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Facemasks as environmental risk: An observational study using street - Survey in Hisar District of Haryana State

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ABSTRACT

The present pandemic has increased especially the single use plastic waste across globe and the developing countries might find it hard to dispose them safely. The use of single use plastic Personal Protective Equipments (PPE), especially the face mask, as a result of universal masking, has increased manifold. The researchers conducted a study, using 'observation' as a tool to gauge the quantity of littered facemasks, at specific locations in District Hisar, Haryana, India. Two rural and two urban localities were chosen. Density of facemasks per unit area was measured to quantify the problem. Out of total 1063 littered discarded facemasks across 10 localities in district Hisar, 52 percent were surgical facemasks which contain a considerable amount of plastic. Overall, density of littered facemasks was found to be 0.81 masks per 100 square meters. Reusable cloth masks also contain variety of non biodegradable materials which pose serious risks to the environment. Littered facemasks are potential biomedical waste which may pose challenges to human environment if not disposed of properly. The ecosystem, humans, flora and fauna of the earth, all are being affected by the huge amount of single use plastic waste. The safe disposal of such waste is the need of the hour and should be tackled earnestly employing inter agency coordination.

Key words: *Facemasks, "Microplastic", "Biomedical waste", "Covid-19" and "Mass Masking".*

Introduction

More than 40 pathogens have emerged in the past three decades, many of which like HIV and novel-influenza have caused pandemics, and novel-corona virus is latest in this series. Tandon (2020). Covid-19 was declared as global health emergency by World Health Organization (WHO) on 31st January 2020 and it has caused not only economic and social crisis but also the global panic (Yu *et al.*, 2020). According to WHO, till 7th July 2021, more than 184 million confirmed cases of Covid-19 have been reported across the globe leading to near 4 million deaths with an impact on 223 countries (WHO, 2021). In India, more than 30 million confirmed cases and more than 4 lac deaths have been reported till 7th July 2021.

Containing the spread of Covid-19 requires basically two things; limit the contacts of infected patients by measures like social and physical distancing, isolation, contact tracing with quarantine at first instance and secondly, by reducing the probability of transmission by using face masks. Howard *et al.* (2020). Facemasks are considered as best vaccine by

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the researchers across the globe. Taking this into account, Covid-19 pandemic has induced a sharp increase in the demand of medical facemasks especially in East Asia Chan and Yuen (2020).

Historically, face masks were used to contain the spread of contagious diseases. Indeed, there is a description of use of face masks along with other measures during the Influenza pandemic of 1918-19 in USA. Chin (1991). With the outbreak of Covid-19, use of facemasks has become ubiquitous in many Asian countries such as China, Japan, South Korea and China, Feng *et al*. (2020). In India, the government initiated several control measures in March 2020 to mitigate the effects of pandemic on population. These precautionary measures were; imposition of complete lockdown, maintaining of social and physical distancing, working from home and use of PPEs such as facemasks and face shields and gloves in certain settings. Many governments across the globe not only recommended the use of PPEs but also enforced such usage De-La-Torre (2021). With continuous upsurge in the pandemic, there was a rush to buy as many surgical facemasks as government could manage to buy Dharmaraj *et al.* (2021). The pandemic reinforced the importance of single use plastic especially for the management of virus Okuku *et al*. (2021).

With the current pandemic, 'hazardous medical waste', which is mostly constituted of plastic, is posing a great threat to earth's ecosystem. The environmental impact of such waste would affect not only health of the human population but also affect natural habitat of other organisms and species. Sadat *et al*. (2020). A lot of studies are being conducted which are reflecting upon extent and type of biomedical waste generation under the influence of current pandemic. Though, there is a dearth of such studies in Indian context especially in the state of Haryana. Present study aims to put emphasis on assessment of current ground situation with reference to management of discarded facemasks, at community level both in urban and rural areas in district of Hisar, Haryana.

