AN APP FOR EFFICIENT MANAGEMENT OF COVID-19 WASTE DISPOSAL BAGS

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by

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Problem Statement

To improve the existing Covid-19 waste management app to benefit people involved in the whole waste management system, including rag pickers, sanitation workers, and other frontline workers.

1. Problems in hospital waste generation
2. Problems in collection
3. Problems in transport and storage
4. Problems in disposal

Objective

This study was aimed to develop an application to ensure a smooth collection of COVID-19 disposal bags from hospitals and care centers by introducing a priority-based collection with QR stickers containing information about the bag.

Prior Artwork: Review of Literature

Biomedical waste (BMW) is distinct from ordinary municipal waste in that it poses a variety of health risks. After China, India is the world's second-most populated country and the second-worst-affected country after the United States of America by the coronavirus illness 2019 (COVID-19) (As of 9th June 2021) [1]. India is suffering serious consequences during COVID-19 due to a faulty biological waste management system and a lack of resources. BMW that is not treated or managed appropriately is leading to a high risk of infection. The careful treatment and management of BMW can help to minimize hospital-acquired infections and reduce disease transmission rates. Furthermore, neglected or rudimentary BMW handling is inconvenient and reduces patient satisfaction. According to the Central Pollution Control Board (CPCB) data in 2018, the overall BMW produced in India was 517 tons per day in 2016 and roughly 501 tons per day in 2015. Approximately 4–5% remained untreated [2]. According to the CPCB's annual report for 2018/2019, 557 tonnes/day of BMW were produced in 2017, with 517 tonnes/day being treated. There are 198 certified common biomedical waste disposal facilities (CBMWFs) in India, with another 28 under construction.

Process for handling and managing the BMW in India

Biomedical waste is not treated in the same way as municipal garbage. Under the Ministry of Environment, Forest, and Climate Change (MoEFCC), the Central Pollution Control Board (CPCB) is the main body for monitoring the country's BMW management operations. Each state has its own state pollution control board, which monitors and regulates BMW activity in that state and reports its results to the CPCB. The country has a firm rule for onsite segregation of generated BMW, incinerators, storing, transporting, and disposing of them as per the

Ministry of Health and Family Welfare's biological waste standards. These recommendations must be followed by all minor clinics, diagnostics, laboratories, nursing homes, hospitals, and other healthcare or organizations [3-4]. Previously, the country had ten separate waste sorting categories. It was later divided into four classes to make segregation easier. Infected or potentially infected waste is labeled yellow, seemingly non-infected, and recyclable waste is designated red, sharps and small metallic items are designated white, and waste made up entirely of glass is designated blue.

