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Original Research Article

Bio-medical waste management practices of personal protective equipments pre and post Covid -19: A cross-sectional study

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ABSTRACT

Background: Covid-19 pandemic and the influx of polypropylene Personal Protective Equipments have created a new challenge in segregation and disposal of plastics. The general guidelines for disposal and segregation during the pre-covid period has emphasised recycling.
Objective Our aim was to find out whether the PPE kits were adequately recycled during the pandemic and whether any toxic fumes were produced while incinerating them, resulting in any environmental hazard.
Materials and Methods: We collected the data on Bio-medical waste disposed in the entire Kerala state from 2017 to 2022. It was divided into pre-covid and covid-relaxation period. The amount of biomedical waste recycled and incinerated were measured and compared. The amount of new cases and its correlation to recycling and incineration was done. The stack emission data during pre-covid and covid-relaxation period was collected and compared.
Results: Our results showed that during the covid-relaxation years there was a significant increase in incineration as compared to the pre-covid years. The incineration was much more when compared to recycling. Fortunately the stack emission didn't show any toxic fumes and environmental hazards.
Conclusion: We concluded that recycling of PPE was not adequate during covid-19 pandemic. Health care system should take more steps to be compliant with national guidelines. Awareness has to be made to decrease in the use of these disposable materials and shift to more eco-friendly materials or reusable materials.

1. Introduction

The combination of textile technology and medical sciences led to the emergence of a new field called medical textiles or healthcare textiles. They have contributed immensely towards healthcare hygiene and personal protection, especially in the last 2 years of the Covid-19 pandemic. Though many natural and synthetic materials are utilized, polypropylene and polyester are the most widely used for manufacturing Personal Protective Equipment (PPE), surgical gowns, and drapes.

During the Covid -19 pandemic, Central Pollution Control Board (CPCB) of India issued guidelines for collection and disposal of medical textile waste according to the biomedical waste (BMW) management rule 2016.[1] This rule has been updated to promote disinfection and recycling of these waste products to the best possible extent.

Polypropylene and polyester, though biologically inert and non-toxic, when burned will produce water (H2O) and carbon dioxide (CO2) as major products and aliphatic and aromatic toxic hydrocarbons as minor products.[2] Our aim was to find out whether medical textiles especially Personal Protective Equipment (PPE) were recycled adequately during Covid-19 pandemic. The stack emission sample data

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for 2019 and 2021were collected to find out the parameters of the fumes that are emitted into the atmosphere and the possibility of any environmental hazard.

2. Materials and Methods

National Institute for Transforming India (NITI AAYOG) has selected Kerala state as having the best health care system in the country during the Covid-19 pandemic (2020 –2021). Kerala state is the only large state in the country where the entire Bio Medical Waste (BMW) is disposed off at one facility: IMAGE. (Indian Medical Association Goes Eco-friendly). IMAGE also has a barcoding system that enables it to correctly segregate, transport, track and dispose the BMW of the entire state. Therefore we decided to take Kerala state as the representative sample of the entire country.

Waste segregation was done at the source into color-coded bags in which the red bag goes for recycling and the yellow bag goes for incineration (Figure 1). We collected the data on the monthly disposal pattern (recycling and incineration) of BMW from Jan 2017 to April 2022. IMAGE stringently follows the barcoding system mandated by the biomedical waste management rule 2016 and revised CPCB guidelines. The bar code is scanned at the collection area and disposal area. The code gives information on the bag color, supplier, distributor, territory, and unique identity of the bag. All bags are individually weighed and entered into the data bank along with the corresponding bar code. The data regarding disposal of the BMW and stack emission data was collected after obtaining consent for the study from the IMAGE general body meeting conducted in April 2022.

We divided data into 3 periods, pre-covid (Jan 2017 – to March 2020), covid lockdown (April 2020 – September 2020) & covid relaxation period (Oct 2020- April 2022). We recorded the BMW recycled and incinerated in the entire state during this period. The covid lockdown period was excluded from analysis because of a lack of clarity regarding BMW management and constant revision in the guidelines for covid-19 pandemic.

Through the Right to Information Act of the Indian Government, we got the data regarding new covid cases from March 2020 to April 2022. May 2021 showed the maximum number of Covid-19 cases. We correlated this data with the BMW disposal pattern during the pre-covid and covid relaxation time periods.

3. Statistical Analysis

Data were analyzed in SPSS version 21. Student'sT-test and Pearson correlation test were used for statistical analysis.

