

Biomedical Waste Management in the wake of Covid-19: Challenges and Current state of Affairs in India

Rajbir Singh Rathee

*Department of Applied Sciences
MSIT Jankapuri, New Delhi, India*

Abstract: *The prevailing crisis in the area of biomedical waste management (BMW) has been exacerbated by the ongoing Covid-19 pandemic. Proper handling of biomedical waste is of utmost importance as hazardous and infectious nature of the waste can have severe repercussions for the human life as well as the environment. Also, it poses a number of challenges for safe collection, storage, transportation and disposal of the infectious waste. In this context, Government of India laid down Biomedical Waste (Management and Handling) Rules in 1998 which have been updated from time to time as per the need of hour. Recently, Government has revised the guidelines multiple times due to rapid increase in the number of Covid-19 related cases and deaths. In this scenario, this review article discusses about: (a) the revised guidelines along with practical issues in their effective implementation and (b) the impact of Covid-19 on biomedical waste generation and challenges faced for its management in India.*

Keywords: *Biomedical Waste, COVID-19, India, Waste Management Challenges.*

Date of Submission: 06-11-2020

Date of Acceptance: 19-11-2020

I. INTRODUCTION

Following the outbreak of SARS-CoV-1 in 2002 and MERS-CoV in 2012, COVID-19 i.e. SARS-CoV-2 is the third virus in the family of coronaviruses to have affected the world in past two decades [1]. COVID-19 is highly infectious and the number of infected persons has been continuously and rapidly increasing throughout the world [2]. In order to contain the pandemic, lockdowns have been imposed across the globe; advisories have been issued to use mask and sanitizer. Apart from this face shields, gloves, shoe covers and personal protective equipment are mandatory for healthcare workers and at hotels, airports, railway stations, crematoriums and burial grounds. Except masks, all these are mostly made up of plastic. Thus, along with economic, social and health crisis, this pandemic has given birth to a new waste crisis. Due to the outbreak, additional infectious and hazardous medical waste is getting generated which includes infected masks, gloves, protective equipment, syringes, empty ampules, samples, drain bags, urine bags, body fluids-soaked cotton etc. Moreover, infected masks, gloves and other protective equipment in the households end up being mixed with other household waste and dumped to landfills without any proper treatment which poses grave danger for human and environmental health. In these circumstances, proper handling and safe disposal of infectious and hazardous biomedical waste is very challenging but extremely essential.

Biomedical waste is defined as “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 biologicals” [3]. The major sources of biomedical waste include hospitals, clinical establishments, nursing homes, dispensaries, veterinary establishments, blood banks and research institutions. According to World Health Organization (WHO), 85% of the biomedical waste is non-hazardous and rest 15% of hazardous waste includes 10% of infectious wastes [4]. Around 15-35% of total quantity of waste generated in hospitals is designated as infectious waste. If not treated properly, infectious and hazardous waste poses health risk for humans (viral, bacterial and fungal infections) as well as environment (water, air and soil pollution).

According to the annual report of 2016 published by Central Pollution Control Board (CPCB), approximately 517 tonnes per day (TPD) of BMW is generated in India. Another joint report of 2018 prepared by Associated Chambers of Commerce and Industry of India (Assocham) and Velocity, states that BMW generated in the country is 550 TPD and it is projected to increase to 775.5 TPD by 2022 [5]. With the onset of COVID-19, a large number of isolation wards, quarantine centers (institutional as well as home) have been set up which have reinforced the amount of BMW generation. The use of disposable items such as masks, PPE kits, face shields, gloves, sanitizer bottles and shoe covers etc. has led to increase in amount of waste generated per day. Though exact numbers are not available, a six-fold increase in biomedical waste generation has been estimated as compared to pre-COVID-19 times [6]. Also, not only the amount is large but the waste generated is highly infectious in nature. Given the huge population size of India, rapidly rising number of COVID-19 related

infections & deaths (as of this writing, a total of 14,84,136 cases have been reported India with 33,461 deaths [2]) and limited resources to cater their healthcare needs, proper scientific handling and disposal of BMW is the last line of defense for controlling the COVID-19 infections. Keeping this in mind, CPCB has revised the guidelines for BMW so that the waste generated, especially during testing and treatment of COVID cases, is handled in a proper scientific manner. The revised guidelines are discussed next.

