Chapter 10
Impact of Biomedical Waste Management System on Infection Control in the Midst of COVID-19 Pandemic

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Abstract The emergence of modern medicinal practices and diagnosis process has resulted in health risks and threat to the environment, and thus it is a matter of global concern. However, the improper waste management rules adopted in healthcare hospitals around the world cause a potential health impact to ecosystem which generates contagious and deadly diseases affected by human beings. In this chapter, an attempt is made to investigate an overview of biomedical waste management practices in healthcare facilities in India as well as around the world. This chapter intends to provide the origin and types of biomedical waste, requirement of waste management rules and containment in hospitals and research centres and followed by the safe disposal of wastes which are unaffected to the environment. More emphasis was given to the biomedical health risks, handling and disposal methodologies adopted by different countries and the steps taken to eradicate the infections caused due to COVID-19 pandemic in much reliable ways.

Keywords Biomedical waste management · Incinerator · COVID-19 · Infection control · Health risks · Segregation of wastes · Colour codes for wastes · Treatment of waste · Disposal methods

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10.1 Introduction

10.1.1 Biomedical Waste: Universal Problem

Resembling other industrial pollutants, biomedical waste pollutants produced from healthcare units also have a huge impact on the survival risk of human, animals and plants. More specifically, the proper management of biomedical wastes has become a recent research interest on worldwide level due to this highly infectious pandemic state. A study on biomedical wastes by “The Associated Chambers of Commerce and Industry of India (ASSOCHAM)” stated that India can generate 550.9 tons of medical waste per day of 2020 from hospitals and research laboratories. Improper management of biomedical wastes is taken into account and concern all over the world as it may lead to serious harmful effects on human health, aquatic systems and environment. The exposure to untreated biomedical wastes can cause serious health risks and can induce infectious diseases including tuberculosis, typhoid, cholera, hepatitis, AIDS, respiratory and abdominal infections. Additionally, the hazardous biomedical waste can also affect the natural water reservoirs and aquatic life when it is directly discharged into the streams without prior treatment with reduced toxic effects. Generally, the biomedical wastes are classified into three major categories such as chemical/radioactive (5%), infectious (10%) and general municipal (85%) wastes respectively. As recommended by Worlds Health Organization (WHO), the biomedical wastes can be segregated into infectious, pharmaceutical, pathological, sharps and radioactive wastes and suggested to practice suitable disposal method for the total eradication of the effects. Hence, in order to have improved healthcare waste management system, it is necessary to have better understanding and knowledge on how to handle, segregate, store and dispose different types of hazardous medical wastes to avoid serious health risks. This chapter provides an overview of the urgent need for the proper management of biomedical wastes through better treatment processes on par with environmental regulatory acts during this pandemic condition. In addition, it also gives an idea about the global scenario and the biomedical health risks and different methodologies adopted to reduce the COVID-19 infected persons and death ratio through following proper biomedical waste management systems.

10.1.2 Types and Sources of Biomedical Waste

Classification of Biomedical waste According to World Health Organization (WHO) biomedical waste has been classified into eight categories such as General Waste, Infectious waste, Chemical, Sharps, Radioactive, Pathological, Pharmaceuticals, and Pressurized containers.
Table 10.1 Primary sources of BioMedical waste

| Primary sources                      | Mortuaries                                      |
|-------------------------------------|------------------------------------------------|
| Hospitals                           | Mortuaries                                     |
| Nursing homes                       | Research and training centres (Medical)         |
| Clinics                             | Biotechnology Institution/Manufacturing units  |
| Medical laboratories                | Animal houses                                  |
| Blood banks                         | Home healthcare unit                           |

Whereas, according to Bio-medical Waste (Management & Handling) Rules, 1998 [1], wastes were classified into ten categories as Human Anatomical Waste, Microbiology & Biotechnology Waste, Animal Waste, Waste Sharps, Liquid Waste, Soiled Waste, Unwanted Medicines & Cytotoxic drugs, Incineration Ash, Solid Waste, and Chemical Waste. Bio Medical Waste Management Rules, 2016 categorizes the biomedical wastes into four categories and the medical wastes are segregated based on four colour code as yellow, blue, red and white category.

**Sources of biomedical waste** Biomedical wastes generated during analysis, handling/treatment or vaccination of human beings or animals are considered to be more infectious than the municipal solid waste. Hence, management of biomedical waste is an essential part of controlling infections and conducting healthcare training programs. The sources of biomedical waste [2] can be classified into two types as primary and secondary sources based on the amount of waste produced. Based on training component of the Project “Environmentally Sound Management of Medical Wastes in India”, 2018, primary sources of biomedical waste are as follows in Table 10.1. The secondary sources include industries, educational institutes, ambulance service, funeral service, research centres and slaughter houses.

### 10.1.3 Levels and Analysis of Biomedical Waste

**Location of source** Based on the BMWM rule of 2016, the biomedical wastes are first collected at a particular point of source location e.g. nearby area of hospital or medical research institute [3]. The collection and accumulation of BMW has to be supervised by ring of doctors or nurses. Based on BWM rule 2016 the anatomical wastes from human and animal, biotechnology waste has to be collected on daily basis form each ward of the hospital and must be disposed within 48 h.

**Segregation of waste** After sorting out the source of BMW, segregation of waste has to be performed using coded colour bags and containers. Only three fourths of the waste bags are filled with its capacity, and packaged securely with proper labelling about that material. The materials which need pre-treatment such as plastic, metals and sharps must be removed. BMW has four categories of colour coded bags as
Handling and Storage of waste The coded colour plastic bags should be properly labelled with the cytotoxic symbols, date of entry, types of materials and exact quantity of BMW as well as the sender’s and collector’s information to which waste was transported to disposal points. Used bags, containers and bins should be labelled with Bio-Hazard and Cytotoxic-Hazard symbols in order to have effective BMW management. Untreated BMW should not be stored beyond 48 h in any case if necessary prior permission should be acquired from the authorized person to store even after 48 h. The BMW must be stored in a separate common room or place facility which is situated very far from the patient and visitor paths in accordance with BMW guideline, 2018.

Transportation

BMW has to be transported within limits of same hospital or only across the nearby district level with secured packaging and means of transport [4] without any leakage of bio-wastes. Separate wheeled trolleys are used within the hospital premises and they should be frequently disinfected after usage to avoid infections due to spillage of wastes. BMW has to be transported only in authorized vehicles by skilled authority as stated by the government to the common disposal point for the treatment process.

