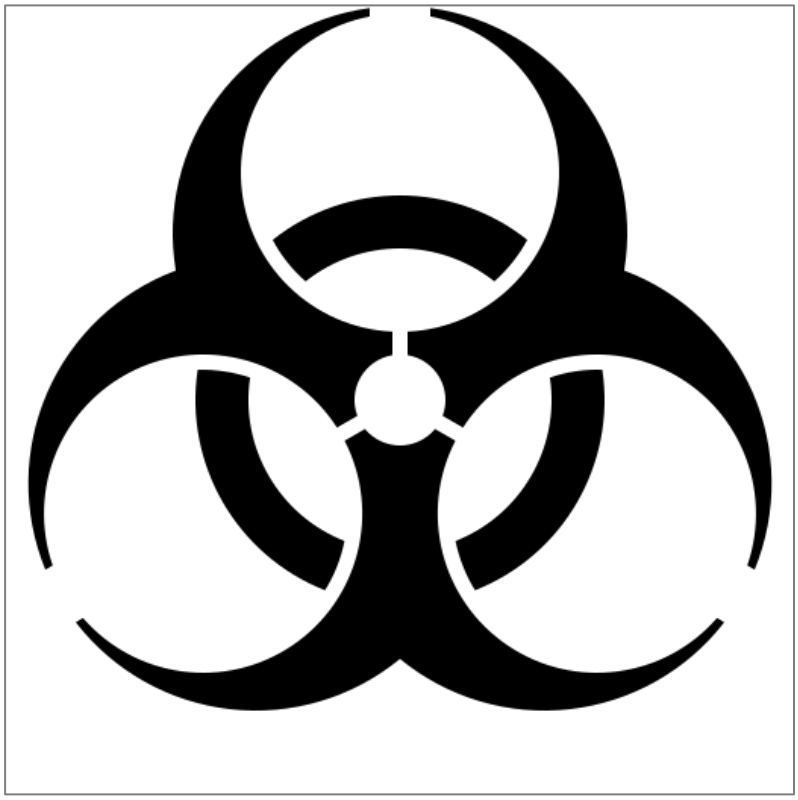

Operational Challenges in Adopting Bio-Medical Waste Management Protocols in Public Health Facilities

Draft report

Submitted to: Tamil Nadu Health Systems Research Project, & Indian Institute of Technology (Madras)

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Abbreviations

BMW	Bio-Medical Waste
BMWM	Bio-Medical Waste Management
DH	District Hospital
DME	Directorate of Medical Education
ETP	Effluent Treatment Plant
CPCB	Central Pollution Control Board
CBMWTF	Common Bio-Medical Waste Treatment Facility
GH	General Hospital
GPS	Global Positioning System
HCF	Health Care Facility
HCW	Health Care Workers
NACO	National AIDS Control Organization
NGT	National Green Tribunal
OT	Operation Theatre
PPE	Personal Protection Equipment
SOP	Standard Operating Procedure
SPCB	State Pollution Control Board
WHO	World Health Organization

Executive Summary

Health Care Facilities (HCF) generate significant waste. However, only a portion of the waste is hazardous. It is essential that this hazardous waste, also called the Bio-Medical Waste (BMW) waste, is segregated and not mixed with the other waste from a health and environmental perspective.

The BMW rules 2016 signifies the effort of the government to ensure an efficient and cost-effective way to manage waste. By focusing on segregating the small proportion of the hazardous waste created in the HCFs, the effort ensures a more significant gain, both from a health perspective and environmentally. There is a significant emphasis on recycling waste to conserve resources and reduce the carbon footprint.

The assessment was done to understand the process and the challenges in four public health facilities in Tamil Nadu. Two facilities, each in Chennai and Kancheepuram districts, were chosen. These districts were chosen based on the quantum of the BMW generated. In these districts, a medical college and a general hospital were chosen, given that these facilities do generate significant waste. The data collection involved two methods. One was qualitative interactions using semi-structured questionnaires with key respondents. The other was the observation of the four facilities using a checklist.

30 respondents were interviewed for the study. It included personnel, who generate, segregate, transfer, transport, and process the waste in an HCF. It also included officials who monitor the process. The nodal officers are responsible for oversight and monitoring the BMW management. The Nodal Officers at the state-level too were interviewed to assess their perspectives on the BMW management. The other key stakeholders in the BMW value chain are transporters, the CBMWTF, and the officials of the Pollution Control Board. They were interviewed for the study.

Following the BMW rules 2016, the processes appear to be significantly systematized in the four facilities surveyed. The segregation, pre-treatment, removal, and storage process appear to be functioning. The waste generated is recorded both at the point of generation and in the storage room. There are systems for monitoring, which appear to be working reasonably well. Most of the personnel were also trained in BMW management. Their functionality appears evident because during COVID, despite an increase in the quantum, the waste was managed. However, there were challenges in segregation, handling of waste, and liquid waste management. Some of the key aspects are

- Segregation was a challenge due to improper disposal or non-availability of color bags.
- Although secured in most places, storage was observed to be a challenge.
- Constraints of human resources and administrative aspects were also mentioned.
- Barcoding of the bags is still to be done by the health facilities.
- The need for better handling of waste by transporters was also evident.
- Liquid waste management was a major challenge.

Based on the assessment, the following recommendations are made.

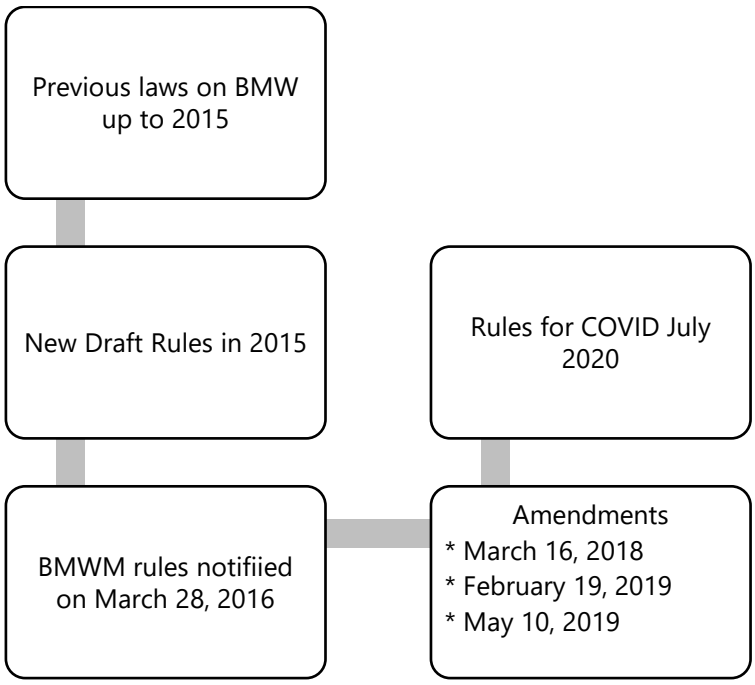
- Consider a dedicated team for BMW management at all levels, from the health facility upwards to the state level. A dedicated team in TNPCB also be considered.
- Implementation of BMW rules 2016 rules requires resources. Adequate provision of resources should be considered.
- Training of contractual staff should be streamlined.
- The BMW committee should also focus on audits of the BMW practices in the HCFs.
- Liquid waste management needs early attention.
- Compliance, specifically, uploading Form IV as required by the BMW rules 2016, should be undertaken.
- For efficient management of the BMW, barcoding of bags should be considered.

Section 1: Context setting – an overview of biomedical waste management in India

Health Care Facilities (HCF) generate significant waste. However, only a portion of the waste is hazardous. It is essential that this hazardous waste, also called the Bio-Medical Waste (BMW) waste, is segregated and not mixed with the other waste. Ensuring proper segregation of BMW, at source, from the overall waste that is generated has a significant impact on health and the environment. Based on the desk review, this section outlines the context of BWM management in India. It outlines the legal framework, the governance system, and the processes for BMW management. It also outlines the gaps and challenges in the BMW management in India, based on literature.

Legal Framework (Rules) for BMW management

The nodal framework for regulating the disposal of bio-medical waste is the Bio-Medical Waste (BMW) Management Rules, 2016[1], with a minor amendment in 2018[2] and 2019. The rules provide comprehensive guidelines to the government and medical units at all levels to dispose of BMW. The rules are framed under Environment Protection Act (EPA), 1986, which is the statutory framework for the State to ensure a clean, safe, and healthy environment. The Government of India had initially enacted Hazardous Waste (Management and Handling) Rules, 1989 under the Act. However, based on a decade of experience, the need for a separate regulatory framework for BMW management was felt. This led to the enactment of the Bio-Medical Waste (Management and Handling) Rules, 1998[3]. However, a revision was realized, and the BMW Management Rules, 2016, was framed.



The BMW Management Rules, 2016, are divided into 18 sub-rules and a couple of schedules. They provide comprehensive guidelines to the implementing authorities to interpret the law covering hospitals, clinics, and other institutions which generate such waste. Specifically, sub-rules 4, 5, and 6

[1] Bio-Medical Waste (BWM) Management Rules, 2016
[2] The amendment was on phasing out of chlorinated bags by March 2019, publication of annual reports on the website. See Press Information Bureau, "Bio-medical Waste Management Rules Amended to Protect Human Health": Dr. Harsh Vardhan". https://pib.gov.in/Pressreleaseshare.aspx?PRID=1526326 (accessed on February 5, 2022).
[3] Bio-Medical Waste (Management and Handling) Rules, 1998

outline the duties of various bodies involved in BMW's generation, handling, and management at an executive and policy level[4]. The sub-rule 7 focuses on the treatment and disposal of BMW[5]. The sub-rule 8 outlines the segregation, packaging, transportation, and storage of bio-medical waste. Segregation should happen at the point of generation itself, and transportation of BMW to a treatment facility should happen as per schedule IV. The rule also mandates the vehicles carrying BMW to comply with the State Pollution Control Board rules and that the said waste cannot be stored for more than 48 hours. Sub-rule 9 mentions the state pollution control board as the implementing authority. Sub-rule 10 outlines the procedure for authorization required from the Board to handle and treat BMW[6]. Sub-rules 13 and 14 outline the accountability measures to ensure compliance with rules. The health facilities must submit an annual report to the state pollution control board and maintain relevant records on the BMW waste generated and segregated. The annual report is sent to the Central Pollution Control Board by the State Board. The sub-rule 17 Outlines the mandate of the relevant department to provide suitable common disposal/incineration sites for the biomedical wastes generated in that area. The sub-rule 18 fixes liabilities of the health facilities and waste treatment facilities wherever there is improper handling of bio-medical wastes

Apart from the rules, the Central Pollution Control Board (CPCB) issues regular guidelines for handling, packaging, transportation, storage, and disposal of BMW at treatment facilities[7]. The Board also issues auditing standards for treatment facilities regarding the infrastructure available at the site, prevailing land use, functional operation, compliance, and safety standards followed for its personnel[8] [9].

