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Redefining bio medical waste management during COVID- 19 in india: A way forward

Parul Saxena [a,*], Indira P. Pradhan [b], Deepak Kumar [c]

[a] Sharda University, Knowledge Park -III. Greater Noida, UP 20310, India
[b] Galgotias University, Yamuna Expressway Greater Noida, UP 201310, India
[c] Karvy Insights, Delhi 110016, India

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ABSTRACT

India is ranked 120 among 165 nations with respect to sustainable development and critically suffers from insufficient waste treatment provisions and amenities. And the abrupt occurrence of the COVID-19 virus has aggravated the issue of managing of medical waste in India, manifolds. As a result, the safe disposal of a huge volume of hazardous medical waste has become a top priority. This conceptual study evaluates India's management of medical waste during the COVID-19 pandemic. Additionally, this article aims to highlight the inadequacies in India's implementation of the BMW 2016 standards by a synthesis of multiple agency reports (government and non-government) and data obtained directly from the Central Pollution Control Board (CPCB). The findings indicate that India is well behind in terms of COVID-19 waste management and requires comprehensive monitoring and implementation systems to enable the achievement of SDGs related to environmental health.

Selection and peer-review under responsibility of the scientific committee of the 4th Online International Conference on Science & Engineering of Material

1. Introduction

Biomedical waste (BMW) is a substantial pollutant generated in the healthcare sector as a result of operations such as medical diagnosis, treatment, and vaccination of humans and animals, as well as biological research and development. Several studies have been published on this topic [7,8,12]. According to the World Health Organization (WHO,2018), the composition of bio-medical waste is as follows- non-hazardous waste (85%) and hazardous waste (15 %), with infectious waste accounting for 10 percent and radioactive or chemical waste accounting for 5 percent, every year, it is estimated that more than 5.2 million people, including 4 million children, die as a result of diseases caused by medical waste throughout the world [10]. It has been determined that the severe acute respiratory syndrome, commonly known as Coronavirus disease (COVID-19) was responsible for the sudden increase in healthcare waste generation. Public health and the environment have been put to grave dangers as a result of this increased BMW. Moreover, given the technical, practical, and budgetary restrictions, India is already rassling with poor BMW practices which has been compounded by a dramatic surge in the volume of medical waste due to COVID-19. The WHO has declared a global public health emergency in response to the COVID-19 outbreak in Wuhan, China [13]. By March 12th, 2021, 219 countries had been affected, claiming 2.62 million lives out of 110.82 million confirmed cases [14] In India, around 11,30 million confirmed positive cases, and 0,15 million deaths are reported (as of March 12th, 2021) [9]. Annual BMW growth in India is 7% with estimated estimates of up to 775,5 metric tonnes per day by 2022 [6]. There are 2,907 hospitals, 20,707 quarantine camps, 1539 collecting sites, and 264 testing laboratories in India involved in the generation of COVID-19 waste [4]. The overall COVID-19 generation of BMW is also shown to be roughly 101mt/day. Maharashtra, Kerala, Gujarat, Andhra Pradesh, and Delhi were the top 5 BMW generating states in December 2020, according to current figures. Thus, from the given statistics, it is obvious that the on-going pandemic has worsened the seriousness of the BMW industry's issues in India. Because the infrastructural treatment capacity of India was already insufficient and because COVID-19 instances have exceeded the 11-million-mark, BMW safety disposal is a greater concern. For this reason, preventative actions are urgently needed to reduce BMW growth and avoid public health and environmental hazards. The present study presents a full evaluation of the production, collecting and management of

* Corresponding author.
E-mail address: Parul.saxena@sharda.ac.in (P. Saxena).

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BMW throughout the 28 States and eight UTs of India during the onset and peak of COVID-19 epidemic. As reported in [3] annual report, 29,062 no. of HCFs/CBWTFs observed to be violating the provisions of the BMW Rules. CPCB's annual report for 2018/19, states that 23,942 HCFs were found to have breached the BMW regulations in 2016, and 18,210 HCFs were issued a warning as a result of their violations. The report reveals that India has a tremendous amount of BMW generation per day, and that approximately 13 percent of HCFs have broken BMW regulations, demonstrating the country's inadequate biomedical handling and management. [2]/2019.). The precise amount of BMW produced is difficult to calculate, although one study suggests that the increase in BMW production could be as much as six-fold when compared to the scenario before the outbreak of the virus [14,18] Table 1.

1.1. Bio- medical waste status in India (December 2019)

Approximately 619 tonnes of biomedical waste per day were generated by 3,22,425 healthcare facilities during the fiscal year 2018–2019. [3]. Only 544 tonnes of biomedical waste was processed and disposed of daily, out of 619 tonnes by 202 CBWTFs and 18,015 captive treatment facilities built by healthcare facilities. Around 74 tonnes of biomedical waste per day might be disposed of by deep graves in remote locations. Assam, Bihar, Chhattisgarh, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Nagaland, Odisha, and Rajasthan are the states with the greatest disparity in biomedical waste generation and treatment.