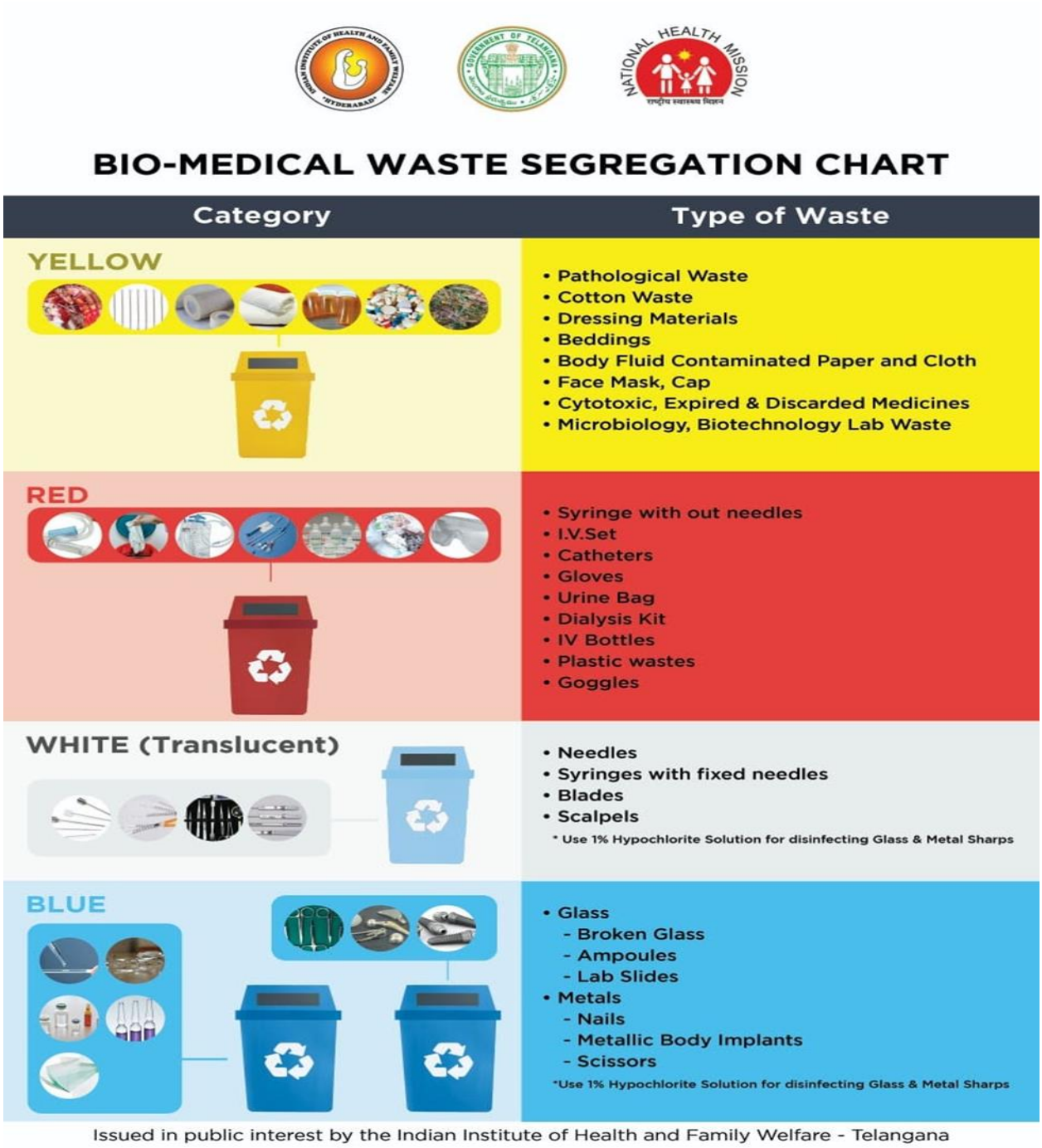


Fig. 1 Biomedical waste segregation chart

Waste is separated and stored in a well-ventilated location before being transported to a disposal facility (also known as a joint biomedical waste disposal facility) for treatment and disposal. The garbage should be delivered in a specially designated closed vehicle with a GPS tracker. According to the waste type, the BMW in the Common Bio-Medical Waste Treatment Facilities (CBMWFs) is subsequently handled, disinfected, and transferred for recycling, incineration, or landfilling [5]. Healthcare establishments and disposal facilities that violate these criteria will face fines. Despite the government's strict restrictions and liability, the country records many infractions cases.

Existing problems of BMW and crisis during COVID-19 pandemic

COVID-19 has the most significant impact on the most populated cities, such as Delhi, Mumbai, Bangalore, Chennai, and Hyderabad. According to data released by NDTV on 18th September 2020, the country produces a significant volume of COVID-19-related biological waste (over 100 tonnes per day) [6]. Maharashtra is responsible for roughly 17% of the total COVID-19-related BMW. The national daily waste generation rate has already risen to approximately 850 tonnes per day [7]. Table 1 provides information on the monthly creation of COVID-19-related BMW in numerous Indian states (from June 2020 to December 2020). Following the increase in pandemic cases, the average creation of COVID 19-related biological waste in the country increased from 75 tonnes per day in March to 203 tons per day in May, according to the Central Pollution Control Board (CPCB) [8].

In April, the average monthly production rose to 139 tonnes per day, up from 75 tonnes in March. The matching figure as of 10th May was 203 tonnes per day. On 10th May, peak production of roughly 250 tonnes per day was reported. According to CPCB projections, the last peak in 2020 was 180 to 220 tonnes per day. The country's infrastructure and human resources are insufficient to accommodate this massive influx of BMWs. 198 CBMWFs and 225 captive incinerators were insufficient to dispose of 700 tons of garbage each day. This additional BMW wreaked havoc on BMW's disposal. To meet this demand, BMW management employees are putting in more hours. Moreover, the BMW generation has been increasing, resulting in inadequate segregation on the disposal site and enhancing the environment's risk. In addition, insufficient safety measures for BMW employees continue to be a vital issue in the Indian scenario. Around five million sanitation workers are currently executing their duties and cleaning the country, and these laborers (Cleaning service people) are also processing biological waste. Unfortunately, they do not have access to the appropriate personal protective equipment. During the second wave of the pandemic, the generation of

Covid-19-related biomedical waste (BMW) increased significantly, according to a recently released report titled "State of India's Environment in Figures 2021". According to a report: In April 2021, India created 139 tonnes of Covid-19 related biomedical waste per day as it prepared for the second wave. In May 2021, the figure had risen to 203 tonnes per day, a 46 percent increase. The numbers presented by the Centre for Science and Environment (CSE) on World Environment Day also illustrate the issues caused by inappropriate biological waste disposal during the Covid-19 pandemic [9].

Table 1: State-wise COVID-19 biomedical waste generation details (till 10/05/2021) [8].

S No.	Name of States/UTs	COVID 19 BMW (Tons/day)	No. of CBWTFs engaged
1	Andaman & Nicobar*	0.014	0
2	Andhra Pradesh	9.99	11
3	Arunachal Pradesh*	0.112	0
4	Assam	0.52	1
5	Bihar	1.06	4
6	Chandigarh	1.91	1
7	Chhattisgarh	2.76	4
8	DD & DNH	0.065	1
9	Delhi	18.79	2
10	Goa*	0.45	0
11	Gujarat	21.98	20
12	Haryana	13.11	11
13	Himachal Pradesh	2.27	2
14	Jammu and Kashmir	2.49	2
15	Jharkhand	0.56	4

16	Karnataka	16.91	26
17	Kerala	23.71	1
18	Lakshadweep	0.01	0
19	Madhya Pradesh	7.32	13
20	Maharashtra	19.02	29
21	Manipur	0.13	1
22	Meghalaya	0.25	2
23	Mizoram*	0.033	0
24	Nagaland*	0.074	0
25	Odisha	6.65	5
26	Puducherry	1.81	1
27	Punjab	4.00	5
28	Rajasthan	4.98	8
29	Sikkim	0.015	0
30	Tamil Nadu	13.57	8
31	Telangana	4.96	11
32	Tripura	0.02	1
33	Uttarakhand	1.98	2
34	Uttar Pradesh	15.91	18
35	West Bengal	5.72	6
	Total	**203 Tons/day**	**198**

*As per earlier information provided by States/UTs

Primary intended beneficiaries

During the increasing number of cases of the COVID-19 pandemic in May 2021, single-use plastics increased tremendously. The entire waste management system was under tremendous pressure along with the health care facilities. Central Pollution Control Board (CPCB) of the Ministry of Environment, Forest and Climate Change, India issued guidelines for Handling, Treatment, and Disposal of Waste Generated during Treatment/ Diagnosis/ Quarantine of COVID-19 Patients.

