

**Red category:** Wastes generated from disposable items such as tubing, bottles, intravenous tubes and sets, catheters, urine bags, syringes without needles, fixed needle syringes with their needles and gloves.

**White category:** 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 discarded and contaminated metal sharps.

**Blue category:** Broken or discarded and contaminated glass including medicine vials and ampoules except those contaminated with cytotoxic wastes.

**Bio-medical waste management**

**Biomedical Waste Management in India:** Biomedical wastes in India are handled and managed under Biomedical Waste Management (Management and Handling) Rules, 1998 and exercising powers under Section 6,8,25 of Environmental Protection Act, 1986 (Under the ministry of Environment and Forests). Till date, four amendments have been made in 2000, 2003 and 2011 with these latest guidelines coming into force from 28th March 2016 (Singhal *et al*., 2017) [20].

**Guidelines of biomedical waste management, 2016**

Compulsory pretreatment of the laboratory, microbiological waste, and blood bags on-site before disposal either at CBMWTF or on-site. The method of sterilization/disinfection should be in accordance with National AIDS Control Organization (NACO) or WHO.

The use of chlorinated plastic bags, gloves, blood bags, etc. should be gradually stopped and this phasing out should be within 2 years from the date of notification of these rules.

Training should be provided to all its HCWs and protect them against diseases such as hepatitis B and tetanus by immunization. Liquid waste should be separated at source by pretreatment before mixing with other liquid waste. To set up a barcode system for BMW containing that is to be sent out of the premises for treatment and disposal. All major accidents including accidents caused by fire hazards, blasts, during handling of BMW, and remedial action taken by the prescribed authority should be reported. The existing incinerator should be upgraded/modified to achieve the new standard within 2 years from the date of this notification. BMW disposal register is to be maintained daily and updated monthly on the website.

The segregation, packaging, transportation, and storage of BMW have been improved. Biomedical waste has been classified into four categories based on color code-type of waste and treatment options. In addition, untreated human anatomical waste, animal anatomical waste, soiled waste, and biotechnology waste should not be stored beyond a period of 48 h. In case, there is a need to store beyond 48 h, the occupier should take all appropriate measures to ensure that the waste does not adversely affect human health and the environment (BMW guidelines by Ministry of Environment & Climate Change, 2016) [9].

Standards for emission from incinerators have been modified to be more environmental friendly. These are permissible limit for SPM-50 mg/nm3; residence time in secondary chamber of incinerator-two seconds; standard for dioxin and furans-0.1 ng TEQ/Nm3 (Datta *et al*., 2018) [10].

Ministry of Environment, Forest and Climate change will monitor the implementation of rules yearly. The responsibility of each state to check for compliance will be done by setting up district-level committee under the chairpersonship of District Collector or District Magistrate or Additional District Magistrate. In addition, every 6 months, this committee shall submit its report to the State Pollution Control Board.

**Steps involved in bio-medical waste management**

First five steps (Segregation, Collection, pre-treatment, Intramural Transportation and Storage) is the exclusive responsibility of Health Care Facility. While Treatment and Disposal is primarily responsibility of CBWTF operator except for lab and highly infectious waste, which is required to be pre-treated by the HCF. The management of bio-medical waste can overall be summarized as; Waste segregation in color coded and barcode labeled bags/containers at source of generation followed by pre-treat of Laboratory and highly infectious waste then Intra-mural transportation of segregated waste to central storage area for temporary storage of biomedical waste in central storage area finally followed by Treatment and Disposal of biomedical waste through CBWTF or Captive facility (CPCB guidelines, 2016) [9].


**Fig 1:** Illustration of Biomedical waste management including segregation, processing, treatment and disposal

**Biomedical waste management & disposal**

**Mechanical processes:** Compacting (Reducing size and volume of waste (useful for general non- hazardous wastes)**;** Shredding (Breaking the material into smaller pieces by grinding/cutting/granulation; useful for plastics, rubber and soft metals); Landfills (Oldest method of waste disposal mainly of two types: Open dump and Sanitary landfill).

**Effluent treatment plant:** Liquid waste generated due to use of chemicals or discarded disinfectants, infected secretions, aspirated body fluids, liquid from laboratories and floor washings, cleaning, house-keeping and disinfecting activities should be collected separately and pre-treated prior to mixing with rest of the wastewater from HCF (CPCB, 2018) [9]. The combined wastewater should be treated in the ETP having three levels of treatment; primary, secondary and tertiary; Primary treatment with neutralization, precipitation and clarification and Secondary treatment including high rate aerobic biological treatment, secondary settling tank followed by tertiary Treatment with pressure Filtration, Disinfection and disposal to drain/sewer (Chakraborty *et al*., 2021) [7].

