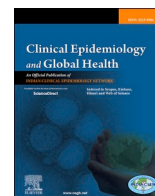




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Review article

Updates on biomedical waste management during COVID-19: The Indian scenario

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ABSTRACT

Biomedical waste poses various health and environmental hazards. Hence, it should be handled with the utmost care and disposed off safely. Several lacunas exist in the management of biomedical waste in India, and the pandemic posed by the coronavirus has made it even more challenging. The sudden outbreak of the virus led to an exponential rise in the quantity of biomedical waste. Furthermore, the poor infrastructure and lack of human resources have aggravated this situation. To combat this serious problem in a timely manner, the government has formulated various standard operating procedures and has amended the existing rules and guidelines.

1. Introduction

Biomedical waste (BMW) differs from general municipal waste as it poses various health hazards. BMW management rules 2016 and the amendment rules 2018 are the latest guidelines from the ministry of environment, forest & climate change to regulate the handling of BMW activities in the country.^{1,2} India is the second-most populous country after China and the second worst-hit nation by the coronavirus disease 2019 (COVID-19) after the United States of America (As of November 9, 2020).^{3,4} Due to the flawed biomedical waste management system and lack of resources, India faces severe consequences during the COVID-19.⁵ Untreated and improperly managed BMW is a potential source of infection.⁶ The diligent handling and management of BMW can prevent the occurrence of hospital-acquired infection and lower the rates of disease transmission. In addition, the untreated or the rudimentary handling of BMW creates a nuisance and decreases patient satisfaction.⁷ According to the data published by the central pollution control board (CPCB) in the year 2018, the total amount of BMW generated in India is 517 tonnes/day in the year 2016 and around 501 tonnes/day in the year 2015, out of which around 4–5% remains untreated.⁸ The annual report 2018/2019 released by CPCB showed the generation of 557 tonnes/day BMW in 2017, out of which 517/day was

treated. The country has a total of 238,170 healthcare facilities, out of which 87,267 are bedded while the remaining 151,208 are non-bedded healthcare facilities (HCFs) generating BMW. There are 198 approved common biomedical waste disposal facilities (CBMWFs) in the country and 28 are under construction.

2. Ground-level process for handling and managing the BMW in India

Biomedical waste is not handled like a municipal waste. The central pollution control board (CPCB) is the apex body to monitor the country's BMW management activities under the ministry of environment, forest, and climate change. There are separate state pollution control boards in each state to monitor and regulate the BMW activities within the state and report the findings to the CPCB. The country has a stringent policy of onsite segregation of the generated BMW and storing, transporting, and disposing of them in adherence to the biomedical waste rules framed by the ministry under the Government of India.^{9–12} It is mandatory for all the small clinics, diagnostics, laboratories, nursing houses, hospitals and other healthcare institutions to comply with these guidelines. Previously, the country had ten different categories of waste for segregation. Later, it was amended into four classes for easy segregation. Infected or

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potentially infected waste is labeled as yellow, apparently non-infected and recyclable fall in the red category, sharps and small metallic items comes under the white category while waste consisting of glass is segregated into the blue category. Segregated waste is stored in a well-ventilated area and the stored waste is carried to the disposal facility (commonly known as common biomedical waste disposal facilities) for further treatment and disposal.^{8,11} The treatment of solid waste at the site of generation or storage is prohibited according to the updated guidelines. The waste should be transported in a designated closed vehicle that is equipped with the global positioning system tracker. The BMW in the CBMWFs is then treated, sterilized, and sent for recycling, incineration, or landfilling based on the waste category. The qualitative process and quantitative data on the generated and disposed off BMW should be accurately documented and reported to the state pollution control board. Violating these guidelines by healthcare facilities and disposal facilities will subject them to penalties.^{8,9} Despite stringent rules and liability, the country reports a high degree of non-adherence to these guidelines. According to the annual report, 2018/19 published by the CPCB, 23,942 HCFs violated the BMW rules 2016, and 18,210 HCFs were issued a warning for their violation.⁹ The report shows the massive amount of BMW generation per day and around 13% of HCFs have violated BMW rules, which show the poor biomedical handling and management in India.