II. REVISED GUIDELINES FOR BMW IN INDIA

India was one of the first countries who were cognizant of COVID-19 crisis and took proactive measures to contain the pandemic. Though Bio-Medical Waste Management Rules, 2016 [7] were already in place, CPCB issued new guidelines [8] on 18th March 2020 for safe handling and scientific disposal of BMW waste generated due to diagnosis and treatment of COVID-19 patients. These guidelines are applicable to waste generated at healthcare centers, quarantine facilities, sample collection centers (SCC), urban local bodies (ULB), state pollution control boards (SPCBs) common biomedical waste treatment facilities (CBWTFs) etc. These guidelines were revised [9] on 25th March 2020 based on the current knowledge of COVID-19 and prevailing practices for handling infectious BMW generated during diagnosis and treatment of other contagious diseases such as H1N1, HIV etc. The major objectives of revision were to include: (i) the responsibilities of the persons taking care of quarantine camps or home quarantine and (ii) to specify the duties of ULBs. The guidelines were again revised [10] on 18th April 2020 to modify the existing rules and procedures and to incorporate the responsibilities of entities managing sewage treatment plants (STP). On 10th June 2020, CPCB augmented the existing rules and published yet another set of revised guidelines [11] which touches upon almost all the aspects of guidelines issued in Revision 2. All these guidelines issued particularly w.r.t. Covid-19 are shown in Table 1.

Table 1: Guidelines issued for BMW for Covid-19 waste.

Entity	Original Guideline (issued on 18 th March 2020)	Revision_1 (on 25 th March 2020)	Revision_2 (on 18 th April 2020)	Revision_3 (on 10 th June 2020)
COVID-19 Isolation wards	<p>To ensure proper segregation of waste in separate color coded bins. Double layer bags to be used for Covid-19 waste collection.</p> <p>BMW to be collected and stored separately before handing over to CBWTF; Covid-19 waste to be collected in dedicated bin labeled with "Covid-19".</p> <p>Non-contaminated general waste should be handled as per SWM Rules, 2016.</p> <p>To maintain separate record for Covid-19 waste.</p> <p>Dedicated trolleys and collection bins to be used with a label "Covid-19 Waste" pasted on them.</p> <p>1% sodium hypochlorite solution to be used for disinfecting the Covid-19 waste containers.</p> <p>SPCB needs to be informed if any new Covid-19 ward is operated.</p> <p>Dedicated sanitation</p>	No Change	<p>If diaper is used by Covid-19 confirmed person then treat his feces as BMW and use yellow bag for its collection. If bedpen is used, wash it with neutral detergent and water, disinfected with 0.5% chlorine solution and wash it again with clean water.</p> <p>Used PPEs, which include goggles, splash proof apron, face-shield, plastic coverall and nitrile gloves etc, to be collected into Red bag.</p> <p>Used masks, shoe-cover, head-cover, semi-plastic/non-plastic coverall and disposable linen gowns to be collected in yellow bags.</p>	<p>The color coded bins should be foot operated.</p> <p>General solid waste items not contaminated with secretions of Covid-19 patient should be collected separately as per SWM Rules, 2016.</p> <p>In order to check the waste generation, non-disposable items should be used and these should be kept cleaned and disinfected.</p> <p>The wet and dry solid waste bags to be securely tied and handed over to authorized waste collector of ULB's on daily basis.</p> <p>Items like left over food, disposable plates, glass, used masks, used tissues, used toiletries, etc. used by COVID-19 patient shall become BMW and shall be segregated in yellow bag. Used gloves and plastic bottle from patients will be disposed of in red bag.</p> <p>Training to be imparted by nodal officer in local language to the Waste handlers regarding infection prevention measures, respiratory etiquettes, hand hygiene, social distancing and use of PPE, etc.</p>

Biomedical Waste Management in the wake of Covid-19: Challenges and Current state of ..