**Thermal processes**

Heat disinfection (Boiling for 20 minutes, it is useful for pre-treatment of sharps and plastic waste); Hot air oven (Causes sterilization and mutilation at 160 °C, used for glassware, powders and oils impermeable to steam); Autoclave (steam sterilization under pressure is a low-heat thermal process, waste is subjected to 121°C for 15 minutes at 15psi pressure); Inertization (Process of mixing biomedical waste with cement and other substance before disposal, so as to minimize risk of toxic substances contained in waste to contaminate ground/surface water). Inertization is especially suitable for pharmaceuticals and for incineration ashes with high metal content; Hydroclave (Steam sterilization under pressure causes fragmentation of wastes), Waste is subjected to the temperature of 121 °C or 131 °C; Microwave (Volumetric heating for microbial hazardous wastes using frequency of 2450 MHz and wavelength 12.24nm, waste destruction occurs by heat conduction).

**Incineration:** High temperature dry oxidation process which reduces waste volume and weight (up to 70-80%). Waste is subjected to 850± 50 °C (Primary chamber) and 1050 °C (Secondary chamber). Incineration does not require pre-treatment. The major disadvantage of incineration is generation of smoke. Medical waste incinerators emit toxic air pollutants and toxic ash residues that are the major source of dioxins in the environment (Clasen and Edmondson, 2006) [8]. Combination of autoclave and shredder is used as an alternative. In a process combining shredding, direct heated steam, and high pressure to achieve complete sterilization of infectious materials, the contaminated waste is loaded into the top of the machine in which a heavy-duty shredder is mounted. Once the machine is sealed, the waste, including the containers and other large resistant material, is shredded and falls by gravity into the lower chamber. A minimal temperature of 121 °C and a pressure usually of 2-5 bar (200-500 kPa) should be maintained during the total contact time of 1-4 h.

**Plasma pyrolysis:** Plasma pyrolysis technology is a non-incineration thermal process that uses extremely high temperature in an oxygen starved environment to completely dissociate waste in to their elemental constituents. Heat generated by graphite electrode-based plasma arc system.

Graphite electrode-based plasma arc system converts the electrical energy into heat energy with more than 90% efficiency.

**Chemical processes:** Includes use of Disinfectants and chemicals. A disinfectant is a chemical agent which destroys or inhibits growth of pathogenic micro-organisms in the non-sporing or vegetative state. Disinfectants are applied to inanimate objects and materials such as instruments and surfaces to control and prevent infection E.g. Sodium hypochlorite (0.1% and 0.5% solution), Hydrogen peroxide (0.5% solution) and Ethyl alchohol (70-90%) (Chakraborty *et al*., 2021) [7].

**Recycling of wastes:** Use of 3R and 4R policy; 3 R policy (Avoid any disease spreading and contamination of other kind it is required to reduce the direct disposal. Reuse and Recycle of can also be possible option to reduce the waste disposal as incinerating also results in polluting environment. 4 R policy: Reduce, Reuse, Recycle and Recover after having reduced, reused and recycled, it is important to recover! Recovering is the process of giving a value to a material believed to be waste. Recovering means to transform wastes into resources. The best example of recovering is composting. It transforms our fruit and vegetable wastes into rich soil conditioners, commonly known as compost.

**Risk from infectious and pathological wastes**

The pathogens in the waste can enter the body by absorption through puncture, abrasion, opening or cut in the skin; absorption through the mucous membranes; inhalation, and ingestion. However, except for the highly infectious wastes, concentration of the indicator microorganisms in other types of health care waste is generally no higher than that found in the domestic wastes. (Pruss *et al*., 1999) [18].

**Risk pathogens involved in biomedical waste:** Microbes will adapt and grow at subzero temperatures, as well as extreme heat, desert conditions, in water, with an excess of oxygen, and in anaerobic conditions, with the presence of hazardous compounds or on any waste stream reported that truly pathogenic forms may survive in waste (Pavoni *et al*., 1975) [17].