Treatment and Disposal of Waste (General and biomedical)

As 80–90% of waste produced in the hospital is covered under general waste category, this waste has to be collected separately in black coloured polyethylene plastic bags and has to be hand-over to the local municipal authorities for proper disposal procedures. Biomedical wastes are segregated as per BMWM rules, 2016 and are disposed by adopting appropriate disposal treatment methods like autoclaves, incineration, landfills, pit dump, deep-burial, etc. The following flowchart defines the different levels of BMW management Fig. 10.1.

![Flowchart of BMW Management](image-url)
Statistical Analysis of BMW Management Systems

BMW management is solely dependent on various steps of handling wastes including collection, segregation, transportation, treatment and final disposal of waste. Therefore, District Level Health Survey (DLHS) has been recorded to get recommendations based on biomedical waste management systems in accordance with Annual Health Survey (AHS). The DLHS-4 was conducted in 30 states and Union Territories (UTs) comprising of nine states (AHS) and 21 states were non-AHS states preceded by DLHS-1 (1998–1999), DLHS-2 (2002–2003) and DLHS-3 (2008–2009) [5]. Therefore, statistical survey analysis can be conducted at district levels and city levels to collect the ideas and recommendations from public and hospital managements to arrive at the best BMW management system to protect human health and environment. Generally, survey analysis was conducted on the following parameters such as, role of segregations of waste-coloured bins/bags (yellow, red, blue, white and black) having cytotoxic symbols, biohazard symbol, usage of huge plastic container for needles and syringes, treatment and disposal methods adopted in waste management such as autoclave, microwave, chemical disinfectant, shredder, incinerator, deep burial pit, Sharp pit and usage of Personal Protection Equipment (PPE) aids.

10.2 Biomedical Waste Management System in India and Other Countries

10.2.1 History and Development of Biomedical Waste Management System (BWMS)

The first BMW rules were introduced by the government of India (G.S.R. 343(E), S.O. 630 (E)) dated 20 July 1998. This act describes the segregations of wastes into 10 categories which are found to be a difficult task for the scavengers/housekeeper staff to sort out different kinds of biomedical wastes without having prior knowledge about its infectious risks. The major drawback of this act was, the scavengers were found to get exposed to infectious waste with no gloves, masks and used syringes without sterilization. Before this act, there was only general environmental act (The Environment (Protection) Act, 1986).

Later on, International Clinical Epidemiology Network (2002–2004) reframed the BMW setup as $1^0$, $2^0$ & $3^0$ Healthcare facility (HCF) among 20 states of India. They found that there is no incredible BMW System for 82%, 60% and 54% of $1^0$, $2^0$ & $3^0$ HCF units in India [6]. More specifically, it was reposted that around 240 peoples were infected with Hepatitis B due to the reuse of unsterilized syringes (Gujarat). After this incidence, India made necessary action to improve the already existing regulatory acts for better management of biomedical waste. Further, minor modifications of 1998 BMWM rules were proposed on 2000, 2003 & 2011. Again in 2016, the Ministry of Environment and forest climate change has introduced
BMWM rules with wider coverage among all areas of protection. The New BMWM rules formulated in 2016 consist of Four Schedules, five forms and eighteen rules to bring about the clarity of handling biomedical wastes. Other wastes which are not categorized under biomedical wastes are collected and segregated based on specific rules for municipal wastes, solid wastes, lead acid batteries, e-waste and radioactive substances. Further, amendments of BMWM rules, 2016 was given (G.S.R. 234(E) dated 16 March 2018) in order to have improved waste management system.

**Salient features of BMWM (Amendment) Rules, 2018 are as follows:**

All Biomedical waste source units will have to totally eradicate the usage of chlorinated plastic bags (excluding blood bags) and gloves by 27 March 2019. As per amended BMWM rules 2018, blood bags are exempted from phase-out, and all healthcare facilities should post their regular annual report on their portal within two years of period. The most recent revised guidelines were given by the Central Pollution Control Board (CPCB) on 10 June 2020 stresses the safety of sanitation workers who handle the biomedical waste in isolation wards. These guidelines state that all the basic necessities used by COVID-19 patients were classified as biomedical waste and should be put in yellow-coloured bags, while the used gloves must be collected in red bags. It also describes the role of Nodal officers, Operators and Maintenance Staff in sample collection centres, isolation wards of COVID-19, confinement centres, diagnostic and research laboratories, Urban Local Bodies (ULBs) and common biomedical waste treatment and disposal facilities (CBWTFs).

### 10.2.2 Prominent Hallmarks of Biomedical Waste Rule 2016 in India

- **Scope** to conduct various camps like vaccination, blood donation, surgical or training pertinent to healthcare hygiene;
- **Ruled-out** the use of gloves, chlorinated plastic bags, and blood bags within two years;
- **Pre-treatment** of biomedical wastes such as wastes from laboratory, microbiological units, blood samples and blood bags through appropriate decontamination or sterilization as prescribed by World Health Organization (WHO) or National AIDS Control Organization (NACO);
- **Provide training** to all its healthcare workers and protect them from diseases such as hepatitis B and tetanus by immunization regularly;
- **Launching a Bar-Code System** for bags or containers containing BMW for disposal;
- **Existing incinerators** have to achieve the standards for permissible emission of Dioxin and Furans and retention time in secondary chamber within two years;
(g) Biomedical waste was classified into 4 categories rather than 10 according to BMWM, 1998 to enhance the segregation process of waste from different sources;
(h) Processing rules to get authorization was simplified. For bedded hospitals automatic authorization was provided and one-time approval for Non-bedded HCFs;
(i) It describes the operating standards for incinerator to control the pollutants emission.
(j) Insisting the State Government to offer land area to set up CBMWTF.
(k) Duties of the occupier of HCFs have been revised. There should not be any on-site treatment and disposal facility, CBMWTF must be setup at distance of 75 kms.
(l) Operator of a CBMWTF is responsible for timely collection of biomedical waste from the HCFs and training of HCF.
(m) Ministry of Environment, Forest, and Climate change will monitor/follow up the execution of rules yearly and the committee shall submit its report for every 6 months once to the State Pollution Control Board.

