Green Technologies for Handling and Management of Biomedical Waste

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Abstract Biomedical waste management is of great significance because biomedical waste can adversely affect health, causing serious implications for people who come into contact with it. Segregation, storage, and safe disposal of biomedical waste is the key to effective management of it in a workplace. The health of a community or a society is estimated according to the health status of each individual residing in it. Various factors affect community health. One of the major factors associated with it is waste generated by health care institutions. Waste generated by health care activities includes a broad range of materials, from used needles and syringes to soiled dressings, body parts, diagnostic samples, blood, chemicals, pharmaceuticals, and radioactive materials. The biomedical waste that is generated may carry risks of various infections and diseases (typhoid, cholera, human immunodeficiency virus, hepatitis, etc.) in the long run. Therefore, use of proper storage, disposal, and treatment techniques are needed in order to minimize waste generation by hospitals. Effective management procedures should be employed for proper prevention and control of these types of waste. Various methods are used for treatment of biomedical waste, such as chemical methods, mechanical processes, biological processes, and irradiation processes. Green technologies—such as water treatment, solid waste treatment, and air purification—also play major roles in management of biomedical waste. Governments need to make arrangements for dedicated trash bins

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to be provided for disposal of hazardous waste. Appropriate management strategies are crucial for preservation of an equilibrium between the environment and mankind.

Keywords Health · Biomedical waste · Infectious ailments · Green technologies · Hospitals

1 Introduction

As a consequence of developments in automation, infrastructure, health care services, computer technology, and the cultivation sector in the past 20 years, people have become more fulfilled, comfortable, and secure, but the environment has been badly affected by enormous growth in environmental contamination due to our high waste generation rate. Waste material that consists of infectious, hazardous, or radioactive agents released during production processes, diagnostic processes, and treatment of medical conditions is defined as biomedical waste (BMW) [17]

Health care is essential for achievement of a good quality of life. Generation of waste from medical-related activities causes major concern regarding contamination of the environment [50]. Inappropriate control of waste generation from medical facilities has led to adverse impacts on the health of communities, workers, and the environment [41]. On average, each day, an abundance of contagious and hazardous waste is produced in medical care facilities and hospitals all over the world [35]. Untreated biomedical waste and its release into water are polluting the environment and threatening the health of human beings. Earlier studies estimated that approximately half of the entire world's residents are affected by improper biomedical waste management (BMWM), which causes increased prevalence rates of various diseases [42, 57].

Advancements in science and technology are expanding further to improve the future of mankind. As a result of automation, treatment of various illnesses and ailments that were previously hard to detect and diagnose is now possible, but this evolution in the health care field has also had major adverse effects and drawbacks [53]. It has been shown that in many countries across the world, the problem of biomedical waste is managed very poorly. According to information from the World Health Organization (WHO), of the total amount of waste generated by health-care activities, about 85% is general, non-hazardous waste. The remaining 15% is considered hazardous material that may be infectious, toxic or radioactive.

Numerous communicable diseases can be spread by waste generated by hospitals. Examples are hepatitis B, hepatitis C, human immunodeficiency virus (HIV), and tetanus. As a result of unprofessional mismanagement, the rate of the spread of these diseases has increased rapidly over the past few decades. Improper sterilization of needles, intravenous (IV) sets, glass bottles, and syringes is also one of the main reasons for the extensive spread of contamination [39]. In addition to these causes, insects, flies, and rodents play roles in transmission of these diseases. The places where this waste is most likely to be found are domestic areas, and hospital and industrial waste is often found on the outskirts of cities. While searching for useful waste among the junk, rag pickers and slum residents are more vulnerable to infections. Serious harm may be caused to their health by direct exposure to toxic chemicals and other substances [13].

Basically, developing countries are at high risk of health hazards due to improper handling procedures and mismanagement of remunerative and technological processes ([6]). Developed countries are at lower risk than developing countries because they have better infrastructure and techniques for disposal of waste. Thus, appropriate systems for management of biomedical waste must be introduced urgently throughout all countries to lessen the associated environmental hazards [23]. In many countries, waste management is not addressed in legislation; however, it is the responsibly of every human to help preserve the environment. The majority of health-related problems are due to inappropriate disposal of waste, which can be decreased by providing proper education to the population [27].