Class I states cities such as Chennai, Kolkata, New Delhi, and Mumbai have a minimum of 28 tonnes/day of biomedical waste. However, large amounts of biomedical waste were also produced by the states such as Bihar, Gujarat, Karnataka, Kerala and Uttar Pradesh. In order to regulate the BMWWM 2016 rules, the CPCB had identified 12 key performance indicators (KPI). These indicators were set in order to evaluate States with regard to monitoring efficiency, compliance, and implementation thereof. These indicators (as listed below) have been monitored, and the improvement incoherence/gap found has been passed on to State Pollution Control Boards (SPCBs) and PCCs (Pollution Control Committees) of various Member States/UTs:

- All healthcare and biomedical waste generation inventory.
- Authorization of all healthcare facilities, such as those without beds HCFs.
- Assist in the establishment of an adequate number of Common Biomedical Waste Treatment Facilities (CBWTFs) to service the entire State or all HCFs

Table 1
The brief bio-medical waste management scenario in the Country is given below.

No. of HCFs	3,22,425
No. of bedded HCFs	1,06,796
No. of non-bedded HCFs	2,15,780
No. of beds	24,86,327
No. of CBWTFs	202* + 35**
No. of HCFs granted authorization	1,53,885
No. of HCFs having Captive Treatment Facilities	18,015
No. of Captive Incinerators Operated by HCFs	1362
Quantity of bio-medical waste generated in Tonnes/day	619
Quantity of bio-medical waste treated in Tonnes/day	544
No. of HCFs violated BMW Rules	29,062
No. of Show-cause notices/Directions issued to defaulter HCFs	17,435

Source: CPCB [3]
(i) * - CBWTFs in operation
(ii) ** - CBWTFs under installation

- Establishment of the State Regulatory Authority and the District Monitoring Committee.
- Barcode system implementation status
- Oversight of healthcare facilities other than hospitals/clinics, such as veterinary hospitals, animal shelters, and AYUSH clinics.
- Monitoring SPCB/PCC infrastructures
- Staff capacity building of SPCB/PCC personnel and healthcare facilities
- Installation of OCEMS by CBMWTs as a self-monitoring tool and data transmission to SPCB/PCC servers.
- Preparation of Annual Compliance Status Reports
- Common Facility Compliance (emission/discharge norms, barcoding, appropriate operation, and so on)
- Healthcare Facility Compliance (Segregation, pre-treatment, on-site storage, barcoding, and other restrictions, among others).

2. Problem statement and objectives

During the second wave of the pandemic, the recently released report titled 'State of India's Environment in Figures 2021′ reported a significant increase in the generation of Covid-19 related biomedical waste (BMW) The report mentions that, ''India produced 139 tonnes per day of Covid-19-related biomedical waste in April 202 and in May 2021, the figure escalated to 203 tonnes per day, an increase of 46 per cent". Thus, COVID-19 has undoubtedly placed India's biomedical waste management in an appalling state. This has also highlighted one of the major challenges posed by improper disposal of biomedical waste during the Covid-19 pandemic. India's COVID-19 waste management is marred by many flaws such as non-reporting/ under- reporting, poor segregation and lack of responsiveness. The situation has been further graved by the novel coronavirus disease (COVID-19). With its prolonged stay and spread, the face of bio clutter is rapidly changing in the country. This COVID-19 waste could further foster the novel coronavirus and other infectious pathogens. And be as harmful to humans and the environment as any other bio- medical waste. Thus, this conceptual study highlights the gaps in the implementation of BMW rules during COVID-19 in India. It also attempts to make recommendations for better bio- waste management

3. Materials and methods

The following materials and methods have been employed for this study:

3.1. Materials

This study is based on a survey of existing literature, news stories, and reports of information obtained from public reports and official websites by the government and not government agencies. The information presented here comes from multiple sources published on the WHO, the PIB Ministry of Health and Family Welfare websites (MoHFW). Literature has been obtained from reputable databases such as Springer, Research Gate, and Google Scholar through electronic means. No systematic sequence for the selection of sources was followed.

3.2. Method

To demonstrate the shortcomings in the application of BMW guidelines, the researchers gathered data from government publications (Gap analysis compliance report, CPCB, 2020 and COVID −19 Medical waste Status Report May 2021). These papers explicitly noted the disparity in BMW regulation compliance among India's States and Union Territories by examining the twelve indicators indicated above (see to introduction). However, for the pur-

pose of this, study the authors have selected the following five important indicators, for which the data was available for almost all of the states:

- Facilities for the treatment of common biomedical waste (CBMWTFs) are available.
- Adequacy of existing treatment facility
- Use of deep burial
- Training and awareness programs conducted
- Implementation of CPCB Waste tracking App.

4. Findings

4.1. COVID-19 waste management scenario in India

When the pandemic tightened up its hold on the country, the COVID-19 litter was designated as hazardous biomedical waste because of the inherent risk by the Central Pollution Control Board (CPCB). The CPCB has published monthly since March 2020 directions under the 2016 Bio-Medical Trash Management Rules to ensure that COVID-19 waste is collected with the greatest care. Additionally, it has published recommendations for the transportation and storge of this garbage to "biomedical waste treatment and disposal facilities." These facilities are dedicated to the management of biohazardous waste generated by health camps, morgues, hospitals, pathological and clinical laboratories, and other medical organisations.