10.2.3 Global Scenario of COVID-19 Pandemic

Globally, as of 3 September 2020, there have been 25,842,652 confirmed cases of COVID-19 and 858,629 deaths reported to WHO. The number of confirmed cases in WHO regions like (1) United States of America, (2) South-East, (3) Europe, (4) East-Mediterranean, (5) Africa and (6) Western Pacific and the major COVID-19 affected countries are given in Fig. 10.2. The current scenario of COVID-19 has made tremendous deviations from our everyday routines and affected the flow chain

![Global Scenario of COVID-19](image.png)

Fig. 10.2 Global scenario of COVID-19
of usual happenings globally [7]. More specifically, it disrupted the production and supply chains, it caused political, logistical and economical challenges. Importantly, it twisted the well-being of human beings and imparts an acute health risk. The economy is under recession in many countries because of this pandemic. To emphasize, countries with already weaker growth and economy are facing greater challenges during this crisis period. Apart from these above mentioned issues, each country is facing its difficult times to manage the biomedical wastes generated during this crisis time. Many countries are now taking efforts to monitor and report on the therapeutic uses of antibiotics to control this infectious disease. Several Universities and Research Institutions are thriving their complete energies to discover a Novel/New vaccine which can act as an appropriate shield to save this human era from the deadly effects of corona virus.

Recently, the United Nations Industrial Organization (UNIDO) has sanctioned a project titled “Environmental Sound Management of Medical Waste” to India to reduce the Persistent Organic Pollutants (POPs) which was due to the emission of toxic gases during incineration process. This project was launched in five states viz., Gujarat, Maharashra, Karnataka, Orissa and Punjab.

10.2.4 Critical Appraisal on BWMS in India and Other Countries

Due to the existence of large population in India, huge amount of biomedical wastes is generated which needs special treatment facilities. Various treatment processes are existing for the disposal of biomedical wastes in India including autoclave treatment, microwave irradiation, dielectric heating, chemical disinfectant, depolymerization, landfills, dry heat, Pyrolysis-Oxidation, etc. Among other methods, incineration of biomedical waste is the usually used method in India because of its low cost. The following Fig. 10.3 gives an idea of various treatment and disposal methods employed in India and other countries [8–13].

10.2.5 Requirement of Biomedical Waste Management in Hospitals and Research Centres

Hospitals and Research labs can act as a source for various hazardous wastes and infectious contaminants which can cause harmful effects. The hospitals and labs working with biological organs or organisms are prone to generate huge sources of biomedical waste. There is great need of BMW management in hospitals wastes because, the injuries from sharps can lead to infection, transmission of disease through air, water and soil, risk of infection to the outsiders and general public who are nearby hospital area, risk of allergies to the inside patients and possibility of
reselling disposable items. Number of experiments were performed in Research labs which employs the usage of either microorganisms, animal cells, animals, animal wastes, pathological wastes, human wastes or sharps and specialized apparatus used for handling those wastes. These materials can serve as a source of bio-hazardous wastes. Hence, most of the research labs follow the guidelines of the RCRA (Resource Conservation and Recovery Act) for handling, storage and nature of treatment process and disposal methods. According to these rules, all the infectious wastes should be totally decontaminated or disinfected before its disposal stage. The Center for Disease Control (CDC) considers medical waste which are sourced at research labs to be the most hazardous of all medical waste that is generated. Hence the waste generated from hospitals and research labs needs extra caution and protector action in BMW management system.

### 10.3 Risk of Biomedical Waste

With the increase in population, the number of hospitals, clinics and nursing homes increases drastically leading to increase in the generation of biomedical waste. More than 30 tons of biomedical is generated by hospitals in metropolitan cities each day [14]. Bio-medical waste is hazardous to the open population and causes great risk to patients, healthcare workers, scavengers and the community at large, if the disposal is not methodically managed properly. Babanyara et al. [15] have shown that the inadequate management of biomedical waste can cause pollution to the environment, produce unpleasant odour, growth and division of insects, rodents and worms which
further enhances the spread of diseases like cholera, typhoid and hepatitis through injuries caused by sharps which are contaminated with blood.

10.3.1 Biomedical Effects of COVID-19

According to the World Health Organisation report, the Non-communicable disease (Cardiovascular disease, Cancer, Chronic respiratory disease, and Diabetes) and other health services are highly influenced by COVID-19. Almost majority of countries (53%) are partially or completely interrupted by COVID-19. The medical emergency was highly concerned for patients with diabetes (49%), cancer (42%) and cardiovascular (31%). Significantly, COVID-19 infection rate is increasing day by day, this imposes pressure on the demand of hospitals and medicines to tackle the challenges. Specifically, the requirement for medical resources (ventilators, masks, gloves, face shields, gowns and hand sanitizer) is in greater demand. In addition, the mental and physical pressure of healthcare workers on hospitals is becoming very high. The inadequate providence or inappropriate usage of Personal Protective Equipment (PPE) has highly affected many healthcare workers and general public. Especially, psychological context of humans has been profoundly affected by this pandemic. Notably, many adolescents have committed suicide by stress, anxiety, fears and loneliness. The over reactions of the body immune system (cytokine storm) also have induced in COVID-19 cases [16], because their infection did not only affect the lungs, but some of them have reported with gut issues, kidney failure and multi organ failure [17].

Even after global quarantine and containment, COVID-19 reported 26.3 Million infected persons with 869 K reported deaths (3.3% mortality) as on 04-09-2020. At present, there is no proper medication reported for treating COVID-19, government and private organizations are struggling to find out the effective drugs to fight against new coronavirus. The spread of COVID-19 infected patient and more asymptomatic carriers are the reason for pandemic emergence of the disease which are reported with minimal of 7–14 days of incubation period, and the longest in few cases are reported with 21 days [18]. Dry cough, fever, fatigue, conditions of respiratory distress syndrome, shock, sepsis followed with death are the most commonly observed. Even though COVID-19 shows varying symptoms from mild to moderate level, most of the infected people recover by their own without hospitalization. Meanwhile, many patients have recovered from the COVID-19, whereas the effects of COVID-19 may influence the future health of comorbidity patients.

10.3.2 Understanding the Actual Status of Medical Waste

According to World Health Organization (WHO), biomedical waste may be defined as clinical waste resulting from patient operations and clinical specimens and all
related to laboratory diagnostic tests within the research centres or resulting from the medical and research laboratories during the training of students. Health care is indispensable for our life, however the waste produced from medical actions may be highly toxic and hazardous and are likely responsible for disease transmission. The waste products produced include sharps, non-sharps, blood, body parts, pharmaceuticals products, chemicals, medical outfits, radioactive substances, etc. 75–90% of biomedical waste is non-hazardous which comprises of food remains, paper cartoons, fruit peels, packaging materials, etc., and 10–25% is hazardous also known as risk medical waste such as injuries to humans or animals and cause pollution to the environment [19]. It is very crucial to be aware of the fact that if both hazardous and non-hazardous wastes are mixed the whole waste becomes harmful.