3. Existing problems of BMW and crisis during COVID-19 pandemic

The most populous cities like Delhi, Mumbai, Bangalore, Chennai, Hyderabad, etc. are the most affected cities by COVID-19. According to data published by NDTV on September 18, 2020, the country is generating a considerable amount (Above 100 tonnes/day) of COVID-19 related biomedical waste in the country. Maharashtra contributes for approximately 17% of total COVID-19 related BMW. Now the national daily waste generation is reaching around 850 tonnes/day.^{10,11} The details on the monthly generation of COVID-19 related BMW across several state of India (From June 2020–December 2020) is referenced in Table 1. The country does not have sufficient infrastructure and human resources to handle this huge amount of BMW. The presence of 198 CBMWFs and 225 captive incinerators was insufficient to dispose off 700 tonnes of waste generated in a day. This additional BMW stirred up havoc in the disposal of BMW. The workers involved in BMW management are pitching in extra hours to cater to this need.¹¹ According to the Supreme Court report, there is an increment in the quantity of BMW ranging from 25 to 349 tonnes/day during the month of May–July and it is expected to have doubled during the months of August–October. Presently, there is a poor practice of segregation at the site of generation due to the exponential rise in the generation, thus elevating the risk to the environment. Additionally, inadequate safety measures for the BMW workers continue to remain another major challenge in the Indian

Table 1

Details on the generation of COVID-19 related BMW in Indian States/UTs from June 2020 to December 2020.

S. No.	States/UTs	Generated BMW (In tons)							Total Number of CBMWFs (Till December 2020)
		June 2020	July 2020	August 2020	September 2020	October 2020	November 2020	December 2020	
1	Andaman & Nicobar ^a	0.42	INP	INP	0.42	0.434	0.42	0.43	0 ^a
2	Andhra Pradesh ^a	165.48	182.81	118.82	112.35	116.095	317.91	328.51	11
3	Arunachal Pradesh ^a	3.36	3.36	3.80	3.36	3.472	3.36	3.47	0
4	Assam	28.38	20.68	12.57	62.61	51.739	50.07	23.41	1
5	Bihar	6.84	20.76	41.54	45.36	44.64	28.08	23.31	4
6	Chandigarh ^a	29.85	5.65	55.34	43.02	73.191	70.83	73.19	1
7	Chhattisgarh ^a	11.19	INP	13.39	9.3	9.61	9.3	9.61	4
8	Daman & Diu	0	INP	0.00	0.48	2.387	1.08	1.15	1 ^b
9	Delhi	333.42	389.58	296.14	382.5	365.893	385.47	321.32	2
10	Goa ^a	0.81	0.81	INP	15	7.75	5.43	5.39	0 ^a
11	Gujarat	350.79	306.14	360.04	622.89	545.879	423.51	479.57	20
12	Haryana	75.33	184.18	210.69	278.31	238.452	239.4	209.93	11
13	Himachal Pradesh	3.81	12.50	4.94	25.2	28.117	30.03	48.24	2
14	Jammu & Kashmir	10.71	9.77	51.77	57.39	59.303	44.82	35.12	2
15	Jharkhand ^a	INP	INP	2.59	4.8	4.96	4.8	11.63	4
16	Karnataka ^a	84	540.28	588.03	168	218.023	210.99	218.02	26
17	Kerala	141.3	293.32	588.05	494.1	641.979	600.39	542.47	1
18	Lakshadweep ^a	0.3	INP	INP	0.3	0.31	0.3	0.31	0 ^a
19	Madhya Pradesh	224.58	56.40	106.59	339	308.419	208.65	249.49	13
20	Maharashtra	524.82	1180	1359	524.82	542.314	609	629.30	29
21	Manipur	5.13	0.20	2.09	5.13	5.301	5.13	9.27	1
22	Meghalaya	5.1	1.74	6.34	9.9	12.028	7.65	8.56	2
23	Mizoram ^a	4.2	INP	INP	4.2	3.224	3012	3.22	0 ^a
24	Nagaland ^a	3.6	3.4	3.10	2.85	3.317	1.86	2.29	0
25	Odisha	31.86	106.63	109.19	134.01	183.458	222.66	125.58	5
26	Puducherry	18.63	35.82	41.54	63	58.652	28.74	17.11	1
27	Punjab	48	35.59	21.19	234.42	149.606	96.51	86.99	5
28	Rajasthan	177	7.15	50.43	145.08	171.554	141.93	105.93	8
29	Sikkim	6	0.20	0.30	6	4.216	3.69	2.45	0
30	Tamil Nadu	312.3	401.29	481.10	543.78	524.179	300.75	251.22	8
31	Telangana	12.3	10.50	24.04	188.82	144.801	103.89	68.82	11
32	Tripura ^a	0.45	INP	INP	0.45	0.465	0.45	0.47	0 ^a
33	Uttarakhand	0.45	0.82	41.45	21.72	108.996	56.76	76.26	2
34	Uttar Pradesh	210	307.54	408.86	507.15	478.082	316.71	276.46	18
35	West Bengal	195	136.37	235.12	434.76	486.793	330.84	279.06	6
Total		3025.41	4253.46	5238.45	5490	5597	4864.53	4527.55	198