Fig. 1 Shows the amount of bio- medical waste generated in India in Peak generation of about 250 TPD as on 10/05/2021. Trend of average monthly generation of COVID-19 biomedical waste is shown in chart below*:

The BMW management rules for 2016 require health centres to adopt a color-coded waste-separation system and to transmit waste within 48 hours to treatment facilities. After sterilisation, a substantial amount of garbage is sent to a recycling facility in red and blue bags and white containers. The colour coded criteria for the correct disposal of bio-medical waste as shown in Fig. 2 are as follows:

- Yellow Bin: For the collection of anatomical waste, chemical waste and dirty garbage. Chemotherapy waste, medicinal products and laboratory garbage disposed of.
- Red Bin: To be used for Contaminated plastic waste
- Blue Bin: To be used for Glass waste and metallic implants
- White Bin: To be used for Metal sharps
- Black Bin: To be used for Hazardous and Other waste
- Green Bin: To be used for Biodegradable General waste

The details of bio-medical waste (category -wise) generated by some major Central Government Hospitals under Ministry of Health and Family Welfare are as belowFig. 3:

As per the reports the number of Covid cases climbed dramatically from June 2020 to May 2021. Despite this, data reveals that the number of Common Biomedical Waste Treatment Facilities (CBMWTFs) is declining in several states. CBMTWFs have fallen from two to one in states like Puducherry. At the same time, the number of CBMWTFs in states like Jharkhand, Karnataka, Madhya Pradesh, and Meghalaya grew. The data demonstrates that the current BMW treatment facility is adequate, compared to captive facilities in Andaman and Nicobar, Andhra Pradesh, Chandigarh & DNH, while States & UTs such as Gujrat. Assam and Arunachal Pradesh rely on captive facilities and burial pits for the treatment of biomedical waste and show lack of adequate treatment facilities. The comparison chart below (Refer Table 2) gives a detailed information about the three important indicators selected for this study.Table 3.

Comparison Chart prepared by authors.

Data Source: CPCB (2021d);

In May 2021, India had a greatest number of new instances, with COVID-19 inducing bio-waste being 33% of the total biomedical waste created in that country. The additional pressure appears to have collapsed the country's already over-burdened biomedical waste treatment system. In this month, the volume of bio trash generated was enormous. Sates like Haryana, COVID-19 trash accounted for 47% of the biomedical waste, 42% for Chhattisgarh second, 40% for Himachal Pradesh and 40% for Andhra Pradesh and 39% in DelhiFigs. 4 and 5.

Furthermore, the examination of the CPCB records from January and May 2021 reveals that 22 out of 36 states and Union territories generated more biomedical waste than they were capable of handling during that period. Because of the proliferation of the virus, biomedical waste treatment facilities in states such as Maharashtra, Goa, Manipur, Andhra Pradesh, Meghalaya, Rajasthan are almost saturated.

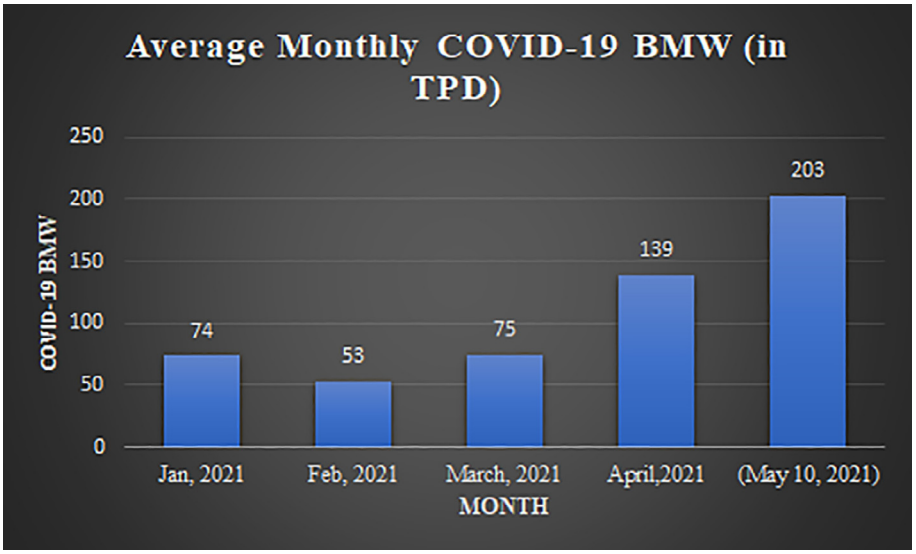

Fig. 1. Average Monthly COVID-19 BMW (in TPD) from January 2021- May 2021. Source: CPCB Status Report May 2021. * As per the information submitted by State Pollution Control Boards/Pollution Control Committees as well as daily data received from COVID19BWM tracking App.

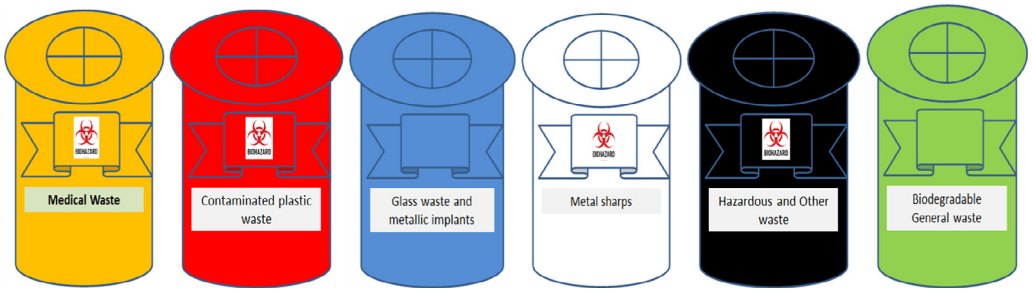

Fig. 2. Colour coded bins for the proper disposal of the bio- medical waste as recommended by CPCB. *Figure generated by authors. Data Source: The Pictorial Guide on Biomedical Waste Management [5] (BMWM) Rules, 2016 (amended in 2018 & 2019).