**Bacteria:** *Escherichia coli* (Most strains are harmless, although there are serotypes that cause food poisoning in humans, and strains such as O157:H7, which can cause serious illness or death in the elderly, the very young and the immuno-compromised animals. (Sahlström *et al*., 2003) [19]. Treatment at 70 °C for 30min was sufficient to inactivate E. coli. Inactivation of non-pathogenic E. coli and pathogenic E. coli O157:H7 has been reported during composting of several types of waste, including animal manure and sewage sludge (Vogt *et al*., 2005) [21]. There are other notorious bacteria living as opportunistic pathogens such as *Pseudomonas aeruginosa* and *Acinetobacter baumannii* are commonly found adhering to medical devices, for example, hypodermic needles, blades, etc., and capable of causing serious infections in immunocompromised individuals. Salmonella is often used as an indicator organism to test whether a particular treatment process has been successful in the inactivation of microorganisms. Generally, Salmonella is not able to survive at temperatures above 70 °C. The aerobic heterotrophic counts from hospital waste were higher than anaerobic heterotrophic counts. E. coil was found to be the predominant species isolated (Anitha and Jayraaj, 2012) [3]. The hospital wastes could have contributed immensely in the increased number of bacterial counts. Live pathogens found in hospital wastes, the most predominant (80-90%) is the genus Bacillus with Staphylococci and Streptococci varying between 5 and 10% (Oyeleke and Istifanus, 2009) [16].

**Viruses:** It has been estimated that the chances of infection for Hepatitis B, HIV and Hepatitis B after a needle-stick injury from a contaminated syringe. The hepatitis B virus is very persistent in dry air and can survive for several weeks on a surface, brief exposure to boiling water and to some antiseptics, including 70% ethanol.

**Biosafety levels hazard control**

**Biosafety Level 1 (BSL-1)** is suitable for work involving well-characterized agents not known to cause disease in healthy adult humans and of minimal potential hazard to laboratory personnel and the environment. E.g. Bovine Respiratory Syncytial virus, Fowl pox virus, SV40, ILT virus etc. Biosafety Level 1 (BSL-1) is suitable for work involving well-characterized agents not known to consistently cause disease in immunocompetent adult humans and that present minimal potential hazard to laboratory personnel and the environment. BSL-1 laboratories are not necessarily separated from the general traffic patterns in the building (Meechan and Potts, 2020) [14].

**Biosafety Level 2:** Primary hazards to personnel working with BSL-2 agents relate to accidental percutaneous or mucous membrane exposures, or ingestion of infectious materials. Extreme caution should be taken with contaminated needles or sharp instruments. Hazard in a microbiology laboratory refers to exposure to BSL-2 biological agents during technical laboratory work such as reading culture plates, removing caps or swabs, sub culturing and streaking plates (Al-Shammari *et al*., 2021) [21]. Necessary measures taken such as avoid spilling and splashing of hazardous chemicals and Personal protective equipment should be used as appropriate, such as splash shields, face protection, gowns, and gloves.

**Biosafety Level 3 (BSL-3):** BSL-3 is applicable to clinical, diagnostic, teaching, research, or production facilities where work is performed with indigenous or exotic agents that may cause serious or potentially lethal disease through the inhalation route of exposure. Laboratory personnel must receive specific training in handling pathogenic and potentially lethal agents and must be supervised by scientists competent in handling infectious agents and associated procedures. Animal Biosafety Level 3 (ABSL-3) involves practices suitable for work with laboratory animals infected with indigenous or exotic agents, agents that present a potential for aerosol transmission, and agents causing serious or potentially lethal disease. ABSL-3 builds upon the standard practices, procedures, containment equipment and facility requirements of ABSL-2 (Meechan and Potts, 2020) [14].

**Biosafety Level 4 (BSL-4):** BSL-4 practices, safety equipment, and facility design and construction are applicable for work with dangerous and exotic agents that pose a high individual risk of life-threatening disease, which may be transmitted via the aerosol route and for which there is no available vaccine or therapy. Agents with a close or identical antigenic relationship to BSL-4 agents also should be handled at this level. Viruses such as Marburg or Congo-Crimean hemorrhagic fever are manipulated at BSL-4. The primary hazards to personnel working with BSL-4 agents are respiratory exposure to infectious aerosols, mucous membrane or broken skin exposure to infectious droplets, and autoinoculation. All manipulations of potentially infectious diagnostic materials, isolates, and naturally or experimentally infected animals, pose a high risk of exposure and infection to laboratory personnel, the community, and the environment. The laboratory worker's complete isolation from aerosolized infectious materials is accomplished primarily by working in a Class III BSC or in a full-body, air-supplied positive-pressure personnel suit. The BSL-4 facility itself is generally a separate building or completely isolated zone with complex, specialized ventilation requirements and waste management systems to prevent release of viable agents to the environment.