Materials and Methods

Using cross-sectional study design, present study applied 'observation' as a method of data collection. Method of street/ locality surveys was used to collect the data. In Hisar district, total 10 localities/ streets were chosen in two urban and two rural areas. Further, half of the localities were chosen on the basis of intraday aggregation of population. Given the higher aggregate possibilities, bus stations in these regions were chosen. Additionally, rests of the localities/ streets were chosen purposively. Secondary data from reliable sources were incorporated to complement the primary data and discuss the phenomena.

A 'transect walk' was performed in each of the localities/streets. Observations were made to collect the data, i.e. number of discarded face masks littered in the streets/ localities. The duration of the observation in each street/ locality was ranging from one to two hours, respectively. In addition to the facemasks littered in streets/ localities, municipal dustbins or aggregate of waste (in case of rural areas) were observed for number of discarded facemasks. Geo-coordinates using Google Maps were recorded for each start and end point in every locality. Data entry and analysis was done using Microsoft excel.

The density of littered discarded facemasks was obtained using following formula;

C= n/a. Okuku *et al*. (2021)

Where, C = Density of facemasks per square meter.

n = Number of facemasks observed

a = Area travelled/ observed (square meter) = (net mouth width × d)

d = Distance travelled (Flow meter final-flow meter initial) × correction factor

Results

Key Observations

A total of 1063 facemasks were found littered as discarded facemasks across 10 localities/ streets in Hisar district. Out of total facemasks 52 percent were surgical facemasks, 4 percent were KN95 masks and rests were cloth masks made up of a variety of different fibers. Overall, density of littered facemasks was found to be 0.81 masks per 100 square meters across all 10 localities/ streets in Hisar district. This density was higher in urban areas (0.83 masks per 100 square meter) as compared to rural areas (0.66 masks per 100 square meter). It was observed that in district Head Quarter (HQ) of Hisar, there was highest (0.93/ 100 square meter) number of masks discarded or littered per unit area followed by Haibatpur village (0.71/ 100 square meter), Barwala (0.78/ 100 square meter) and Kheri village (0.58/100 square meter). This may be attributable to the relatively higher use of PPE in more urbanized population, mainly due to better administrative implementation of universal mass masking policy in urban areas. Further, this may also be attributable to relatively higher population density in observed localities of district HQ Hisar as compared to other observed areas. Bus stations and market areas receive higher number of people every day. Such sites are constantly vulnerable to mismanagement of harmful biomedical waste like discarded masks.

Additionally, it was observed by the researchers that dustbins were not placed in rural localities and streets. It is a common practice for local rural population to throw such litter in aggregated waste agglomerations at different sites in a particular street/ area. Waste management process is not streamlined in rural areas. In such scenarios, communities tend to litter their waste in segregated sites within or outside community adjacent areas. These agglomerations are often fed upon by stray animals who can ingest such harmful waste.

Discussion

Many studies are being conducted across the globe which have demonstrated the extent and type of waste or biomedical waste generation while combating current pandemic. Large amount of single use discarded masks were found floating at 100 meter long beach stretch in Hong Kong Sadat *et al*. (2020). There is huge increase in plastic waste comprised primarily of PPEs along the coasts of Kenya following 100 days of pandemic Okuku *et al*. (2021). Similarly, there was unprecedented presence of discarded PPEs in Jakarta bay, Indonesia during the peak of pandemic times. It accounted for 15-16 percent of collected river debris. Such plastic waste persists in the marine environment for centuries Cordova *et al*. (2021). Similar study was conducted across beaches in Lima, Peru where facemasks were most common (87.7 percent) type of discarded PPEs followed by other PPEs. Out of total, 54.5 percent of the masks were surgical, 12.4 percent were KN95 and rest were cloths or unidentified type of masks. De-La-Torre *et al*. (2021). There were photographic evidences of discarded facemasks in Columbia,

Table 1. Surveyed Street/Localities including localized dustbins in Hisar District Region