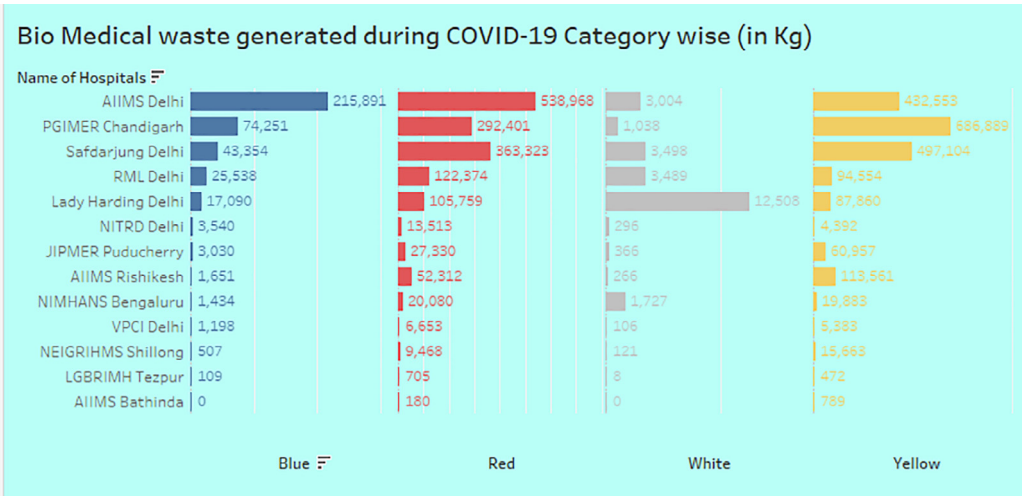

Fig. 3. Bio-medical waste (category -wise) generated by some major Central Government Hospitals as on February 2021. *Figure generated by authors. Data Source: https://www.pib.gov.in/PressRelease; [1] Posted On: 02 FEB 2021 by PIB Delhi.

CBWTF capacity is insufficient for states like Jammu Kashmir, and one facility cannot meet the needs of the entire state. The treatment facilities were poorly equipped to handle the surge in COVID-19 waste at its peak (about 754 tonnes per day) in September 2020 or in May 2021. The picture surely seems appalling on comparison of the waste generated by each of the states with the available treatment capacity.

The numerous sources of COVID-19 waste present a significant obstacle to monitoring the flow. Due to the fact that these sources range from private residences to isolation centres and temporary quarantine camps, it's impossible to keep track of their generation and treatment. For this reason, the CPCB mandates COVID-19 waste generators in states and union territories to submit statistics on generation and treatment on a regular basis. And to that end, the CPCB launched a mobile application, COVID-19 Biomedical Waste Management (BWM) App, in May 2021 to enable real-time monitoring of this rapidly rising waste stream. The Supreme Court also provided compulsory reporting through the BWM App on the basis of the Environmental Pollution (Prevention and Control) authority report (EPCA). However, only a few states/UTs have registered, and even fewer report consistently. Countries like Andaman, Nicobar Islands, Arunachal Pradesh, Goa, and Sikkim have not used the CPCB Waste Tracking App, which in May of this year has decreased to 168. (Refer Figs. 6 and 7).

Another critical indicator of the CPCB in regards to the treatment of bio medical waste is creating awareness and engaging the stakeholders in training from time to time. As per the CPCB annul status report May 2021, almost all the states, with the exception of Andhra Pradesh, Arunachal Pradesh, Sikkim, and West Bengal, have organized training and awareness initiatives.

4.2. Issue of unaccounted Bio- medical waste

Indi started a rigorous campaign in January 2021 and has been making sincere efforts to vaccinate its population. This is definitely a good news but at the same time it is also alarming because every injection results in a waste syringe, and every 10–20 shots of vaccine generate glass vial waste, all of which ultimately adds up to bio medical waste. Further, due to lack of proper storage facilities a significant number of vials are discarded after few hours of opening adding to the litter. Using self-disabled syringes protects vaccine users and healthcare providers, limiting the use of syringes twice but at the same time creates a big volume of biomedical waste. Also, the central government is expected to take the responsibility of disposing of 1.3 billion syringes & needles and over 100 million wasted glass vials, as stated in the COVID-19 operations guidelines on vaccines issued on 28 December 2020 that may be generated at the end of vaccination campaign. The disposal of medical masks, face shields, gloves, shoe coverings and protective equipment is another major obstacle (PPE). These protective paraphernalia can be easily found littered all around. Awareness needs to be created among different stakeholders for its proper treatment and sterilisation even before it is sent for recycling and the autoclave may be of serious concern in this context. As the volunteers in the vaccination centres are not trained and knowledgeable, it

Table 2
A comparison Chart State-wise details of COVID-19 Biomedical Waste Generation and Treatment June 2020-May 2021.

