International Journal of Waste Resources
ISSN: 2252-5211
OPEN ACCESS Freely available online
Research Article

Challenges and Strategies for the Management of Biomedical Waste Generated During the COVID-19 Pandemics

Jai Singh*

Department of Chemical Engineering, School of Engineering, Shiv Nadar University, Greater Noida, India

ABSTRACT

The Coronavirus disease-2019 (COVID-19) is one of the most deadly viral infections of the present time globally. At present, in India second wave of the pandemic is showing a declining trend. However, government authorities have issued an advisory for the third wave of Coronavirus. Due to many patients in the hospitals and clinics, it resulted in the generation of biomedical waste (BMW), and it is not always possible to carry out the pretreatment or disinfection of the huge BMW properly. Therefore, resulting in the further spread of the virus and breaking off the chain and control of the virus remains a challenge. Various other problems related to BMW management need to be tackled as per the government's safety guidelines and environmentally sound technologies. Some of these problems that need immediate attention of the concerned authorities are the proper segregation of BMW, collection, transportation, final disposal at the designated facilities, and lack of trained staff. For human health safety and to control the Coronavirus, it is essential to handle the biomedical waste very carefully and as per the prescribed standard guidelines because untreated BMW is a severe threat and can be a potential source of infection to human beings. Solutions to these problems need long-term planning, especially for the developing countries, as vaccination to huge populations will take time, as well as there is always a risk of mutations in existing variants of the Coronavirus.

Keywords: Biomedical waste management (BMW); COVID-19; Infectious disease; Hospitals, Pandemic

INTRODUCTION

Coronavirus disease 2019 (COVID-19) is the name of the disease manifested first time in December 2019 from Wuhan city, China, from the virus named SARS-CoV-2 [1,2]. According to Zhang and Liu [3], there are three important conditions for the spread of virus infection: source, transmission route and susceptibility. The mode of the infection may be from person to person, close contact, personal contacts to the infected surfaces and the waste generated from the hospitals, quarantine centers and homes [4]. When waste generated from the health care units is mixed with the other wastes, the infected waste may cause further spread of the virus to the healthy persons. Developing countries are already facing problems in handling the ever-increasing amount of solid waste in the metropolitan cities because of the large population, as these metropolitan cities are the centers of commercial activities. The waste generated from the hospitals, clinics, pathological labs is called biomedical waste, which belongs to hazardous waste. The management of biomedical waste is vital in controlling infectious diseases and maintaining the hygiene of the community. There is a need to take proper care during handling and disposal, as this waste includes sharp waste (needles, blades, etc.), pathological/ anatomical waste (used gloves, contaminated bandages), toxic wastes and radioactive waste [5]. Out of all the waste generated from the hospitals, 85% of the waste is non-hazardous and the rest 15% being hazardous waste. The aim of this review is to understand the challenges in the management of BMW generated during the COVID-19 pandemics, especially in the Indian context and possible strategies in handling the BMW to safeguard the environment and human life.

Current Scenario of COVID-19 Pandemics in India

In India, Maharashtra spiked the maximum number of cases, around 6,336,220 (19.89%) (Figure 1) and this state also had the highest number of deaths amounting to 133,530 (31.29%) of overall deaths in India. After Maharashtra higher number of cases came from Kerala 3,493,603 (10.97%), Karnataka 2,913,512 (9.15%), Tamil Naidu 2,569,398 (8.07%), Andhra Pradesh

***Corresponding to**: Jai Singh, Department of Chemical Engineering, School of Engineering, Shiv Nadar University, Greater Noida, India, E-mail: jaipragya1999@gmail.com

Received: November 08, 2021; **Accepted:** December 02, 2021; **Published:** December 06, 2021

Citation: Singh J (2021) Challenges and Strategies for the Management of Biomedical Waste Generated During the COVID-19 Pandemics. Int J Waste Resour 11: 441. doi: 10.35248/2252-5211.21.11.441