2 Biomedical Waste Sources

The origination of biomedical waste is variable in many aspects, both qualitative and as quantitative, depending upon various health care factors. Analysis has shown that the quantity of biomedical waste produced by the health sector is expanding yearly [32]. Types of waste that contribute to biomedical waste are pathological waste, pharmacological waste, sharp material waste, and cytotoxic waste. They differ in their composition, their sources, and the percentages they contribute to the total waste that is produced. Health care waste contributes about 80% of all biomedical waste, pathological waste and pharmacological waste contribute 15% and 3%, respectively, and sharp material waste and cytotoxic waste each contribute less than 1%. As shown in Table 1 [1, 27], biomedical sources of waste can be classified into major and minor sources.

3 Biomedical Waste Classification

3.1 Hazardous Biomedical Waste

This class can be subdivided into two types.

Contagious Hazardous Biomedical Waste: This waste has the ability to spread or cause infections in humans and animals. According to the WHO, "It is suspected that pathogens (bacteria, fungi, viruses or parasites) are present in contagious waste in enough amounts and concentrations to cause infectious disease in hosts" [20]. Only 10% of the total biomedical waste that is produced is contagious hazardous waste. The types of infectious biomedical waste that are generated are laboratory waste; pathological waste; dressings and swabs contaminated with blood, pus, or other fluids; sharp materials; and plastics [22].

Table 1 Major and minor sources of biomedical waste

Sources
Major sources
Hospitals, nursing homes, and dispensaries
Primary health centers
Medical colleges
Animal research facilities
Blood banks and mortuaries
Production units
Biotechnological institutions
Minor sources
Physician's and dentists' clinics
Animal housing facilities
Blood donation clinics
Vaccination centers
Funeral services
Institutions for disabled persons

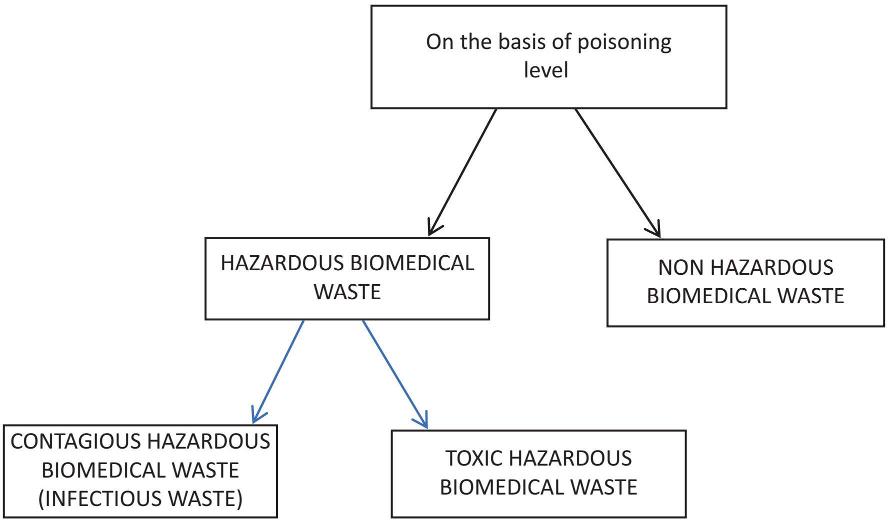


Fig. 1 Classification of biomedical waste

Toxic Hazardous Biomedical Waste: This waste can increase toxicity levels in various ways, such as contamination by radionuclides from radioactive waste, cancer therapies, or medical equipment. Other types of toxic biomedical waste are pharmaceutical waste, chemical waste, genotoxic waste, and cytotoxic waste.