Mind Map

The mind map (Fig. 2) was prepared in-depth search for the root causes of the problem and related aspects of waste management. For each node of the diagram, represent a statement and its associated results were analyzed. The problems that were thought upon were the near-collapse of the waste management systems in different countries. An app already exists which connects the waste collectors to the hospitals. Still, the van capacity is often compromised many times, resulting in waste collection in lower quantities or sometimes overloading resulting in dropping bags midway through the transportation.

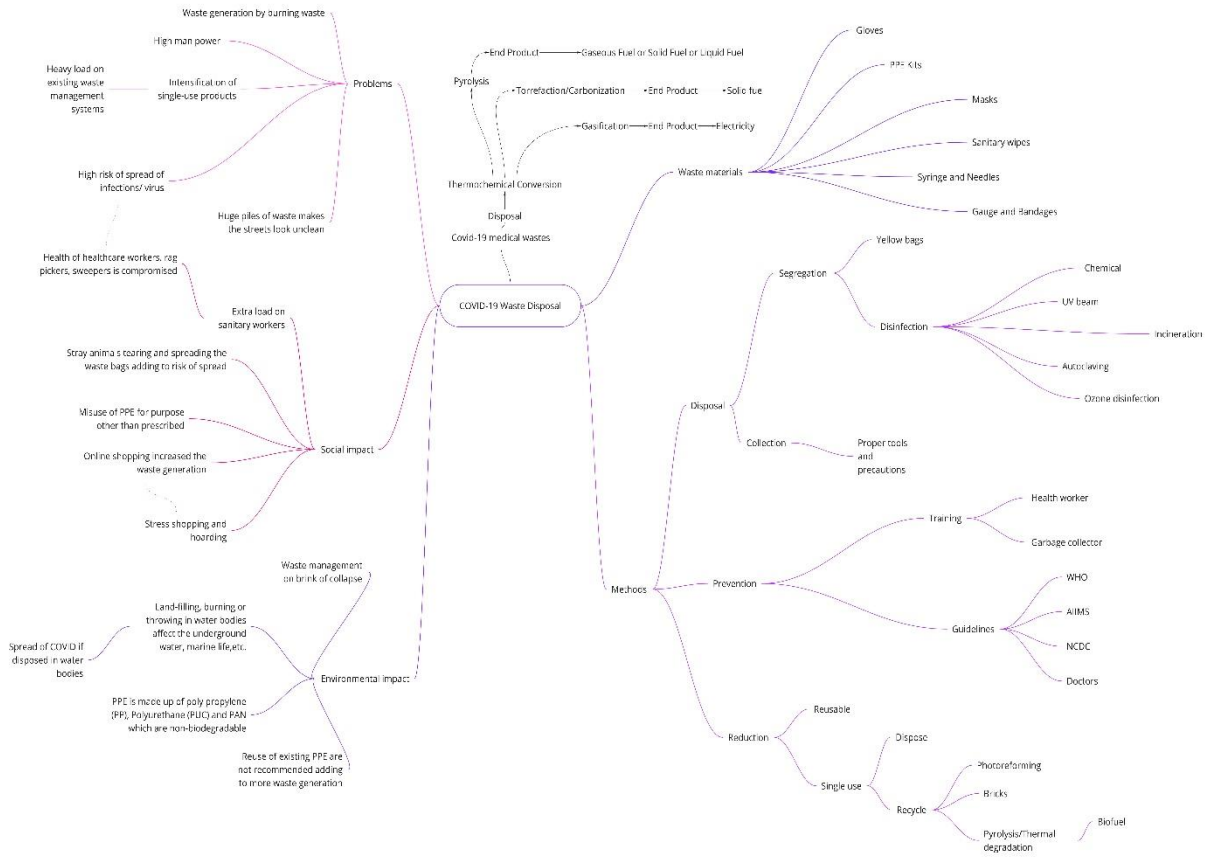


Fig. 2 Mind map

The people who are most affected by improper COVID waste management are the health care workers, people working at the disposal sites, stray cows, dogs, birds (face masks entangled in their legs), and aquatic life. Existing solutions of disposal of waste is by incinerating the plastic waste and putting the domestic in landfills. As the home quarantine increased because of the shortage of several beds in cities like Mumbai, Delhi, and other metropolitan areas, the COVID-19 waste was getting mixed up with domestic waste. As a result, it ends up in landfills, which would take many years to get degraded.

A user survey was conducted of a few questions regarding the awareness of covid waste disposal methods, and we received few responses.

- 28 out of 86 knew about disposal bags at home.
- 19 out of 86 knew about yellow bags for biomedical waste.

From the data collected from multiple cities across the nation, it was observed that more than 20% of people were unaware of the management system, which shows a lack of awareness.

The following pictures are emphasized that there is a dire need for a proper waste management system.