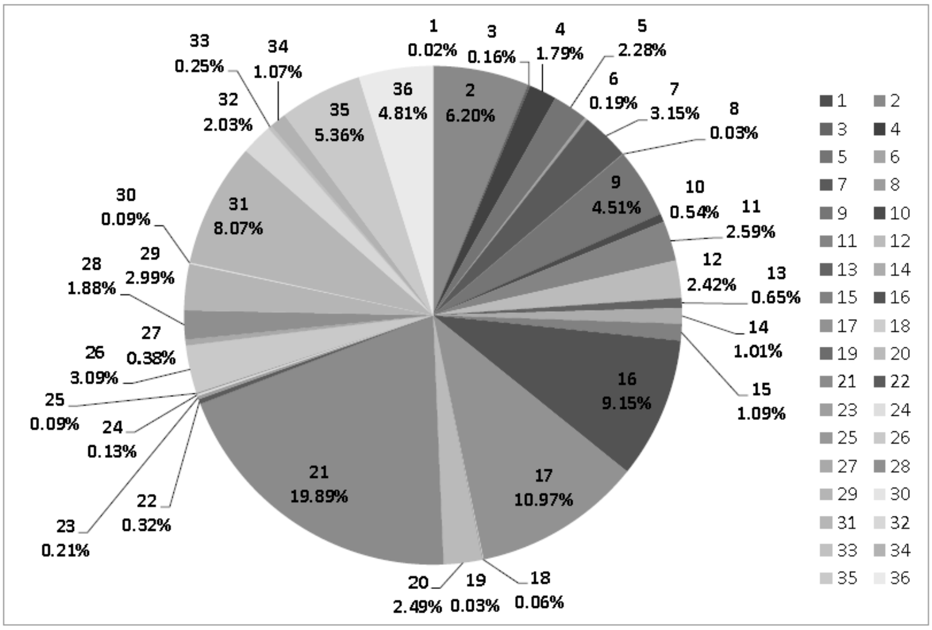

Figure 1: Percentage of COVID-19 confirmed cases in different states of India (Ministry of Health and Family Welfare, 06 August 2021, 08:00 IST (GMT+5:30), (www.mohfw.gov.in).

*1- Andaman and Nicobar Islands, 2- Andhra Pradesh, 3- Arunachal Pradesh, 4- Assam, 5- Bihar, 6- Chandigarh, 7- Chhattisgarh, 8- Dadra and Nagar Haveli and Daman and Diu, 9- Delhi, 10-Goa, 11-Gujarat, 12-Haryana, 13-Himachal Pradesh, 14-Jammu and Kashmir, 15-Jharkhand, 16-Karnataka, 17- Kerala, 18-Ladakh, 19-Lakshadweep, 20-Madhya Pradesh, 21-Maharashtra, 22-Manipur, 23-Meghalaya, 24-Mizoram, 25-Nagaland, 26-Odisha, 27-Puducherry, 28-Punjab, 29-Rajasthan, 30-Sikkim, 31-Tamil Nadu, 32-Telangana, 33-Tripura, 34-Uttarakhand, 35-Uttar Pradesh, 36-West Bengal.

1,976,141 (20%), Uttar Pradesh 1,708,649 (5.36%) and West Bengal 1,531,212 (4.81%). All these adding up to 64.45% of the total cases confirmed in India. When it comes to the number of deaths, after Maharashtra, Karnataka with 36,705 (8.60%), Tamil Naidu with 34,230 (8.02%), Delhi with 25,060 (5.87%), Uttar Pradesh with 22,770 (5.34%), West Bengal with 18,193 (4.26%) and Kerala with 17,328 (4.06%) of Deaths. In these states, deaths cumulating to 67.44% of deaths out of total deaths occurred in India (Figure 2) [6].

At present, across the world, the total number of confirmed cases are over 193,740,594, with approximately 4,152,662 deaths had been reported [7]. In terms of population, India ranks second after China and the worst-hit country with 31,371,901 people infected and the United States of America with 34,430,608 ranks first in terms of infected people with COVID-19. Other countries which were severely affected by this virus were Brazil (19,670,534 persons), France (6,041,146), Russia (6,025,698), United Kingdom (5,694,462), Turkey (5,587,378), Argentina (4,839,109), Colombia (4,716,798), Italy (4,312,673), Spain (4,280,429), Germany (3,761,869) as of now (25/7/2021, 13:00 IST). From the data of WHO [5], India is the worst-hit country globally; however, the main reason is its huge population size and their early vaccination is not such an easy task.

Generation of BMW

In May 2021, the average generation of BMW was 203 TPD (till 10.05.2021), as per the data from the COVID19BMW tracking App of State Pollution Control Boards/Pollution Control Committees. The maximum quantity of BMW is about 250 TPD (10.05.2021), whereas, in the year 2020, the generation of BMW ranges from 180–220 TPD.

However, there was a steep rise in the number of infected persons, but the increase in the generation of BMW was not proportional to the increase in the number of infected people. The reason was proper segregation, which was carried out at the generation site itself. In the year 2021, COVID-19 pandemics, another important observation was that food waste was not mixed up with BMW at hospitals and quarantine homes as happened in the year 2020. There is a gradual increase in the quantity of COVID BMW generation since February 2021. The monthly averaged generation of COVID-19 BMW in different states of India is represented in Figure 3.

Indian states with a higher number of deaths and cases have produced a considerable quantity of BMW. Thind et al. [8] reported that during the pandemic outbreak of COVID-19, there was a sudden increase in the quantity of BMW and incineration units were working beyond their capacities. The similar situation were also reported from other parts of the world where the generation of the yellow category of BMW increased exponentially. In the treatment of BMW, about 198 CBWTFs were operational as per the reports of SPCB's. An application "COVID19BMW" was developed in May 2020 by CPCB for tracking COVID-19 BMW. All generators/operators of BMW are required to send details regularly to the above application. Maharashtra, Karnataka, Gujarat have 29, 26, 20 numbers of CBWTFs, respectively, with a handling capacity of 19.02, 16.91, 21.98 tons of COVID-19 biomedical waste per day. Delhi has two, and Kerala has one CBWTF to handle 18.79 and 23.71 tons of biomedical waste per day, whereas Uttar Pradesh has 18 CBWTF, treating 15.91 tons of waste per day [9].