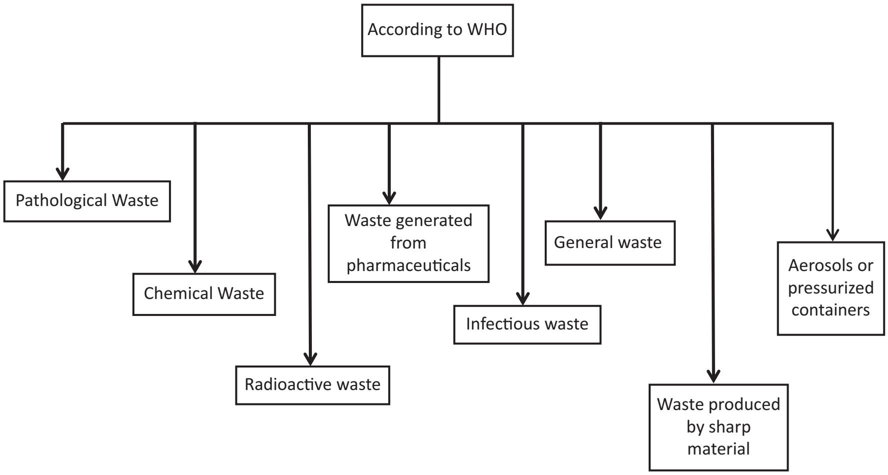


Fig. 2 World Health Organization classification of nonhazardous biomedical waste

3.2 Nonhazardous Biomedical Waste

This waste causes no direct harm to animals or humans. It is neither infectious nor toxic. It includes leftover food, fruit and vegetable peel, and paper cartons. About 85% of the total biomedical waste that is generated is nonhazardous biomedical waste [60]. According to the WHO, nonhazardous biomedical waste is classified into various categories on the basis of its sources, as shown in Fig. 2.

4 Elucidation of Nonhazardous Biomedical Waste Types

4.1 Pathological Waste

This is waste that originates mainly from the health care sector (e.g., from hospitals and dispensaries) in various ways and includes contaminated equipment, human excreta, body organs, and other tissue. It can be pathogenic, thus leading to various diseases [9].

4.2 Chemical Waste

This is waste that is generated from poisonous chemicals during forensic research, disinfection processes, cleaning, and detection of disease. The chemicals that release this type of waste can be in different forms. Some examples are listed in Table 2.

Table 2 Examples of chemical waste

Form of waste	Examples
Heavy metals waste	Mercury and cadmium waste
Liquid waste	Organic and inorganic solvents, formaldehyde, and photographic chemicals
Gaseous waste	Anesthetic, ethylene oxide, oxygen, and compressed air

Table 3 World Health Organization classification of different types of radioactive waste

Type of waste
Waste that has leaked from sealed sources
Generated radionuclides
Low-level liquid waste
Radioactive chemical residues
Radioimmunoassay materials
Gas released through fuming cabinets
Solid waste (including swabs, syringes, and glass equipment)
Materials used in decontamination of radioactive spills
Excreta from patients treated with radionuclides

4.3 Radioactive Waste

This is the most dangerous type of waste, as it is produced by an atomic reactor or an atomic power plant (nuclear energy). It includes substances such as unused radiotherapy liquids, contaminated glass equipment from laboratories, blotting paper, and radionuclides (e.g., α emitters, β emitters, and γ emitters) used during radiotherapy for cancer etc. [30]. The WHO classifies radioactive waste into different classes, as shown in Table 3.

4.4 General Waste

This is waste that is generated from household products, such as polythene, damaged packaging, leftover food, vegetable and fruit peel, carrier bags, food containers, and broken crockery or glasses. It generally causes no direct harm to human beings.

4.5 Waste Originating from Pharmaceuticals

This type of waste consists of expired medicinal stocks; leftover medicines; adulterated pharmaceutical products; unused vaccines; waste discharged by the pharmaceutical industry; and discarded cartons, gloves, masks, bottles, syringes, etc. It causes major harm to the environment.

4.6 Infectious Waste

This waste is produced during any medical procedure, such as treatment or testing processes (for diagnostic purposes). As its name indicates, this type of waste has adverse impacts on humans because it causes infections. Examples are contaminated needles, blood products, bandages, and dressings.

4.7 Sharp Material Waste

This refers to sharp-edged materials from any equipment employed for medical purposes, such as needles, syringes, blades, glass Pasteur pipettes, glass slides, and cover slips. [61]. This category is further divided into four subcategories:

1. Sharp materials that are either contaminated or uncontaminated with other materials
2. Radioactive sharp materials
3. Sharp materials that are infected with chemotherapy drugs
4. Laboratory glass sharp materials

4.8 Aerosols and Pressurized Containers

This type of waste includes aerosols and compressed gas cylinders or cartridges. Sometimes, it can cause fatalities if it explodes.

5 Case Study of Biomedical Waste Management at KVG Hospital

A case study performed in India showed that the awareness and implementation of biomedical waste management by health care professionals is suboptimal [18].

In India, people involved in the health sector have inadequate knowledge and practices related to waste management. Hence, this case study was performed to appraise the awareness, knowledge, and execution of various methods for disposal of biomedical waste by health care workers at KVG Medical College and Hospital in Sullia (Karnataka, India) [49].