	workers to be deputed separately for BMW and general waste.			
SCC & Laboratories	Opening and operation of Covid-19 SCCs and laboratories to be reported to SPCBs. Guidelines issued for isolation wards to be applied suitably	No Change	Viral transport media, vacutainers, plastic vials, pipette tips to be pre-treated as given in BMW Rules, 2016.	No Change.
Quarantine camps/homes	Routine waste from quarantine facilities to be treated as general solid waste and to be disposed of according to SWM Rules, 2016. BMW to be collected in yellow colored bags and bins. To inform CBWFT operator for waste collection. For suspected patients in home care, BMW should be collected separately in yellow bags by CBWFT.	General solid waste from quarantine centers can either be disposed through prevailing local methods or can be given to ULB designated waste collector. BMW should either be handed at the doorstep over to authorized waste collectors engaged by ULBs or at designated deposition center established by ULBs or to the waste collector engaged by CBWTF.	Used masks and gloves from home to be disposed as general waste after keeping them in paper bag for a minimum of 72 hours. In order to avoid reuse, masks should be cut before disposal.	A nodal person should be designated by operator of quarantine camp to manage the waste and keep its record. The nodal person should use 'COVID19BWM' app to update the quantity of BMW collected on daily basis.
CBWTFs	To inform SPCBs about BMW received from Covid-19 facilities. COVID-19 waste need to be disposed-off as soon as it is received. To provide PPEs and to ensure regular sanitization of workers. To ensure dedicated vehicle (no separate label required) is used for collecting BMW from Covid-19 ward and vehicle is sanitized after each trip. Information is to be maintained separately w.r.t. handling and disposal of Covid-19 waste. To operate the facility for extra hours if required. Not to allow workers having symptoms of disease by providing leaves while protecting the salary.	No change	No Change	In order to keep a record of amount of BMW collected and disposed, CBWTF operator should register on 'COVID19BWM' App and to ensure that the Waste Handler (along with the vehicle) is also registered on the app. Training to be imparted in local language to the Waste handlers regarding infection prevention measures, respiratory etiquettes, hand hygiene, social distancing and use of PPE, etc. Sanitation workers aged more than 50 should handle non-COVID waste.
SPCBs	To maintain records of institutional and home facilities for Covid-19 in respective states. To ensure that BMW is properly collected and	If the States as well as rural areas do not have access to CBWTFs, then as per BMW Rules 2016, COVID-19 waste can be disposed of using captive facilities of any hospital.	Deep burial pits can be utilized for dumping of yellow category waste in accordance with BMW Rules, 2016.	If the amount of yellow colored Covid-19 waste exceeds the capacity of captive BMW incinerators, then HW incinerators or captive industrial incinerators may be permitted.

Biomedical Waste Management in the wake of Covid-19: Challenges and Current state of ..

	<p>disposed of in accordance with BMWM Rules 2016.</p> <p>To allow CBWFTs to work for extra hours if needed.</p> <p>Not to insist on authorization of quarantine camps.</p>	<p>To coordinate with ULBs and CBWFTs for establishment of adequate resources for collection and disposal of COVID-19 waste.</p> <p>If large amount of yellow colored COVID-19 waste is generated then HW incinerators at existing TSDFs may be permitted but separate arrangement should be in place for handling and waste feeding.</p>		<p>SPCBs should direct the ULBs to collect dry general solid waste from Covid-19 facilities in disinfected bags for disposal in waste to energy plants/ industrial incinerators/ landfills, as per the availability and requirement of the state.</p> <p>‘COVID19BWM’ web-portal to be used by each SPCB for tracking and verification of COVID-19 BMW and to upload the data on daily basis.</p>
ULBs	-----	<p>To maintain the information about each of the quarantine facilities and communicate it to SPCB.</p> <p>To engage, support and authorize the staff of CBWFTs.</p> <p>To ensure safe collection and disposal of BMW by providing yellow bags to persons managing quarantine facilities.</p> <p>To ensure door step waste collection by authorized waste collectors. In order to fulfill this objective, ULBs are expected to create teams of workers for door step collection and to ascertain that BMW is collected only by the designated staff; to provide safety equipment to the workers and to impart training for sanitization and methods for safe handling of BMW; to ensure sanitization of waste collection vehicles and bins with 1% hypochlorite solution after each trip.</p> <p>Common waste deposition facilities to be established as per SWM Rules 2016.</p> <p>To ensure that general solid waste from quarantine homes is treated in accordance with SWM Rules 2016.</p> <p>To consider the services of CBWFT as essential services.</p>	<p>ULBs may take additional measures as required by prevailing situation and should adhere to guidelines when implementing such measures.</p>	<p>To make sure that BMW and general solid waste from quarantine camps/homes/Homecare is collected separately and is not mixed.</p> <p>As a precaution, the bags consisting of general waste may be disinfected with 1% sodium hypochlorite solution before disposing.</p> <p>To create awareness about segregation of BMW and municipal solid waste generated in homes/ home care establishments.</p> <p>A nodal person should be designated by ULB for a quarantine center or an area to manage the waste and keep its record.</p> <p>The nodal person should use ‘COVID19BWM’ app to update the quantity of BMW collected daily from home quarantine facilities.</p> <p>Training must be imparted in local language to the waste handlers regarding social distancing, hand hygiene, respiratory etiquettes, use of PPEs and their disposal.</p> <p>As a precautionary measure, the bags consisting of general waste to be sterilized with 1% sodium hypochlorite solution before their collection or disposal and these bags should be disposed according to SWM Rules, 2016</p> <p>If quantum of solid waste is too high to be handled by existing staff of ULBs, professional waste management agencies may be engaged to ensure timely collection of waste.</p>
Wastewater Management			<p>Agencies managing STP should ensure that treated waste water is appropriately disinfected to inactivate</p>	