Total waste generated from June–December 2020 = 28,747.91 tonnes

INP: Information Not Provided.

^a As per earlier information provided by States/UTs.

^b Using CBWTF, Surat, and Gujarat for disposal of biomedical waste.

context. At present, around five million sanitation workers are performing their duty and cleaning the country and these laborers (*Safai karamchari*) are simultaneously handling the biomedical waste as well. Sadly, they are not provided with the necessary personal protective equipment. These workers are at high risk and subsequently pose a threat to the residing community. According to the evidence from scientific literature, the virus may stay for more than 24 h within the cardboard, boxes, other rigid substances and around 72 h on the surfaces of metals and sharps, which is a significant threat for the workers collecting the waste for their daily survival. There is an estimated two to four million ragpickers or korales in India. However, they do not have sufficient information and adequate awareness about the necessary precautions to be taken.¹² Consequently, the pandemic has recorded that more than thousands of waste workers have contracted the virus and hundreds of them have lost their lives.

4. The approach of the nation toward biomedical waste handling during the COVID-19 pandemic

The pandemic scenario added to an unexpectedly high BMW amount from the hospitals, testing laboratories, and quarantine centers. The calculation of the exact amount of BMW is challenging, although a study has suggested the increment in BMW generation to be as high as six-fold in comparison to the pre-pandemic situation.¹³ This increment in the volume and quantity places a high demand for additional resources and training. There is an urgent requirement for additional personal protective equipment and workers to manage biomedical waste safely. A lack of sufficient data and accurate information on BMW during COVID-19 exaggerates the problem further. The unexpected rise in biomedical waste during the pandemic has raised fear among biomedical waste handlers^{13–15} because the virus created an uncertain work environment and increased the occupational risk of exposure, leading to occupational stress.¹⁶ New materials have been added to the biomedical waste generated during the pandemic, especially from the quarantine centers. Hence, the ministry's existing guidelines will need to be updated.¹⁷ To overcome this panic situation, the central pollution control board and the All India Institute of Medical Sciences, New Delhi, framed new guidelines for the safe handling and disposal of BMW. The state and central pollution control board suggested strict adherence to all the guidelines laid previously in BMW rules 2016 and adopted additional precautionary measures.^{18,19} BMW's rudimentary disposal and the lack of a proper system heightened the risk of hospital-acquired infection and several other environmental hazards. The likelihood of health hazards has seen an increase by many folds during the pandemic due to the high infectivity of the virus.¹³ Additional precautionary measures and amendments to lessen the probable transmission of COVID-19 via biomedical waste are explained below.

5. Measures required in the healthcare facilities for safe handling and disposal of biomedical waste

5.1. Handling of solid biomedical waste^{17–20}

- The guidelines recommend the use of color-coded bins for onsite segregation and the usage of double-layered bags in the COVID-19 isolation areas.
- There should be additional and temporary bins for disposable PPEs, gloves and masks and separate containers for reusable materials (e.g., N95 mask for cleaning and sterilization).
- The feces from the confirmed COVID-19 positive patient should be collected in a diaper and segregated as the yellow category BMW or it can be collected in a pan and flushed in the toilet, following which the toilet should be disinfected in adherence to the SOPs.
- There should be separate segregation bags and carrier trolleys for handling the BMW generated at COVID-19 areas. The bags and containers should be well labeled as "COVID-19" for easy

identification, treatment, and disposal of BMW. The outer and inner surfaces of the containers and trolleys should be cleaned daily by using a 1–2% sodium hypochlorite solution.