Face masks, gloves, goggles, head covers, face shields, shoe covers, PPE's and other protective equipments are essential for the protection of the health care workers. The use of protective equipments and PPE's is essential for a person suffering from COVID-19 infection to control the spread of the virus to other healthy persons [10]. According to UN [11] reports, the production of masks increased the global sale by US $166 billion. During the normal period, the daily generation of BMW was 0.68Kg/

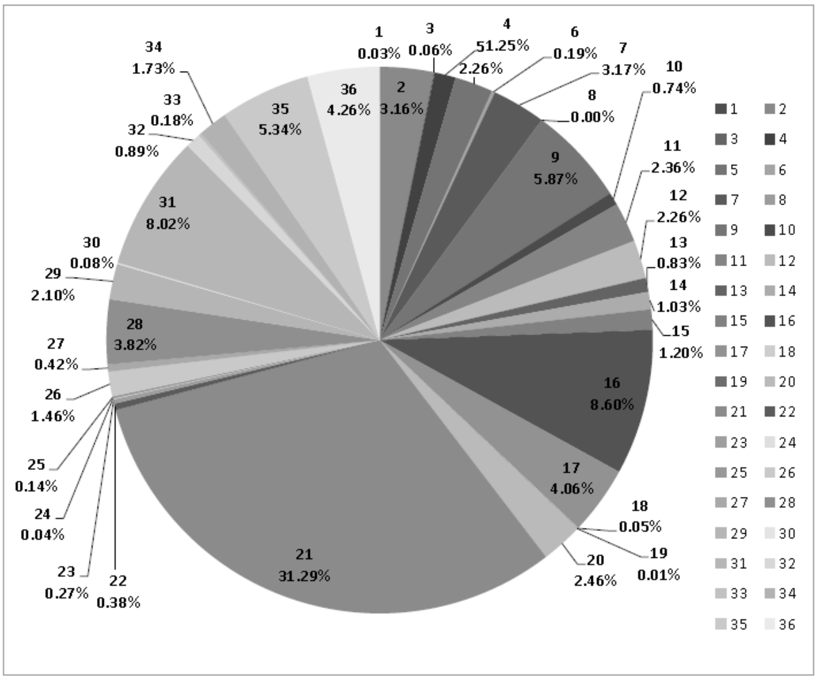

Figure 2: Percentage of deaths due to COVID-19 in different states of India (Ministry of Health and Family welfare, 06 August 2021, 08:00 IST (GMT+5:30) (Serial number denotes the name of states as in Figure-1).

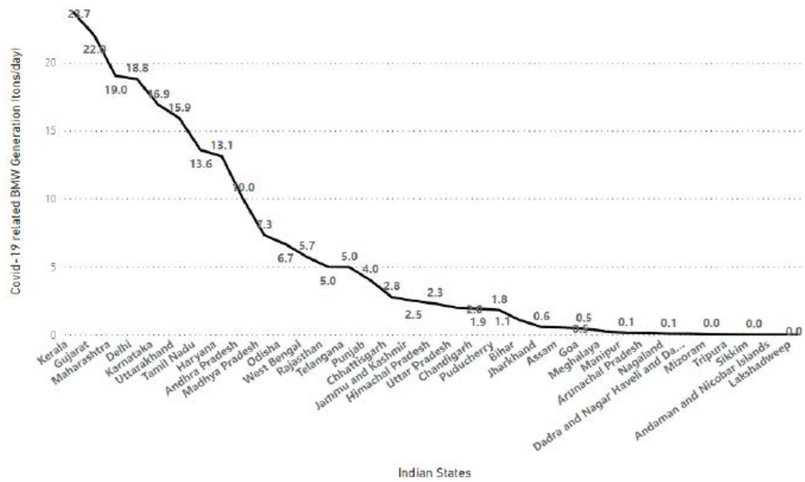

Figure 3: Generation of BMW in different states of India during May 2021 (i.e., till 10/05/2021).

bed, whereas Yu et al. [12] reported that during the peak time of pandemics, it was 2.5 Kg/bed/day. Zuo [13] also reported about 240 tonnes of BMW production per day. Ma et al. [14] reported that the used PPE's, face masks and other protective equipments had increased the BMW volume to a great extent. Thind et al. [8] found a tremendous increase in daily hospital waste, which required the construction of more treatment plants and mobile BMW treatment facilities in China. In the waste reduction and recycling process, ragpickers plays a crucial role, especially in developing countries. However, ragpickers could not collect the recyclable materials from the waste sites during the lockdown period, increasing waste volume. Further, Cruvinel et al. [15] stated an occupational risk to these ragpickers and may further spread the disease to healthy persons (Figure 4).

Environmental Impact of BMW

During the first and second waves of COVID-19 pandemics, the lockdown was posed to break the chain of virus spread. It was the best possible preventive measure to control the pandemics at that time, as vaccines were not available. Before starting the lockdown period, there was panic about purchasing household items and preventive medical equipment such as face masks, gloves, thermometers, oximeters, sanitizers, clinic products, toilet papers, etc. Due to many patients in hospitals, laboratories, home isolation, and quarantine have tremendously increased the volume of biomedical waste. Sarkodie and Owusu [16] reported that due to COVID-19 pandemics, there was a vast increase in the purchase of face masks, gloves, cleaning products and other protective devices.