The governance of BMW management

The Ministry of Environment, Forest & Climate Change, Government of India has the overarching role of framing the guidelines and the rules for the BMW. The Central Pollution Control Board (CPCB) has the oversight role. It supports the State Pollution Control Board (SPCB) in implementing the rules.

The Health Department and the SPCB have a key role in BMW management within the state. The roles of each stakeholder at the state level are outlined.

[4] It is important to note that as per BMW Rules, 1998, the role of operators at a waste treatment facility, and in fact, of various ministries and departments involved in BMW management at a policy level weren't delineated, thereby resulting in significant ambiguity when it came to implementation of the Rules.
[5] It is important to note that in the BMW Rules, 1998, the medical unit was to set up the infrastructure including, but not limited to, incinerator, autoclave, and microwave system for treatment of the generated BMW. BMW Management Rules, 2016 require the medical units to hand over segregated waste to a common bio-medical waste treatment facility for treatment, processing, and final disposal. When such a common waste treatment facility is unavailable within 75 kilometers, the medical unit needs to build its infrastructure.
[6] In the BMW Rules, 1998 there was an exception for medical units operating less than 1,000 patients per month. This has been removed in the 2016 rules.
[7] https://www.mpcb.gov.in/sites/default/files/biomedical-waste/Guidelines_for_Handling_of_Biomedical_Waste_for_Utilization03032020.pdf
[8] https://cpcb.nic.in/uploads/hwmd/Guidelines_HW_3.pdf
[9] https://cpcb.nic.in/uploads/Projects/Bio-Medical-Waste/SOP_covid_1.pdf

Table 1.1: The roles of key stakeholders in BMWM at the state level.

Stakeholder	Roles & Responsibilities
Health and Family Welfare Department, State Government.	• To ensure implementation of the rule in all HCFs or occupiers • Allocation of adequate funds to Government HCFs for BMW management • Procurement and allocation of treatment equipment and make provision for consumables for BMW management in Government HCFs • Constitute State or District Level Advisory Committees under the District Magistrate or Additional District Magistrate to oversee the BMW management in the districts • Advise SPCBs or Pollution Control Committees on implementation of these Rules • Implementation of recommendations of the Advisory Committee in all the HCFs
State Pollution Control Boards or Pollution Control Committees[10]	• Inventorization of occupiers and data on BMW generation, treatment & disposal • Compilation of data and submission of the same in the annual report to CPCB within the stipulated time • Grant and renewal, suspension, or refusal cancellation or of authorization under these rules • Monitoring of compliance of various provisions and conditions of the authorization • Action against HCFs or common BMW treatment facilities for violation of these rules (Rule 18) • Organizing training programs to the staff of HCFs and CBMWTFs and SPCBs or Pollution Control Committees staff on segregation, collection, storage, transportation, treatment, and disposal of BMW • Undertake or support research or operational research regarding BMW management • Any other function under these rules assigned by the Ministry of Environment, Forest and Climate Change or Central Pollution Control Board from time to time • Implementation of recommendations of the Advisory Committee • Publish the list of registered or authorized (or give consent) recyclers • Undertake and support third-party audits of the CBMWTFs in their State
Municipalities or Corporations, Urban Local Bodies, and Gram Panchayats	• Provide or allocate suitable land for the development of CBMWTFs in their respective jurisdictions as per the guidelines of CPCB • Collect other solid waste (other than the BMW) from the HCFs as per the Municipal Solid Waste (Management and handling) Rules, 2000 or as amended from time to time • Any other function stipulated under these Rules

[10] The State Pollution Control Board (SPCB) is to be constituted under section 4 of the Water (Prevention and Control of Pollution) Act, 1974. Therefore, in the context of Tamil Nadu, the state government is empowered to constitute it. Even though there is no specific provision in the 2016 Rules allowing the prescribed authority, i.e., the SPCB, to undertake delegated legislation, the Board - by virtue of being the nodal pollution regulator - is empowered enough to issue circulars and guidelines for the concerned health and treatment facilities

As per the BMW Rules 2016, all healthcare facilities need authorization from SPCBs. The authorization process is critical as it allows an SPCB to track the status of compliance in the state. Approval is granted once a healthcare facility has signed a contract with a CBWTF for biomedical waste management.

The duties of the occupier of a HCFs have been revised. The occupier is the person having administrative control over the HCF that is generating BMW

- Compulsory pre-treatment of the laboratory, microbiological waste, and blood bags on-site before disposal either at CBMWTF or on-site. The method of sterilization/disinfection should follow the National AIDS Control Organization (NACO) or WHO
- The use of chlorinated plastic bags, gloves, blood bags, etc., should be gradually phased out.
- To provide training to all its HCWs and protect them against diseases such as hepatitis B and tetanus by immunization
- Liquid waste to be separated at source by pre-treatment before mixing with other liquid waste
- To set up a barcode system for BMW containing that is to be sent out of the premises for treatment and disposal
- All major accidents, including accidents caused by fire hazards, blasts, during handling of BMW, and remedial action taken by the prescribed authority should be reported
- BMW disposal register is to be maintained daily and updated monthly on the website.

The duties of the CBMWTF are also specified.

- Assist in training personnel in HCF from where the waste is being collected.
- Barcoding and global positioning system established for the handling of BMW
- Maintain all records for operation of incineration/hydroclaving/autoclaving for 5 years

The process of BMW management

There is general waste and the BMW in every unit or department within a health facility. According to World Health Organization (WHO), nearly 75-90 percent of the hospital waste is non-hazardous. About 10 to 25 percent of the hospital waste is potentially hazardous. About 10 percent of the hospital waste is infectious hazardous, and 5 percent is radioactive. Approximately in India, about 0.25 kilograms of BMW is generated per hospital per day, based on the data from the Central Pollution Control Board[11]. Though infectious waste is relatively small, it poses high risks if mixed with general waste. The patients, health care workers, waste handlers, waste-pickers, and the general population are at risk if the waste is mixed.

The classification of the waste in a Health Care Facility (HCF) as outlined in the Bio-Medical Waste Rules 2016 is outlined

[11] Central Pollution Control Board (CPCB). Ministry of Environment, Forest, and Climate Change. Government of India. Annual Report on Biomedical Waste Management as per Biomedical Waste Management Rules, 2016 For the year 2019. The total BMW waste generated per day is 619 tons and there are 24,86,327 hospital beds according to the CPCB data.

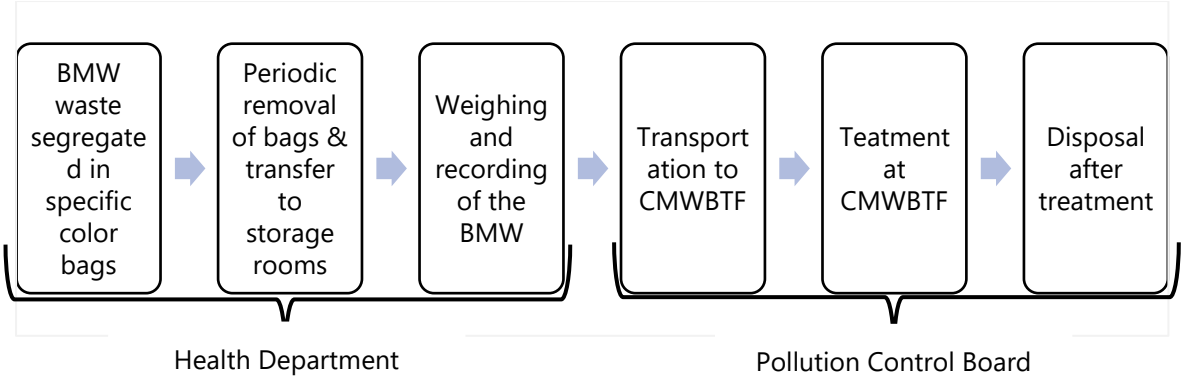
Table 1.2: Waste classification in a Health Care Facility (HCF).

Type of waste		Color codes	Waste Components
Hospital waste	Bio-medical waste (Bio-medical waste management rule 2016)	Yellow	Human and animal anatomical waste
			Soiled waste
			Expired or discarded medicines
			Chemical waste and chemical liquid waste
			Discarded linen and mattresses, contaminated with blood and body fluid, routine mask, and gown
			Microbiology, biotechnology, and other clinical laboratory waste
		Red	Contaminated plastic waste
		White	Waste sharps, including metals
		Blue	Metallic body implant
			Glassware
	General waste (Solid waste management rule, 2016)	Wet waste	
		Dry waste	
		Construction and demolition waste	
	Other waste (includes batteries, e-wastes and radioactive wastes governed by Atomic Energy Act, 1962.	Batteries	

According to the Bio-Medical Waste Rules 2016, BMW is "any waste, which is generated during the diagnosis, treatment or immunization of human beings or animals or in research activities pertaining thereto or in the production or testing of biological or in health camps, including the categories mentioned in Schedule appended to these Rules." For the year 2019, according to the CPCB data, the total BMW waste generated per day is 619 tons,

There are about six stages for BMW management. They are 1) segregation; 2) removal and storage; 3) weighing and recording; 4) transportation to CBMWTF; 5) treatment at CBMWTF; 6) disposal (see figure 1.1).

Figure 1.1: Process of BMW management



Of the six stages, the first three stages are within the purview of the health department. The other three stages are in the purview of the Pollution Control Boards.

Table 1.3 The methods of disposal of bio-medical waste as outlined in BMW Rules 2016

Category and Type	SubTypes	Method of disposal for HCF linked to CBMWTF	Method of disposal by CBMWTF
Yellow- Highly infectious waste	A. Human anatomical waste	Collect in a yellow non-chlorinated bag. No treatment required	Incineration, plasma pyrolysis, or deep burial
	B. Animal anatomical waste		
	C. Soiled waste		
	D. Expired and discarded medicine	Collect in a separate yellow non-chlorinated bag and return to the manufacturer or CBMWTF for incineration. Cytotoxic drugs to be labeled	
	E. Chemical waste	Wastes are to be collected in different yellow bags labeled for treatment by CBMWTF. Containers are to be collected in yellow bags for incineration by CBMWTF.	
	F. Chemical liquid waste	Collected, pre-treated, and disposed of through Effluent Treatment Plant (ETP).	
	G. Discarded linen, masks, gown	Collect in a yellow non-chlorinated bag.	
	H. Microbiology, biotechnology & other clinical lab waste	Pre-treatment before handing over to CBMWTF in yellow bags.	

Red- Contaminated waste (recyclable) Waste from disposable items like tubing, bottles, tubes, syringes (without needles)			Autoclaving, microwaving, or hydroclaving followed by shredding or mutilation. Treated waste to be sent to registered or authorized recyclers, energy or plastics recovery, or diesel or road making. It should not be sent to landfill sites
White Waste sharps, including metals— needles, syringes with fixed needles, etc.		No pre-treatment is required. Needles and sharps to be collected in white translucent, puncture, leak, and tamper-proof containers.	Autoclaving or dry heat stabilization, followed by shredding or mutilation and encapsulation in metal or cement containers to be sent for final disposal to iron foundries, sanitary landfills, or designated concrete waste sharp pits.
Blue Glassware: Broken or discarded and contaminated glassware, including medicine vials.		Residual chemicals should be collected as chemical waste in yellow containers/ bags as yellow waste. The rest must be in blue bags, and no pre-treatment is required.	Disinfection (by soaking and cleaning with detergent and sodium hypochlorite or through autoclaving or microwaving or hydroclaving. Then it should be sent for recycling.