A comparison Chart State-wise details of COVID-19 Biomedical Waste Generation and Treatment June 2020-May 2021									
S.No.	Name of States/UTs	COVID 19 BMW (TPD) May 2021	COVID 19 BMW (Tons/day) June 2020	Increase or Decrease/ No change	No. of CBWTFs engaged (May 2021)	Details of Facilities for Disposal of COVID-19 BMW (June 2020)			Adequacy of existing treatment facility (As on June 2020)
						No. of CBWTFs engaged (June 2020)	Captive facilities Yes/ No	Deep burial pits Yes/No	
1	Andaman & Nicobar*	0.014	0.014	No Change	0	0	Y	N	Adequate with captive facilities
2	Andhra Pradesh	9.99	5.516	Decrease	11	11	N	N	Adequate
3	Arunachal Pradesh*	0.112	0.112	No Change	0	0	N	Y	Need to depend on Burial pits
4	Assam	0.52	0.52	Decrease	1	1	Y	Y	CBWTFs capacity is not adequate and 1 facility cannot cater to entire State. Need to depend on captive facilities and burial pits.
5	Bihar	1.06	0.228	Decrease	4	4	N	N	80% of incinerator capacity utilised. Need to ensure proper
6	Chandigarh	1.91	0.995	Decrease	1	1	N	N	Adequate
7	Chhattisgarh	2.76	0.373	Decrease	4	4	INP	INP	Adequate capacity of CBWTFs. Details of other disposal options not provided
8	DD & DNH	0.065	0.015	Decrease	1	1	N	N	Adequate. Waste is being disposed through CBWTF at Surat, Gujarat
9	Delhi	18.79	11.114	Decrease	2	2	N	N	70% of existing capacity of 2 incinerators utilised. Need to ensure proper segregation.
10	Goa*	0.45	0.027	Decrease	0	0	Y	Y	No CBWTF. Need to depend on captive facilities and Burial pits.
11	Gujarat	21.98	11.693	Decrease	20	20	N	N	Adequate
12	Haryana	13.11	2.511	Decrease	11	11	N	N	Adequate
13	Himachal Pradesh	2.27	0.127	Decrease	2	2	Y	Y	Adequate capacity with incinerators. 2 CBWTFs may not be adequate to cover entire State
14	Jammu and Kashmir	2.49	0.357	Decrease	2	2	Y	Y	2 CBWTFs may not be adequate to cover entire State. Need to depend on captive facilities and burial pits.
15	Jharkhand	0.56	No Information		4	2	Informa tion not provide d	Informa tion not provide d	Compiled Information not provided hence adequacy could not be assessed.
16	Karnataka	16.91	2.8	Increase	26	25			Adequate
17	Kerala	23.71	4.71	Increase	1	1	Y	N	All COVID biomedical waste sent to CBWTF. Capacity of CBWTF not adequate for total BMW. Hence captive facilities need to be operated
18	Lakshadweep	0.01	0.01	No Change	0	2	Y	Y	Adequate. May use 2 captive incinerators in 2 islands and deep burial pits in rest of the islands
19	Madhya Pradesh	7.32	7.486	Decrease	13	11	N	N	Adequate
20	Maharashtra	19.02	17.494	Increase	29	29	N	Y	Adequate. Stand-by arrangement also made with TSDFs in Mumbai, Pune and Nagpur cities
21	Manipur	0.13	0.171	Decrease	1	1			Adequate. However single facility may not cater to entire State
22	Meghalaya	0.25	0.17	Increase	2	1	Informa tion not provide d	Informa tion not provide d	Adequate Information not Submitted. Existing incinerator cannot dispose entire waste from State

(*continued on next page*)

Table 2 (*continued*)

A comparison Chart State-wise details of COVID-19 Biomedical Waste Generation and Treatment June 2020-May 2021									
S.No.	Name of States/UTs	COVID 19 BMW (TPD) May 2021	COVID 19 BMW (Tons/day) June 2020	Increase or Decrease/ No change	No. of CBWTFs engaged (May 2021)	Details of Facilities for Disposal of COVID-19 BMW (June 2020)			Adequacy of existing treatment facility (As on June 2020)
						No. of CBWTFs engaged (June 2020)	Captive facilities Yes/ No	Deep burial pits Yes/No	
23	Mizoram*	0.033	0.14	Increase	0	0	Informa tion not provide d	Informa tion not provide d	Adequate Information not Submitted
24	Nagaland*	0.074	0.12	Decrease	0	0	Y	Y	Adequate Information not Submitted
25	Odisha	6.65	1.062	Increase	5	5	N	N	79% of common incinerators capacity utilised. Need to ensure proper segregation.
26	Puducherry	1.81	0.621	Increase	1	2	N	N	Adequate
27	Punjab	4	1.6	Increase	5	5	N	N	Adequate
28	Rajasthan	4.98	5.9	Decrease	8	8	N	Y	88% of common incinerators capacity utilised. Need to ensure proper segregation and identify alternate facilities
29	Sikkim	0.015	0.2	Decrease	0	0	N	N	Adequate Information not Submitted
30	Tamil Nadu	13.57	10.41	Increase	8	8	N	N	91% of incinerator capacity utilised. Need to ensure proper segregation and identify alternate incinerators / disposal options
31	Telangana	4.96	0.41	Increase	11	11	N	N	Adequate
32	Tripura	0.02	0.015	Decrease	1	1	Y	Y	71% of incinerator capacity utilised.
33	Uttarakhand	1.98	0.53	Increase	2	2	N	Y	2% of Incinerator capacity utilised. Only 2 incinerators may not be adequate to cater entire State area. Need to depend on deep burial
34	Uttar Pradesh	15.91	7	Increase	18		N	N	Adequate
35	West Bengal	6.5	5.72	Increase	6	6	N	N	Adequate
	Total	203 MTPD	101 MTPD		198	195			

Table 3
State-wise Status Report Scientific Disposal of Bio-Medical Waste arising out of Covid-19 treatment - Compliance of BMWM Rules, 2016.