- A separate record should be maintained for BMW generated from COVID-19 related activities, and the same should be reported to the pollution control board.
- The facilities can download the official application of the central pollution control board (COVID19BWM) from the Google play store and register in the app in order to upload the details with ease.
- A separate arrangement for the transportation of BMW from the hospital to the common BMW disposal and treatment facility should be made.
- There should be dedicated vehicles for the transportation of BMW, and it should be sanitized after every trip.
- BMW generated from COVID-19 related activities should be strictly disposed of within 24 h.
- All the waste collected from the nearby isolation and quarantine centers should be treated as BMW generated within the hospital and the details should be documented and reported to the pollution control board.
- Liquid waste should be treated chemically, and the disinfection process should ensure the inactivation of coronaviruses in an effluent treatment plant.
- All the persons involved in the handling of BMW (COVID-19) should be given the required training and personal protective equipment.
- These individuals should adhere to the standard operating procedures, follow basic hygiene and infection control measures, and undergo regular health screening. This should be accompanied by education, training and awareness is given at regular intervals.
- The amendments mentioned in the guidelines should be communicated to all the people involved and should follow prompt implementation.

5.2. Managing the liquid waste and wastewater from hospitals and laboratories^{16–19,21,22}

Although the evidence of virus transmission through sewage is low, individuals working with the sewage treatment plant (STP) are at high risk. The wastewater and liquid waste generated in the healthcare facilities while performing COVID-19 related activities should be handled and treated with the utmost care. The management of liquid waste differs from solid waste due to its physical nature and hence, the processes used for the management of solid BMW are not applicable to liquid waste. The following measures as directed by the central pollution control board can be considered;

- All the healthcare facilities operating STP and the terminal sewage plant operators are responsible for treating the liquid waste.
- The hospital and the person involving in its handling should ensure the inactivation or death of coronavirus.
- All the STP should strictly follow the SOPs framed by the pollution control board.
- The workers involved in the handling of wastewater treatment should be protected with PPE.
- The utilization of treated water from the STP can be avoided during the pandemic.

6. Measures to follow in quarantine centers^{16–21}

The waste generated within the quarantine centers should be considered as general waste, but the waste generated from the suspected and confirmed cases within the quarantine centers should be treated as BMW. The waste generated in the quarantine centers should be segregated at the site of generation and kept in the designated bags/bins/boxes like the handling of BMW in healthcare facilities.

6.1. How to segregate the biomedical waste generated from the quarantine centers?¹⁹⁻²²

The pandemic led to the generation of an unexpectedly high amount of BMW as various new materials were introduced in the market for prevention, screening, diagnosing and treating the patients. Some of the additional items generating the BMW in quarantine and isolation centers are divided into various color codes, as shown in [Table 2](#):

6.2. How to store, transport, and dispose of biomedical waste generated from the quarantine centers?

All the quarantine centers should be adequately supplied with yellow and red bags, blue cardboard and white puncture-proof containers for onsite segregation and waste collection. The collected waste should be kept in the designated storage area. The biomedical waste generated in the quarantine centers should not be stored for more than 24 h after

Table 2

Onsite segregation of biomedical waste generated in the hospital and temporary BMW generating centers during COVID-19.

BMW Waste Category	Types of box/bags	Types of waste	Treatment and disposal
Yellow	Non-chlorinated plastic bag (Autoclavable)	<ul style="list-style-type: none"> Personal protective equipment (PPE) with spill Donned of PPE Disposable linen gowns Non-plastic and semi-plastic materials Soiled Gloves Headcovers Disposable bed sheets Thermal scanners Soiled masks Disposable mask Tissues and toiletries Swab contaminated with blood and other body fluids 	<ul style="list-style-type: none"> Plasma pyrolysis or Incineration or Deep burial
Red	Non-chlorinated plastic bag (Autoclavable)	<ul style="list-style-type: none"> Goggles (eye protection) Reusable bed sheets Nitrile gloves Hazmet suite Plastic water bottles used in quarantine or isolation area Other recyclable materials like pens Plastic coveralls Face shields Splash-proof aprons Empty sanitizer bottles 	<ul style="list-style-type: none"> Sterilizing the waste by autoclaving, hydroplaning or radiation-based Treated/Sterilized waste should be sent for the recycling This waste should not be incinerated or buried.
White	Leak and puncture-proof containers	<ul style="list-style-type: none"> All the sharps generated in quarantine, isolation or screening areas Sharp metallic waste 	<ul style="list-style-type: none"> Wet or dry heat sterilization Sterilized waste is shredded/mutilated/encapsulated and sent for landfill
Blue	Cardboard boxes	<ul style="list-style-type: none"> All the glassware's Tube lights and bulbs CFL and LEDs All the glass bottle Metallic waste (recyclable size) 	<ul style="list-style-type: none"> Disinfection or sterilization Sent for the recycling