Gaps and challenges in BMW management

According to a study conducted by International Clinical Epidemiology Network, it was found out that 82 percent of primary, 60 percent of secondary, and 54 percent of tertiary healthcare facilities in India had no credible BMWM system[12]. One of the primary reasons for such non-compliance was the lack of resources at all levels, i.e., segregation, storage, and transportation of BMW. The majority of officials implementing the BMW regulatory framework were either insufficiently trained on BMW disposal or were not sensitized to the harm from improper disposal of BMW. The study identified a divide between primary healthcare facilities on the one hand and secondary and tertiary on another when it came to complying with the rules. The key differences were the lack of awareness, information, and training among the hospital staff.

Another study found low compliance with BMW Rules, 2016. The study felt that this might be due to the low priority accorded by the state government to such a framework[13]. The study emphasized how information and training programs on effective BMW management could address the limited capacity of resources. It was found that the common waste treatment facilities were cost-effective compared to individual hospitals setting up their processes. If this information could be effectively communicated to all the healthcare facilities in the given region, it could lead to the adoption of better BMW disposal techniques within the given resources across geographies. The study also emphasized the lack of

[12] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5784295/

[13] https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.985.1669&rep=rep1&type=pdf

willingness of SPCB officials when imposing punitive measures on erring healthcare facilities, thereby promoting a lax attitude among them.

As per a survey conducted by the Center for Science and Environment (CSE), it was found that over 40 percent of the BMW generated in Jharkhand goes untreated. Despite clear guidelines and regulatory framework, the hospitals surveyed could not segregate the waste and clear off the waste within 48 hours. It was found that most of the HCFs did not maintain annual records to be submitted to the SPCB for compliance. They relied on the bills issued by CBWTFs to estimate the waste generated over a year and have no accident-reporting measures in place[14].

National Green Tribunal (NGT) took *suo moto* cognizance of the poor state of BMW disposal in Chennai based on a newspaper report in the Times of India dated 17th September, 2020[15]. The Tribunal ordered a detailed investigation into the matter. It formed a committee comprising officials from the CPCB (Chennai Regional Office), SPCB, Chennai Municipal Corporation, and the District Collector to submit a detailed report on BMW disposal affairs in the city of Chennai. The Committee submitted that all the HCFs and urban local bodies were disposing of the COVID –19 BMW generated through the CBMWTFs as per the guidelines issued by the CPCB. All the local bodies were reported to have executed an agreement with the CBMWFs; and were segregating and disposing of the BMW generated from the HCFs as per the BMW Rules, 2016.

As per another study, it was found that the formation of an internal BMW management committee within the HCF resulted in better compliance with the Rules[16]. Such committees ensured that the hospital staff underwent regular training on BMW disposal. Attention is paid to various stages involved in waste management, including segregation, handling, and transportation. One of the surveyed hospitals also upgraded the techniques of BMW management as per the latest guidelines.

The study conducted by the International Clinical Epidemiology Network and the one in southern India agree that the non-segregation of BMW at the generation site was one of the major challenges for efficient disposal techniques. At least two other studies conducted in different contexts confirmed the same[17][18]. One of these two other studies also held that handling of BMW required urgent reform as most of the medical facilities were either understaffed or lacked the required protective gear and knowledge to handle BMW. The ills of contracting an unverified agency or having untrained staff handling BMW run much beyond immediate environmental concerns. Sometimes, used medical products find their way back to the market. The study also identified plasma pyrolysis as a better technique for BMW treatment than incinerators.

There are other product-specific related issues regarding operational and logistical challenges. The central government had introduced auto-disposable syringes in 2005, and over 210 million units are produced every year. As per the current framework, it would be either burned or incinerated. In either

[14] https://www.cseindia.org/over-40-per-cent-of-bio-medical-waste-generated-in-jharkhand-goes-untreated-seriously-endangering-public-health-cse-6847

[15] https://greentribunal.gov.in/sites/default/files/news_updates/1_19.pdf

[16] https://www.researchgate.net/publication/319259254_Assessment_of_biomedical_waste_management_of_a_multispeciality_hospital_in_the_light_of_new_BMW_rules_2016_what_has_changed_from_the_past

[17] https://www.researchgate.net/profile/Jayanthi-Singaram-2/publication/268055661_Performance_Study_on_Common_Biomedical_Waste_Treatment_Facility_Chettipalayam_Coimbatore/links/557aa49d08ae753637572097/Performance-Study-on-Common-Biomedical-Waste-Treatment-Facility-Chettipalayam-Coimbatore.pdf

[18] C. N. Ray, Bashir Ahmadi, & Arvind Kumar Singh. (2001). Neglect of Hospital Waste Control: A Case Study in Ahmedabad. Economic and Political Weekly, 36(2), 105-107. Retrieved August 23, 2021, from http://www.jstor.org/stable/4410163

case, it would be harmful to the environment. CPCB said open burning could not be permitted, and a recommendation was made to deep-bury this waste based on the experience abroad[19].

At a regulatory and governance level, various studies have shown that the lack of information and resources is the primary issue affecting the implementation of the rules. Budgetary allocation by the government at various levels for the efficient disposal of BMW is not a part of the legal framework. It comes under the policy decision-making of the state. Without adequate priority to the issue of BMW management, fund allocation is often limited. The SPCBs and HCFs conduct training programs for various officials implementing the Rules. However, it is far from the requisite state.

The advent of COVID-19 led to new challenges as far as the disposal of BMW is concerned. The government, at least at two levels, i.e., the central and the state, had issued several guidelines on treating COVID-19 waste. For instance, the guidelines issued by TNPCB talks about the duties of various stakeholders involved in the process, including health care establishments, CBMWTFs, home-quarantine facilities, and the public[20]. But as it has emerged, the major challenge related to effective disposal of COVID-19 waste is operational, contrary to legal or lack of any policy framework.

Significant waste was generated due to COVID. Some reports and analyses indicate that the waste generated due to COVID-19 is highly underreported. This compounds the existing challenges in BMW management at facility and state levels – limited awareness and know-how, poor processes compliance, and limited waste treatment capacity. There were challenges in managing the waste generated. Reports indicated no mechanisms to track the generation of COVID-19 BMW at isolation wards and home-quarantine centers[21].

Given the context of BMW management in India – its regulation, governance, and the challenges in process implementation; this study seeks to understand the challenges in BMW management in public health facilities in Tamil Nadu. This report further outlines the objectives and study methodology, followed by insights from the study.

[19] Sharma, D. (2004). Concern over Immunization Waste in India. Frontiers in Ecology and the Environment, 2(8), 397-397. doi:10.2307/3868419

[20] https://tnpcb.gov.in/pdf_2020/PublicNoticeBMW_ENglishcorrected.pdf

[21] https://www.downtoearth.org.in/news/waste/covid-19-will-place-india-s-biomedical-waste-management-under-terrible-strain-77714

Section 2: Study objectives and methodology

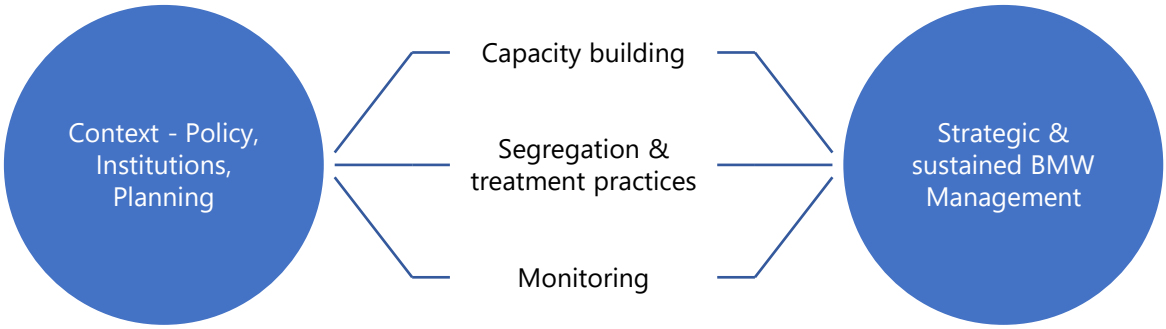
In line with the 2016 Rules, the Tamil Nadu Health Systems Development Project (TNHSDP) supported establishing a healthcare waste management system by setting up treatment facilities in 29 districts to cover all private and government hospitals. A proper segregation system, color coding, transportation, and end disposal were proposed. The Tamil Nadu, Pollution Control Board, authorized 6261 Private and Government hospitals to treat biomedical waste, and there are 10 CBWTFs in the state. However, as seen in section 1 of this report, despite regulatory systems and infrastructure, there are several challenges in the safe disposal of BMW. This study seeks to understand the challenges in public health facilities in Tamil Nadu.

Study Objectives

The study seeks to assess the operational challenges for strategic and sustained BMW management in four public health facilities in Tamil Nadu.

Study framework and areas of enquiry

Figure 2.1: Study framework



The study mapped and understood the regulatory and policy framework; and the process for BMW management, to understand the operational challenges in BMW management in public health facilities. This was outlined in Section 1. The implementation of the rules, the process of BMW management, and systems for capacity building and monitoring were studied at the facility level in four public health facilities.

The key areas of enquiry for the study were:

- Understanding of regulatory and policy framework for BMW in the country and state
- Awareness and knowledge of key stakeholders on the policy and regulatory framework
- Understanding and assessing the BMW management for the public health facilities
    - Processes at HCFs for BMW handling on-site before processing, including safe segregation, collection, storage, transportation, management, and reporting
    - Understanding and identification of challenges and bottlenecks across the value chain
    - Relationships between key stakeholders – such as Tamil Nadu State Health Department, TNPCB, CBWTFs, and HCFs in BMWM
- Systems and protocols for monitoring, if any, at the different facilities and across stakeholder groups
- Capacity building mechanisms across stakeholders including State and District Health Officials, TNPCB, CBWTFs, HCFs
- Impact of COVID19 on HCF personnel attitudes towards safe handling of BMW, changes in processes, increase in quantum of BMW generated, and related issues

Study methodology

Given the study objectives, a mixed-method study was undertaken to – (1) understand and examine the context of BMW management in India and Tamil Nadu, followed by (2) Understanding the processes and operational challenges for sustained BMW management. The study methods comprised

- Desk review
- Qualitative interactions with key stakeholder groups
- Facility assessment in the public health facilities and

Desk review

Guidelines and policies for BMW management were reviewed, along with studies and grey literature on the state of BMW management in the country and Tamil Nadu.