Unscientific disposal of PPE, face masks and gloves, spread the virus in the environment. Emily [17] stated about heavy disposal of face masks and gloves on the roadside and sidewalks polluting the cities and spreading Coronavirus. Plastic and other nonbiodegradable material pose a severe risk to other life forms, including wildlife and aquatic life [18]. Klemes et al. [19] observed an increased use and production of plastic material which is again a significant threat as the life of a virus is three days on the plastic. Safe disposal of plastic products is still a significant problem. Microplastic has been reported from the freshwater, marine ecosystem, and even

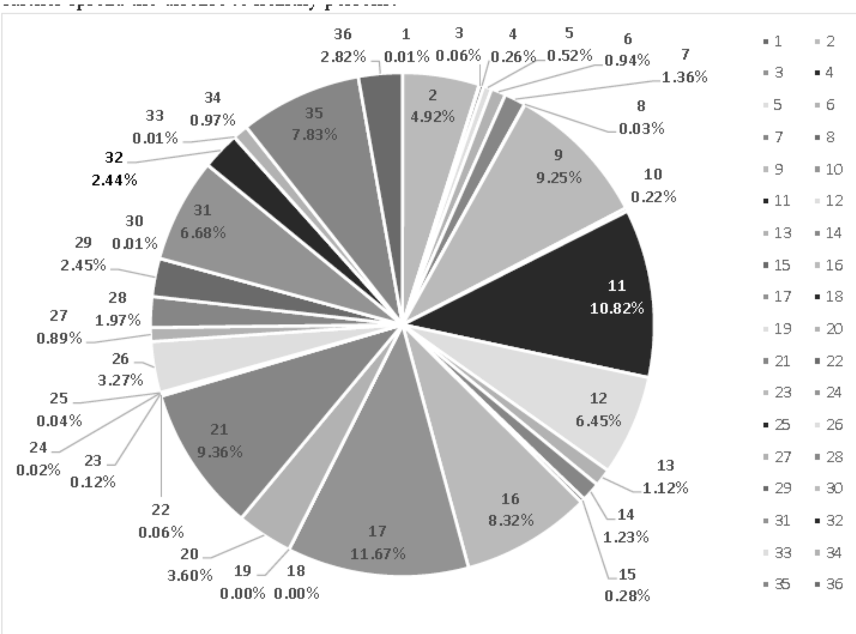

Figure 4: The number of CBWTF's engaged in the treatment of biomedical waste in different states of India. (Ministry of Health and Family welfare, 06 August 2021, 08:00 IST (GMT+5:30) (Serial number denotes the name of states as in Figure-1).

from the pristine environment of polar regions [20], thereby disturbing the whole ecosystem by entering the food chain. Plastic products are responsible for the increase in air pollution because, during its incineration or incomplete combustion, the release of harmful gases such as dioxin and furans, which are carcinogenic, are emitted into the atmosphere [21] or heavy metal release, for example, mercury into the environment might endanger public health. The open dumping, disposal, burning, improper landfilling and incineration with other waste quantities resulted in an increase of waste and might affect the quality of soil and surface or ground water, this may result in severe consequences on a long-term basis. Silpa [22] observed that during the COVID-19 pandemics, recycling activities of waste were affected due to social distancing and lockdown. Hence BMW is disposed off rather than recycling. Mihai [23] reported that the improper management of BMW has a potentially hazardous impact on waste managers, doctors and health workers, causing infections and air pollution-related health issues. At the same time, irresponsible behavior of the public towards the disposal of used face masks and PPE was a great challenge for the waste managers and municipalities in handling the BMW as well as in controlling the spread of the virus.

Strategies for BMW Management

The CPCB, under the Ministry of Environment, Forest and Climate Change (MOEF&CC), is the Apex body, Government of India, New Delhi, to monitor India's BMW management. For the proper management of BMW, MOEF&CC has issued BMW management rules 2016 and the amendment rules 2018. In March 2020, CPCB issued "Guideline for handling, treatment, and disposal of waste generated during the treatment/diagnosis/quarantine of COVID-19 patients 2020 and further amendments in April 2020 [24] (Figure 5). There are stringent guidelines for the onsite segregation, storage, transportation and disposal of BMW as per the rules. These rules are mandatory for all hospitals, clinics, nursing homes, pathological laboratories to follow. As per the guidelines, BMW is segregated into four categories; 1. Yellow category -for infected or potentially infected, 2. Red category-apparently non-infected and recycle label, 3. White category-sharp

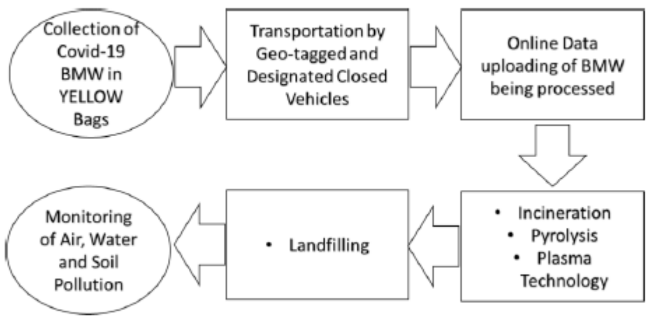

Figure 5: Representation of management of BWM as the standard guidelines.

Table 1: Infection capability of Coronavirus for different materials.