Region	Specific Area	Classification	Surveyed Length/ area	Start Coordinates	End Coordinates	No. of discarded masks found in	
						Street/ Locality	Dustbins
Hisar City District HQ	Rajguru Market	Urban	20000 m²	29.162146, 75.721443	29.160441, 75.724369	107	212
	Bus Stand	Urban	40000 m²	29.164973, 75.719802	29.165802, 75.717917	56	176
	Street no:18 Surya Nagar	Urban	4000 m²	29.136228, 75.759206	29.137793, 75.760364	11	36
Barwala City	Main Road	Urban	40000 m²	29.360720, 75.895718	29.380018, 75.911854	122	82
	Bus Stand	Urban	10000 m²	29.362850, 75.897710	29.362383, 75.898286	29	87
	Street no. 1, Ward 11	Urban	2500 m²	29.362895, 75.903693	29.366201, 75.904403	12	43
Haibatpur Village	Bus Stand	Rural	1600 m²	29.299823, 76.076180	29.299818, 76.075745	6	12
	Main Street	Rural	3500 m²	29.301146, 76.076678	29.299895, 76.079641	5	17
Kheri Village	Bus Stand	Rural	5000 m²	29.330391, 76.094585	29.330140, 76.096079	6	19
	Main Street	Rural	3500 m²	29.323882, 76.083978	29.330178, 76.087685	8	17
Total				130100 m²		362	701

Chile and Argentina. Similar evidences were reported from city or urban areas of Canada, Nigeria, Portugal and Brazil De-La-Torre *et al.* (2021). These developments have added to the challenges of public health concerns related to environment as macro and micro plastic persists in the environment for very long and mismanagement of discarded PPEs put environment under stresses of different kinds. Aragaw (2020). Discarded PPEs are not only contributing to quantum of plastic waste but also, it is infectious waste. Discarded facemasks are potential infectious waste as it could be laden with a variety of microorganisms.

According to WHO, there is huge upsurge in global demand of PPEs as 89 million medical masks, 76 million gloves, and 1.6 million goggles for healthcare workers alone were required monthly across the globe. Single use mask production in China observed a huge increase as 200 million facemasks were produced per day in June 2020 as compared to twenty times less production in early February 2020 (Aragaw, 2020). It is not hard to assume that all this production will ultimately land up in trash as infectious waste. Globally, following government directives on universal masking, there has been huge upsurge in demand of single use masks. This has led to a situation of unmet demands. Such a context triggered the local production of fabric made reusable masks.

Composition of Masks

Single use masks are made of certain plastic polymers including Polypropylene, Polyurethane and Polyacrylonitrile, Tamir (2019). Not only single use facemasks, other covid-19 related single use products contain plastic polymers including packaging material that ultimately accumulate and persist in the environment and degrade into microplastic, Silva *et al*. (2020). About 60 percent of clothing material used for manufacturing of reusable masks contains plastic which includes polyester, acrylic and nylon textiles. Plastic breakdown in smaller particles (<5 mm) known as microplastic, put huge environmental stress on marine environment De-La-Torre *et al.* (2021). While degrading, such microplastic and microfibers might enter food chains through different channels and may pose serious challenges and threat to terrestrial and aquatic life UNEP (2020). Such mismanaged waste poses environmental risks and exposure of harmful microorganism to human health in a number of ways.

Unprecedented Environmental Effects of Mass Masking

Many countries experienced significant increase in discarded PPEs due to their mandatory use policies (Silva *et al,* 2020). Additionally, recycling process also gets hampered in lockdown period. (Monserrate *et al*. 2020). Medical waste generation increased from 40 tonnes per day to 240 tonnes per day during the peak of epidemic in Wuhan (Klemes *et al*, 2020). Many big Asian cities were producing tonnes of extra medical waste in current pandemic e.g. Manila 280 tonnes/day, Jakarta 212 tonnes/day and Bangkok 210 tonnes per day (ADB, 2020). Discarded PPEs and single use products are major components of increased medical waste. Magnitude of this problem must be huge as usage of PPEs especially facemasks may far exceed usage by healthcare workers and it remains unquantified (Okuku *et al*. , 2021). A study by Hantoko et al in 2021 attempted to estimate the use of facemasks in Asian countries and it was revealed that total amount of estimated daily mask usage in India is 777,017,207 which resulted in 2331 tons of biomedical waste due to discarded facemasks per day. Many studies reported that there is huge increase in garbage due to single use plastic in Covid-19 pandemic. Similar increase in PPE related garbage was observed in USA. (Calma 2020).