Interviews with key stakeholders

Interviews were conducted with key stakeholders responsible for generating, managing, and monitoring the BMW in the HCFs. The focus was on assessing their understanding of the waste segregation systems, the practices they follow, the capacity building they have undergone, and challenges and bottlenecks they perceive in the process of BMW management. Changes and perceptions in the context of COVID-19 were also explored.

Interactions were also undertaken with officials from the state health department and TNPCB to understand the policy and regulatory considerations, systems of monitoring, and perceived challenges in BMW management in the state.

Facility Assessment

Facility assessment, through a semi-structured checklist, was undertaken in the four public health facilities to assess the following:

- Processes for bio-medical waste collection segregation and storage
    - In-house transportation of bio-medical waste
    - Availability of a central waste collection room for bio-medical waste
    - Treatment and disposal of bio-medical waste
- Systems and processes for record-keeping for BMW management
- Authorizations and approvals for bio-medical waste management
- Occupational safety measures, immunization, and health check-up of BMW management staff
- Monitoring and review mechanisms of any

The facility assessment comprised observations and interactions with key stakeholders involved in BMW management in the HCFs.

Details of the study locations and respondent groups are provided as follows.

Study locations

The districts for the study were selected based on the following:

1. Quantum of waste generated per day in a district and
2. Existing BMW management capacity within the district

As per the BMW management annual report for 2018[22], Chennai and Kancheepuram are some districts that generate large amounts of BMW. No HCFs in both the districts have the facility of captive treatment[23]. Therefore, all the HCFs rely on CBMWTFs. As per the report, Chennai has one CBMWTF

[22] https://tnpcb.gov.in/Waste_MGT/BMW_Annual_Report_2018.pdf

[23] Definition of captive treatment: https://cpcb.nic.in/uploads/hwmd/Guidelines_HW_3.pdf

covering parts of Chennai and Kancheepuram. Similarly, Kancheepuram has one CBMWTF, which covers parts of Kancheepuram and Chennai. The combined total of BMW treated by these CBMWTFs is approximately 24.51 tons per day. The following table shows the total quantity of waste generation and waste treated.

Table 2.1: BMW waste generation and treatment in the study districts.

District	BMW Generation (in Kg/per day)	No. of CBMWTFs	No. of HCFs Covered by CBMWTFs	The total quantity of BMW treated at the CBMWTFs (in Kg/per day)
Chennai	11959	1	861	17151.8
Kancheepuram	4590.84	1	254	7753.54

Source: BMWM – Annual Report for the Year 2018

Hence, the districts of **Chennai and Kancheepuram** were selected for the study.

Respondent groups and interactions

The HCFs covered, the respondent groups, and the number of interactions undertaken are presented.

Table 2.2: Sample of respondents covered

Stakeholder interviews	Kanchipuram	Chennai
Medical college – Nodal officer-in-charge	1	1
Medical college – Nurses	2	2
Medical college – lab technicians	2	2
Medical college- waste handlers	2	2
District Hospital- Nursing supervisor/ Nodal officer	1	1
District Hospital – Nurses	1	1
District Hospital – Pharmacist	1	1
District hospital – waste handlers	1	1
District officer in charge of BMW/Tamil Nadu Pollution control board	1	1
Common BMW agency	1	
Transporters	1	1
Total	**14**	**14**

Table 2.3: Sample of state-level officials covered

State Health Department officials	2
Tamil Nadu Pollution Control Board	1
Total	**3**

30 respondents were interviewed as against the 31 proposed for the assessment. The TNPCB state official at Chennai was also a district official. Hence, the number was limited to 30.

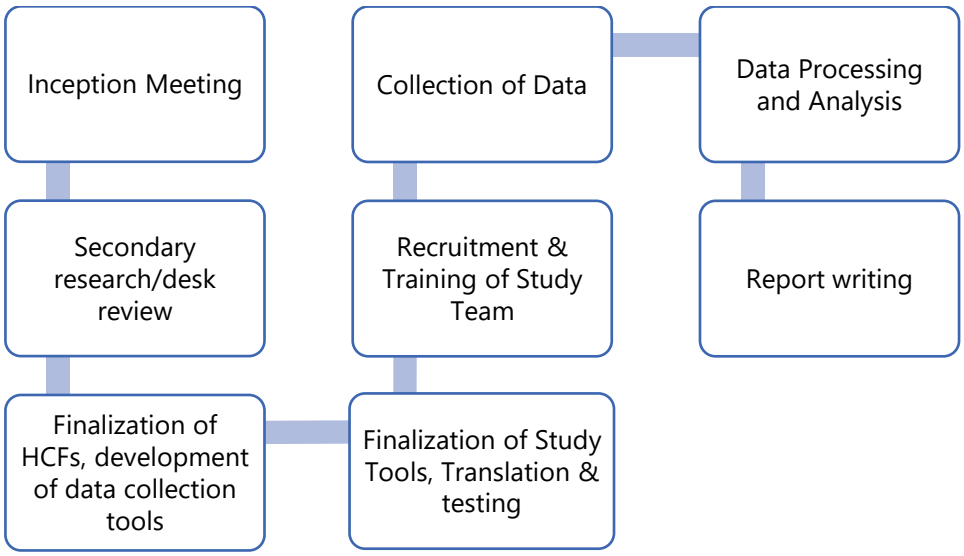
Table 2.4: Details of HCFs covered

Observations/ assessment	Kanchipuram	Chennai
Medical College	Chengalpattu medical college	Stanley medical college)
District Hospital	Kanchipuram district hospital	Tambaram district hospital)
Total	**2**	**2**

Conduct of the study

The study was conducted over six months, between August 2021 to January 2022. The key stages in the execution of the study are presented in figure 2.2.

Figure 2.2: stages in the conduct of the study



At inception, the study method, districts, and timeline were discussed. A desk review was undertaken to understand the context and management of BMW in India; this helped refine the areas of enquiry for the study. The draft tools for the facility observation and interactions with key stakeholders were developed. The tools were shared with the IITM team and finalized based on feedback. The study protocol and tools were then submitted and presented to the Development Solutions IRB for ethical review. Following the ethical approval, a team of three researchers was engaged for data collection. The researchers were trained on the study objectives and methods, tools, ethical protocols, and documentation processes for two days. The data collection was undertaken with support and facilitation by the TNHSRP. The qualitative narratives were transcribed and entered in excel templates and thematically analyzed. The report was drafted, triangulating insights from the qualitative interactions and facility observations.

There were challenges in data collection due to COVID. The Tamil Health System Report Project (TNHSRP) support was significantly instrumental in ensuring data collection from the health facilities.

Section 3: The Findings

The section outlines the findings based on the interviews and the facility survey done in the health facilities. As mentioned in the previous section, there are six stages in the management of the BMW. The section is outlined to address each of the stages

Generation of bio-medical waste

As mentioned in the earlier section, significant waste is generated within each HCF. The bulk is general waste, and only a portion is BMW, which needs to be appropriately binned, transported, stored, and treated. The general waste, for instance, is binned in green bags. For the year 2019, according to the CPCB data, the total BMW waste generated per day is 619 tons, and there are 24,86,327 hospital beds. It translates to about 0.25 kilograms of BMW generated per bed daily[24].

Table 3.1. An overview of the BMW generated by units in an HCF

	Infectious and pathological waste	Chemical, pharmaceutical, and cytotoxic waste	Sharps
Pharmacy		• Expired drugs	
Laboratories	• Blood and body fluids • Microbiological cultures • Tubes and containers contaminated with blood or body fluids	• Fixatives (Formalin) • Solvents (Xylene, methanol) • Used disinfectants (sodium hypochlorite solution)	• Needles, • Broken glasses, • Petri-dishes, • Slides, • Broken pipettes
Wards	• Dressings, bandages, gauze, and cotton contaminated with blood or body fluids • Gloves and masks contaminated with blood or body fluids	• Broken thermometers and blood pressure gauges • Split medicines • Used disinfectants	• Hypodermic needles • Intravenous set needles • Broken vials and ampoules
Operating theatres	• Blood and other body fluids • Suction canisters • Gowns, gloves, masks, gauze contaminated with blood and body fluids • Tissues, organs, fetuses, body parts	• Used disinfectants	• Needles • Intravenous sets • Scalpels • Blades • Saws
Radiology	• Syringes • Discarded plastic containers	• Silver, fixing and developing solutions • Acetic acid	• Needles

[24] Central Pollution Control Board (CPCB). Ministry of Environment, Forest, and Climate Change. Government of India. Annual Report on Biomedical Waste Management as per Biomedical Waste Management Rules, 2016 For the year 2019. The total BMW waste generated per day is 619 tons and there are 24,86,327 hospital beds according to the CPCB data.

Chemotherapy	• syringes	• Bulk chemotherapeutic waste • Vials, gloves, and other materials contaminated with cytotoxic agents • Contaminated excreta and urine	• Needles
Dental clinics	• Extracted tooth, • Cotton, gauze, gloves, masks contaminated with blood and other body fluids	• Dental amalgam • Used disinfectants	• Needles and syringes • broken ampoules
Housekeeping		• Disinfectants • Cleaners • Pesticides	

The precise proportion of the BMW and general waste in the facilities surveyed is not evident. The proportions vary by unit and by respondents. For instance, in the Chengalpattu Medical College laboratory, a fair number of containers and plastic waste are generated. According to the Lab Technician, including needle waste and slides, about 7-8 kilograms of BMW are generated. The general waste may be around 10 kilograms.

In the four hospitals surveyed, the quantum of BMW generated is higher in the medical colleges, more so the Stanley Medical College in Chennai than other facilities. This is understandable given the bed strengths: about 1000 in Chengalpattu Medical College and 1400 in Stanley Medical College, compared to about 350 in Kancheepuram DH and 130 in Tambaram GH. Three of the four facilities, excluding Tambaram GH, have over 300 beds. These are designated as large-bedded hospitals by the TNPCB.

Table 3.2. Quantum of BMW generated in each facility

Facilities	BMW generated (Kilograms per day)
Stanley Medical College	275
Chengalpattu Medical College	215
Kanchipuram District Hospital	77
Tambaram District Hospital	25

Before COVID, in January and February 2021, the Stanley Medical College generated about 275 kilograms of BMW per day. The nodal officer said that the average generation is about 283 kilograms of BMW daily. The red category of contaminated recyclable plastics was about 40 percent; IV bottles were about 4 percent. The yellow category waste was about 37 percent, the blue category waste was 18 percent, and the white was less than one percent. In Chengalpattu Medical College, based on the bed strength and assumption of 0.15 kilograms of BMW per bed, the expected generation is about 140 to 150 kilograms every day. However, the nodal officer mentioned that the average daily BMW ranges between 215 to 230 kilograms per day. The red waste accounted for 42 percent, yellow for 33 percent, blue for 23 percent, and white for 2 percent.

In Kancheepuram DH, the average BMW generated per day is around 77 kilograms. According to the hospital superintendent, about 2000 to 2300 kilograms of BMW are generated every month. The details of the waste generated in Tambaram DH for two months, as provided by the nodal officer, are below.