The brainstorming session (Fig. 3) was carried out to improve India's existing COVID-19 waste management methods.

Fig. 3 Brainstorming session (first)

The following certain limitations were found out as a result of brainstorming session and literature review:

- Excess waste generation failed waste management
- Garbage dumped on roads
- Stray animals tearing bags and spreading waste in search of food
- The mixture of COVID-19 waste with domestic waste
- Increase in the number of rats infestation

- The burning of waste was limited, resulted in the accumulation of a large volume of garbage at the dumped sites.

Another brainstorming session (Fig. 4) was carried out to improve the various strategies to tackle the problems mentioned above.

Fig. 4 Brainstorming session (second)

Field Research Briefing

Excess waste is being generated, failing the existing waste management system.

Wastes being dumped on the road increases the risk of the spread of the virus and reduces the aesthetic value of any locality.

Improper handling of waste causes stray animals to tear up the bags in search of food. A rat infestation has increased.

Problems in hospital waste generation

- Mixing of COVID-19 waste with regular waste.
- Disobeying the government guidelines on Covid-19 waste by the hospitals.
- Some Hospitals are not using the COVID19BWM app.
- Implementing the bag's color-coding regulations for covid-19 waste is challenging for hospitals.

Problems in transport and storage

- Less garbage collection as the truck collection capacity is limited
- More labor is required. Risk in the increased number of infections.
- 72-hour window (3 days) as recommended by CPCB and other health authorities is not maintained.

Problems in collection

- No proper safety equipment
- Garbage dumped on roads. Uncleanliness. Reduces aesthetic value of any locality.
- multiple trips for waste collector vans
- No fixed waste collection timing.

Problems in Disposal

- Stray animals rip bags, resulting in the dispersal of garbage.
- Mixture of COVID-19 waste with domestic waste. Resulting in plastic getting dumped into landfills.
- Burning of waste was limited and resulted in accumulation of large amounts of waste at the disposal collection sites. Majority of it was dumped in landfills.

Prototype 1

Prototype Model

After contacting seven hospitals in 2 different states, We identified the two main problems that were-

1. Waste generators mix non-covid waste and covid waste in the same bag resulting in no proper segregation.

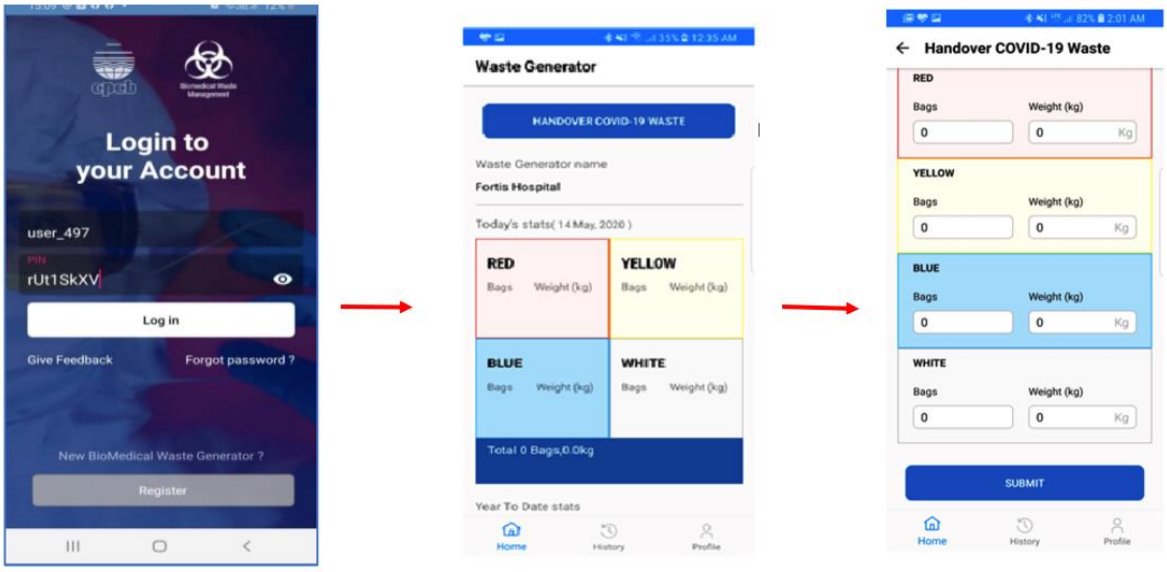
2. Excess waste generation failed waste management, like the burning of waste was limited and resulted in the accumulation of large amounts of waste at the disposal collection sites. The majority of it was dumped in landfills or deep burial pits.

A probabilistic emergency disposal model was created when the waste produced was more significant than that which can be disposed of in an incinerator or by burning, so the remaining waste was deposited in burial grounds /landfills, increasing the spreading of the waste virus.

Prototype Detailing

Step 1 Waste Generation

All The Waste generators are allotted a fixed time slot in a day (E.g. Till 10:00 A.M). They have to request the waste disposal and fill out all the necessary details like type of bag, weight, etc., on the app itself.