Apart from the waste burden, magnitude of pandemic has impacted the waste handling and recycling activity in USA and it promoted the mixing of

Table 2. Area-wise distribution of litter of discarded facemasks in Hisar district

Area	Total Area Observed	Number of Discarded masks in Street/ Locality/ Dustbins			Number of masks per 100 square meter
		Street/ Locality	Dustbins/ Waste aggregate	Total	
Urban	116500 m²	337	636	973	0.83
Rural	13600 m²	25	65	90	0.66
Total	130100 m²			1063	0.81

contaminated waste such as masks, gloves and expired medicine with domestic waste. Silva *et al.* (2020). Most of the waste which cause marine pollution is basically transferred from land to oceans. Dharmaraj *et al*. (2021). It was estimated that 1.56 billion facemasks were likely to enter the ocean in 2020 (Ocean Asia, 2020). Microplastic particles serve as a vector of chemical and pathological contaminants and may produce ecotoxicological effect in organisms (De-La-Torre *et al*, 2021). Due to micron size particles, microplastic is mistaken as food and consumed by a variety of marine biota. Human beings also consume a variety of seafood. Such microplastic is persistent throughout the aquatic environment. Moreover, there was suspension on bans of single use plastic considering upsurge in pandemic in USA. Additionally, this upsurge favored the shifts toward single use plastic due to increased safety and hygiene concerns and increased packaging as well as online shopping activity. (Okuku *et al*, 2021).

Upsurge in the pandemic and India's utmost efforts in dealing with this pandemic have increased the quantity of biomedical waste generation. This manifold increase will ultimately put huge environmental stress on ecosystem. (Goswami *et al*, 2021). According to Central Pollution Control Board's (CPCB) annual report of 2018, a total of 2,60,889 healthcare facilities are estimated to generate 608 MT biomedical waste per day. Out of which only 528 MT is treated and disposed through common biomedical waste treatment facilities. According to National Green Tribunal, available capacity of incineration is 840 MT per day and only 55 percent of cumulative incinerator capacity is being utilized. However, in current scenario where Covid-19 related waste generation has multiplied the quantity of biomedical waste generation due to increased use of single use PPEs and other products, developing countries are under enormous pressure of environmental challenges. Moreover, points of biomedical waste generation have increased manifold due to universal masking and other processes. Distribution of biomedical waste generation is very wide which includes hospitals, quarantine facilities, isolation centers and households. (Hantoko *et al*, 2020). Huge fractions of cases were home quarantine and were generating biomedical waste. Therefore, actual quantity of biomedical waste, from all the points of generation, will be huge. Biomedical waste generated from healthcare activities may find its way to a common biomedical waste treatment facility but it is hard to imagine the fate of such trash generated from households or on individual basis.

Effects on Sanitation workers

In addition to the potential environmental hazards, there is a risk of contamination to waste collector and street cleaner. WHO (2020). There are around 5 million sanitation workers in India and nearly half of them are females. (Goswami *et al*, 2021). Waste handlers and sanitation workers have an unmatched importance for mitigating environmental threat or risks to general population. Occupational exposure to pathogenic microorganisms is an important public health concern. (Shivalli and Sowmyashree, 2021). As facemasks are used by general public on large scale, out of those, many may be asymptomatic but many might be infected from Covid-19 patients and or other pathogenic microorganisms. As observed from the field settings in Hisar, such infectious trash which is being openly thrown as litter or mixed with general municipal waste, could pose serious challenges for such vulnerable population. Additionally, such waste could be ingested by stray animals who feed on aggregated waste in open. Therefore, mismanaged discarded facemasks could pose serious challenges to earth's ecosystem and stress on environment affecting health of a variety of organisms.