State-wise Status Report Scientific Disposal of Bio-Medical Waste arising out of Covid-19 treatment - Compliance of BMWM Rules, 2016			
S. no	State	Training and awareness programs	Implementation of CPCB Waste tracking App.
1	Andaman & Nicobar*	Conducted	Not Implemented
2	Andhra Pradesh	Information not provided	Implemented
3	Arunachal Pradesh*	Information not provided	Not Implemented
4	Assam	Conducted	Partially Implemented
5	Bihar	Conducted	Partially Implemented
6	Chandigarh	Conducted	Implemented
7	Chhattisgarh	Conducted	Implemented
8	DD & DNH	Conducted	Implemented
9	Delhi	Conducted	Implemented
10	Goa*	Conducted	Not Implemented
11	Gujarat	Conducted	Partially Implemented
12	Haryana	Conducted	Partially Implemented
13	Himachal Pradesh	Conducted	Partially Implemented
14	Jammu and Kashmir	Conducted	Implemented
15	Jharkhand	Conducted	Not Implemented
16	Karnataka	Conducted	Partially Implemented
17	Kerala	Conducted	Implemented
18	Lakshadweep	Conducted	Not Implemented
19	Madhya Pradesh	Conducted	Partially Implemented
20	Maharashtra	Conducted	Implemented
21	Manipur	Conducted	Implemented
22	Meghalaya	Conducted	Partially Implemented
23	Mizoram*	Conducted	Implemented
24	Nagaland*	Conducted	Information not provided
25	Odisha	Conducted	Partially Implemented
26	Puducherry	Conducted	Implemented
27	Punjab	Conducted	Implemented
28	Rajasthan	Conducted	Partially Implemented
29	Sikkim	Information not provided	Not Implemented
30	Tamil Nadu	Conducted	Implemented
31	Telangana	Conducted	Implemented
32	Tripura	Conducted	Not Implemented
33	Uttarakhand	Conducted	Implemented
34	Uttar Pradesh	Conducted	Partially Implemented
35	West Bengal	Information not provided	Partially Implemented

Comparison Chart prepared by authors.
Data Source: CPCB (2021d);

has been also noticed that the majority of plastic, metal and glass components are sold to local wholesalers.

5. Conclusion and limitations

The following study gives a full evaluation of the generation and treatment of COVID-19 waste. It also seeks to highlight the shortcomings in India's current waste management system. The data show that most Indian states/UTs have low COVID-19 waste management performance in conjunction with the earlier study [11]. In their study, the authors have assessed gaps in compliance of BMWM Rules over a period of five years (2014–18) and concluded that there much left to be done in terms of handling of bio- medical waste in India. Note that the sudden surge in biomedical waste generation has created a severe scenario in States with 70 percent or greater incinerator capacity utilisation. It is also observed that due to poor awareness and lack of communication, there is poor segregation. This results in incineration of large quantity of contaminated plastics which leads to scaling of the incinerators' inner lining thereby decreasing their efficiency. Moreover, this plastic burning also adds up to the air pollution as it releases toxic gases like dioxins and furans. Mixing common waste material with bio - medical waste would cause additional burden on CBWTF incinerators not intended for the treatment of residential solid waste.

This study not only gives a picture of the current scenario in terms of bio medical waste management but also highlights the deep gap in terms of the compliance of BMWM rules 2016 by the concerned stakeholders. Thus, it may help policy makers, monitoring bodies, researchers and academicians design efficient BMW management with vigorous execution strategies. It is high time that sincere efforts are made by the concerned authorities for the safe handling and disposal of COVID-19 waste to make sure that it does not mount into a big catastrophe.

Though this study provides a comprehensive overview of the disposal and treatment of biomedical waste it just takes into account the data available for the past one and half year. Therefore, this study represents only the current scenario of BMW generation in India. Further, it does not employ any statistical analysis Hence, for the future research it would be prudent to gauge the scenario of BMW in India over the years through statistical analysis.

In accordance with the BMWM Rules 2016, only litters wrapped in yellow bags, notably pathological and laboratory waste should be incinerated when health facilities follow the protocol, although home quarantine centres cannot be equated with this protocol. In the absence of proper guidelines and monitoring, home quarantine