STEP 2 Priority sorting of waste and allotment of the priority number

A sorting algorithm is used to sort the generator's request, and based on that priority number is allotted. For sorting algorithm input taken is equal to:-

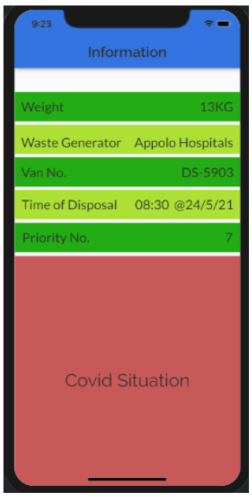
$$\frac{\textit{No. of Covid Patients}}{\textit{Total Weight of Bags}}$$

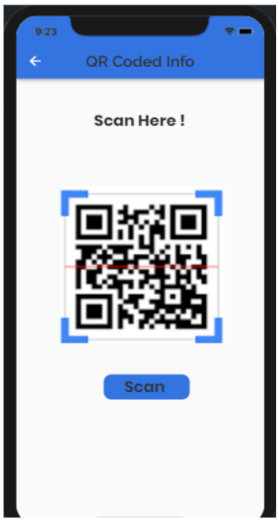
8
5
2
6
9
3
1
4
0
7

STEP 3 QR code sticker allotment

After getting the priority no.s, the data is displayed to ULBULB'sLB will print the QR Codes, and vehicle allotment takes place as to which vehicle will go to which waste generator with the QR coded sticker. The printed QR code contains all the necessary information about the waste.

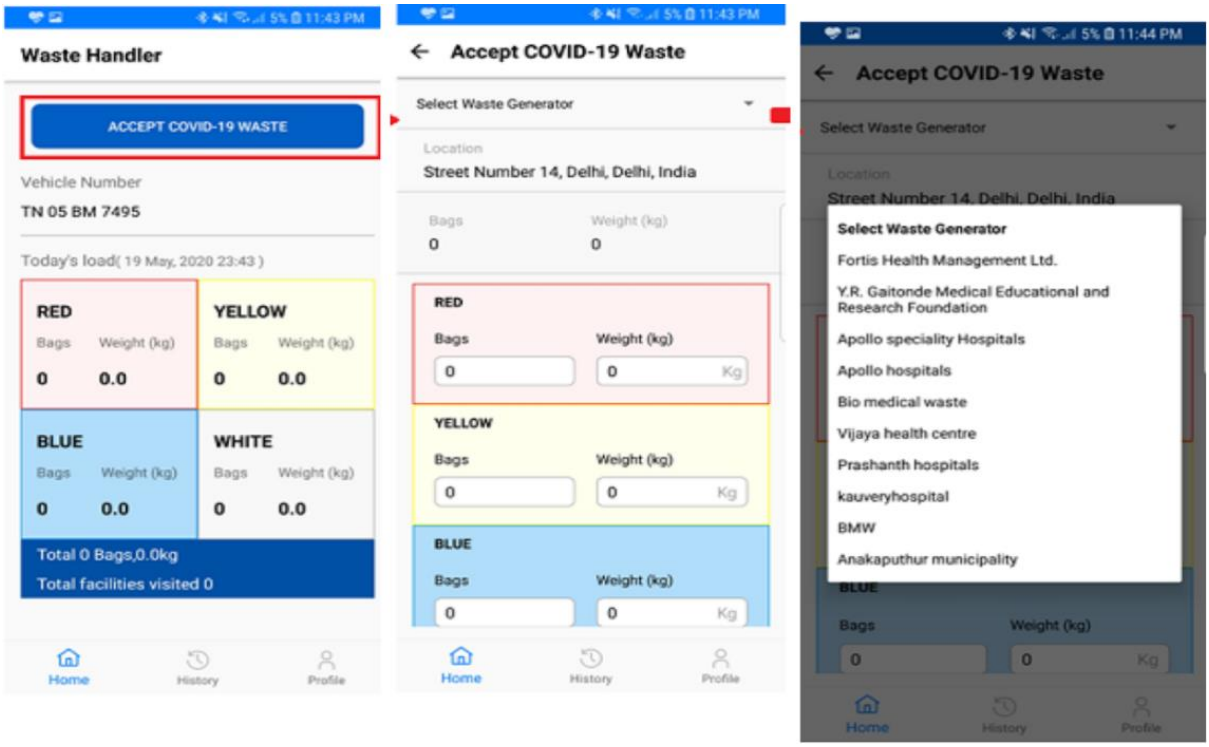
- Weight of bags
- Waste generator
- Time of disposal
- Van collection no.
- Priority no.
- Covid situation





STEP 4 Accepting the waste

After reaching the allotted facility, the van driver will accept the waste and put a QR code sticker on it and take it to the nearby facility for further procedure.



Step 5 Waste disposal

After reaching the facility, the QR code is read when the waste is deposited, and the facility's time is recorded.

After sanitization, non-covid waste must be isolated for 72 hours before being treated as solid trash. By scanning the QRcode and noting the time, the 72-hour time window can be maintained.