Policy Guidelines

As the generation of biomedical waste is inevitable during current pandemic, safe handling, treatment and disposal of waste must be prioritized. (Goswami *et al*, 2021). CPCB is the implementing agency for the implementation of Biomedical Waste Management (BMWM) rules in India. Under Environment Protection Act 1986, these rules were notified first in (1998), and revised several times, thereafter. Latest amendment came in 2019. In the light of current pandemic, CPCB has enacted guidelines for Handling, Treatment, and Disposal of Waste Generated during Treatment/Diagnosis/ Quarantine of COVID-19 patients in addition to the existing BMWM rules and revised them four times since then. However, these guidelines are focused on institutions and urban areas as Urban Local Bodies (ULBs) are one of the stakeholders. Revised guidelines also touched upon responsibilities of ULBs for effective management of yellow category waste from households. However, household collection of waste is still a major challenge in Indian context. Moreover, majority of population lives in villages which have no access to regulated collection & management of solid waste. In such contexts, it is difficult to ensure the adequate management of waste or biomedical waste generated from households.

Despite the guidelines, biomedical waste related to pandemic, especially facemasks, could be seen littered in public places. Discarded PPEs especially facemasks from households is still a major concern. (Okuku *et al*, 2021). Most of the people have little or no information on safe handling or disposal of masks. (Anastopoulos and Pashalidis, 2021). There are apparent challenges and gaps in implementing the guidelines due to inadequate infrastructure across nation and inconsistent operational efficiency of different implementing agencies. Mixing of biomedical waste such as discarded PPEs with general solid municipal waste is a common practice which poses a major challenge to Covid-19 related biomedical waste management in India. (Goswami *et al*, 2021).

Challenges and future prospects

Plastic waste pollution has been a continuous challenge and considered as a huge threat to the ecosystem, even before Covid-19. However, a new form of pollution from single use PPE is threatening our planet. Millions of masks and other PPEs are being used on daily basis, all of which is going to be a trash ultimately. Discarded facemasks can be observed in streets, parks and coast lines. (Anastopoulos and Pashalidis, 2021).

Earlier reusable masks were essential part of medical supply. However, industrial production of such masks was halted by increased use of disposable masks since 1960. (Strasser and Schlich, 2020). Disposable face masks are certainly essential part of PPEs but their use should be restricted by general public. Cloth masks are used in settings with resource crunch due to their reusable option. Therefore, they can be retained longer and reused multiple times. There is scope of research w.r.t. cloth masks design and development to increase the efficacy and provide low cost and viable solution to countries. (Maclntyre *et al*, 2015). Additionally, there are potential social and economic benefits of using cloth masks by promoting individual enterprise and community integration WHO (2020).

Moreover, biomedical waste generated from healthcare facilities may find its way towards a treatment site for safe disposal but biomedical waste generated from households or public places would be difficult to manage effectively. Facemask is such a typical product which will be used by general population on daily basis. It will be a hazardous waste which can contaminate our environment if not managed properly. Therefore, future prospects of universal masking may be devastating for the physical environment. It is very much uncertain that how current pandemic would progress and culminate. Keeping such context in mind, responses to waste management should be focused on short-term, mid-term and long-term sustainable measures. (Hantoko *et al*, 2020). Additionally, these responses must be developed along with disaster preparedness.

Minimizing the trash of discarded PPEs

In the context of increased medical waste due to pandemic and global shortage of PPEs, decontamination and repurposing is the need of the hour. (Tirupathi *et al*, 2020). Some of the research studies attempted to recycle and reuse the face masks by applying different disinfection method and found promising results. Hot air (75 degree, 30 minutes), UV light (254 nm, 8W, 30 minutes) and steam (10 minutes) were found effective disinfection methods with varying degree of effects on filtration efficacy for different number of cycles. (Liao *et al*, 2020). Gamma radiation at 20kGy can be employed for large scale sterilization. (Tirupathi *et al*, 2020). Such investigations could be upgraded and implemented with appropriate precautions. Studies have suggested that given the 72 hour viability of coronavirus on surfaces, reuse of masks after 72 hours could be considered. Elastomeric respirators with exchangeable filter cartridge could be an option. Also, disinfecting the PPEs through available methods such as autoclaving, gamma radiation, microwave, bleaching, copper sulfate, iodine, chlorine, isopropyl alcohol and methylene blue with light and reuse may solve the problem to some extent Livingston *et al*. (2020).