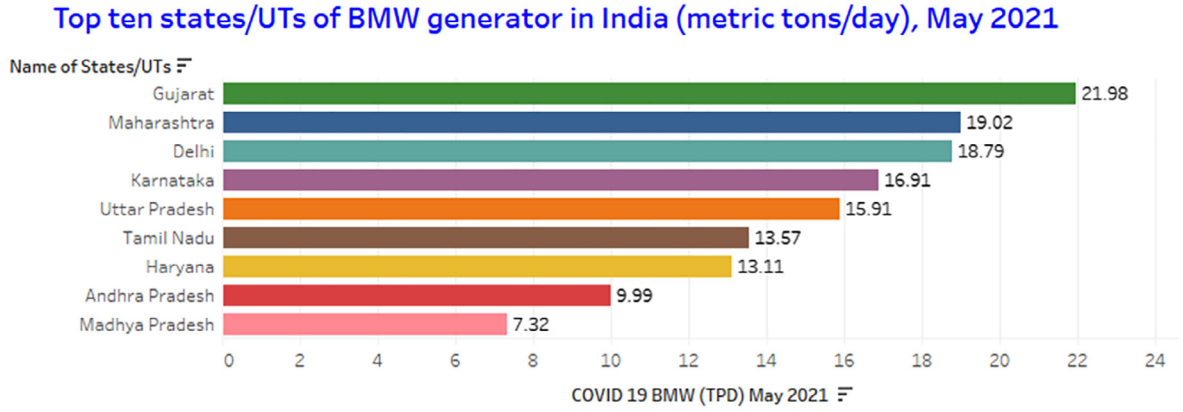

Fig. 4. Top Ten states/UTs of BMW generator in India (metric tons/day), May 2021. *Figures generated by authors. Data Source: CPCB (2021), January-May Status Report 2021 COVID-19 waste management. Central Pollution Control Board. https://cpcb.nic.in/covid-waste-management/

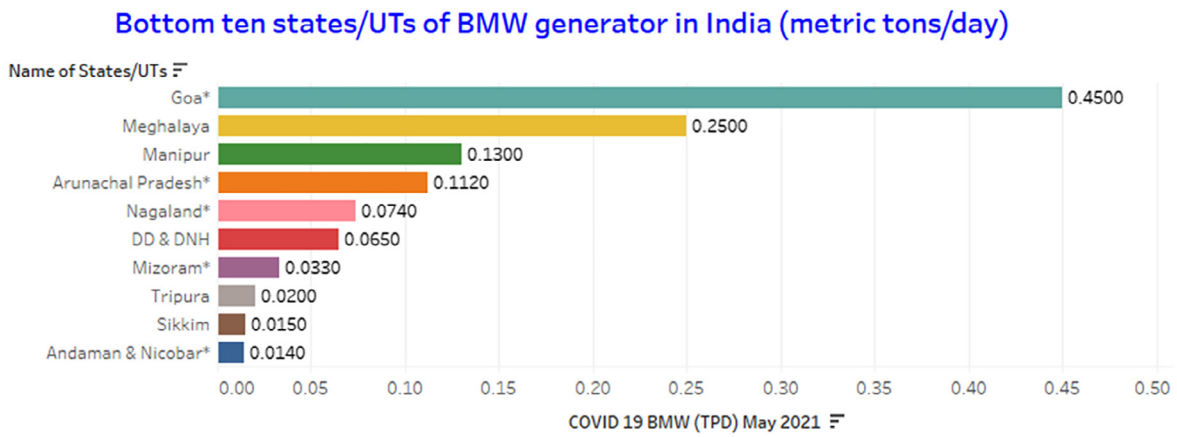

Fig. 5. Bottom Ten States/UTs of BMW generator in India (metric tons/day), May 2021. *Figures generated by authors. Data Source: CPCB (2021) January-May Status Report 2021 COVID-19 waste management. Central Pollution Control Board. Available at: https://cpcb.nic.in/covid-waste-management/

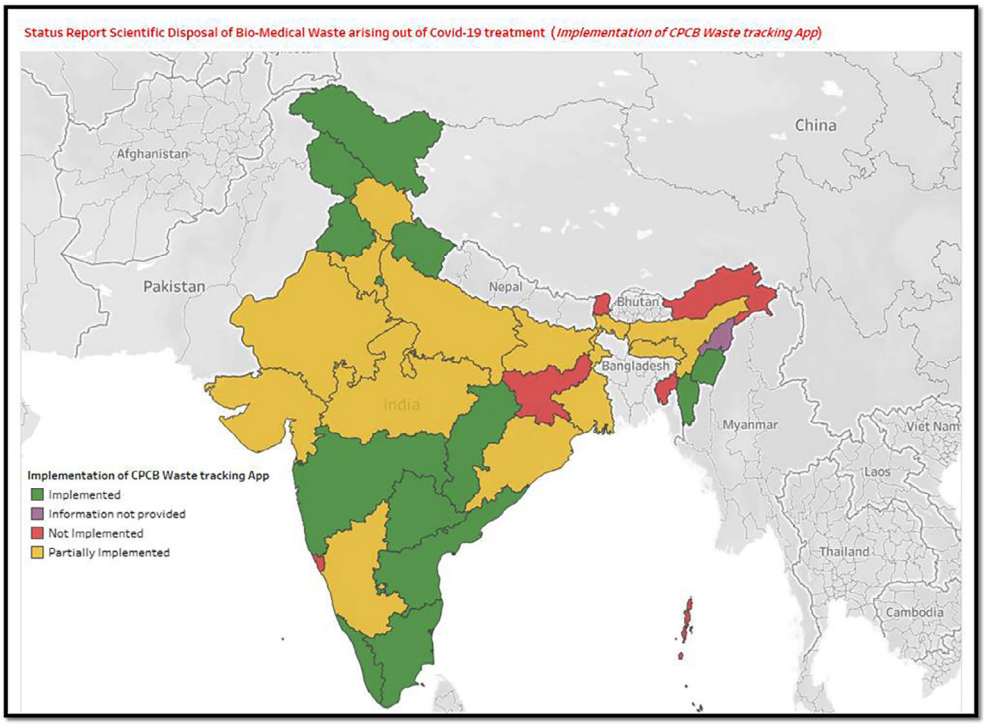

Fig. 6. State wise status report for Implementation of CPCB Waste tracking App. *Figure generated by authors. Data source: State-wise Status Report Scientific Disposal of Bio-Medical Waste arising out of Covid-19 treatment - Compliance of BMWM Rules, 2016, May 2020.

centres rarely engage themselves in the proper segregation of COVID-19 waste. Further, the guidelines mention discarding of PPE kits, goggles and other paraphernalia in the red bag which is for the collection of contaminated plastic waste to be sent for sterilisation and recycling. But in the absence of red bags distribution in home quarantine centres, these facilities throw food waste, masks, PPE kits, disposable cutlery and gloves into yellow bags, which are then sent for incineration.