5.1 Subjects and Methods

Transverse data collection was performed among health care workers employed at KVG Medical College. The survey was started in May 2012 and ended in August 2012. There were 391 workers who were who are working in three slots in alternating sequences at KVG Medical College. By use of a suitable sampling method, 120 health care workers were chosen by a selection panel. They consisted of four clusters of 30 respondents: physicians, nurses, laboratory technicians, and class IV waste handlers.

This cross-sectional study, conducted among 30 health care workers and was done using an opinion poll. The data for the study were gathered in different departments, the emergency department, and laboratories by the main analyst, in the presence of the superintendent of high-ranking members of the medical staff [58]. In addition to being selected by the sampling method, these individuals had to have had more than 6 months of work experience in the organization. The individuals were free to leave the study if they were not interested in participating. Consent and behavioral clearance of each participant was received from the organization. SPSS software version 17 was used for data compilation and analysis. Percentages and proportions were used to elucidate the results [55].

5.2 Outcomes

The study disclosed poor knowledge about management of biomedical waste among all four groups (physicians, nurses, laboratory technicians, and class IV waste handlers) [38] (Table 4).

Only 47% of doctors had sufficient knowledge about color coding of biomedical waste. Only a few respondents had knowledge about the total generation of hospital waste and knew that the percentage of infectious waste was less than 25%. The fact that isolation of biomedical waste had to be done at the first step of waste generation was known by 98% of doctors and 70% of nurses [26]. With the exception of class IV waste managers, all groups had adequate information about the hazards of transmission of disease through biomedical waste management, as shown in Table 5.

Ninety percent of the study volunteers considered it their responsibility to properly dispose of biomedical waste generated by various medical procedures. Participation of the private sector, along with the government sector, in conventional

Table 4 Knowledge about biomedical waste (BMW) among health care workers

Accurate knowledge	Physicians; *N* = 30 *n* (%)	Nurses; *N* = 30 *n* (%)	Laboratory technicians; *N* = 30 *n* (%)	Class IV waste handlers; *N* = 30 *n* (%)
Regulation of BMW management in India	3 (10.00)	1 (3.33)	0 (0.00)	0 (0.00)
Waste sorting using a color-coding method	14 (46.67)	13 (43.33)	9 (30.00)	5 (16.67)
Proportion of infectious waste out of all waste produced by the hospital	8 (26.67)	6 (20.00)	4 (13.33)	4 (13.33)
Initial separation of BMW	28 (98.33)	21 (70.00)	14 (46.67)	11 (36.33)
Decontamination of BMW prior to disposal	30 (100.00)	25 (83.33)	27 (90.00)	8 (26.67)
Diseases communicated by BMW	29 (96.67)	22 (73.33)	21 (70.00)	3 (10.00)
Techniques for individual safety from BMW-associated risks	25 (83.33)	20 (66.67)	22 (73.33)	13 (43.33)
Storage of BMW	11 (36.67)	21 (70.00)	6 (20.00)	9 (30.00)
Management and final disposal of BMW	14 (46.67)	7 (23.33)	5 (16.67)	0 (0.00)
Recognition of danger signs	23 (76.67)	9 (30.00)	19 (63.33)	7 (23.33)

Table 5 Viewpoints about biomedical waste (BMW) among health care workers

Viewpoint	Doctors; *N* = 30 *n* (%)	Nurses; *N* = 30 *n* (%)	Laboratory technicians; *N* = 30 *n* (%)	Class IV waste handlers; *N* = 30 *n* (%)
Appropriate separation and disposal of BMW considered part of respondent's duty	28 (98.33)	30 (100.00)	27 (90.00)	23 (76.67)
Agreement with contribution of private sector to BMW disposal	27 (90.00)	21 (70.00)	19 (63.33)	21 (70.00)
Agreement with requirement for strict application of BMW management rules	28 (98.33)	29 (96.67)	23 (76.67)	20 (66.67)
Agreement with necessity for training in BMW management	23 (76.67)	18 (60.00)	19 (63.33)	27 (90.00)

waste disposal was referred to by two-thirds of participants. Laboratory technicians and class IV waste handlers were not trained for management of biomedical waste, although it is essential to train all workers properly [3, 53]. Separation of biomedical waste according to color coding was done by 36% of doctors, 43% of nurses, 30% of laboratory technicians, and 13% of class IV waste handlers. Fewer than two-thirds of all groups took care to dispose of sharp objects in puncture-proof bags or containers. Only 30% of class IV waste handlers used personal protective devices [59].