generation. The BMW should be transported to the common disposal facilities (CBMWFs) for final disposal. The generated waste can also be transported to the nearby hospital approved for incineration in case of non-availability of CBMWFs, and the same should be disposed of complying with the BMW rules 2016. The guideline recommends the use of PPE by all the persons handling the BMW in quarantine centers. The state pollution control board should continuously monitor the BMW handling and management procedures in the quarantine centers and ensure compliance with the standard guidelines.^{21,23-25,28-32}

7. Duties of the authorities and people involved in the BMW handling during the COVID 19

The duties of the persons and authorities involved in BMW's handling and management are clearly described in BMW rules 2016 and amendment rule 2018. All the healthcare facilities should strictly comply with the roles designated by the CPCB. The authorities should give the utmost priority to the management of BMW to prevent virus transmission. The current setup might lack the information and resources for the safe handling of BMW, similar to quarantine centers. Therefore, an excellent team who are trained, prepared and informed on the updated guidelines should be in charge of the handling and processing of biomedical waste in these centers.

7.1. Duties of quarantine facility authorities^{21,28,29}

- Providing all the legal authority for the establishment and allocation of resources for of the BMW storage area.
- Arranging authorized vehicles for the transportation of BMW to the hospital or disposal facilities.
- Conducting induction, orientation programs and training the personnel involved in the handling and management of BMW.
- Monitoring the processes and ensuring its compliance with SOPs that have been laid down.
- Issuing the authorized identity card to the person entering the quarantine facilities.
- Handing over the generated BMW to the authorized collectors.
- Maintaining accurate documentation and reporting the same to the higher authorities.

7.2. Duties of biomedical waste management company, hospital or CBMWFs^{21,26,27}

- Timely collection of BMW from the quarantine centers (at least twice a day).
- Providing all the personal protective equipment to the persons involved in the transportation and disposal of BMW.
- Regular sanitization of the BMW workers.
- Encouraging the strict adherence to the guidelines during the transportation and disposal of waste.
- Providing the information regarding the reception of BMW to the generating facilities.
- Handing over the disinfected or sterile waste to the respective agency for recycling.
- Providing updated information to the BMW handlers.
- Assist healthcare facilities and quarantine centers during the training.
- Maintaining proper records and documents for at least five years.
- Auditing the records with the generating facilities.
- Any injury or accident case should be reported to the quarantine facility in charge or the sanctioned authority.
- Continuous education, training, monitoring and supervision of BMW handling processes (daily basis).

7.3. Duties of state pollution control board^{21,27}

- They should ensure the compliance of healthcare facilities and other BMW generating centers to the BMW rules 2016.
- They can allow the CBMWF for additional hours of work, but it should be monitored and recorded accurately.
- They should make sure that the minimum documentation for the authorization of quarantine centers is received and maintained.
- They shall monitor and supervise the BMW handling activity of all the facilities regularly and document the same.
- Remote quarantine centers beyond the reach of CBMWFs should be permitted for the deep burial of BMW.
- The state control board should assist CBMWFs with any required resource collection and disposal during the pandemic.
- In case the amount of BMW exceeds the capacity of CBMWFs, the hospital or healthcare setting can be permitted for incineration within the health care setting
- State pollution control should download and use the COVID19BMW app and stay updated with the uploaded data regularly

8. Conclusion

Biomedical waste is a serious health concern. Untreated biomedical waste serves as a potential source of pathogens. Literature has reported more than 40 species of harmful micro-organism to possess the potential to transmit and cause human illness. The etiological agent of the pandemic is highly contagious and rapidly transfers from one person to another via various routes. Due to its high transmission rate, the risk of getting infected is persistently high. Realizing the threat of disease, state and central pollution control boards in association with AIIMS New Delhi have framed various guidelines. These guidelines are focused on the prevention of healthcare personals and workers involved in its handling and management. This update has enabled the preparation of policies for the temporary centers and has emphasized the roles and responsibilities of the concerned persons and authorities'. Strict compliance with these newly framed guidelines will make the management of the exponential increase in BMW easier and safer for the environment and community.

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Declaration of competing interest

Authors declare no conflict of interest.

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