	-----	-----	coronaviruses. Operators of STPs handling the effluents from Covid-19 facilities should wear PPEs prescribed for STPs and should practice basic hygiene precautions. Treated waste water not to be utilized.	No Change
--	-------	-------	----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	-----------

In order to combat the Covid pandemic, these guidelines need to be strictly adhered to but the implementation of BMW regulations is unsatisfactory and inadequate. The challenges involved in implementation of BMW are discussed next.

III. COVID RELATED BMW CHALLENGES IN INDIA

The number of Covid-19 cases have been continuously increasing in India and every day a new record is being set up w.r.t. new cases. Due to this, the amount of BMW generated has increased many folds. In pre-Covid time, hospitals in India used to generate around 500 grams of BMW per bed per day [12]. After Covid-19 outbreak, this number has increased to 2.5kg-4kg per bed per day [12]. Due to the huge population size and limited resources, management of Covid-19 related BMW is a huge task. Several factors influence the BMW capability of a country which include existing collection, storage, transportation and disposal facilities, existing excess capacity, dominant methods of BMW treatment, policymaking and enforcement. The major challenges faced by India for Covid related BMW are as follows:

3.1 Unprecedented Nature of Pandemic

Pandemic like COVID-19 which is highly infectious and spread over such a large scale has not been observed in recent past. Therefore, arrangements are not in place to manage the huge quantity of waste generated due to COVID-19. In the wake of Covid, 2900 hospitals, 20700 quarantine centres, 260 laboratories and 1540 SCCs have been designated in India to deal with the pandemic [12]. Apart from these a large number of home isolation facilities have been set up. The amount of biomedical waste generated from these facilities provides a glimpse of the sheer scale of the problem. After the outbreak of Covid-19, in addition to health-care facilities, BMW is also generated by general population in their residential as well as public spaces.

3.2 Treatment Facility Crunch

Due to Covid-19, the amount of BMW has increased many folds. According to a report by CPCB, total 38 tonnes of BMW is generated every day in Delhi out of which 11 tonnes is Covid-19 related waste. According to an estimate by BMC, out of total 15 tonnes of BMW generated daily, 9 tonnes is Covid-19 waste. Moreover, the contaminated plastic (e.g. goggles, nitrile gloves, plastic coverall and splash proof aprons etc.) was earlier used to be sterilized, shredded and recycled but now, as per the CPCB guidelines, it is to be included in red bag and to be incinerated. Another part of problem involves organic biomedical waste which should ideally be sent to waste to energy plants but CPCB has prescribed incineration for the same. Due to these reasons, load on the BMW treatment facilities has risen sharply. India has only around 200 BMW treatment facilities. However, given the quantum of BMW, the existing facilities are utterly inadequate.

3.3 Lack of Segregation Practices

Segregation is needed in order to avoid mixing of infectious waste with non-infectious waste. The lack of segregation practices results in significant increase in the amount of infectious BMW as the mixing renders the whole mass as potentially infectious [13]. Starting from the source to the destination, the practice of segregation of BMW has been inadequate in Indian hospitals. Even if segregation takes place at source, it has been observed that waste handlers mix the wastes during collection thus defeating the purpose of segregation [14]. Covid-19 has further aggravated this problem as possibly infectious waste, i.e. discarded masks, face shields and gloves etc., are being dumped into public bins stationed for general waste. This has led to sharp increase in the amount of infectious waste which in turn has increased the pressure on waste treatment facilities.