Table 3.3. BMW generated in Tambaram GH

	November 2020			April 2021		
	No. of bags	Weight	Percent	No. of bags	Weight	Percent
Red	92	304	46.3	96	304	35.8
Yellow	63	282	42.9	145	441	51.9
Blue	29	65	9.9	37	97.5	11.5
White	1	6	1	2	7	0.8
Total	185	657	100	280	849	100

The form IV submitted by the Stanley Medical College for 2020 mentions an average of 0.15 kilograms of BMW per day. Compared to this norm, all four facilities appear to be generating more BMW than the norm.

The quantum of BMW generated in a pharmacy is virtually nil within each facility. According to the pharmacists, there are no expired medicines for disposal. The BMW generated in a laboratory ranges from 2 to 6 kilograms in a day. In the Chengalpattu Medical college laboratory, one lab technician said that about 8 kilograms of BMW are generated daily. The lab technician also said that blood and urine samples are collected on Tuesdays and Thursdays, as the neurology Outpatient clinic is open. There are more blood samples on Monday and Friday as the diabetic outpatient clinic is open. In Stanley medical college, the Lab Technician said that about 2.5 to 5 kilograms of BMW are generated daily.

The nurses in Stanley Medical college said that daily, about 5 to 6 kilograms of BMW are generated. The staff nurse in Tambaram GH said that about 0.5 kilograms of BMW are generated daily in her duty station. The waste generated is higher in November due to more maternity cases. One nurse said that about 8 kilograms of BMW are generated in an intermediate care unit in Chengalpattu medical college.

On the day of the visit, on September 17, 2021, the Nurse Superintendent in Chengalpattu medical college mentioned the quantum of BMW generated as follows

Color	Number of bags	Weight (kilograms)	Average/ bag (kilograms)
Red	36	75.3	2.09
Yellow	28	77.3	2.76
Blue	27	17.3	0.64
While	6	3.9	0.65
Saline bottles		31.4	
Total	97	173.8	1.79

The visit was during COVID, which might have impacted the BMW generated in a day.

Segregation

Segregation is the key aspect of BMW management. Ensuring proper segregation of waste specific to each color is the responsibility of the personnel working in that unit/ward where the waste is generated. The units/wards are issued bags monthly to enable segregation. Depending on their conditions, the bins are replaced either annually or every six months. In Chengalpattu medical college, the Nodal Officer said they drafted a Standard Operating Procedure (SOP) to simplify the central guidelines for easy understanding of the staff for segregation.

In pharmacies, usually yellow bags are kept for discarded or expired medicines. However, the pharmacists and nodal officers said that there are usually no expired medicines in the pharmacies.

Tambaram and Kancheepuram GH pharmacists mentioned that the blue bags are kept to discard ampoules and any glassware. However, the BMW generated is a very small quantum in a month.

Usually, all the color bags are kept in all the wards and the various units. However, in OT and labor wards, the size of bags may be bigger than the other places, given the quantum of waste generated.

The saline bottles are binned in red bags for recycling. In Tambaram hospital, the segregation of the saline bottle as a recyclable waste was mentioned to them in August 2021. Hence, they keep a separate red bag/bin for segregating the IV bottles alone. According to the nodal officer, it would be helpful to put all the recycling wastes in the red bags instead of having two separate red bags. The reporting on BMW to the nodal officer and then upwards do mention the details of the segregated saline bottles.

There are challenges to segregation. These include improper segregation, either by health personnel or the patients and their relatives who visit the HCFs. Respondents mentioned house surgeons who are often not mindful of the segregation protocols. Also, patients and their relatives[25] tend to throw food waste in bins meant for BMW than in the general waste bins. If incorrect segregation is observed by the personnel monitoring the BMW, they request the waste-handlers to segregate it properly. Incorrect segregation is also mentioned in the record books and reviewed in the BMW committee meetings. This is discussed further below.

Once a bag fills about three-fourths, it is removed, tied, and set aside, and a new bag is placed. The removal of these bags is discussed below.

The observation in the HCFs surveyed indicated that the color-coded bins were usually available in all the places. The bags were fitted well too in the bins. The labels were clear, and the bio-hazard symbols were found in the bins/ near the bins. However, signages and poster guides were not present in the three facilities (see table below). In one HCF, all the bins were not covered. The observation also indicated that segregation was an issue in the general male and female wards. The condition of the bins too in these wards was not very good compared to the other places in the HCFs.

Table 3.4. Availability of bins, signages for BMW segregation – Based on observation

Aspects	Chengalpattu Medical College	Stanley Medical College	Kanchipuram District Hospital	Tambaram District Hospital
Availability of color-coded bins	Yes	Yes	Yes	Yes
Proper fitting of the bags	Yes	Yes	Yes	Yes
Clear labeling	Yes	Yes	Yes	Yes
Bins covered	No	Not all wards	Yes	Yes
Presence of Bio-hazard symbol	Yes	Yes	Yes	Yes
Poster guides	Not all wards	Not all wards	Yes	Not in general ward male
Signages	Not all wards	Yes	Yes	Not in general ward male

[25] In instances where the public mixes the waste incorrectly, it is difficult to identify the person responsible. Hence it often falls on the waste handlers to segregate the waste.

However, according to the transporters, segregation is the major challenge in some hospitals. Improper segregation creates an issue in their treatment at CBMWTF. In case of improper segregation based on the labels, the HCFs are informed.

Pre-treatment of waste

As per the 2016 rules, microbiology, biotechnology, and other clinical lab wastes must be pre-treated, put in yellow bags, and handed over to the CBMWTF. Other than that, no other wastes must be pre-treated as per the new rules. The materials used for testing cancer and ART patients are pre-treated before disposing of. According to the Nodal Officer, body tissues from pathology were also pre-treated in Chengalpattu. The glass slides in the labs, too, were pre-treated.

However, in the Tambaram GH, the gloves used in the Operation Theatre (OT) are put in a hypochlorite solution, neutralized, and then cut and put inside a red bag. The rules do not specify this, but this could be rechecked.

Removal of BMW

Usually, the BMW is removed from all the wards once a day. Usually, it is collected in the morning from all the wards by the waste handlers and transported to the central storage area through trolleys in covered drums. The frequency could vary depending on the type of waste. For instance, waste from ICU and anatomical waste is not kept for long at the point of generation. They are transported at shorter frequencies, depending on the quantum of generated waste. In the case of other wastes, such as sharps, or soiled wastes, it appears that once the bags are filled, they are tied up and new bags replaced. The filled bags are kept in the place of generation and taken out the next morning. The frequency of the collection also depends on the personnel available. In some facilities, it was mentioned that since they are short-staffed, the bags are often removed only once a day.

Once the bags fill, they are tied securely and labeled. The source of generation, number, time of collection are affixed on the bag signed by the Nursing Superintendent. The bags are weighed again at the storage room and details recorded.

Table 3.5. Removal of BMW- availability of PPE and covered trolley -Based on observation

Availability	Chengalpattu Medical College	Stanley Medical College	Kanchipuram District Hospital	Tambaram District Hospital
PPE kits for staff removing & storing BMW	Yes	Yes	Yes	Yes
Covered trolleys for transporting waste	Yes	Yes	No	No

Table 3.6. Use of Protection by workers in BMW Management – Based on observation

Use of Protective gears	Chengalpattu Medical College	Stanley Medical College	Kanchipuram District Hospital	Tambaram District Hospital
Gloves while handling/working with BMW	Yes	Yes	Yes	Yes
Wearing a gown while handling /working with BMW	No	Yes	Yes	Yes
PPE kits while engaged in transportation and storage of BMW	No	Yes	Yes	Yes

Storage

All the interviewed facilities had a dedicated storage facility within the premises for storing BMW. During COVID, the waste from COVID patients and non-COVID patients was stored and disposed of separately.

Table 3.7. Status of storage facility – Based on observation

Aspects	Chengalpattu Medical College	Stanley Medical College	Kanchipuram District Hospital	Tambaram District Hospital
Dedicated covered storage facility for BMW	Yes	Yes	Yes	Yes
Bio-hazard symbol displayed at the BMW storage facility	No	No	Yes	Yes
Storage facility/location away from patient area	Yes	Yes	No	Yes
Storage facility/location with proper road connectivity	Yes	Yes	Yes	Yes
Storage facility secured against pilferage and reach of animals and rodents	Yes	Yes	No	Yes
Hand washing facility for persons working in the storage area	Yes	Yes	Yes	Yes

As mentioned in the table above, in Kancheepuram DH, the storage area is not well secured. Animals seemed to gain entry to the storage area, which needs to be addressed.

Roles of various personnel in an HCF

Dean/Hospital Superintendent

- Apply for authorization
- Form BMW Committee
- Overall responsibility of implementing all policies and rules on BMW.
- Overall responsibility to ensure proper segregation, collection, storage and transport of BMW.
- Provide required human resources
- Appoint a Nodal Officer to oversee the process.
- Liaise with the health department as required
- Ensure submission of reports to the TNPCB.

Nodal Officer BMW

- Report to the Head of the facility.
- Ensure provision of bags, disinfectants, and other materials and equipment as required by different units
- the availability and continuous Supply of Waste disposal bags and chemical
- Monitor and ensure standards
- Oversee record keeping
- Ensure implementation at various levels
- Address challenges in storage and transportation
- Liaise with Department Heads and Nursing Superintendent.
- Identify training needs and conduct training.

Nursing Superintendent / Head Nurse

- Continuous monitoring of BMW management across the hospital
- Liaise with Nodal Officer and other department heads as required
- Monitor the weighing of Bio-Medical Waste.
- Supervise record keeping

Waste Handlers

- Collect waste from the various units in the HCF
- Ensure that the bags are placed in the bins
- Segregate waste if required
- Ensure that the BMW is weighed and recorded at the storage unit.

Transfer to CBMWTF

The BMW is transferred from the HCF to the CBMWTF by vehicles.

The vehicles transport about 600 kilograms to 2 tons of BMW every day, depending on their size. Each vehicle has spaces earmarked by the color to place the bags by color. The number of HCFs from which waste is collected ranges from 50-60. They start their trip in the morning go to facilities based on the route map provided by the supervisor. They usually reach the CBMWTF in the evening. On average, they travel around 250 kilometers per day. The vehicles are equipped with GPS. Apart from a driver, a person transfers the waste into the vehicle. A Supervisor usually monitors the process daily.

When collecting the BMW, they usually wear personal protection, including gloves, masks, and shoes. If the bags are not tied properly, the transporter may refuse to load them till the hospital staff properly secures them. If any bag splits, they have spare bags to transfer the content. If the vehicle breaks down

or there is an issue, they call the supervisor, and a replacement vehicle may be sent. The transporters, however, said that such instances are not very common.

The CBMWTF trains the transporters regularly. One transporter mentioned that he was paired with another transporter for 10 days to understand the process. They also undergo health check-ups regularly at the CBMWTF. They are provided with TT injections. in case of any pricks or accidents, they are referred to an HCF.

Treatment at CBMWTF

The BMW is usually disposed of every day. The waste is transported from the health facility by the CBMWTF.