6. Way forward

In accordance with the findings of this investigation, the states/UTs that in recent months have generated COVID-19 waste at an average of 100 mt/month (December 2020-May 2021) should be controlled with a feeling of urgency and high priority. It is also proposed that all states / UTs designate their districts according to their BMW status and treatment ability as low, medium, and high priority zones. As it would be easy for the authorities involved to scale up the installations according to their categories. These provisions can then be periodically monitored to improve their BMW treatment capability to achieve an effective waste management system. Government and policymakers should promote the promotion of alternative treatment techniques such as autoclaving, mechanical and chemical disinfection to alleviate the strain on common biomedical waste treatment facilities. It is not only the Central Pollution Control Board (CPCB) that should give data that can be separated from generating sources, waste types, and treat-

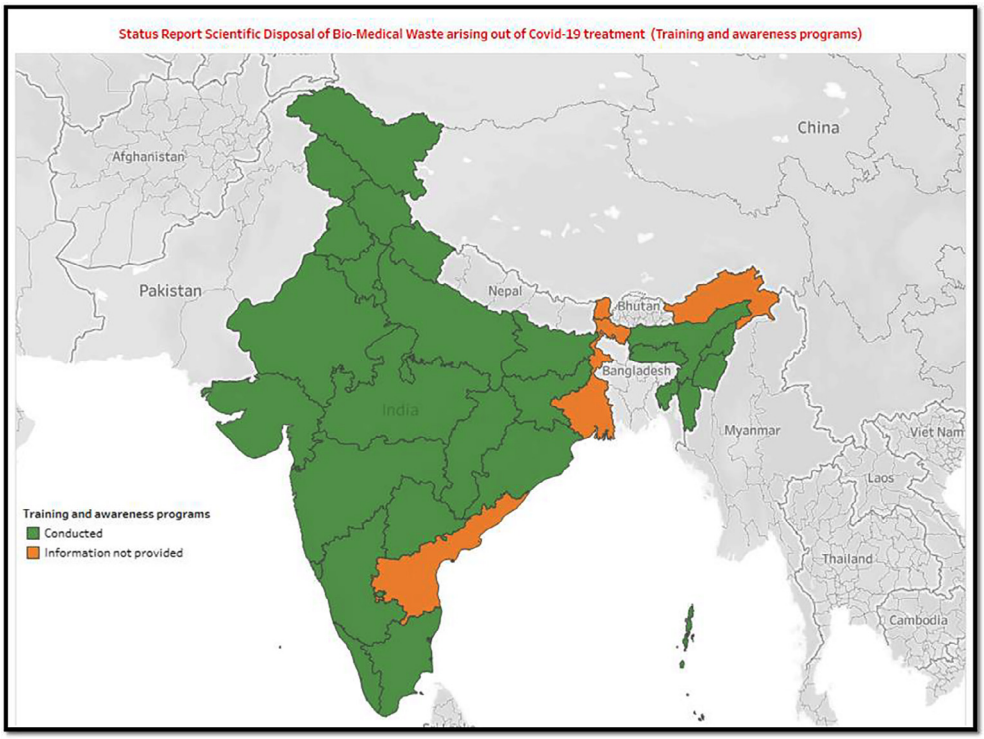

Fig. 7. State wise status report for Training and Awareness program conducted. *Figure generated by authors. Data source: State-wise Status Report Scientific Disposal of Bio-Medical Waste arising out of Covid-19 treatment - Compliance of BMWM Rules, 2016, May 2020.

ment plants, but also ensure the adequacy of the plant and the ecosystem. CPCB should likewise take serious measures concerning the quantity of production in rural areas and general procedures for disposal of biomedical COVID-19 waste. Some of the measures that can be taken rigorously by CPCB to deal with the waste generated out of the severe pandemic outbreaks are mentioned below:

- Stand-by facilities such as common hazardous waste incineration plants, industrial captive waste incineration to be identified by States with large-scale biomedical waste generation.
- The waste generated at the vaccination camps outside hospitals should be segregated properly
- Proper implementation for bar-coding for collection biomedical waste to ensure proper tracking of the source of the waste upon its reach at the treatment facility
- Create and improve stakeholder awareness to impose source segregation.
- All waste generators and processors should be registered by the regulatory authorities relevant on the COVID-19 BMW application.
- Installation and monitoring of online continuous emission monitoring system central biomedical waste treatment facilities, appropriate usage of incinerators and autoclaves concerning COVID-19.
- Extensive training & awareness programs for healthcare workers and State Board officials to be conducted at the grass root level by State Pollution Control Board (SPCB) and Pollution Control Committees (PCC).
- Stringent measures to impose ECC (Environment Compensation Charge) by regulatory authorities against Healthcare Facilities (HCFs) for non-compliance of BMWM Rules 2016

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CRediT authorship contribution statement

Parul Saxena: Conceptualization. **Indira P. Pradhan:** Supervision. **Deepak Kumar:** .

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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