Pros

- Automation of Process thus involves less labour and spreads less infection
- Better management at CBWTF which removes most virus infected waste
- Enhanced Safety measures for collecting waste from high priority area

Cons

- If someone is following guidelines his priority may become low
- Difficulty for CBWTF people to find prioritised No. in 1001000's bags
- App won't work if the government hospital data is not available.
- Missed Time Slot
- Not applicable in village areas/ rural areas with no incineration facilities

Failure of Prototype 1

Prototype 1 was based on a logical idea that was ethically and scientifically wrong. Priority of high infection and low infection was wrong and

Developmernt of Prototype 2

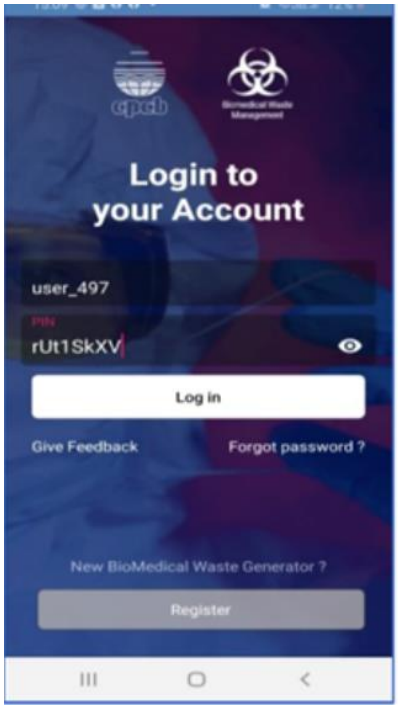
Prototype Model

The model was designed keeping in mind the drawbacks faced in prototype 1. The prototype can be explained in 5 steps. First, the model is based on providing a fixed and automated system in the covid waste mechanism. Our main aim is to reduce manual labour in the process, thus decreasing virus spread.

Prototype Detailing

Step 1 Waste Generation

All The Waste generators are being allotted a fixed time slot in a day (E.g. Till 10:00 A.M). Till this time, they have to request the waste and its details on the app itself. Through the below process, the Waste Generator registers waste and its details [10].

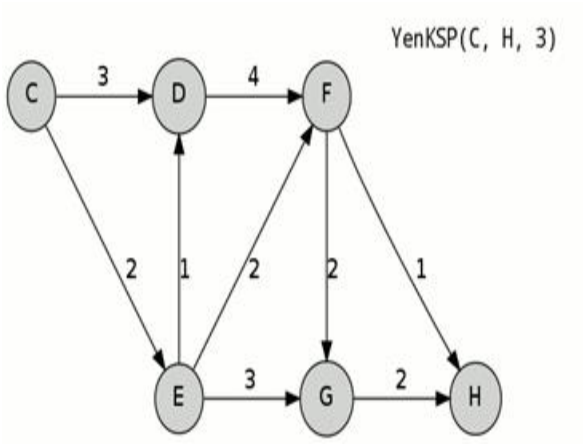


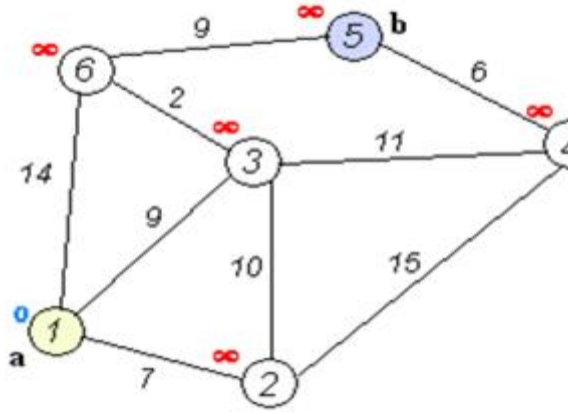
Step 2 Algorithm Scheduling

After collecting waste details, our algorithm works on Dijkstra's weighted shortest path algorithm [11].

Working of Algorithm

- The algorithm takes input as Waste generator Location, Waste generated, No. of vans available, and VanVan'spacity.
- Then it creates the shortest path available for each van keeping the constraint that Van collection capacity < total waste collected by the truck.





The Graphic version of the algorithm is represented above. The code is also available [12].

Step 3 Sticker Allotment

Our algorithm has allotted waste collection vans to different waste generators and displayed corresponding QR-coded stickers on the login interface of the Urban Local Body(ULB). Thus, the urban local body prints these unique stickers corresponding to a Waste generator and the Number/type of bags. The latter then hands them over to the Waste Vehicle Drivers.

QR Coded Information

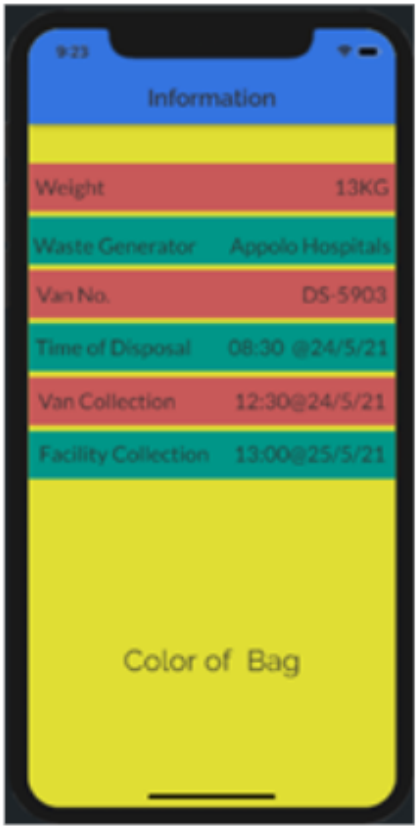
The QR Code contains the following information-

- The total weight of the bags
- The name of the Waste Generator
- The collection Van no.
- The time of disposal of the bag by the Waste Generator
- The time of bag collection by the Waste Collection Vehicle
- The time of bag deposit into the storage facility / CBWTF by the Waste Collection Van