Materials	Aerosol	Plastic	Stainless Steel	Copper	Cardboard
Duration	3h	72h	48h	4h	24h

and small metallic items, 4. Blue category- waste consisting of glass. Color coding is of great help in segregating the BMW, as by adopting this scheme, treatment of waste becomes more systematic and in control of waste managers. A two-layered bag is recommended for the transportation of BMW to ensure safety against leakage during the transportation. WHO [5] also categorized the different forms of BMW, including non-hazardous waste, chemical waste, cytotoxic waste, and pharmaceutical waste.

Open burning and incineration of health care wastes can, under some circumstances, results in the emission of toxic gases and particulate matter [25]. Measures to ensure BMW's safe and environmentally sound management can prevent adverse health and environmental impacts from disposal sites, including the unintended release of chemicals or biological materials, into the environment, thus protecting workers, the general public, and the environment [26]. Investigations of various researchers have indicated that the Coronavirus can remain active for a long time. Suman et al. [27] reported the activeness of the virus on different materials, Table 1, which is of importance for waste management purposes and accordingly, different surfaces and the materials can be disinfected before the segregation, transportation and disposal.

Developing Nations were already facing solid waste management problems because of the ever-increasing population, urbanization, and shortage of funds for Municipal corporations. According to UN Habitat [28], a vast population is not having facilities for waste collection, and waste disposal. Ramteke and Sahu [29] reported that BMW originated due to coronavirus pandemics is a great challenge for waste management authorities. In the developed world, guidelines for waste management are stringent, with high standards of safety and environmental protection [30]. We must learn the lesson from Covid pandemics for sustainable waste management to minimize the spread of the virus and safeguard human life. There is a need to develop low-cost technological innovations for achieving zero waste and zero carbon waste management techniques. Proper waste management practices ensure the safety of health workers and others involved in waste management and are further helpful in controlling the spread of Coronavirus. As this is a global pandemic, there is a danger of more such waves of viral infection; therefore, there is a need for urgent upgradation of existing facilities to control the increasing amount of BMW, eventually preventing the viral spread.

Challenges in BMW Management

Initially, during the breakdown of COVID-19 pandemics, the compliance of standard guidelines of CPCB was not proper, resulting in the increase of amount of BMW. The main challenges in biomedical waste management in developing countries, including India, are segregation before the disposal, and treatment of massive BMW amounts as per guidelines, lack of knowledge of handling the hazardous waste, and insufficient funds. As there is a tremendous surge in BMW, technical knowledge needs a significant improvement in waste segregation, transportation, storage. Long-term sustainable management of BMW requires continuous and authentic information from the waste management centers to formulate consolidated future plans backed by technologically sound practices that can be implemented to deal with pandemic situations. Long-term planning and solutions to these challenges are essential for waste management so that we all can together fight Coronavirus and save humanity (Figure 6).

Solutions for the management of BMW

The waste management technique needs immediate upgradation of infrastructure to handle such emergencies as the human race faces during the COVID-19 pandemics [31]. The BMW generated from COVID-19 patients must be treated and disposed off scientifically, following the guidelines of Biomedical Waste Management Rules, 2016 and its amendments. CPCB has prepared guidelines for "Handling, treatment and disposal of waste generated during treatment, diagnosis and quarantine of COVID-19 Patient". Stored BMW needs to be transferred in different colored red bags to the common biomedical waste disposal facilities for the final treatment and disposal, Table 2. The transportation of BMW should be well labeled, and in a closed vehicle, after reaching CBMWF's, it is sterilized, treated, and further processed depending on the waste type. The data generated at CBMWF's site must be reported to the state pollution control boards. However, there are many reports of nonadherence at the CBMWF's and inadequate data reporting to the SPCB [32].

According to IIyas [33], the use of incineration in treatment for biomedical waste and proper handling of waste products is mandatory. According to EPA [34] and Wang et al. [35], high-temperature based incineration of BMW at temperature 800°C to 1200°C destroys the pathogen and organic matters to a maximum extent. However, some toxic gases also emitted out such as Furans and Dioxins, which requires further treatment before discharge into the atmosphere.

Alternatives to incineration such as autoclaving, microwaving, and steam treatment integrated with internal mixing minimize the formation and release of chemicals or hazardous emissions.