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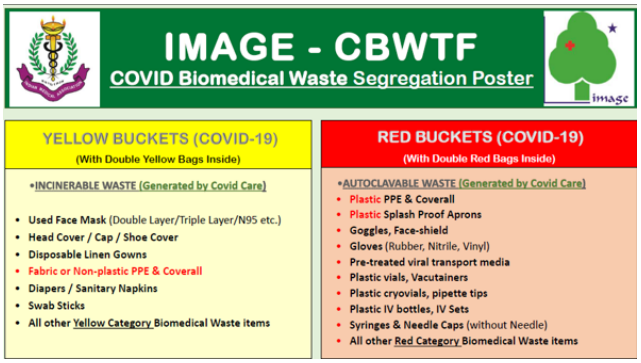

Fig. 1: Revised biomedical waste segregation guidelines 2021

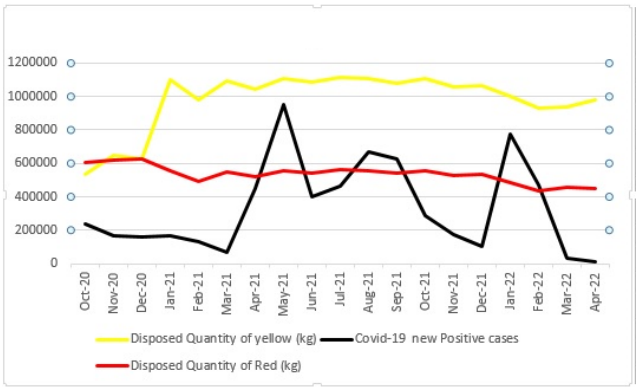

Fig. 2: Covid relaxation period pattern of recycling, incineration and new cases

4. Results

During the three pre-covid years, Kerala incinerated 20622 tons of BMW, with an average of 572 tons every month and recycled 12899 tons with an average of 358 tons per month. The ratio of recycling to incineration was1:1.5 and showed a significant difference (p-value<0.05). In the Pre-Covid times, incineration was considerably more when compared to recycling of BMW. The total amount of BMW incinerated and recycled from January 2017 to April 2022 is shown Tables 1 and 2.

During covid relaxation period, the total BMW burnt was 18602 tons at a monthly average of 979 tons. This was a two fold increase in the incineration of BMW from the pre-covid situation and it was significant (p value<0.0001). This was equivalent to almost 90% of the total waste incinerated in 3 years during the pre-covid period. At the same time, total BMW recycled during the covid relaxation time was 10170 tons at a monthly average of 535 tons. The recycling increased significantly during covid relaxation when compared to the pre-covid times.(p-value- 0.05). However, the incineration to recycling ratio during pre-covid period was significantly less when compared to that of covid relaxation time period (p value<0.001). This suggests

Table 1: Pre Covid period waste generation

Month	**2017**		**2018**		**2019**	
Container	Red (In tons)	Yellow (In tons)	Red (In tons)	Yellow (In tons)	Red (In tons)	Yellow (In tons)
January- March	941.989	1402.395	1032.533	1723.234	924.557	1794.178
April-June	1031.96	1597.826	1076.790	1689.164	1048.354	1692.266
July-September	1077.72	1702.727	1151.004	1822.996	1213.068	1789.455
October-December	1058.06	1710.309	1116.182	1860.941	1227.655	1837.323
Total	4109.75	6413.257	4376.509	7096.335	4413.634	7113.222

Table 2: Covid relaxation period waste disposal and new cases

Month	**Recycled(In tons)**	**Incinerated(In tons)**	**Covid New Cases**
October-December 2020	1851.746	1799.958	564827
January-March2021	1594.242	3181.656	363651
April-June 2021	1622.465	3237.920	1799581
July-September 2021	1653.129	3299.176	1756693
October-December 2021	1621.350	3235.754	566319
January-April 2022	1828.055	3847.676	1294551
Total	10170.987	18602.140	6345622

Table 3: May 2021Covid waste

State	**Tons /Day**	**No: CBWTF**
Andhra	9.99	11
Bihar	1.06	4
Delhi	18.79	2
Gujarat	21.98	20
Haryana	13.11	11
Karnataka	16.91	26
Kerala	23.71	1
Maharashtra	19.02	29
Odisha	6.65	5
Tamil Nadu	13.57	8
Uttarpradesh	15.91	18