World Health Organization in 2000 had given a statement that the improper treatment of medical waste caused 21 million infections of Hepatitis B, 2 million infections of Hepatitis C and 260,000 infections of HIV each year worldwide due to very poor waste management systems. Hospitals and other healthcare facilities, laboratories and research institutes are some of the major source of medical waste. Akter [20] has shown that about 5.2 million people die every year from waste-related diseases. Medical waste also contains infectious microorganisms which can infect other patients, sanitation workers and the general public. BMWM rules introduced on 20 July 1998, provides uniform guidelines for the entire nation. Under this law, it is mentioned clearly that a person/ institute who is the source of generation of biomedical waste will take the responsibility of collecting, handling and segregation of wastes properly without causing any contrary effect to environment and human health.

10.3.3 Inappropriate Biomedical Waste Disposal Quantification

Medical waste can be infectious to both people and the environment causing high contamination and cross contamination risks. Based on the references of World Health Organization (WHO) and other guidelines medical waste must be treated near to its source of its generation. This needs responsibility from every employee working in the hospital who is involved in the segregation process. Suitable location and equipped waste disposal facilities can reduce the necessary transportation of hazardous materials. There is high risk considering the transportation of biomedical waste such as illegal or inappropriate disposal (dumping and obsolete treatment technologies) by haulage personnel and accidents. In addition, transportation of hazardous waste to the treatment centres is prohibited in some urban areas.

Dumping or landfilling of biomedical waste cause pollution to the ground water if the site is not managed properly. Some of the various techniques used for the disposal of biomedical waste include incineration, chemical disinfection, wet thermal treatment also known as steam sterilization, landfill disposal, microwave irradiation,
and inertization. Increase in population increases the generation of biomedical waste. Hospitals in metropolitan cities especially government run hospitals have become a matter of great concern as the biomedical waste produced is dumped alongside city garbage and not managed properly and appropriately. According to Mohankumar and Kottaiveeran [21], India has 6 lakh hospital beds in 23,000 (primary healthcare units) and 15,000 (private and small hospitals), majority of which fail to follow the Bio-Medical Waste Rule 1998 which is mandatory for every hospital and hence we are facing challenging conditions due to the improper management of pathological wastes.

Hospitals safeguard human life however the biomedical waste generated causes countless damage to the environment as it is not managed properly. This improper management of biomedical waste upsurges the airborne pathogenic infectious organisms, which also affects the hospital environment and society. The most affected people are healthcare workers, patients, scavengers, members of the public, visitors of health care establishment workers at waste disposal facilities [22]. Researchers have found that about 82% (primary), 60% (secondary) and 54% (tertiary) health care facilities (HCFs) across 20 states in India had no sustainable biomedical waste management systems (INCLEN Program Evaluation Network et al. [23]. Despite India, being continuously taking vital steps for the safe disposal of Bio-Medical Waste, in 2009 around 240 people contacted hepatitis B due to the usage of unsterilized syringes in Gujarat [24].

10.3.4 Exposure and Emission of Toxic Gases During Incineration

As per the regulations all biomedical waste should be treated within 48 h and hence every hospital and other HCFs generating bio-medical waste is required to set up proper BMW treatment facilities to ensure proper treatment of waste. Incineration in a widely used and the most popular method of disposing majority of hazardous medical waste. However open burning or burning of medical waste in incinerator emits harmful and toxic gases such as black smoke, toxic flue gas, fly ash, and odors which lead to atmospheric pollution causing respiratory and skin disease or even cancer. US Environmental agency has found that medical waste was the third main source of dioxin emission and 10% of mercury emission. Burning of medical waste such as plastic materials which are generated from polyvinyl chloride (PVC) products is the major producer of dioxin [25].

Incineration of materials and heavy metals containing chlorine, mercury, lead and cadmium in particular generate dioxin and furan and can lead to the evolution of toxic metals in the environment. International Agency for Research on Cancer (IARC) recognized dioxin cancer causing potential and regarded as human carcinogen. Dioxin is one of the most toxic chemical development which cause cancer, immune
system disorder, birth defects, diabetes, and sexual disorder [26]. To check the presence of dioxin in the atmosphere, a collaborative research was initiated by Council of Scientific and Industrial Research and National institute for Interdisciplinary Science and Technology in Thiruvananthapuram in January 2017.

### 10.3.5 Spread of COVID-19 Pandemic

Meanwhile scientist and researcher are giving attention for finding the cure of the ongoing Coronavirus (COVID-19), medical garbage waste contaminated with body fluids or other infectious materials is becoming a larger distress for hospitals and other healthcare facilities as they can spread COVID-19 worldwide. In China’s Wuhan, with the support from government officials and strategic plan of healthcare professionals, new hospitals along with new medical waste storage units were built to handle 30 tonnes of wastes and use 46 mobile treatment systems [27]. The waste generated during this crisis time was an outbreak than normal wastage as six times greater.

The daily output of medical waste was about 240 metric tons, which is similar to the weight of an adult blue whale. Patients, healthcare and sanitation workers are accessing the medical provisions and disposable PPEs, like masks, gloves etc., in larger quantities these days therefore, these materials requires safety disposal.

The Central Pollution Control Board (CPCB) of India, apart from the Bio-Medical Waste Management Rule, 2016 it already had, recently released a new specific guidelines to ensure the handling and safe disposal of biomedical wastes during this COVID-19 in a scientific and logical manner. According to the Bio-Medical Waste Management Rule 2008, medical waste would not be combined with any waste and it must be segregated and processed separately based on the classification. Waste formed during patient’s treatment inclusive of those person with confirmed COVID-19 infection is infectious and should be safely handled and managed with best practices. People handling healthcare waste are in dangerous risk of infectious diseases since the medical waste out of COVID-19 can be contagious when in contact with skin, inhalation or ingestion. However, there is no proof that, defenseless human interaction will transmit COVID-19 virus, according WHO report. As the pandemic situation grows, the quantification of waste also increases and custody of safe management of waste and containment of wastes will be a great task for societies until the crisis situation is over.
10.4 Biomedical Waste Containment

10.4.1 Formation of Containment Vision and Missions

The healthcare sector has unpredictable demand because of the overpopulation on the earth. The huge volume of medical waste has been generated by improper medical waste mismanagement as well as inadequate knowledge and awareness of medical waste containment that will influence various diseases [28]. Generally, the vision of the bio-containment is properly organized form of management which generates biomedical waste such as healthcare and health research facilities and associated laboratories to control the spread of disease as well as prevent the hazards of land, air, and water pollution.