5.3 Discussion

Inadequate knowledge was reported in all groups, mainly in class IV biomedical waste handlers. There was lack of awareness of the government's biomedical waste management rules for appropriate disposal of waste. The main reasons were insufficient training and leniency in execution of biomedical waste management policies. Across all groups, knowledge about color coding of biomedical waste was very limited [46]. Mathur et al. undertook a similar study in Lucknow (Uttar Pradesh, India), in which 91%, 92%, 85%, and 27% of clinicians, nurses, laboratory technicians, and hygiene staff, respectively, had sufficient knowledge of biomedical waste management. Knowledge about proper decontamination of waste prior to its final disposal was limited among all groups. Only 10% of class IV waste handlers were aware of the risks involved in disposal of biomedical waste. Comparable findings were documented in other studies performed by Mathur et al., Bansal et al., and Pandit et al., who reported awareness rates of 27%, 43%, and 43%, respectively.

It was noted that knowledge about color coding and the hazards involved in management of biomedical waste was very deficient, specifically among class IV waste handlers; therefore, there is a necessity to provide teaching programs and reskilling workshops and seminars on biomedical waste management [12]. It is essential to supply suitable protective gear—such as masks, gloves, and protective footwear—to class IV waste handlers and to instruct them on how to use it. They also need to be instructed to immediately contact their managers in the event of any damage or injury. Record keeping and management of needle stick injuries are inadequate; every department must record the names and emloyee code/ numbers of the affected individuals in all instances of needle stick injuries [29]. Every medical care provider must be immunized against tetanus and hepatitis B. The cost of immunization should be subsidized by the employer.

6 Requirements for Biomedical Waste Management

The main reasons for the great necessity of biomedical waste management in hospitals are:

1. The risk of infection transmission to waste handlers, waste scavengers outside the hospital, and citizens living near the hospital site
2. Injuries associated with sharp needles and syringes, which can lead to infections in hospital workers and waste handlers
3. Illicit repackaging and resale of disposable equipment without proper cleaning and disinfection
4. Air, water, and soil pollution due to the presence of discarded or incompletely combusted ashes, etc.
5. Illicit repackaging and resale of unused materials

6. In-hospital transmission of infection to patients because of inadequate anti-infection practices and substandard waste management [8]

6.1 Benefits of Appropriate Biomedical Waste Management

Appropriate biomedical waste management has the following benefits:

1. Reductions in in-hospital infections and contamination
2. Maintenance of high living standards
3. Robustness of supporting infrastructure [16]
4. Reduced mortality and disease rates
5. Reduced costs associated with infections
6. Reduced total costs with a suitable waste disposal system [39]
7. Reduced occupational health risks [3]

Management of biomedical waste involves the steps detailed below.

1. **Biomedical Waste Production:** As earlier discussed in this chapter, generation of biomedical waste by health care organizations is classified into diverse types, depending upon the degree of toxicity. Sources of waste are classified as either major or minor on the basis of their waste output. The first step in productive waste management starts with doctors (or other experts) and cleaning staff. In addition to these workers, nurses, engineers, chemists, inspectors, etc. are involved [24]. Waste is generated by individual departments and put in specific places where it goes through rectification processes. In the case of liquid waste, it should be sorted on the basis of its contents (chemicals, testing agents, etc.) and then—if appropriate—channeled into drains [37].
2. **Biomedical Waste Separation:** Separation of waste is important for efficient functioning of waste management [31]. Conventional separation of waste depends upon which techniques will be used for treatment of the waste. Appropriate, transportation, and disposal systems are necessary. As a result, waste volumes are decreased [59].
3. **Biomedical Waste Collection:** A crucial step in management of biomedical waste is its storage and agglomeration. The place selected for collection of waste must be situated near the location of waste production and its processing for disposal. Thus, a suitable exterior site needs to be selected, where different large containers (appropriately labeled) can be used for storage purposes. These containers must have a suitable holding capacity and must be made of an appropriate material that does not react with the waste material content. For sharp substances, the containers must be puncture-proof to reduce the risk of needle stick injuries. At big hospitals, the waste should not be stored for more than 8–10 h, and at nursing homes, the storage period should not exceed 24 h. The containers should be properly labeled with this cautionary instruction [60]. Furthermore, proper procedures should be followed for cleaning of the storage site to prevent the

spread of infection. Surfactants and disinfectants can be used for sterilization [11].