Table 4: 2019 stack emission data

No:	**Parameteres**	**Unit**	**May-19 5 incinerators**	**Oct-19 5 incinerators**	**Nov-19 5 incinerators**	**Dec-19 5 incinerators**
1	Temperature	°C	62.4	71.2	71.4	75.25
2	Velocity of Gas	m/sec	5.9	6.14	6.132	5.89
3	Volume of Gas	Nm^3/Hr	5332.2	5413	5961	5123.75
4	Particulate Matter	mg/Nm^3	35.14	34.26	36.86	36.075
5	Hydrochloric Acid	mg/Nm^3	6.59	6.52	6.52	6.92
6	Oxides of Nitrogen	mg/Nm^3	19.26	19.58	20.88	20.725
7	Volatile organics	mg/Nm^3	below detecton	below detection	below detecton	below detection
8	Combustion Efficiency	%	99.38	99.52	99.5	99.48

Table 5: 2021 Stack emission data

No	Parameters	unit	**Feb-21** 4incinerators	**May-21** 3 incinerators	**Sep-21** 5 incinerators	**Dec-21** 6 incinerators
1	Particulate Matter	mg/Nm^3	23.6	18.06	18.38	22.38
2	Hydrochloric Acid	mg/Nm^3	2.7	2.23	3.07	4.39
3	Oxides of Nitrogen	mg/Nm^3	13.15	13.8	18.54	32.51
4	Volatile organics	mg/Nm^3	below detection	below detection	below detection	below detection
5	Combustion efficiency	%	99.65	99.3	99.5	99.61

that, although there was a significant rise in incineration during the Covid times, the amount of BMW recycled was more or less constant suggesting that recycling did not increase significantly as expected.

Also, the increase in incineration and recycling during the covid relaxation period was not directly proportional to the fluctuation in the new cases reported (Table 2 and Figure 2). May 2021 also showed the highest number of new cases reported. From December 2020 when the new cases increased, the incineration increased but the recycling did not increase. Similarly, during the omicron wave that started in December 2021, the incineration numbers remained steady while recycling numbers came down. Though there was a substantial increase in incineration, it did not follow the same trend with respect to new cases (correlation coefficient r-value 0.15, p 0.98). Kerala state had produced the maximum Covid 19 BMW in May 2021 (Table 3) ie, 23.71 tons/ day (11% of the total covid waste of India). While in the year 2021 the total biomedical waste incinerated was 12954 tons (35.5 tons per day) and recycled was 6491tons (17.7tons/day). This increase is seen in the amount of incineration and not in recycling. This data shows that proper recycling was not carried out during the covid 19 pandemic.

The stack emission sampling data regarding the emission of any toxic fumes from incinerators were collected in 2019 and 2021. (Tables 4 and 5). Hydrochloric acid, oxides of nitrogen, and volatile organic compounds were within normal limits and did not show any change during the pre-covid and covid relaxation period. Five incinerators were functional in 2019. But, May 2021 showed only 3 functional incinerators. Four more new incinerators were added on by end of December 2021 with a stack diameter 0.90m.

5. Discussion

India has the second-largest population in the world. Kerala state is the the 13th largest state in the country contributing to 2.6 percent of the Indian population. Kerala state had implemented a triple lock containment strategy which was found to be a very successful model in fighting Covid 19 pandemic.[3] The state treated 65,41,728 new patients from January 2020 to April 2022. Strategies and challenges in Kerala's response to the initial phase of the Covid-19 pandemic were also well appreciated,[4] though the inappropriate reporting of the mortality rate was criticised by Karthik Natashekara through Benford's law analysis.[5]

Biomedical waste management of the entire Kerala state is done by a non-government organisation named IMAGE. There are 13,057establishments in the state which includes 911 government establishments and 12095 private establishments in addition to old-age homes, dialysis centers, blood banks, Ayush institutions, and palliative clinics. This makes a bed strength of 93,266 and all these are registered with and managed by IMAGE. All the BMW is collected every day from all hospitals and disposed off within 24 hours. All waste is collected using color-coded and bar-coded bags with a unique identification number that can trace the BMW back from the disposal area to its origin. All the yellow bags go for incineration after weighing but without opening, while all red bags are weighed, opened autoclaved shredded compressed, and then sent for recycling. Therefore proper segregation is needed for ideal disposal especially to avoid plastic or PPE getting into incineration.[6]