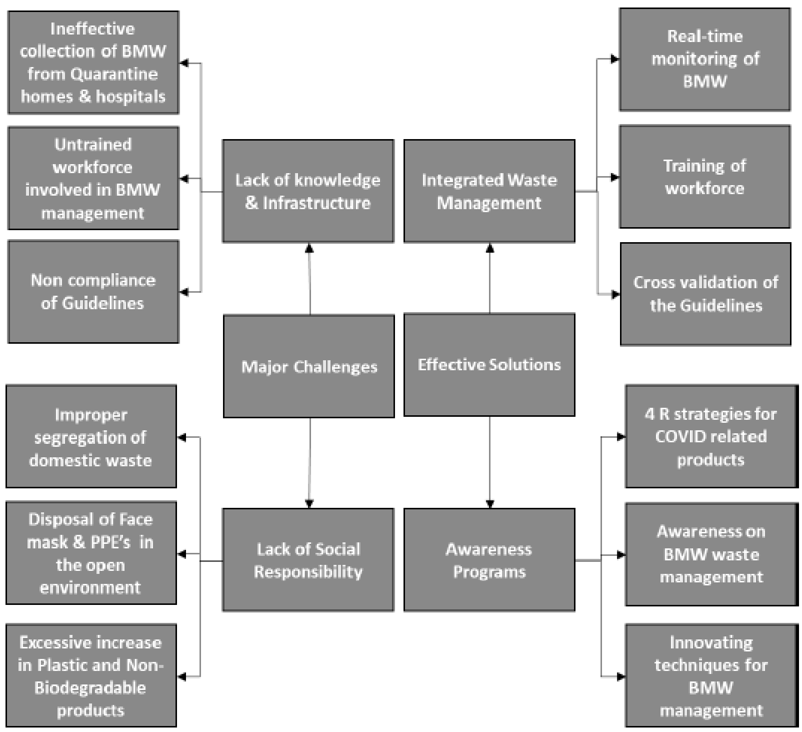

Figure 6: Schematic representation of challenges and their solutions of BMW management.

Table 2: Different color codes for BMW prescribed treatments and end products.

Different Categories of BMW	Category-1	Category-2	Category-3	Category- 4
	Yellow Bag	**Red Bag**	**White Bag**	**Blue Bag**
Definition as per CPCB, 2016	Infected or potentially infected	Apparently, non-infected and recycle label	Sharp and small metallic items	Waste consisting of glass
Proposed Treatment	Thermal Treatment by incinerator	Autoclaved	Autoclaved	Chemical Disinfection
Outcome of process	Ash, flue gas Heat,	Materials can be reused/ recycle	Materials can be reused/ recycled	Materials can be reused/ recycled

These alternatives should be considered in treatment facilities with sufficient resources to operate and maintain such systems to dispose off the treated waste. As per the report of Prüss-Üstün [36], autoclaving is one of the cost-effective and environmentally friendly technology, but the waste reduction is not upto the level of satisfaction. Autoclaving is primarily done in hospitals to sterilize reusable medical equipments and treat only limited quantities of waste. Nearly 99.99% inactivation of microorganisms can be achieved during autoclaving.

In the microwave irradiation of medical waste, inactivation of microorganisms occurs due to the thermal effect of electromagnetic radiation Neto et al. [37]. The heating occurs inside the waste material in the presence of steam. Most microorganisms are destroyed by the action of microwaves of a frequency of about 2450 MHz and a wavelength of 12.24 cm. Hoffman and Hanley [38] observed that microwaves rapidly heat the water contained within the waves, and the infectious components are destroyed by heat conduction. The specially designed microwave devices under the controlled conditions can efficiently inactivate SARS-CoV-2. Wang et al. [35] discussed the disinfection technique and stated that killing viruses is of great help for onsite disinfection of COVID-waste, reducing the risks of spread. The microwave technique can also be used in combination with autoclaving to treat COVID-19 generated waste properly.

In the health care sector, chemical disinfectants are being used to kill microorganisms in the BMW. Chemicals are added to waste to kill or inactivate the pathogens present; this treatment usually results in disinfection rather than sterilization. Chemical disinfection is most suitable for treating liquid biomedical waste such as blood, urine, stools, or hospital sewage. The most commonly used chemicals for disinfection of biomedical waste are sodium hypochlorite, hydrogen peroxide, and Fenton reagent [39]. Duarte and Santana [40] reported that the chemicals such as ethanol, povidone-iodine, formaldehyde, isopropanol, and ethyl alcohol could also inactivate the Coronavirus.

As per Central Pollution Control Board's guidelines for COVID-waste management in India [24,32,41] the collected COVID-waste is to be stored in a dedicated collection bin labeled as "COVID-19" after the disinfectant spray on the inner and outer surface of bags. For the chemical disinfection of COVID-waste, various factors like the quantity and type of waste, costs, and maintenance are important before finalizing the disinfection technology. In the case of smaller hospitals with a limited investment that cannot afford the installation, the chemical disinfectant in combination with heat and UV disinfection technique gives better results [42]. Solar heating as an alternative technology to heat medical waste is also being used alongside other expensive technologies. Plasma incineration is a new waste disposal technique where the transfer of energy through plasma takes place to efficiently decompose waste into smaller particles or even atoms [43]. According to Messerle et al. [44], plasma incineration is very efficient compared to conventional incineration. Looking at the rapid spread potential of SARS-CoV-2, Wang et al. [35] emphasized the use of plasma incineration for a faster decomposition of COVID-waste to control the spread of Coronavirus. Emmanuel [45] discussed the technology of using ozone for decontamination of BMW. Being a strong oxidant, ozone destroys microbes and converts them into molecular oxygen. Ionizing radiation cause damage to DNA and by producing free radicals cause further damage proteins and enzymes of infectious particles. The various advantages of this method are that it does not produce toxic emission, no liquid effluent, no ionizing radiation after the machine is switched off, fully automated, and low operational cost.

Future technologies and methods of treatment of BMW

Biological methods for disposal of BMW include an emerging system called "Bio-converter" 9 Biomedical Disposal, Inc.). It uses an enzyme solution to decontaminate medical waste, and the resulting sludge is put through an extruder used to remove water for sewage disposal, and the solid waste is sent to a landfill. Another method of environmental BMW disposal is the use of biodegradable plastics. Many biomedical implants built with biodegradable plastics undergo biological degradation with microbial extracellular enzymes. These microbes utilize these biodegradable polymers as substrate under starvation and in the unavailability of suitable substrate. However, research needs to be done for the large-scale economical manufacturing of biodegradable plastics.