### Measures for disinfection in laboratories

**U-V radiation:** UV C radiation (100-280 nm wavelengths) has maximum ultraviolet germicidal irradiation (UVGI) activity between 240-280 nm wavelength by causing destruction of nucleic acids of DNA and RNA by production of thymine dimers (Hamzavi *et al*., 2020) [12]. UV radiation at 240-260 nm have wide applications in routine terminal disinfection of unoccupied rooms and biosafety cabinets and also used for decontamination of N95 masks, available as UV tube light or UV lamp or mercury vapour lamp emitting 253.7 nm wavelength radiations and has wide applications in routine terminal disinfection of biosafety cabinets, corridors, isolation rooms, mainly air disinfection of unoccupied space in health care settings (Chakraborty *et al*., 2021) [7].

**Use of chemical disinfectants:** Useful in dealing with viral infected wastes such as during COVID-19 pandemic. Three disinfectants have become most important to combat this novel corona virus, which are 70-85% ethanol, 0.1% sodium hypochlorite for routine environmental disinfection and 0.5% sodium hypochlorite for large spillage management and ≥0.5% hydrogen peroxide with a minimal contact time of 1 minute for all three disinfectants are highly recommended. Fogging with 2% hydrogen peroxide solution can be other good option for air disinfection for unoccupied rooms and N95 masks decontamination (Chakraborty *et al*., 2021) [7].

### Risk to the community health and environment

Unintentional exposure is through inadequately disposed waste, resulting in the possible pollution of the air, water and soil. It also includes the use of strong disinfectants and chemicals having a strong impact on environment (Moore *et al*., 2003) [15].

**Impact on environment:** Treatment and disposal of healthcare waste may pose health risks indirectly through the release of pathogens and toxic pollutants into the environment. The disposal of untreated health care wastes in landfills can lead to the contamination of drinking, surface, and ground waters if those landfills are not properly constructed. The treatment of health care wastes with chemical disinfectants can result in the release of chemical substances into the environment if those substances are not handled, stored and disposed in an environmentally sound manner.

### Cautions to deal with different biomedical waste

**Personal protective equipment (PPE) kit:** PPE plays an important role in guaranteeing overall safety and health to the waste disposal workers in treatment or in disposal sites. Ensure that all sanitation workers are equipped with protective kits suited to the nature of their work, along with soaps and hand sanitizers. PPE acts as a barrier between the suspected infectious substance and the healthcare worker; PPE eliminates contact with an infectious agent.

Components of PPE kits include masks, gloves, goggles, glasses and gowns. Health institutions and waste disposal services should have practices and regulations that describe the correct order of donning and safely doffing these PPEs. The order for donning the PPE after performing hand hygiene is gown, then mask, goggles, face shield, and gloves; the order for removing the PPE is gloves, face shield, goggles, gown and then the mask should be removed (Ağalar *et al*., 2020) [1].

To reduce the severity of the identified hazards, the BMS department needs to ensure the laboratory safety equipment-including fume hood and biosafety cabinet class 2 (BSC 2) are available in the laboratory when handling any toxic or hazardous agent. This is the first step in securing a proper and safe laboratory environment and reducing the likelihood of hazards exposure (Al-Shammari *et al*., 2021) [21].

## Conclusions

Finally, to conclude health care waste is a health risk to medical, paramedical staff and housekeeping personnel involved in handling & treatment facility, patients their attendees and visitors at the Health Care Institutions. Treatment and disposal of HCW should be nearer to the point of generation of the waste. Biomedical waste is an emerging serious concern in a majority of health care organizations. Proper disposal of healthcare waste and awareness about the handling, segregation, and transport of biomedical waste is vital for all health care workers. Improper handling of healthcare waste results in mitigation of risk factors and becomes a threat to the ecosystem causing environmental hazards and occupational health hazards. Treatment and disposal of HCW should be nearer to the point of generation of the waste. The principle of the 3 R's includes reduce, recycle & replace the most hazardous waste to non-hazardous or less hazardous activities such as segregation at source, colour coding, storage within and outside the health care setting, collection and transportation.

## Abbreviations

**HCF:** Health Care Facility.
**BMS:** Biomedical Safety.
**BMW:** Bio Medical Waste.
**BMWM:** Bio Medical Waste Management.
**CBWTF:** Common Bio Medical Waste Treatment Facility.
**CPCB:** Central Pollution Control Board.
**SPCB:** State Pollution Control Board.
**PHC:** Primary Health Centre.
**PPE:** Personal Protective Equipment.
**ETP:** Effluent Treatment Plant.

**HCW:** Health Care Waste.
**WHO:** World Health Organization.

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