- The color of the bag

The QR coded sticker

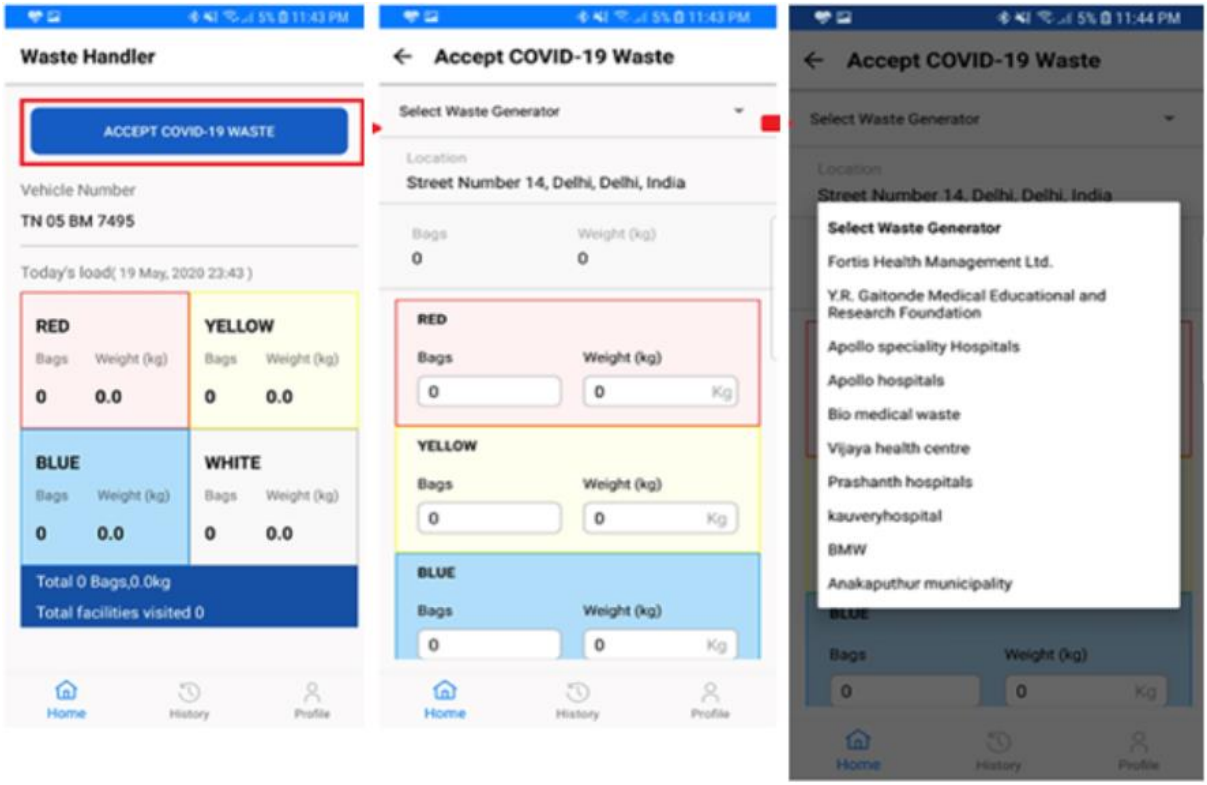
QR Code Sticker



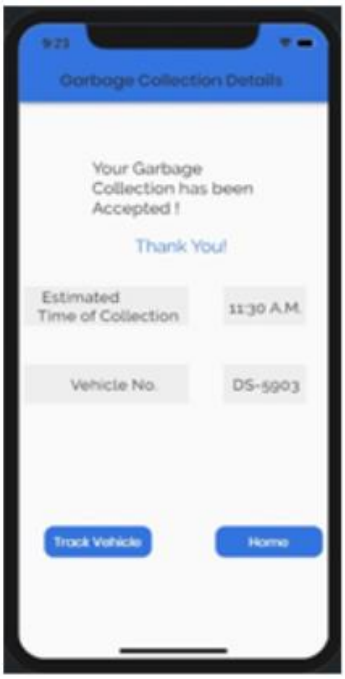
QR Coded Information

Step 4 Waste Collection

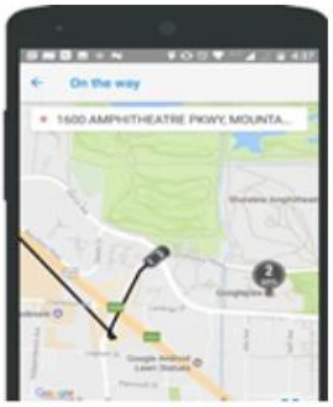
- After successfully distributing QR-coded stickers and waste generator allotment to the Collection van, the waste generator accepts the collection request of allotted waste generators on the app.



- The waste generator gets notified after acceptance and can see
  a) Waste Collection Van No.
  b) Estimated Time of Collection
  c) Live Tracking of the Collection van



Waste Generator Acceptance



Real-Time Tracking

- After collection of waste, the vehicle driver puts the QR Coded sticker onto the bag.
- The bag is then deposited into the Storage facility / Common Bio-medical Waste Treatment and Disposal Facility (CBWTF) by the collection van.

Step 5 Waste Disposal

- On the deposition of waste into the CBWTF, the QR code is scanned, which inputs the time of arrival in the facility.
- The non-covid waste requires 72 hours of isolation after sanitization for treating it as solid waste [13]. The 72 hour time window can be maintained by scanning the QRcode and noting its time.

User Review and Feedback

Seven hospitals in 3 different cities were contacted and interviewed via a telephonic conversation about the prototype. We also interviewed 3 Covid waste collectors in 2 cities in person. After getting the review, a critical analysis of the designed product was done as pros and cons.