Amelioration of healthcare efficiency and effectiveness is the only key to control the biomedical wastes. The government of India has realized and the Ministry of Environment & Forests has revealed the rules for Bio-Medical Waste (Management & Handling) under the Environment Protection Act 1971. In 2016, these rules have upgraded and ameliorated their standards for biomedical waste containment. These rules and regulations have used to achieve the vision of biomedical waste management systems and these rules are shall apply for all healthcare research facilities and workers. The schedule-I rule is to define the biomedical waste as well as indicating the standard methods for handling and disposal methods of biomedical waste. Importantly, the National Policy document have explored infection control, medical waste management and Infection Management and Environment Plan (IMEP) framework for the amelioration of healthcare facilities by Ministry of Health & Family Welfare. Infection Management and Environment Plan (IMEP) consists of two documents includes policy framework and operation guidelines for healthcare facilities. The current status of biocontainment system is step forwarding whereas, Gadicherla et al., have revealed the actual status of biocontainment in healthcare facilities of Karnataka, India. Among 116 HCF categorized into large (9), medium (17), small (90). Segregation, storage efficiency, containment of sharps have focused. Except for storage efficiency rest of the things have revealed their poor condition, viz segregation efficiency (24.4%) in small HCF’s, containment of sharps (small—34.7%, medium—23.4%, large—26.8%) and the final disposal treatment facility ratio is about large 88.8% and medium 88.2%.

10.4.2 Medical Waste Regulations and Segregations

Even though BMWM has various rules and guidelines for appropriate management system, the real challenge lies in the segregation of biowastes from different sources. HCFs units are instructed to segregate the BMW in approved colour codes. In case of general public, people should collect their household waste as wet and dry wastes in individual containers or bags in order to minimize the spread of infections to the
sanitary workers. Authorities have to provide emphasis on the benefits of the usage of PPEs, collection bins and isolated vehicles and to conduct appropriate training programs to maintenance staffs in their regional languages. The different colour codes as mentioned in BMWM rules, 2016 and its appropriate disposal method are given below in Fig. 10.4.

### 10.4.3 Restricted Access for Medical Waste

Waste minimization is termed as the inhibition of waste creation and/or its decrease. It includes explicit approaches, variations in waste management and environmental changes. Approaches of waste lessening include modification of manufacturing, procuring actions, control of invention and generation of less toxic materials. But that should not compromise the quality of healthcare products and its access and usage. General solid and liquid wastes are disposed as municipal wastes and the infectious and contagious wastes are treated first before disposal. Generally, the disposal of infectious wastes is 10 times more costly than ordinary waste disposal. Any method which reduces the quantity of infectious waste generation as well as the cost of waste disposal is said to be the better method for BMW management. In a
nutshell, the “4Rs” are most important in minimization of waste, (i.e.,) reusing, repurposing, recycling and reducing offer more effective strategies for garbage disposal. Reducing the amount of waste produced at source, reusing the waste products for useful purpose, e.g. as manure for garden plants, recycling the waste products with proper decontamination. When these strategies are followed we can definitely have waste minimization and have better management system to segregate, process and dispose small quantities of wastes in high-level decontamination.

10.4.4 Awareness and Training to the HealthCare Professionals

The recent existing BMWM rules have to be displayed and circulated among all the healthcare professionals, scavengers and waste management staffs to create awareness on how to collect, handle, segregate, treat and dispose bio-wastes which are more infectious and hazardous [29]. In order to create awareness among the hospital staff, a survey analysis containing about 100 questionnaire on BMWM rules and regulations can be performed among doctors, nurses, management staff, scavengers, training students. Based on the results obtained from those survey analysis, appropriate training can be given to different professionals based on the requirements, risky environment and their knowledge about safety on handling wastes. Training for scavengers and waste segregating staff has to be given in the local regional languages for better understanding and practice. Existing rules for collection, segregation of bio-wastes from general waste, the risk of untreated wastes and the measures to minimize the risks must be elaborated to each individual who was engaged in the BMW management process. Training on Standard operating procedures for handling safety equipment, chemicals and infected patients and animals must also be provided. Safety laboratory acts like Occupational Exposure to Hazardous Chemicals in Laboratories, the Hazard Communication Standard and the Formaldehyde Standard acts should be explained to the staff working biohazards, chemical hazards, and radiation hazards to reduce the infectious risks. The importance of usage of Personal Protective Equipment (PPE) like gloves, masks, goggles, etc., during collection or segregation of wastes from different contaminated sources of areas and importance of immunization must be clearly explained to the scavengers in order to reduce environmental and health risk of air-prone infectious hazards through transmission.

10.4.5 Alternatives for PolyvinylChloride Products

Polyvinylchlorides (PVC) is mainly used for the manufacture of flexible bags/containers and un-breakable tubes in medical devices. PVC offers excellent durability, bio-compatibility, flexibility, chemical resistance, low maintenance costs
and affordability, which have made this material a best choice of usage in all healthcare units. Almost 40% of all hospitals use this PVC made medical devices [30]. Even though it has many beneficial properties, when it is incinerated or burned during disposal process it liberates toxic gases. PVC produces carbon monoxide, dioxins, water, hydrogen chloride, metal chlorides and chlorinated furans on combustion process which threatens human health habits. Even the lower concentration of Dioxins and furans products can cause diseases such as, cancer and birth defects. In addition, the hazardous chemical additives exist in PVC such as phthalates, lead, cadmium, and/or organotins, can be toxic and affect child’s health. When PVC containing medical devices are incinerated, HCl gas emission from incinerators has to be removed from the emission products by continuous monitoring and filtration with suitable scrubbers. Due to the emission of toxic gases into the environment, the usage of PVC in making medical devices is taken into concern to have efficient waste management system. In recent years, many non-PVC materials are also available commercially for a wide variety of medical applications. PVC products softened with plasticizers other than Di (2-Ethylhexyl) Phthalate (DEHP) are also available on the markets such as citrates, adipates and trimellitates. Furthermore, since the alternative products of PVC are free from PVC, they can be more easily recycled or disposed. The following table provides an idea of medical devices fabricated from alternative materials for PVC used in Neonatal Intensive Care Units (Fig. 10.5).