Sangkham [46] reported the production of 381 million masks on a daily average. The littered mask might be infectious and can spread the virus further if not treated properly. Some researchers are working on recycling old masks and developing biodegradable masks. Abaca, a biodegradable fiber from banana plants, has shown promise as a potential replacement for polyester and plastics in medical masks. An eco-entrepreneur in India is working on converting disposable masks into construction bricks. Moreover, a company called Plaxtil is upcycling used PPE into new PPE. Alternatively, Copper masks can also be used as their recycling is easy [47].

CONCLUSION

As there is a continuous threat of more waves with potential dangers of infection due to new coronavirus strains, it is crucial to strictly follow the implementation of biomedical Waste Management rules 2016 and its amendment 2018 issued by the MOEF&CC. During the second wave of pandemics, the number of patients was very high; therefore, in hospitals, clinics, and laboratories, usage of gloves, face masks, PPE's, gowns, and other protective equipment have increased tremendously, and the disposal and dumping of BMW without segregation and without following proper guidelines have increased the potential risk of spreading the virus. Lack of awareness about the health hazards related to BMW, inadequate training, absence of waste management and disposal systems, insufficient financial and human resources, inefficient regulations, lack of willpower of politicians and administration, the low priority given to the BMW are the most common problems connected with healthcare waste, which needs immediate attention of concerned authorities, priorities in government planning, upgradation of guidelines, policies, regulations and their strict implementations.

ACKNOWLEDGMENTS

I gratefully acknowledge the support provided by the Chemical Engineering Department, School of Engineering, Shiv Nadar University, Greater Noida, India.

DECLARATION OF COMPETING INTEREST

Author declares no conflict of interest.

REFERENCES

1. Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, Zhang L, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. The lancet. 2020 Feb 15;395(10223):497-506.
2. Zhang N, Wang L, Deng X, Liang R, Su M, et al. Recent advances in the detection of respiratory virus infection in humans. Journal of medical virology. 2020 Apr;92(4):408-17.
3. Zhang L, Liu Y. Potential interventions for novel coronavirus in China: A systematic review. Journal of medical virology. 2020 May;92(5):479-90.
4. World Health Organization. Novel Coronavirus (2019-nCoV): situation report, 11.
5. https://apps.who.int/iris/handle/10665/328146
6. www.mohfw.gov.in
7. https://www.worldometers.info/coronavirus/#countries
8. Thind PS, Sareen A, Singh DD, Singh S, John S. Compromising situation of India's bio-medical waste incineration units during pandemic outbreak of COVID-19: Associated environmental-health impacts and mitigation measures. Environmental Pollution. 2021 May 1;276:116621.
9. https://cpcb.nic.in/uploads/Projects/Bio-Medical-Waste/Toolkit_BMW.pdf
10. WHO. Shortage of Personal Protective Equipment Endangering Health Workers Worldwide. 2020a.
11. UN. Five things you should know about disposable masks and plastic pollution. 2020.
12. Yu H, Sun X, Solvang WD, Zhao X. Reverse logistics network design for effective management of medical waste in epidemic outbreaks: Insights from the coronavirus disease 2019 (COVID-19) outbreak in Wuhan (China). International journal of environmental research and public health. 2020 Jan;17(5):1770.
13. Zuo M. Coronavirus leaves China with mountains of medical waste. South China Morning Post. 2020.
14. Ma Y, Lin X, Wu A, Huang Q, Li X, Yan J. Suggested guidelines for emergency treatment of medical waste during COVID-19: Chinese experience. Waste Disposal & Sustainable Energy. 2020 Jun;2:81-4.
15. Cruvinel VR, Marques CP, Cardoso V, Novaes MR, Araújo WN, Angulo-Tuesta A, Escalda PM, Galato D, Brito P, da Silva EN. Health conditions and occupational risks in a novel group: waste pickers in the largest open garbage dump in Latin America. BMC public health. 2019 Dec;19(1):1-5.
16. Sarkodie SA, Owusu PA. Impact of COVID-19 pandemic on waste management. Environment, development and sustainability. 2021 May;23(5):7951-60.
17. Emily A. UBC researchers develop biodegradable medical mask. 2020.
18. Farah MAY Chow. Discarded coronavirus masks clutter Hong Kong's beaches, trails. 2020.
19. Klemeš JJ, Van Fan Y, Tan RR, Jiang P. Minimising the present and future plastic waste, energy and environmental footprints related to COVID-19. Renewable and Sustainable Energy Reviews. 2020 Jul 1;127:109883.
20. Mishra AK, Singh J, Mishra PP. Microplastics in polar regions: An early warning to the world's pristine ecosystem. Science of The Total Environment. 2021 Apr 17:147149.
21. Thornton J, McCally M, Orris P, Weinberg J. Hospitals and plastics. Dioxin prevention and medical waste incinerators. Public Health Reports. 1996 Jul;111(4):298.
22. Silpa K. Waste workers are protecting our communities during COVID-19. 2020.
23. Mihai FC. Assessment of COVID-19 waste flows during the emergency state in Romania and related public health and environmental concerns. International Journal of Environmental Research and Public Health. 2020 Jan;17(15):5439.
24. CPCB. Scientific Disposal of Bio-Medical Waste Arising Out of COVID-19 Treatment-Compliance of BMWM Rules, 2016. Central Pollution Control Board, New Delhi, India. 2020b.
25. Xie J, Zhu Y. Association between ambient temperature and COVID-19 infection in 122 cities from China. Science of the Total Environment. 2020 Jul 1;724:138201.
26. WHO. Water, sanitation, hygiene, and waste management for SARS-CoV-2, the virus that causes COVID-19: interim guidance. 2020b.
27. Suman R, Javaid M, Haleem A, Vaishya R, Bahl S, et al. Sustainability of coronavirus on different surfaces. Journal of clinical and experimental hepatology. 2020 Jul 1;10(4):386-90.
28. UN-Habitat. How to continue waste management services during the COVID-19pandemic. 2020.
29. Ramteke S, Sahu BL. Novel coronavirus disease 2019 (COVID-19) pandemic: considerations for the biomedical waste sector in India. Case Studies in Chemical and Environmental Engineering. 2020 Sep 1;2:100029.
30. Mattiello A, Chiodini P, Bianco E, Forgione N, Flammia I, Gallo C, Pizzuti R, Panico S. Health effects associated with the disposal of solid waste in landfills and incinerators in populations living in surrounding areas: a systematic review. International journal of public health. 2013 Oct;58(5):725-35.
31. Rai A, Kothari R, Singh DP. Assessment of available technologies for hospital waste management: a need for society. InWaste Management: Concepts, Methodologies, Tools, and Applications 2020 (pp. 860-876). IGI Global.
32. CPCB. Guidelines for Handling, Treatment, and Disposal of Waste Generated during Treatment/Diagnosis/Quarantine of COVID-19 Patients - Rev. 4. Central Pollution Control Board, Government of India. 2020a.
33. Ilyas S, Srivastava RR, Kim H. Disinfection technology and strategies for COVID-19 hospital and bio-medical waste management. Science