Since 11th March 2020, when WHO declared the outbreak of Covid-19 as a pandemic, there was an increase in the demand and production of PPE all over the world. According to Market reports 2019: WHO 2020 has indicated a monthly increase of 40% in the production of PPE. In India, there are 198 Common Biomedical Waste Treatment Facilities (CBWTF) with an installed incineration capacity of 782 tons per day, with an additional capacity of 72 tons per day. Therefore, we decided to study the disposal pattern of this synthetic waste by a single CBWTF- IMAGE in the state of Kerala, with the highest production of waste in the country (Table 3), and possible environmental hazards that could arise as a result of it.[7]

V. Purohit et al has studied the various by-products of burning Polypropylene and polyester which are the main materials used for the production of PPE, in various environments[6]. Water and carbon dioxide are the major by-products and aliphatic and aromatic hydrocarbons are the minor by-products. When incinerated at more than 1100 degrees centigrade these hydrocarbons are not produced at all. But a large amount of incineration of PPE could lead to large volumes of Carbon dioxide being released into the atmosphere, contributing to an increase in global warming. Similarly, oxides of sulfur and nitrogen produced by BMW other than PPE, can also lead to smog formation.

Parteek Singh Thind et al has mentioned the compromising situation of India's biomedical waste incineration units and associated carcinogenic and no carcinogenic emissions during Covid-19 initial phase in Delhi, Haryana, Rajasthan, Madhya Pradesh, Maharashtra, Mizoram, and Uttarakhand. Overview of the treatment of infectious and sharp waste from health care facilities by WHO 2019 also suggests only 28%hospitals in India segregate properly and 40% dispose of according to CPCB rules and regulations. Parteek et al has also recommended increasing the number of incinerators and looking for alternate technology for disposing of BMW waste.[6]

During the pre-Covid period, IMAGE has 5 incinerators, including one 24 hours rotary incinerator (Thermax, Alpha, Ensys, Alfa Thermax & Rotary) with a stack diameter of 0.60m to take care of the BMW. There was a fluctuation in the amount incinerated and recycled every month. But the wastes recycled showed a direct relation to incineration (1:1.5, p-value<0.05).

During the pre-Covid years, the CPCB had not provided adequate guidelines for disposing of gowns and drapes made of polypropylene. The practice was to segregate PPE into yellow BMW bags which was then incinerated. During the Covid period, Polypropylene-based sterile disposable gowns and surgical drapes were widely used instead of linen. We can notice that this practice of segregation into yellow bags continued into the Covid pandemic years. This was most evident during the relaxation months (Figure 2) where there was a significant increase in incineration but no proportionate increase in recycling (p value<0.0001).

In 2021 two spikes were noticed in the covid -19 case burden. The quantum of incineration of BMW increased but did not follow the same pattern of covid-19 case rise (correlation coefficient r-value 0.15, p 0.98). The difference between incineration and recycling was doubled when compared to the pre-covid years. This suggests that the additionally used disposable kits during these spikes of new cases were mostly incinerated rather than recycled (Figure 2).

The study from 7 north Indian states suggests that a Covid infected patient generates approximately 3.41 kg/d of BMW and the major proportion were PPE. Their study also showed Cadmium emissions from incinerating these wastes and were fatal for adults and children. CPCB in its revisions of the rules during the Covid-19 pandemic has focused on giving more importance to recycling after the disinfection of these PPE rather than incineration. IMAGE also revised its segregation rules accordingly (Figure 1).

Our study shows a similar finding to that of Parteek et al. about the forecasted burden on incineration in phase 2 and the recycling being inadequately utilised. IMAGE's burden in this incinerated BMW is obvious from the data showing the addition of 0.90m stack diameter New parisudh incinerator, New Alpha incinerator, (0.375m stack diameter), 0.9m stack diameter Old Parisudh and a new Rotary incinerator. We did study the stack emission sampling data particulate matter, HCL, Oxides of Nitrogen, Volatile organic compounds, and combustion efficiency. There was no change when pre-Covid and Covid pandemic data were compared for the above parameter. The oxides of nitrogen has shown an increasing trend but was within the CPCB standards. But the large quantity emitted can have environmental effects like global warming.

From our study, it is evident that Kerala although being compliant with CPCB rules, has to be a little more vigilant when coming to the safe and efficient disposal of PPE especially when recycling of waste is concerned. Though IMAGE has issued guidelines regarding disposal of PPE in red coloured bags the reason for non-compliance has to be addressed. Awareness on safe segregation at source so that we remain eco-friendly has to be provided. All manufacturers of PPE should clearly mention that their product has to be strictly recycled by colour coding for segregation at source into red bag.

6. Source of Funding

None.

7. Conflict of Interest

None.

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