3.4 Lack of Regulative Measures

CPCB has issued the guidelines but it lacks the adequate power to enforce the guidelines. Flouting of rules w.r.t. segregation, collection, storage, transportation, treatment and disposal is very common in India. The legal obligation is treated as mere paper formality and there is lack of awareness and motivation. The defaulting facilities generally get suspended or their contracts get cancelled but are never levied heavily for their non-compliance. No healthcare facility collects data about the quantity and the type of waste generated in its premises and the sources of waste generation. The non-availability of this information hampers the decision making regarding segregation, storage, transportation and treatment facilities requirements for the BMW.

3.5 Lack of Awareness and Training Programs

BMWM by untrained and inexperienced staff increases the prospects and risk of the infectious disease. Therefore, it should be a priority to spread awareness among health-care workers regarding potential health hazards due to improper handling of BMW. Training programs should be conducted for appropriate management and disposal of BMW. But, in India, management in most of the health-care and waste handling facilities is not aware of cost savings realized due to BMWM practices and therefore not many awareness and training programs are organized.

3.6 Financial Constraints

Funds are needed for maintain sufficient manpower and for procuring equipment, devices and disinfectants etc. Covid-19 has led to increase in the demand for manpower, materials and machinery required for waste management. Money is also needed for organizing awareness and training programs. But, in Indian healthcare system, funds are not allocated separately for the waste management purposes. As per an estimate in [15], it has been found that INR 3000–4000 per tonne of BMW is needed for its proper management. Over the years, this cost has increased due to inflation and introduction of advanced but expensive technologies. Therefore, BMWM rules are ignored due to financial considerations.

3.7 Reluctance to Change and Adoption

In India, incineration is the principle method for BMW treatment even though better methods such as autoclaving, microwave treatment and advanced chemical treatments are available. Open incineration of the BMW leads to release of harmful gases which pollute the environment and in turn affects the human health. Covid-related waste generation has resulted in increased demand for incineration and thus increase in the adverse impact on the environment. Moreover, BMW is indiscriminately thrown in open landfills and waste handlers are still working without PPEs [12].

IV. STEPS TAKEN& WAY FORWARD

The waste generated due to Covid-19 has overwhelmed the waste management facilities. On top of that BMWM guidelines are blatantly flouted due to lack of awareness, motivation and high cost of BMW treatment. The highly infectious nature of the Covid-19 waste and reports of improper handling and disposal has moved CPCB to regulate the BMWM through “COVID19BMW”, an online platform for tracking the amount of waste generated, collected and disposed of [16]. The Covid-19 facilities are required to upload real-time data for the BMW. The app facilitates the information exchange among various stakeholders and thus helps in coordination between regulatory bodies and the waste generators and collectors. Also, CPCB has mandated to impart training in local language to waste handlers regarding the safer practices for waste collection, storage, transportation and disposal. In order to encourage further action and to devise innovative solutions, COVID-19 BMW Treatment challenge has been announced under the ‘Waste to Wealth Mission’ by government in partnership with Invest India [17].

But the COVID-19 pandemic is going to stay for a while, affecting the care of all the patients and proliferating the burden on health-care facilities. To handle these challenging circumstances and to ensure proper management of BMW, technological solutions from other fields can be adapted. BMWM requires to impart knowledge about best practices in the field to those who produce the waste as well as those who handle it. To achieve this, following stringent measures can be employed:

- An inventory can be maintained both at state level and national level listing all the healthcare facilities and the amount of different types of waste generated from each of these facilities. The amount of waste disposed and method of disposal can also be recorded.
- Awareness and training programs need to be conducted for waste generators, waste collectors as well as the general public.
- Self-regulatory system should be encouraged for monitoring and implementation of BMWM methods.
- Strict legal action should be taken against ill-operated CBWTFs and health-care facilities.
- To handle the waste segregation problem, waste bins can be made smart so that it accepts only designated type of waste.
- To prevent the unintended and illegal dumping, Radio-frequency identification (RFID) can be utilized to track the source and destination of BMW. Also the amount of the waste in the waste bins can be monitored to optimize the timely collection and transportation of the waste.
- Mobile units can be employed to treat the BMW in the areas where BMWM facility is far away which increases the cost of transportation as well as chances of infection.
- In place of incineration and other traditional BMW treatment methods, advanced safer and sustainable techniques such as autoclaving, microwaves and chemical treatments etc. should be employed to alleviate the adverse effects on the environment.