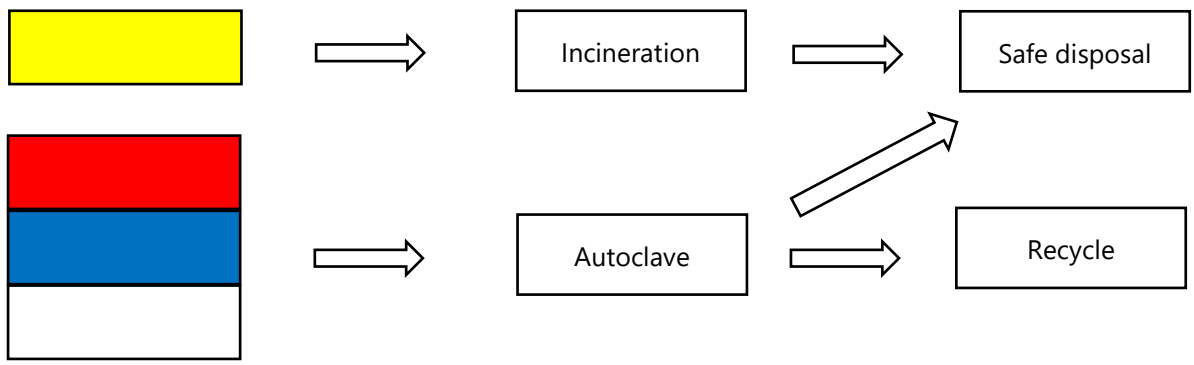
According to the guidelines, the treatment facility must be within a radius of 75kms from the health facility. All the four HCFs surveyed fulfill this aspect.

Advantages of CBMWTF

- The HCF does not have to invest in establishing an on-site treatment and disposal facility
- The HCF does not have to recruit a separate dedicated and skilled team for managing the waste.
- Monitoring a few CBMWTF than many dispersed treatment facilities is easier
- Documentation that a CBMWTF is required to keep enables compliance.
- The waste that can be recycled can only be sent to an authorized recycler. This enables monitoring of how the waste is used.
- The cost of waste treatment also reduces significantly if the CBMWTF operates to its full potential.

The metals, plastics, gloves, and bottles are separated and treated before recycling in the treatment facility. The treatment facility incinerates yellow waste and autoclaves the waste in red, white, and blue colored bags. TNPCB has banned deep pit burial. The CBMWTF personnel said that after incineration and autoclaving, the remains are sent to a plant in Gummidipoondi for safe disposal. The wastes that can be recycled are given to an authorized recycler. In Tamil Nadu, it is given to recyclers authorized by the TNPCB.

Figure 3.1. Treatment by color at CBMWTF



The observation indicated the need for proper handling of the waste by the transporters. In one instance, it was observed that the yellow bags were thrown, which split, and the contents fell to the ground. Then, the contents were swept into a waste pan collector and filled in another bag. The place where the transporter did not treat the waste split.

Recording and reporting

The HCFs maintain the following registers.

- Registers for daily collection- separate registers for labs, outpatient wards, inpatient wards, and Operation Theaters
- Registers of source-wise BMW collection for the day. Ward-wise BMW collected maintained by waste handlers and attested by the Nurse Superintendent or BMW in-charge staff nurse
- Monthly consolidation register. The nodal officer or the hospital superintendent is responsible for maintaining this
- Injury register – details of splash, needle, and other sharp related injuries to be kept
- Saline bottles/plastic infusion bottles register

The register at source details the number of bags and the quantum for each color code. A separate register for the waste pre-treated before disposal is also kept in the micro-biology labs. The registers also mention the time when the waste is taken out. The Nurse or the Medical Superintendent signs the registers. Usually, a daily report is also sent to the nodal officer on the amount of waste by color number of empty saline bottles.

The bags are weighed again in the storage room. The details of the source-wise collection are recorded. A consolidated list of waste by color and weight is prepared for the day. The report is submitted to the nodal officer for verification and signature.

There are also records of the number of bags and quantity transported from the storage area, indent register for the bags, training register, and communication.

In the case of the Tambaram GH, a monthly report is sent to the Health Department. For instance, the Tambaram GH sends the report to the Joint Director in Kancheepuram, who forwards the report to the Pollution Control Board. The GH does not send it directly to the Pollution Control Board. The Nodal Officer at Kancheepuram GH said a report is sent to the pollution control board and the DMS but was not specific to whom the report is sent. The officer said that it was the responsibility of the office. The officer, however, said that it is sent in the first ten days of the succeeding month.

In Medical Colleges, a report is sent to the Directorate of Medical Education (DME) and an annual report to the TNPCB. As the nodal officer at Stanley Medical College mentioned, "an annual report is sent to the District Environmental Engineer, Pollution Control Board at Arumbakkam. The reporting period is a calendar year, from January to December. The report must be sent by June in the succeeding year. There is a prescribed format in which the report has to be shared". The nodal officer from Chengalpattu Medical College also said they send an annual report to the Pollution Control Board and the periodic reports to the DME.

In the CBMWTF, according to one respondent, the waste collected in each facility is weighed and recorded. Weight is recorded while loading and unloading HCF-wise. This is maintained in a logbook. In the treatment plant, machine running time is noted and recorded. Heat maintained in the treatment plant is also recorded. In addition, the records of vehicle movements, ash collection, first-aid register, health check-up registers, accidents, injuries, treatment are also kept.

Table 3.8. Record-Keeping – Based on observation

Record keeping	Chengalpattu Medical College	Stanley Medical College	Kanchipuram District Hospital	Tambaram District Hospital
Records of collection, transportation, storage, and disposal maintained in all departments	Yes	Yes	Yes	Yes

Knowledge and training on BMW:

All the respondents were aware of the color codes and the waste segregated by color in all the facilities. The waste-handlers and transporters were also aware of the color codes.

The waste handlers and transporters were not asked if they knew the act or the rules on BMW management. Among the rest, some did not know the 2016 Act. The table below outlines their knowledge of the rules that guide BMW management. The Nodal officers and the Nurse/Nurse superintendent had better knowledge of the Act among the respondents. The likely reason may be that they are responsible for overseeing the BMW management.

Table 3.9. Awareness about the BMW Guidelines

Chengalpattu Medical College	Nodal Officer	Guidelines of the State and Central Government and DME office.
	Lab Technician	Guideline followed is to dispose of in different color-coded bins
	Lab Technician	Dispose of BMW in different color-coded bins
	Nurse	Dispose of BMW in different color-coded bins
	Nurse	State Government guidelines
Stanley Medical College	Nodal Officer	2016 guidelines and 2018 amendments
	Lab Technician	WHO guidelines
	Nurse	2016 TNPCB guidelines
Tambaram hospital	Nodal officer	2016 guideline and handbook of Tamil Nadu Government
	Pharmacist	State government guidelines
	Nurse	2016-28 state guidelines
Kancheepuram hospital	Nodal officer	2016 guideline and 2018 amendments
	Pharmacist	State guidelines of 2016-2018
	Nurse	2016-2018 Biomedical management book.
State health official		2016 guidelines
		2016 CPCB guidelines
TNPCB		2016 and amendments
		2016 and amendment

The training on BMW management varied by the facility. All the respondents said that they undergo periodic training at Stanley Medical College. The Nodal Officer was trained by the Pollution Control Board about four years ago. While the Lab Technician and the Waste Handlers said they had been trained once, the nurses said the Nodal Officer trains them regularly. The nurses mentioned that they are trained on segregation, careful management of the waste, and adopting precautions in accidents. The Lab Technician and the Waste Handlers said they did not receive refresher training.

In the Chengalpattu Medical College, all the respondents said they had not been trained in BMW management. One respondent said that we essentially know how to segregate. Over and above that, they said they were not aware. Some felt that the training would help in case there were any mishaps. One respondent said that training the students will help as they usually mix the waste during disposal. According to the Nodal Officer, all staff is trained twice a year and the Assistant Professors once a year.

In the Kancheepuram GH, the nurse was trained at Stanley Medical College and subsequently by the NHM in Chennai in 2019. The pharmacist has not undergone any training. The nodal officer had undergone training in NQAS, in which BMW was one part. The officer has had no other training. The waste handler was trained at the time of joining three years ago and trained again in June 2021 at COVID. The nodal officer is also responsible for training the medical interns. Each month, the interns are oriented, and their knowledge is assessed before and after training.

All the respondents in Tambaram GH said that they had been trained. They also mentioned being re-oriented on the BMW management. In the Tambaram GH, the nodal officer had undergone two training on BMW and organized regular refresher training. The new staff is trained as required.

Most respondents said they ask their seniors if they need further details or clarification. Most respondents mentioned that they referred to the internet if they needed any additional information. In Tambaram GH, the nodal officer said that a training manual and a PowerPoint is available if any staff requires them.

The CBMWTF personnel is trained. One respondent said he had three to four months of on-site provided by the Safety Manager. The staff was trained to follow relevant legal regulations and guidelines, waste classification, hazards of BMW, coding, documentation, and appropriate PPE. The supervisors are also trained in autoclaving and hydroclaving. Training is designed based on the roles. While supervisors are trained on technical aspects, all staff are trained on safety procedures. The training is periodic, with weekly training on safety for all staff and fortnightly training for the drivers and others. The CBMWTF also collaborate with HCFs to train the hospital staff, especially the nurse and the waste handlers.

Injuries

The possibilities of injury, especially from needle pricks, were mentioned. There are chances that the needle pricks might lead to HIV infection too. Hence, the instances of needle pricks are immediately addressed. The matter is immediately reported to the casualty or the duty medical officer. The person is provided with a TT injection. The person may also be referred to the ART center for HIV testing. In a recent incident in Chengalpattu medical college, the person was tested for HIV, found to be negative. However, the person was kept under observation.

However, no HCFs reported any major incidents in the last few years.

The transporters mentioned that they must protect themselves from the infection. They said they are aware of the risks involved in handling and being exposed to the waste. Apart from routine hygiene such as bath after finishing work, the transporter mentioned that they get themselves regularly vaccinated with TT vaccine to ensure protection.

Monitoring

As mentioned earlier, all healthcare facilities must obtain authorization from TNPCB. The authorization process is critical as it allows the TNPCB to track the status of compliance in the state. Authorization is granted once an HCF has signed a contract with a CBWTF for biomedical waste management. The authorization also prescribes the duties of the HCF in training, segregation, storage, monitoring, reporting the accidents, immunization, and occupation safety of all personnel involved.

In the health facilities surveyed, two types of monitoring occur. One is regular monitoring, and the other is an oversight by the committee. The regular monitoring includes an inspection by the Nurse Superintendent and an oversight by the Nodal Officer. A committee oversees each facility, which meets every month or in periods designated by the committee. Once the waste leaves the HCF, it becomes the responsibility of the CBMWTF, and it is TNPCB that monitors its functioning.