**Fig. 10.5 Alternative materials to PVC in Neonatal care unit**
10.5 Biomedical Waste Treatment

10.5.1 Conventional Methods

The main objective of BMW management was to either minimize or to totally eradicate the hazardous waste with better treatment method. Various conventional waste treatment methods are existing to decontaminate or destroy or disinfect the infectious bio-wastes such as autoclaves, pyrolysis, incineration, landfills, chemical disinfectants, plasma pyrolysis, microwave irradiation and gasification methods. This section explains in detail about the role of autoclaves, dry heat (pyrolysis), chemicals disinfectants and landfills in the BMW management process.

Autoclaves

Autoclave is a heat treatment process which is more similar to the working of standard pressure cooker. Autoclaves are operated at high temperatures of about 121 °C for 60–90 min and under steam pressure of 15 psi. At higher temperatures, the steam produced inside the system interacts with the waste materials and destroys the microorganisms. Three types of autoclaves are commercially available viz., Gravity type, Pre-vacuum type and Retort type [31]. In Gravity type, air is evacuated with the influence of gravity alone. In pre-vacuum type, vacuum pumps are used to remove air with the reduced time cycle (30–60 min) at 132 °C. Retort type autoclaves are manufactured to achieve much higher steam temperature and pressure to destroy the infectants. Categories like waste sharps, soiled, solid wastes, microbiology and biotechnology waste can be effectively treated with autoclave treatment method.

Dry heat (Pyrolysis)

Pyrolysis is a treatment process for bio-waste decomposition with heat in an oxygen deficient atmosphere. Before dry heating the bio-wastes, metallic components have to be segregated as metals cannot be decomposed at that temperature. During heating process, there is emission of gases like (methane, ethane, hydrogen, and carbon monoxide); liquids (oil and tar); and solids (char and carbon black). The gases can be stored or purified and used as fuel for other purposes to heat the radiant tubes. The solid residues left over after heating process was landfilled.

Chemical Disinfection

Disinfection is one of the best methods to reduce the pathogenic organisms which are involved in the transmission of infectious diseases. The cleaning and disinfection protocols can be performed in many approaches such as simple surface cleaning, sterilization, usage of chemical disinfectants like antiseptics, biocides and sanitizers. Plentiful chemical agents are available to disinfect healthcare facilities. Generally, liquid-based chemical disinfectants are classified into nine wide categories as acids, alcohols, alkalis, halogens (hypochlorites and iodine-based iodophors) aldehydes, biguanides, phenolics, oxidizing agents, and quaternary ammonium
Fig. 10.6   Common chemical disinfectants

compounds [32]. Very recently, hydrogen peroxide silver nitrate products, accelerated hydrogen peroxide products, and Quaternary ammonium/glutaraldehyde or formaldehyde combinations were developed and are shown successful as disinfectants but they are not permitted for usage in veterinary hospitals. No-touch approaches of surface decontamination technologies with hydrogen peroxide dry-mist or vapor (HPV) fogging method and ultraviolet (UV) light are also employed for disinfectant process. An ideal disinfectant should possess the ability to kill wide range of pathogens or microorganisms. It should hold stability, chemical & surface compatibility, non-toxicity, easy solubility in water, non-flammable, pleasantable odour, cleaning ability and more economic. The following figure gives a category-wise detailed list of disinfectants used to reduce pathogenic infections (Fig. 10.6).

LandFills

Treated and untreated waste can be disposed in three ways such as in open dumps, sanitary landfills and landfills. In the case of open dumps, untreated and not segregated solid wastes are dumped in uncovered areas. This open dump will become the place of breeding of many insects and flies through which infectious diseases are transmitted. In rainy season, these dumps run off and contaminate the whole area and affect the ground water purity as well. Hence this kind of open dumps is totally eradicated in many cities in India, e.g. Bilaspur City. Landfills are generally located in urban areas, where huge amount of solid wastes are dumped into a pit. The pit was covered each day with a layer of soil through which the breeding of insects and flies can be prevented. After some time the wastes in the dumped landfills were compressed into cells tightly and then the total area is covered with a thick layer of soil. This kind of landfills is used as parking lot or park in near future. However, landfills also suffer from leachates and contamination of ground water. Sanitary landfills are an alternative to landfills [33]. This sanitary landfill can solve the leaching problem
to some extent. In this method the pits were lined or covered with impermeable materials like plastic and special clays to avoid liquid spillage. Researchers reported that the plastic liner was cracked due to the reaction with different solvents generated from wastes. This method is costlier than the other two methods and the rate of decay of waste is also comparatively better. This was due to the fact that there is existence of less oxygen when the garbage is compressed very tightly. Another drawback is the generation of methane gas, which happens when there is little amount of oxygen during decomposition process. In some countries, the methane gas liberated from the sanitary landfills was stored and retailed as fuel.

10.5.2 Incineration Method—Pros and Cons

Incineration, a treatment method which includes the burning/ignition of organic substances found in waste at higher temperatures. Particularly, this incineration process was employed in various regional zones to treat infectious waste from pharmaceutical, chemical industries, hospitals and research institutes. Incineration process transforms waste into flue gas, ashes and heat, which can be utilized as energy for other processes, for example the generation of electricity [34]. Incineration plants can lessen the quantity of waste in landfills as it produces lower mass of waste from 95 to 96%. Incineration process has plentiful profits, in terms of destruction of contaminant biomedical wastes. The energy production through this incineration plants is in greater demand in Japan, Germany and Sweden as it requires a small area of land. The beneficial advantages and disadvantages of this incineration process in the treatment of biomedical and hazardous wastes will be discussed in the following section.

Pros of Incineration Method as a BMWM Systems

Efficient Waste Management

The key advantage of incineration was decrease in the quantity of waste generation after the combustion process. Almost 90–95% of the solid waste was reduced during organic decomposition process. Therefore this method is found to be in demand rather than dumping of bio-wastes into the landfills. Further, this incineration system occupies a relatively smaller space which is convenient for construction and managing waste. This method is more suited for Nations with shortage of lands like Japan. In addition, these plants can be constructed in the permissible areas of nearby cities or districts which are easily accessible there by ignoring transportation difficulties.