Pros

- Automation of Process thus involves less labor and spreads more infection
- Better management at CBWTF, which removes most virus-infected waste
- No multiple trips for waste collector vans
- A fixed daily timing system
- Better tracking of COVID waste
- Reduces Human Error
- Saving wastage of resources
- User can track waste collection
- Entry of bag in every checkpoint
- 72 Hour disposal window is maintained

Cons

- Missed Time Slot Issue
- The behavioral problem and technological problem for the collectors

- Not applicable in village areas/ rural areas with no incineration facilities

Conclusion

The solution provided in the two prototypes focused on different aspects of the problem statement. Prototype 1 was based on a logical idea that was ethically and scientifically wrong. Prototype two was designed to effectively track the waste generated and its segregation from domestic waste. During the peak time where India broke records in the number of covid cases averaging over three lakhs per day resulted in enormous strains on the medical/ Health care systems. The waste generated was massive, and incineration was under tremendous pressure. As the beds and hospital centers were filled with COVID-19 patients, rickshaws, cartwheels, and stretchers on wheels became new beds for the people. Home isolation for people with mild symptoms of COVID-19 was recommended by AIIMS and other health authorities in India. This results in the mixing of masks and gloves used by COVID infected personnel into domestic waste.

With a survey conducted, people having aged-26 were not aware of the yellow disposal bags for COVID waste. Therefore a priority-based collection application was suggested based on the assumption that waste generated by more infected people should be given priority for burning than the one caused by fewer people. The waste collection vehicle (van) will collect garbage from allotted hospitals in a given time. Prototype 1 failed as the assumption was scientifically flawed. Prototype 2 had no priority-based collection. It focuses on efficient tracking of the waste and efficient filling of the Van capacity. Many further improvements, such as increasing the thickness of the plastic bag to increase its strength, use of animal repellent chemicals, the introduction of a conveyor belt at the incineration facility, could be implemented.

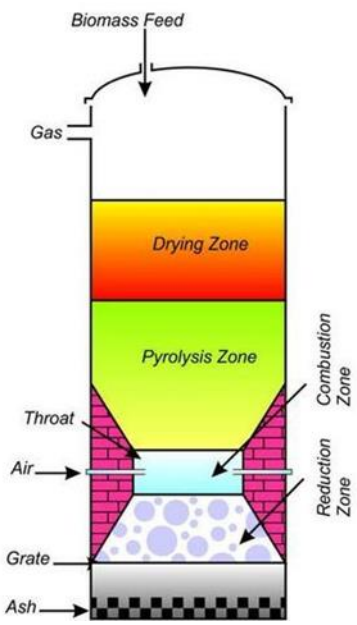
Further Recommendation:

In Prototype 2, some disadvantages were identified after discussing with the users. The following points were suggested to solve each of these points:

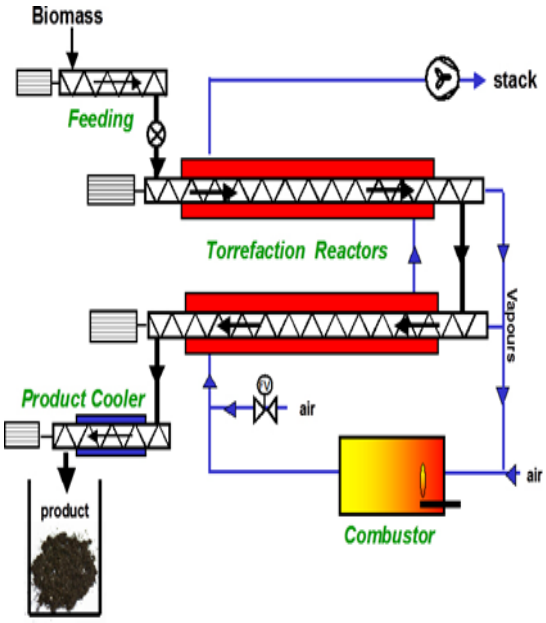
- **Missed Time Slot Issue**: Can have multiple buffer time-slots so that the Van driver can utilize that time in traveling, breaks, etc. If no one covers one slot, the next driver will get to do that job first.
- **The behavioral problem and technological problem for the collectors**: The solution for this problem is awareness and education regarding the device, technology, the potential harm the garbage can cause, etc.

- **Not applicable in village areas/ rural areas with no incineration facilities:** Still, behavioral research is being done to improve the incineration facilities in rural areas. Devices like Gasifiers and Torrefaction methods can be utilized to generate energy.

  These two methods can be used to generate energy from waste. In gasification, generated producer gas can be to generate electricity or heat or other forms of energy. Torrefaction uses a fixed bed reactor for burning waste for energy generation. There is a need to carry out more research to develop the small plant for villages and rural areas. Some areas in Bihar and the East coast of India have been utilizing this method to generate electricity for the whole village, which helps them to meet their energy requirements in agriculture, education systems and other facilities.



(a) Gasification Method [14]



(b) Torrefaction Method [15]

Other suggestions:

- Improvements can be made in prototype 2 in the small-time complexity algorithm.
- Other automation solutions like installing conveyor belt in the incinerating facilities
- Increasing thickness of the disposal bag to avoid tearing and use of double bags, etc.
- Add chemicals like ammonia or inbuilt smell in collection trucks to make bags animal repellant.

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