4. **Biomedical Waste Transportation:** The main objective of biomedical waste management is uncomplicated and protected transportation of waste to reduce threats related to contamination and disease [28]. This duty should be assigned to highly trained personnel who have good experience in transportation of biomedical waste [36]. The vehicles used for transportation must be leakproof, with safe door opening and a combustion-proof interior [37]. Signage regarding hazards and precautions must be displayed on vehicles [20].
5. **Biomedical Waste Treatment and Disposal:** The procedures for treatment of biomedical waste are as follows:
    1. *Thermal processing:* The process of management of biomedical waste includes use of heat for disinfection purpose. This is subclassified into the following types:
        (a) Low-heat systems, using temperatures between 90° C and 180° C
        (b) High-heat systems
    2. *Mechanical processing:* Mechanical shear and stress forces are utilized to change waste material from one form into another to alter its characteristics. The two steps involved in this are as follows:
        (a) Shredding (e.g., of paper or plastic), which is preferred so the material can be utilized again
        (b) Compaction, which applies force to reduce the volume of the waste
    3. *Chemical processing:* Chemicals are used for disinfection purposes in processing of biomedical waste. Examples of the substances used in these processes are ozone, chlorine dioxide, and hydrogen peroxide.
    4. *Biological processing:* Enzymes are utilized for processing of biomedical waste. It is known that suitable biological degradation of components reduces the risk of infection from residue left on glass or plastic.
    5. *Irradiation processing:* Removal of radiation involves utilization of ionizing radiation or ultraviolet (UV) rays in specialized vacuum equipment for destruction of this type of waste [8, 44].

7 Technologies Used to Degrade Biomedical Waste

The following technologies are used to degrade biomedical waste:

1. **Moist Heat Sterilization:** This is a type of low-heat technology. An autoclave is equipment used to kill microbes or disinfect material, using the principle of moist heat sterilization [54]. In this process, steam comes into direct contact with the material to remove all types of contaminants. This technique is employed in treatment of biotechnological waste, microbiological waste, sharp objects used

in laboratory equipment, and infectious waste (including soft waste such as gauze bandages and surgical gowns) ([43]).

There are different types of autoclave:

(a) The vacuum type
(b) The gravity type
(c) Retort autoclave or Canning autoclace for sterlization

In the vacuum type of autoclave, a vacuum pump is used to remove air from the system, then steam is used to sterilize the contents for 30–60 min at 132° C. In the gravity type of autoclave, the air is displaced by steam, with the help of gravity, and the contents are sterilized at a pressure of 15 psi and a temperature of 121 °C for 60–90 min. These types of autoclave can hold large volumes of air at high pressure and high temperature.

2. **Microwave Treatment:** In this process, humid warmth and vapor are created by microwave action to treat contamination. It is mainly used to treat infectious waste. The main advantage is that it involves minimal emissions; however, one disadvantage is the risk of leakage of microwave energy [51].
3. **Incineration:** This is a process by which pathogens and other microbes are killed by use of high temperatures. However, various different types of toxins can be released in this process, such as dioxins and products of incomplete combustion [19]. Metals are not destroyed by this process, and this limitation causes serious medical concerns. Dioxins can be inadvertently generated by incineration of waste. Medical devices made of polyvinyl chloride (PVC) are the main sources of dioxin production. Other very toxic carcinogens can also be generated, which can be very harmful to the human immune and endocrine systems [48].

Method: This thermal process uses high temperatures to convert materials into inert forms, with release of gases. Three different types of incinerator are used in this form of biomedical waste management:

(a) Rotatory incinerators
(b) Multiple-hearth-type incinerators
(c) Controlled-type incinerators

Optimal levels of combustion are achieved by systems that include primary and secondary chambers.

Objective: Reduction of organic waste to inorganic waste and reduction of waste volume and weight.

Disadvantage: Incinerators involve large capital costs.

2. **Hydroclave Treatment:** A hydroclave is basically an autoclave. In it, the pressure is maintained at 35–36 psi and the temperature is kept at 132 °C for 20 min. The treatment involves a multistep process:

(a) Start up
(b) Heat up
(c) Sterilization
(d) Venting

(e) Dehydration
(f) Shredding

Advantages: This is a safe, closed-loop system, with minimal air emissions and chemical emissions [15].