Production of thermal and power Energy

Incineration plants produce energy from waste and that energy can be utilized to generate electricity or heat. In 1950s, due to the higher energy costs, lot of countries (European) have utilized this thermal or power energy generated from the incinerators for the production of electricity by steam turbines. It can be utilized to fulfil the power
requirements of people living in the surroundings of the plant or warming homes and workplaces.

**Reduced pollutants and role of emissions treatment systems**

Incineration is found to be a more eco-friendly treatment method than landfills due to its reduced pollutant generation. Landfills usually release higher quantities of dioxin, hydrocarbons, nitrogen oxides, greenhouse gases, non-methane organic compounds and leachate fluids. Leachate water will destroy the underground water systems. Comparing incineration with that of landfill process, methane gas is generated in landfills and the generation of this gas has to be controlled in order to avoid explosion. The methane gas production also causes serious global warming issues. Whereas, in the case of incineration process there is no generation of methane gas. More over as most of the incineration plants are operated at 850 °C or even higher temperatures, most of the germs and chemical hazardous materials are destroyed to the maximum level. Further, the incineration treatment process can provide better control over the odour and noise pollution. Existing incineration plants are equipped with suitable filters and appropriate emission systems on par with pollution limits recommended by respective pollution control boards, Environmental Protection Agencies and Regulatory Legislations.

**Incinerators coupled with computerized monitoring system and metal recycling**

The incineration plant units were equipped with a computer system to continuously monitor the operation efficiency and emission of products after completion of process. The coupling of plants with computerized system will enable the operator to find out the particular problem and to sort out the exact solution for it in a more precise manner. After incineration process, the metals will remain as such in many cases as it possess higher melting points. The metallic residues can be collected from the respective units and it can be reused for any other application before the disposal stage.

**Incinerators can operate in any weather**

Incinerators operations are not dependent on weather changes, as they ignite waste without any leakages. During drizzling season, waste cannot be disposed in landfills because there is a possibility of washout and formation of leachates due to rain water after the natural underground water system. Incineration plants can work non-stop for 24 h and are more well-organized and effective in managing waste compared to other treatment methods.

**Cons of Incineration Method in BMWM System**

**Expensive Treatment Process**

The infrastructure cost for the construction of incineration plants is very expensive. In addition, the plants require trained manpower to operate by following exact standard operation procedures and regular maintenance is an essential factor to monitor the emission processes.
During combustion process, incinerators liberates smoke into the atmosphere. The evolved smoke produces many toxic pollutants which includes particulates, dioxin, heavy metals, furans, acid gases and nitrogen oxide. These gases are poisonous to the living systems. Long term exposure to these gases may affect the human public health. The people around the incineration plant area will have serious health defects such as birth defects, cancers, reproductive and neurological dysfunctions. An improved technology should focus and encourage about recycling and waste generation process. Whereas, this incineration process does not promote those two factors. Even though the resultant ash content from the incinerated process is very minimum, it requires proper treatment and disposal as it comprises of many toxic which can harm the public health and environmental impact.

10.5.3 Operating and Emission Standards of Incineration

Biomedical waste management rules formulated in 2016 has a detailed explanation on the operation and emission standards of incineration.

Operation Standards of Incineration

Effective incinerator should possess a combustion efficiency (CE) of atleast 99%. The primary and the secondary chamber of the incinerator should be maintained at a temperature of 800 °C and a minimum to maximum level of 50–1050 °C. The gas residence time in the secondary chamber should be atleast two seconds. Combustion Efficiency can be calculated using the given equation as

$$\text{CE} = \ldots \ldots \% \text{ of } \text{CO}_2 / \ldots \ldots \% \text{ of } \text{CO}_2 + \ldots \ldots \% \text{ of } \text{CO} \times 100.$$

The minimum stack height of the incinerator should be 30 m from the ground and the stacks should be fitted with appropriate accessories to have effective incineration process. Preferably, fuels containing low sulfur content like light diesel, sulphur heavy stock, diesel or compressed nitrogen gas, liquid natural gas or liquid petroleum gas can be utilized for incineration in order to have control over emission of toxic gases. Efficient incinerator should produce permissible Total Oxygen Content (TOC) in slag and bottom ashes less than 3% or the loss on ignition should be <5%.

Emission standards of the Incinerator

The incinerator should withhold the emission standards according to the BMWM rules. The limiting concentration of emission after incineration process has to be in the limited or permissible level. The incinerator emissions should correlate well with the standard values given in the BMWM rules. The standard emission levels of various components are given as follows in Table 10.2.

The wastes generated after the incineration process has to be treated in compilation with standard emission levels of different gases. It should not be treated with chemical disinfectants, e.g. chlorinated products. Ash generated from the incinerator has to
| Parameter                        | Limiting concentration in mg Nm³ unless stated |
|---------------------------------|-----------------------------------------------|
| Particulate matter              | 50                                            |
| Nitrogen oxides (NO & NO₂)      | 400                                           |
| Hydrochloric acid               | 50                                            |
| Total dioxins and furans        | 0.1 ng TEQ/Nm³ at 11% O₂                      |
| Mercury and its compounds       | 0.05                                          |

be disposed through common waste treatment procedures and disposed with utmost care. In the most convenient way, the wastes are dumped into municipal landfills. If the end product or the disposal product has any radioactive substance or toxic metals then the wastes or incinerated products have to be disposed through following suitable regulatory systems under the disposal of radioactive or toxic hazardous waste management rules. The operator of the incinerator measures the level of CO₂, CO and O₂ through combustion gas analyser. The operator holds the responsibility to monitor different parameters and the concentration emission levels of incinerator once in a three months and proceed with the precautionary steps to perform changes in the emission monitoring system in accordance with State Pollution Control Board or Environment (Protection) Act, 1986.

### 10.5.4 Nebraska Bio-containment Unit

The Nebraska Biocontainment Unit (NBU), a collaborative project of Nebraska Medicine, University of Nebraska Medical Center and the Nebraska Department of Health and Human Services was commenced in 2005. NBU is one of the largest biocontainment units in the United States with 10-bed capacity for each particular infection. The unit was intended to control highly transmittable diseases like smallpox, Ebola virus and respiratory diseases [35]. In addition, this NBU unit also conducts active research and training programs for the regional and national recognition. The NBU has treated patients with Ebola virus disease emigrant from Africa in 2014. This unit has acquired many awards from the White House, the Nebraska Legislature, and the University of Nebraska Board of Regents and has been esteemed as “Midlanders of the Year” by the Omaha World Herald for their extraordinary performance of care in the control of highly infectious disease, Ebola.