In the Chengalpattu Medical College, the Staff Nurse/ Nurse Superintendent inspects the waste in the specified color bags. They also monitor if the needles are cut before disposing of them in the white bag. In the Tambaram GH, a sheet is kept at every source where BMW is generated. The Nurse Superintendent goes and checks the content in the bags. If the segregation is not done correctly, she puts an X in the sheet. This is reviewed every month. If the practice is repeated, then the staff is oriented. In some cases, as in Kancheepuram GH, CCTVs are also used to monitor BMW segregation.

In the medical colleges, a team from the micro-biology unit also visits the BMW generation points and checks the records.

In addition, all facilities have a committee, as mandated by the law. In Stanley Medical College, the Dean/Medical Superintendent heads the committee. The RMO, Nodal Officer. Health Inspector, BMW Matron, Staff Nurses, and Heads of all departments (HOD) are members. In Chengalpattu Medical College, the Head of the Microbiology department heads the committee. The members include the Dean, RMO, ARMO, HODs, Superintendent Nurse, Health Inspector, and the workers from the outsourced agency. In Kancheepuram GH, though formed earlier, the committee was reconstituted in 2019. The members include the hospital superintendent, chief civil surgeon, chief doctor, resident MO, nodal officer, chief laboratory technician, surgeon, and staff nurse. In Tambaram GH, the committee is headed by the Chief Medical Officer, Nodal Officer, Nursing Superintendents, Lab Assistant, Pharmacist, three Staff Nurse, and one worker.

Therefore, the committees primarily include the key officials and the nurses expected to monitor the workers who transport the waste. Except for Tambaram GH, the Pharmacists do not appear to be a part of the BMW committee in the health facilities surveyed.

Except for Tambaram GH, the meeting is held every month in all the other facilities. In Tambaram GH, the meeting is held every quarter or six months. In Stanley Medical College, the meetings and Hospital Infection Control Committee meetings are conducted.

The agenda for the meeting in all the facilities usually includes sharing the details of the daily/routine monitoring, challenges, decision on any procurement required, and personnel training. The details of the routine monitoring are shared with the head of the department or the units for necessary action. For instance, in Chengalpattu medical college, the meeting highlights the wards where the segregation was good. Wards or places where segregation needs improvement are mentioned too. As the Dean and RMO are present, they also use this opportunity to address challenges. The committee also discusses the training for the staff, especially the new staff. The meeting held in Tambaram GH in June 2021 drafted a training schedule and a timetable.

The meetings also discuss aspects of procurement for the BMW management. In Chengalpattu Medical College, the meeting held in August 2021 decided to procure trolleys, weighing machines, needle cutters, and covers for the wastes. In Tambaram GH, in the meeting held on June 2021, discussed the replacement of damaged posters and signages was done.

In Stanley Medical College, the meetings also discuss preparedness for specific diseases such as Dengue and recently on COVID. In Kancheepuram GH, the meeting in August 2021 discussed the provision of Hepatitis B vaccines to the staff.

The respondents' awareness about the BMW committee in the HCFs is outlined in the table below.

Table 3.10. Awareness about BMW Committee in HCFs

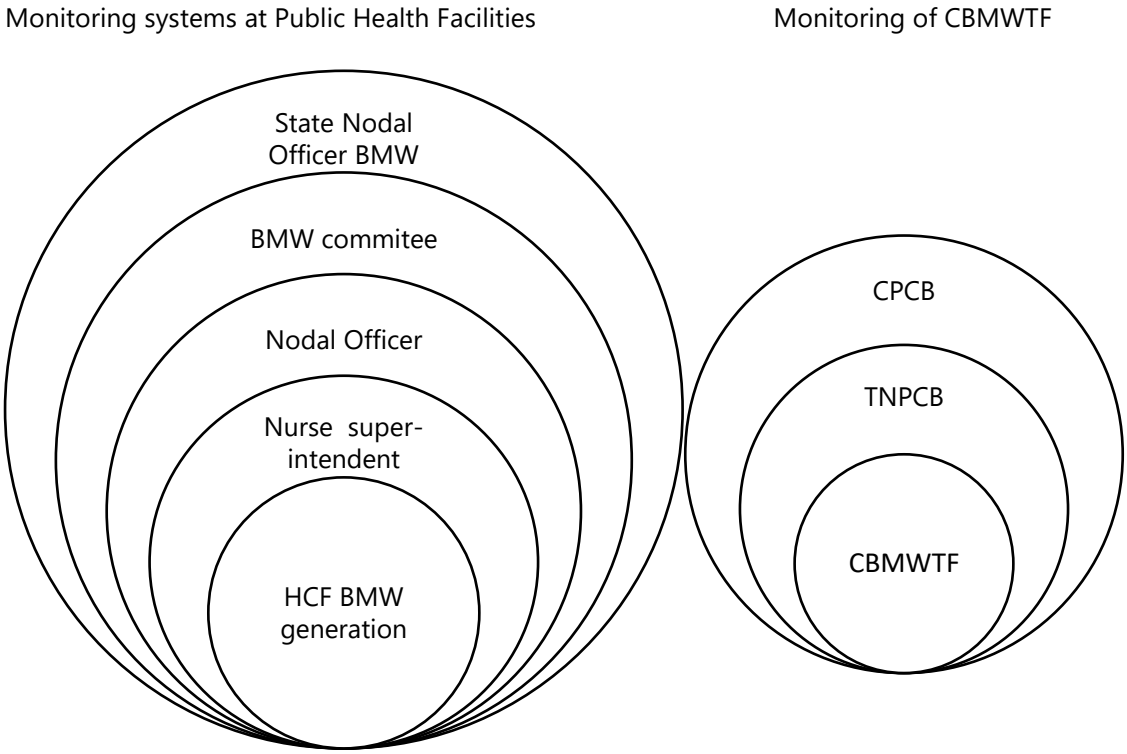
Chengalpattu Medical college	Lab Technician	Not aware
	Lab Technician	Not aware
	Nodal officer	Aware
	Nurse	Aware
	Nurse	Not aware
Stanley Medical College	Lab Technician	Aware
	Nodal officer	Aware
	Nurse	Not aware
Kanchipuram	Nurse	Aware
	Pharmacist	Aware
	Nodal officer	Aware
Tambaram	Nurse	Aware
	Pharmacist	Aware
	Nodal officer	Aware

There is a state-level nodal officer for BMW. The current nodal officer is also a Head of the Department in Kilpauk Medical College. He mentioned that they have a WhatsApp group to guide the HCFs if required. Before COVID, there were half-yearly meetings in the DME office. The meetings were not held due to COVID. The data from all the medical colleges is shared with the DME and managed by the office. The nodal officer and the DME coordinate with the Medical Colleges on BMW management.

In the CBMWTF, too, there are two levels of monitoring. One is routine monitoring that the supervisors do, and the other is the monitoring by TNPCB.

The TNPCB monitors the functioning of the CBMWTF. According to one CBMWTF respondent, the TNPCB monitors the water sample before treatment and inspects the facility periodically. The visits could be weekly to check the functioning of the autoclave, check the liquid effluents every fortnight, and stack emissions every quarter or six months. In addition to the physical monitoring, app and digital-based monitoring are used. Global Positioning Systems (GPS) are also used to monitor the movement of the vehicles that carry the BMW.

Figure 3.2. Monitoring systems for BMW



The TNPCB officials said that the district environmental Engineers /officers are there in each district, monitoring at ground level. The key aspects monitored include collection, handling of BMW, transportation, treatment, and disposal. Specifically, they monitor the functioning of the 10 CBMWTF across the state. As mentioned above, one of their key tasks is to monitor the emission levels. In the CBMWTF, the monitoring also involves quality assurance, reviewing facility records, and verifying the registers. An inspection format with a checklist is used for monitoring.

The TNPCB is also expected to monitor the HCF, particularly the large HCF with over 300 beds. However, the respondents in the medical colleges did not mention any monitoring being done by the TNPCB. The officials interviewed said that they are perhaps carrying out a trial to monitor the generation of BMW in the HCFs. The effort is to monitor and track every process in the BMWM. Training is proposed in the HCFs, too, to enable this. However, this is likely to take some time.

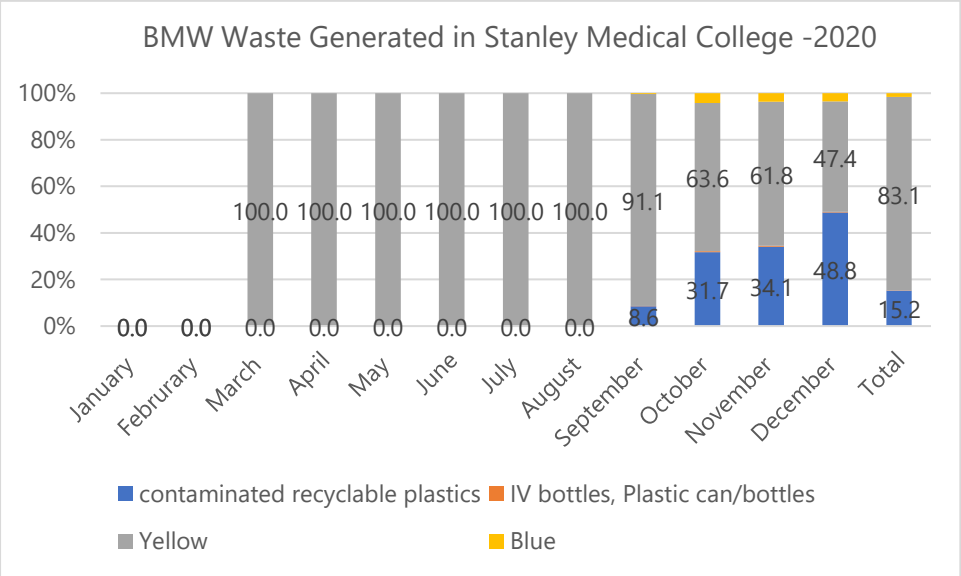
The rules also prescribe a district-level committee and a BMW state-level committee. However, this study did not examine their role in the monitoring process.

BMW during COVID

During COVID, the quantum of BMW, however, increased substantially. The waste increased due to the number of samples for testing and the use of the Personal Protection Equipment (PPE) during the COVID. As mentioned by a nurse in the Stanley Medical College, "the caseload was more from April to June 2021, the entire hospital was accommodated with COVID patients, and around 1500 beds were always full. Extra beds were also arranged. Waste generation was enormously high. During the Covid period from labs, we received 25 covers per day, but it comes around 8 bags only on normal days. PPE kit waste was more. Also, general waste was more as patients were provided with food." According to

the CBMWTF personnel, the PPE was about 50 percent of additional waste. The waste was nearly 8 to 10 tons per day, according to one CBMWTF personnel.

Graph 3.1. BMW Waste Generated in Stanley Medical College -2020



The type of waste generated due to COVID is evident from this graph above for January-December 2020. No BMW of white color was produced due to COVID in the entire year. In March 2020, small quantities of yellow waste were generated. The quantum generated gradually increased, reaching a peak of 7400 kilograms in July 2020 and then declining gradually. However, the generation of contaminated waste and IV bottles gradually increased after September 2020. In December, about 1800 kilograms of contaminated plastic waste were generated from zero waste until August 2020.