3. **Landfilling:** This process is used in order to minimize the volume of waste that requires storage. This machinery used for it is designed in such way that the waste is treated inside the landfill environment. The substances resulting from this process that can be hazardous to humans [45] are:

   (a) Solids
   (b) Liquids
   (c) Gases

8 Applications

Proper management of waste disposal leads to creation of a workplace that is safe for workers, patients, and the environment [4]:

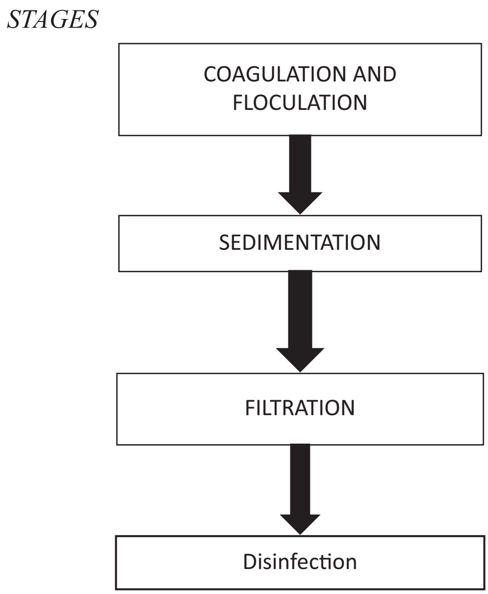
1. Proper waste management facilitates appropriately dispose of every form of waste.
2. Proper waste management creates economic benefits by growing the gross domestic product (GDP).
3. Jobs are created for workers in waste services and in the recycling and recovery sector.
4. Waste incineration (after segregation of recyclable materials) enables energy recovery.
5. Biomedical waste is segregated, contained, transported, and disposed of.
6. Polythene bags, gloves, and blood bags are incinerated in appropriately designed facilities to reduce the emissions of dioxins and furans that would occur if they were incinerated in the open air.
7. As per new rules, a barcoding system enables tracking and identification of rubbish bags and investigations for quality control and assurance.
8. Red- and blue-coded waste is sent to authorized recyclers for processing in order to decrease pollution and conserve resources.

9 Sustainable Green Technologies: An Innovative Strategy for Future Implementation

Water Treatment

One of the most necessary elements in life is water. Water pollution is one of the greatest problems confronting the biosphere. Liquid biomedical waste includes

Fig. 3 Steps involved in wastewater treatment



contaminants that lead to water pollution. These contaminants may be blood, body fluids, liquid residue after forensic research, excreta from patients, etc. [10]. Other undesirable substances include biological, chemical, and physical pollutants [2]. For safety and reduction of water shortage, it is important to treat water before it is used. Water treatment is a common method used to disinfect contaminated water [25], as shown in Fig. 3.

Sewage Treatment
This treatment is one of the advanced technologies that makes management of water resources sustainable. Extraction of solids, organic materials, and nutrients from wastewater generated by households and businesses is known as wastewater treatment. This technology has evolved over the centuries [21]. The main objective is to make effluent eco-friendly by removing contaminants from it.

Some factors that influence the design of wastewater treatment plants [62] are described in Fig. 4. Wastewater treatment includes the following objectives:

1. Removal of solids
2. Removal of pathogens
3. Extraction of organic materials
4. Biodegradation

Solid Waste Management
Developed countries and developing countries use different methods of waste management, which differ in terms of technologies and types of waste production. Schemes launched by governments manage waste materials on a large scale and use the best technology available [47]. The following six solutions are considered

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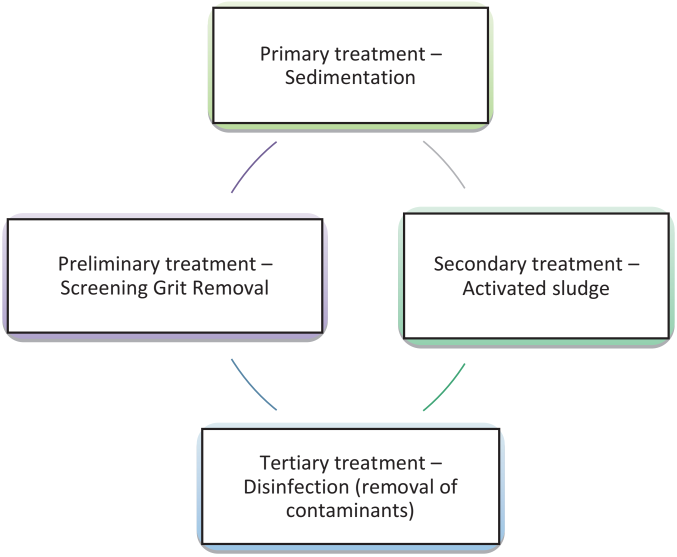

Fig. 4 Steps involved in sewage treatment

important and are specially recommended: reduction, reuse, recycling, recovery, repurposing, and landfilling. The landfilling approach is less favored because it takes more time to replace landfilled resources if one must start from scratch [14]; moreover, it requires large amounts of resources and also results in emissions of carbon dioxide and methane. There are a lot of differences between the old and new technologies that are applied in waste management; for example, old technology generates fertilizer, whereas new technology has led to development of aerobic digesters such as bioreactors ([7]).