**Role of NBU in Ebola Virus Disease Control**

Ebola Virus Disease (EVD) is an infectious disease which can be transmitted easily in contact with infected blood or body fluids with dosage of infections <10 viruses and maximum concentration in blood as 10⁸ virus particles/ml. Even if the patients are negative towards quantitative polymerase chain reaction tests (qPCR), they may
serve as disease transmitters of infections. Therefore it was necessary to adopt inflec-
tional control measures to ensure the safety protocols of the public. NBU provides
guidelines for infection control inorder to manage the risk due to biomedical waste
generated during Ebola or the procedures involved in the decontamination of unit
after patients discharge, waste disposal, surface cleaning and tarsnportation of highly
infectious waste [36]. The U.S. Department of Transportation (DOT) defines the
wastes generated from Ebola patients as category “A” infectious substances. The
Category B components have to be segregated and packaged properly with regulated
markings. Then these bio-wastes have to be transported to the common area of treat-
ment and disposal units in an appropriate leak-proof container in line with medical
waste management rules. NBU uses autoclave sterilization process for Ebola solid
bio-wastes. After completion of autoclave sterilization, the EVD wastes are packed in
a disposable bag (green linen bags) with proper labelling as category B medical waste.
Liquids bio-wastes are treated with suitable chemical disinfectants. After the evac-
uation of the patients, decontamination process such as surface cleaning, ultraviolet
gemicidal irradiation (UVGI), gas or vapour disinfectants is employed to manage
the spread of infections. From all these above inferences NBU was considered as the
best place to provide health care to infectious diseases.

10.5.5 Controlling of Infectious COVID-19

Healthcare Facilities or hospitals having quarantine wards for COVID-19 patients
should mandatorily follow these paces to guarantee safe management and discarding
of biomedical waste generated in treatment process. As per BMWM Rules, 2016 and
CPCB guidelines [37], the segregation of waste should be performed in a separate
colour-coded bags/bins/containers in order to reduce the effects due to improper
management of bio-medical wastes.

1. Usage of two-layered bags for collection of discarded things from quarantine
wards, to guarantee more protection.
2. Separately collect the biomedical waste from CBWTF and stored in collection bin
(bags/containers) and labelled as “COVID-19 Waste” for the easy identification
of CBWTF authorities. The resultant wastes from bin should be handed over to
authorized staff and then it can be shifted to CBWTF collection van for disposal.
3. To collect the used PPEs in isolation wards such as goggles, face-shield, Hazmat
suit and gloves and wastes like eppendorf tubes, plastic vials, vacutainers and
plastic cryovials into red colour bags.
4. Yellow colour bag should be used to collect N95 mask, head and shoe covers,
onlastic or semi-plastic coverall and linen Gown.
5. Usage of black colour Polypropylene bags for general waste.
6. Maintain separate records of waste generation and management in different
quarantine centres.
7. Labelling of “COVID-19 Waste” on trolleys, vehicles and collection bins.
8. To use 1% sodium hypochlorite disinfectant solution for cleaning of inner/outer surface of storage containers.

1. To maintain daily report isolation ward, ICU and respective CBWTF unit of particular area.
2. To appoint devoted sanitation workers to collect, segregate and transport the wastes timely to the nearby storage area.
3. Yellow bag/container should be used to collect feces in diaper from COVID-19 patients, who are not in a better condition to access toilets and excreta. However, bedpan and toilet must be washed and cleaned with a neutral detergent, water, 0.5% chlorine solution followed by rinsing with pure water.
4. Finally, the responsibilities of a person who is operating Quarantine Camps/individual home isolation facilities, duties of CBWTF & Urban Local Bodies and wastewater management on HCFs/Isolation Wards were given detailed on the Revised guidelines on 2 dated 18 April 2020) provided by Central Pollution Control Board, India for Handling, Treatment and Disposal of Waste Generated during Treatment/Diagnosis/Quarantine of COVID-19 Patients.

**Challenges of BMWM during COVID-19**

(a) Adequate training in the context of collection of waste, segregation of waste, barcoding of different kinds of wastes in appropriate containers, necessity for social distancing has to be given to all the Maintenance staff Team in small batches and the person involved in the collection, segregation, transportation, treatment and disposal of BMW.

(b) Necessity of maintaining Hand hygiene, usage of proper Personal Protective Equipment (PPE) and disinfectants in infectious quarantine site/home quarantine unit. The responsibility etiquette of maintenance staff, doctors, nurses and general public in suitable disposal of PPE products through proper channels as per CPCB rules and BMWM rules.

(c) Regular Health checkup/screening of public and patients in quarantine centres, Immunization, disposal of BMW through appropriate treatment process with minimized wastes and reduced transmission of infectious disease. Introduction of CPCB Mobile App for COVID-19 waste management.

**10.6 Conclusion**

A better BMW management system can generate some cleaner and healthier surroundings for human life and green environment. It will create a positive vibe on the reduction of incidences due to infectious diseases, cost of contagion control inside the hospital, sicknesses and demises due to reuse and repackaging of transmittable disposables, public and work-related health hazard, unnecessary waste and generation of revenues through suitable management and disposal of waste. In conclusion, each and every person in the public should sensitise and understand about their
role and responsibility in the complete eradication of the pandemic situation due to COVID-19 through following the guidelines given by CPCB and BMW management system rules to protect our environment and community health. Thus, to eradicate this deadly infectious risk, designing of efficient treatment strategy, policy reforms, proper assessment of waste generation and segregation, waste mapping, financial arrangement, hospital-based waste management plan and upgrading of existing facilities has to be strongly recommended by government, implemented as an urgent requirement and practiced every day in all the healthcare units to improve the public health. In addition, training programs and awareness campaigns to the healthcare workers can inculcate the knowledge on the need for the management of biomedical wastes and responsibility of every citizen in controlling the infectious disease.

New strategies can formulate systematic methodologies to collect the biomedical wastes from sources, segregate, treat and dispose. Research pertaining to the alternative disposal methods other than PVC products can be encouraged. Awareness and training program has to be given to the healthcare professionals and sanitation workers on how to handle bio-wastes, segregate and transport from sources to common disposal sites. In future, different strategies involving minimization of bio-wastes through reuse, reduction and recycling must be enhanced in BMW management systems. Significance of control and prevention of infectious diseases (COVID-19) through proper usage of PPE equipment, social distancing and quarantine will certainly benefit in the eradication of health risks in human and environmental pollution.

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