In Tambaram GH, while red and blue wastes were generated during November 2020 in COVID wards, in April 2021, only yellow waste was generated. It will be interesting to examine the type of waste generated due to COVID over a longer period to understand the reasons.

Table 3.11. Waste generated during COVID in Tambaram GH

	November 2020			April 2021		
	No. of bags	Weight	Percent	No. of bags	Weight	Percent
Red	16	40	12.8	0	0	0
Yellow	71	251	80.2	74	266	100
Blue	12	22	7.0	0	0	0
White	0	0	0	0	0	0
Total	99	313	100	78	266	100

In Chengalpattu and Stanley Medical Colleges, human resources were hired temporarily to manage the waste. The waste had to be removed frequently due to the quantum of waste. As mentioned above, additional personnel were engaged to do this. Separate storage rooms for COVID waste were designated, as was done in Kancheepuram GH. Separate registers, too, were kept recording the waste generated due to treating COVID patients. Some respondents said that the bags were pre-treated by dipping them into hypochlorite solution before sending them to the storage rooms.

The CBMWTF had to hire additional vehicles and personnel to transport the waste due to COVID. In the hospitals, separate registers were kept for the waste generated from the COVID patients. The drivers faced challenges wearing the PPE and gloves. The sweat made driving difficult. Separate vehicles were earmarked for transporting COVID waste.

The CBMWTF also faced challenges in treating the waste. They had to transport the waste to treatment centers far away. One of them said that they had to send part of it to Mathuranthangam and part of it to Gummidipoondi for treatment. On occasions, they also were not able to treat all the wastes in a day, and there was a spillover

Liquid waste management

The hospitals generate liquid waste, too, and the waste needs to be treated as per the rules. In the laboratory in Chengalpattu medical college, about 20-25 liters of liquid waste are generated every day. The quantum of liquid waste generated in the Kancheepuram GH is not known.

However, liquid waste management is one of the serious challenges in all these facilities. In almost all the HCFs surveyed, in the Operation Theatres (OT's) they collect the liquid waste in a tank and then treat it with hypochlorite before discharging it in the sewage. In the Tambaram GH, the hospital has two bins that resemble water cans. They are transparent so that the quantity in the cans is visible. Each can have a capacity of about 20 liters, and when it is nearly filled, hypochlorite is mixed, and after 20 minutes, the waste is disposed of in the drainage.

In Chengalpattu medical college, the blood and other samples are stored separately after tests, treated with hypochlorite, and disposed of in a separate sink. The sink and the containers are also washed with hypochlorite.

The BMW 2016 rules require the HCFs to have an ETP for the liquid waste. None of the facilities surveyed have an ETP covering all the facilities where the liquid waste is generated. According to the Nodal Officer in Stanley Medical College, the liquid waste from Lab and radiology are sent to ETP in the Lab block. The waste is pre-treated with Hypochlorite and drained into the ETP. The officer also said that the radiology block in a new building has an ETP facility.

One of the reasons is that the facilities surveyed for this study are old facilities, and they do not have any significant provision for liquid waste management. In Kancheepuram GH, the buildings in the hospitals have been added over time. Hence, it is difficult to connect the buildings to ensure a unified liquid waste management system. Since the entire HCF cannot be connected to an ETP for various such as the age of the building or space constraint, each department/unit where the liquid waste is generated must manage it by treating it and disposing it into the sewage. In the Chengalpattu medical college, they have submitted a plan to the Public Works Department for setting up an ETP. They are hopeful that it will be done in a year.

Conclusion

The BMW rules 2016 signifies the effort of the government to ensure an efficient and cost-effective way to manage waste. By focusing on segregating the small proportion of the hazardous waste created in the HCFs, the effort ensures a more significant gain, both from a health perspective and environmentally. There is a significant emphasis on recycling waste to conserve resources and reduce the carbon footprint.

The rules also clearly outline the roles of the occupier and that of the treatment facilities. The occupier is responsible for ensuring correct segregation by training the personnel, providing protective gear for the personnel, ensuring their health check-up, addressing injuries, and providing the required color bags and bins. Poor segregation has a cascading effect at the end of the pipeline during treatment. The

role of the common treatment facility is also well outlined. The systems for documentation, reporting, monitoring, and ensuring compliance are also articulated.

Consequently, there has been a significant advancement in systems and processes. For instance, ensuring ventilated storage rooms to trolleys to ensure that the waste is packed well, sent to the storage room, weighed, and sent off the CBMWTF every day.

As observed from the analysis, the processes appear to be significantly systematized in the facilities surveyed. The segregation, pre-treatment, removal, and storage process appear to be functioning. The waste generated is recorded both at the point of generation and in the storage room. There are systems for monitoring, which appear to be working reasonably well. Most of the personnel were also trained in BMW management. Their functionality appears evident because during COVID, despite an increase in the quantum, the waste was managed.

Nonetheless, challenges do remain.

Segregation

- Segregation sometimes poses a challenge. This may be due to the staff, house surgeons being careless, or the patients and their relatives being ignorant. Improper segregation leads to challenges in treating the waste at the CBMWTF. In instances of improper segregation, the HCFs re-segregation the waste. This practice is potentially hazardous. The HCFs should strengthen systems to avoid re-segregation.
- The segregation may also be a challenge due to the inadequate provision of requisite color bags. It may also be because sizes may not be appropriate given the volume of waste generated, requiring a frequent change of bags. Though the staff mentioned this as an infrequent occurrence, the fact that it was mentioned indicates a challenge.
- In Kancheepuram DH, the storage area is not well secured. Animals seemed to gain entry to the storage area, which needs to be addressed.
- Barcoding of the bags, according to the TNPCB, is still an issue. Most HCFs do not follow barcoding, which poses challenges in the management of the BMW.

Handling of waste

- The transporters mentioned that spilling is a rare occurrence. However, during the field visit, it was observed that the yellow bags were thrown in one instance, which split, and the contents fell to the ground. It was observed that the contents were swept into a waste pan collector and filled in another bag. The transporter did not treat with chemicals, where the bag split and the contents fell. The incident did indicate a need for better management in case of the spillage of the BMW.

Liquid waste management

- There are significant challenges in liquid waste management in the absence of ETP in most old HCFs. There is a need to address this.

Human resources

- Human resources are a constraint that all HCFs surveyed mentioned. The HCFs are short-staffed, impacting segregation, removal, and waste management. The TNPCB also mentioned human resource constraint, which impacts monitoring.
- Apart from the waste handlers who are usually engaged on contract, the HCF staff monitors the waste management process. They do this among their other responsibilities and perhaps do not get the needed attention. For instance, the state Nodal Officer is also a HOD in a medical college and perhaps does not find the time to monitor or undertake field visits to the facilities. He has overcome this by forming a WhatsApp group, for instance.
- Annual health check-up of staff was mentioned as an issue.

Training

- The segregation process, once learned, is quite easy to follow. The challenge is to equip the new staff, house surgeons, and others with the knowledge. Hence, there must be a continuous process of training and reorientation. This can become challenging when the key personnel responsible for BMW have other important duties.
- The orientation of newly inducted waste handlers on a contract was a challenge. It was mentioned that the agencies rarely do it. The HCFs perhaps also do not cover this category.

Administrative challenges

- There are also largely administrative challenges. This includes ensuring enough bags; ensuring that the CBMWTF collects the waste regularly and properly. In the medical colleges, it was felt that having an officer with administrative powers, such as an RMO, to manage BMW might help.

Recommendations

1. Although the process of BMW management has been systematized, challenges do remain. The challenges in the segregation provision of bags need to become more systematic. One of the reasons for this is that management and monitoring of BMW is an additional responsibility for the staff. Consequently, there are challenges in training, monitoring, addressing administrative challenges. Although the quantum of BMW generated is not significant, improper management of the waste has a huge cost. Hence, the feasibility of a dedicated team for BMW management should be considered. A dedicated team at the state level and in the facilities will help address some challenges. A dedicated team for BMW should be considered even for the TNPCB.
2. While the BMW 2016 rules pave the way for efficient waste management, it also costs. There is a need for human resources, non-chlorinated bags, recording, and reporting. However, the new process has been overlaid on an existing system without significant additional support. This may impair the efficiency that is anticipated from following the new rules. In only one of the facilities, the budget for the BMW management was mentioned as inadequate. In two other facilities, the respondents skirted the issue. In one, the budget was mentioned as adequate. However, the references to inadequate human resources delay in barcoding bags, for instance, indicate that resources are a challenge. An assessment of the resources for effective implementation of the BMW rules 2016 is needed.
3. All HCFs have BMW committees. However, most focus on procurement rather than addressing the challenges in ensuring proper segregation and management. This aspect should be strengthened in the committees in all the HCFs.
4. Training, especially for the staff engaged on contract, needs to be strengthened. These persons are usually the ones who segregate, transport, and store the waste. The HCFs should ensure that the agency that hires the contract staff trains them.
5. The barcoding of BMW waste has to be expedited for efficient management.
6. Management of liquid waste continues to be a significant challenge. Resources and means of addressing this in public health facilities housed in old buildings must be found.
7. Only one facility has made the form IV public. The other facilities, too, should ensure that the form IV is public on their website or anywhere else. This is required by the BMW Rules 2016. This needs to be considered.

Annexures

Annexure 1. Details of persons interviewed

Name of Facility	Persons interviewed	Date of Interview
Chengalpattu Medical College	Nodal Officer	September 18, 2021
	Nurse	September 17, 2021
	Nurse	September 17, 2021
	Lab Technician	September 18, 2021
	Lab Technician	September 18, 2021
	Waste Handler	September 17, 2021
	Waste Handler	September 18, 2021
Stanley Medical College	Nodal officer	September 21, 2021
	Nurse	September 21, 2021
	Nurse	September 21, 2021
	Lab Technician	September 22, 2021
	Lab Technician	September 22, 2021
	Waste Handler	September 21, 2021
	Waste Handler	September 21, 2021
Kancheepuram District Hospital	Nodal officer	September 23, 2021
	Nurse	September 22, 2021
	Pharmacist	September 23, 2021
	Waste Handler	September 22, 2021
Tambaram District Hospital	Nodal Officer	September 21, 2021
	Nurse (1)	September 24, 2021
	Pharmacist (1)	September 24, 2021
	Waste Handler (1)	September 24, 2021
CBMWTF	CBMWTF	September 23, 2021
	CBMWTF Official	September 27, 2021.
	Transporter	September 23, 2021
	Transporter	October 5, 2021.
Pollution Control Board	District Environmental Engineer	September 24, 2021
	Joint Chief Environmental Engineer	September 22, 2021
Health Department	State Health Official	September 24, 2021
	State Health Official	September 24, 2021

Annexure 2. Details of the Facility survey

Name of Facility	Date of the Facility survey
Chengalpattu Medical College	September 18, 2021
Stanley Medical College	October 1, 2021
Kancheepuram District Hospital	September 23, 2021
Tambaram District Hospital	September 24, 2021