of the Total Environment. 2020 Dec 20;749:141652.

34. EPA. Medical waste incineration. In compilation of air pollutant emission factors In: Stationary Point and Area Emission Units (AP-42), 5th ed. Research Triangle Park, NC. 1995.

35. Wang J, Shen J, Ye D, Yan X, Zhang Y, Yang W, Li X, Wang J, Zhang L, Pan L. Disinfection technology of hospital wastes and wastewater: Suggestions for disinfection strategy during coronavirus Disease 2019 (COVID-19) pandemic in China. Environmental pollution. 2020 Jul 1;262:114665.

36. Prüss-Üstün, A., Giroult, E., Rushbrook, P. and World Health Organizatio. Safe management of wastes from healthcare activities/ edited by A. Prüss, E. Giroult, P. Rushbrook. In Safe management of wastes from healthcare activities/edited by A. Prüss, E. Giroult, P. Rushbrook. https://apps.who.int/iris/bitstream/handle/10665/42175/ 9241545259. Pdf

37. Neto, A.G., de Carvalho, J.N., da Fonseca, J.C., da Costa Carvalho, A.M. and Castro, M.D.M.V., (1999) August. Microwave medical waste disinfection: a procedure to monitor treatment quality. In 1999 SBMO/IEEE MTT-S International Microwave and Optoelectronics Conference, Vol. 1, pp. 63-65. IEEE

38. Hoffman, P. N. and Hanley, M. J. (1994) Assessment of a microwave based clinical waste decontamination unit." Journal of Applied Bacteriology Vol. 77, No. 6, pp.607-612

39. Chitnis V, Vaidya K, Chitnis DS. Biomedical waste in laboratory medicine: Audit and management. Indian Journal of Medical Microbiology. 2005 Jan 1;23(1):6-13.

40. Duarte P, Santana VT. Disinfection measures and control of SARS-COV-2 transmission. Global Biosecurity. 2020 Apr 17;2(1).

41. CPCB. Report on COVID-19 Waste Management. Central Pollution Control Board. 2020c.

42. Price, A.D., Cui, Y., Liao, L., Xiao, W., Yu, X., Wang, H., Zhao, M., Wang, Q., Chu, S. and Chu, L.F. (2020) Is the fit of N95 facial masks effected by disinfection? A study of heat and UV disinfection methods using the OSHA protocol fit test. medRxiv.

43. Nema, S.K. and Ganeshprasad, K.S. (2002) Plasma pyrolysis of medical waste. Current Science, pp.271-278 Case Studies in Chemical and Environmental

44. Messerle, V.E., Mosse, A.L. and Ustimenko, A.B. (2018) Processing of biomedical waste in plasma gasifier. Waste Management, Vol. 79, pp.791-799

45. Emmanuel J. Health Care without Harm; Non-Incineration Medical Waste Treatment Technologies A Resource for Hospital Administrators, Facility Managers, Health Care Professionals, Environmental Advocates, and Community members. 1755 S Street, NW. Suite 6B Washington, DC. 2001.

46. Sangkham, S., (2020) Face mask and medical waste disposal during the novel COVID-19 pandemic in Asia. Case Studies in Chemical and Environmental Engineering, Vol 2, pp.100052

47. www.earth911.com/living-well-being/can-face-masks-be-recycled