V. CONCLUSION

COVID-19 is having a huge impact on biomedical waste generation and management. Revision of the guidelines for waste management is a right step to combat this pandemic. But the lack of awareness and implementation of the rules is a major hurdle in the fulfilment of this objective. Stricter measures are required to enforce the guidelines. Eco-friendly techniques as well as ICT based solutions need to be encouraged to get good results. Awareness needs to be increased among the workers, staff and citizens directly involved in BMWM. This pandemic has entwined and aggravated multifaceted humanitarian and environmental issues and therefore immediate responsive actions are required to combat it.

REFERENCES

- [1]. Wang J, Shen J, Ye D, Yan X, Zhang Y, Yang W, Li X, Wang J, Zhang L, Pan L. Disinfection technology of hospital wastes and wastewater: Suggestions for disinfection strategy during coronavirus Disease 2019 (COVID-19) pandemic in China. *Environmental Pollution*. 2020 Apr 24;114665.
- [2]. COVID, CSSE. "Dashboard by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU)". 2020. <https://coronavirus.jhu.edu/map.html>.
- [3]. Govt of India. Ministry of Environment and Forests Gazette notification No 460 dated July 27, New Delhi. 1998:10–20.
- [4]. World Health Organization (WHO). Wastes from healthcare activities. Fact sheet No. 253, *Geneva*. 2009.
- [5]. ASSOCHAM India (2018), Unearthing the Growth Curve and Necessities of Bio-Medical Waste Management in India-2018.
- [6]. Biomedical waste management during COVID-19. <https://www.investindia.gov.in/team-india-blogs/bio-medical-waste-management-during-covid-19>.
- [7]. Bio-Medical Waste Management Rules. 2016 Published in the Gazette of India, Extraordinary, Part II, Section 3, Sub-Section (i), Government of India Ministry of Environment, Forest and Climate Change. Notification; New Delhi, the 28th March, 2016.
- [8]. Guidelines for Handling, Treatment and Disposal of Waste Generated during Treatment/Diagnosis/ Quarantine of COVID-19 Patients. http://www.dpcc.delhigovt.nic.in/Guidelines_WasteHandling_COVID19.pdf
- [9]. Revision 1: Guidelines for Handling, Treatment and Disposal of Waste Generated during Treatment/Diagnosis/ Quarantine of COVID-19 Patients. http://www.dpcc.delhigovt.nic.in/Rev1_Guidelines_WasteHandling_COVID19.pdf
- [10]. Revision 2: Guidelines for Handling, Treatment and Disposal of Waste Generated during Treatment/Diagnosis/ Quarantine of COVID-19 Patients. http://www.dpcc.delhigovt.nic.in/Rev2_Guidelines_WasteHandling_COVID19.pdf
- [11]. Revision 3: Guidelines for Handling, Treatment and Disposal of Waste Generated during Treatment/Diagnosis/ Quarantine of COVID-19 Patients. http://www.dpcc.delhigovt.nic.in/Rev3_Guidelines_WasteHandling_COVID19.pdf
- [12]. India stares at biomedical waste crisis. <https://www.hindustantimes.com/india-news/india-stares-at-biomedical-waste-crisis/story-SpZrA1tutAAuYhE57p7UL.html>.
- [13]. S. Gupta and R. Boojh. Report: Biomedical waste management practices at Balrampur Hospital, Lucknow, India. *Waste Management Research*. 2006, 24: 584–591.
- [14]. A.V. Athavale, and G. B. Dhumale. A Study of Hospital Waste Management at a Rural Hospital in Maharashtra. *Journal of ISHWM*. 2010,9(1):21-31.
- [15]. A.D. Patil and A. V. Shekdar. Health-care waste management in India. *Journal of Environmental Management*, 2001, 63: 211–220.
- [16]. Central Pollution Control Board tracking COVID-19 waste disposal daily through app. <https://www.newindianexpress.com/nation/2020/jun/09/central-pollution-control-board-tracking-covid-19-waste-disposal-daily-through-app-2154065.html>. Accessed on 11th July 2020.
- [17]. <https://www.startupindia.gov.in/content/sih/en/biomedical-waste-treatment-innovation-challenge.html>. Accessed on 11th July 2020.