Agricultural Technologies

Use of standard agricultural technologies is one of the reasons for disruption of the environment, causing atmospheric release of greenhouse gases (GHGs), and contamination of water. Green development technologies include drip irrigation, which decreases use of water, and use of natural pesticides instead of machinery-based cultivation in the farming sector. The following parameters are influential:

1. Cost effectiveness
2. Consumer preferences
3. Regulatory obligations
4. Public perception

To overcome water and soil pollution, green technologies are being applied to optimize practices used in crop planting and harvesting. Replace the chemicals used for fertilizing soil and for controlling pests, weeds [3]. Research institutes are conducting various investigations into eco-friendly practices aimed at decreasing atmospheric release of methane, replenishing soil, and replacing fossil fuels with fuels generated from plant biomass [34].

Air Purification

Air pollution is one of the major technical issues that need to be resolved. It is defined as emission of injurious chemicals and GHGs into the air. As result of air pollution, various diseases have spread rapidly among humans and animals. Air pollution is a result of human competition with nature to achieve development [33]. Harmful gases (SO_2, NO, CO, and other toxic gases) are released in huge volumes from industry and transport vehicles.

Green technologies that are now being actively applied in industry include air purification. In this process, released air is filtered to reduce its content of GHGs and other pollutants [5]. Along with this, lead-free fuel is now being used in vehicles such as buses, which is also contributing to reduction of air pollution. Fuel-efficient vehicles and hybrid electric cars are also being introduced for reduction of air pollution. These cars are expected to reduce the consumption of gasoline by 50% by the year 2030. These technologies are now being widely implemented in the urban sector [40].

10 Waste Management Initiative and Regulations in India

The following regulatory initiatives have been introduced in India for appropriate waste management:

1. Operation of laboratories, management of microbiological waste, and disposal of blood bags must adhere to WHO and National AIDS Control Organization (NACO) regulations.
2. Use of plastic bags, gloves, and blood bags is now prohibited.
3. Use of a barcoding system has been introduced for use on containers of biomedical waste that leave the premises for disposal.
4. Common biomedical waste treatment and disposal facilities (CBMWTFs) now provide services to health care operators for proper disposal of biomedical waste.
5. If any accident occurs during handling of biomedical waste, it is documented in a report by the appropriate authorities.
6. Biomedical waste disposal has to be regulated on a daily basis and its registration also simplified.
7. Implementation of rules is monitored/maintained by the Ministry of Environment, Forest and Climate Change.
8. District magistrates have the power to ensure maintenance of guidelines at the district level.
9. Every 6 months, reports on waste management must be submitted to the State Pollution Central Board (SPCB).

11 Conclusion

Biomedical waste is classified according to its source, its composition, and the issues involved in its management. Separation of different types of waste is an important step in the process, and the "3Rs" (***r***eduction, ***r***euse, and ***r***ecycling) must be done in a proper manner. Inventive, decisive, and progressive measures need to be taken to improve problems associated with waste disposal in the health care sector. New steps are necessary for compliance with new government regulations for waste management. To save our environment and ensure the health of society, we must take energetic action against this problem not only as health managers but also as part of society. For appropriate biomedical waste management, especially in hospitals, there is a great need to reduce risks associated with hazardous chemicals, drugs, and personal handling of waste at all levels. This type of management system includes proper separation, safe storage, and appropriate disposal to make it more effective. Proper biomedical waste management is also employed in handling of COVID-19-related biomedical waste; thus, it also helps to control the spread of that disease.

In the current scenario, we need to improve management of hospital waste by following proper processes for disposal of biomedical waste, including use of various green technology methods, which are eco-friendly, easy to apply, and less time consuming. The foremost challenge is to control and manage increasing volumes of biomedical waste and to implement regulations for disposal of biomedical waste by health care organizations. The security and safeguarding of all health care professionals and other waste-handling staff should be a major priority. It is the responsibility of both the public and the government to participate equally in proper disposal and management of biomedical waste in an appropriate and environmentally friendly manner.

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