Any intervention strategy, e.g. universal face masking should be evaluated for acceptability, practicability, effectiveness, affordability, spill-over effects and equity (APEASE criteria). (West *et al*, 2020). There is need to formulate methods for safe handling, storage, treatment and disposal of trash especially of medical masks for different stakeholders. Few studies attempted to analyse comparative effectiveness of different types of mask and demonstrated that there is no significant difference between KN95, surgical and cloth masks in preventing infections comparable to coronavirus. (Tirpathi *et al*, 2020). Therefore, people should be well communicated about type of mask use, methods to on and off the masks to reduce the contamination; methods of proper disinfection and its disposal. Also, it should be kept in mind that adherence to the standard terms of use of face masks in turn would depend upon availability of recommended face masks and ready availability of facilities for safe disposal and decontamination. Therefore, using cloth masks or reusable masks would certainly reduce environmental stress. Additionally, there is a need to countering motivation for use of facemasks in a way in which they are counterproductive. West *et al*. (2020).

Conclusion

Current pandemic has led demand of facemasks due to their universal use. Therefore, amount of hazardous medical waste is enormous and will continue to be so. It is very much uncertain that how would this pandemic go on. Developing countries like India lack in biomedical waste management practices and capacities. Therefore, in the current phase of new normal where universal masking would be a normal phenomenon at least for some more time, can lead to huge environmental contamination due to discarded PPEs. This mismanagement of discarded facemasks will lead to terrestrial and marine pollution and may affect a variety of organisms in both the environment, directly or indirectly. Littered or discarded facemasks could carry microorganisms or pathogens which may affect vulnerable population like sanitary workers, waste handlers, manual scavengers and other through different channels. Also, if mixed with general waste, such waste could contaminate general waste turning it into hazardous waste. There is a need for exploration and implementation of sustainable and environmentally sound methods for management of discarded PPEs specific to Indian context. These methods should be clubbed with national bio disaster preparedness plans keeping the current pandemic in mind.

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Conflict of Interest

None

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References

Tandon, P. N. 2020. COVID-19. Impact on health of people & wealth of nations. *Indian Journal of Medical Research.* 151(2) : 121.

Yu, H., Sun, X., Solvang, W. D. and Zhao, X. 2020. Reverse logistics network design for effective management of medical waste in epidemic outbreaks: Insights from the coronavirus disease 2019 (COVID-19) outbreak in Wuhan (China). *International Journal of Environmental Research and Public Health.* 17(5) : 1770.

World Health Organization., *Coronavirus Disease (COVID-19) Pandemic:* (https://covid19.who.int/, accessed on 8 July 2021)

Howard, J., Huang, A., Li, Z., Tufekci, Z., Zdimal, V., van der Westhuizen, H,M., and Tang, V. 2020. Face masks against COVID-19: *an evidence review.*

Chan, K. H. and Yuen, K. Y. 2020. COVID-19 epidemic: disentangling the re-emerging controversy about medical facemasks from an epidemiological perspective. *International Journal of Epidemiology.*

Chin, T. D. 1991. America's Forgotten Pandemic: The Influenza of 1918.

Feng, S., Shen, C., Xia, N., Song, W., Fan, M. and Cowling, B. J. 2020. Rational use of face masks in the COVID-19 pandemic. *The Lancet Respiratory Medicine.* 8(5) : 434-436.

De-la-Torre, G. E., Rakib, M. R. J., Pizarro-Ortega, C. I. and Dioses-Salinas, D. C. 2021. Occurrence of personal protective equipment (PPE) associated with the COVID-19 pandemic along the coast of Lima, Peru. *Science of The Total Environment.* 774 : 145774.

Dharmaraj, S., Ashokkumar, V., Hariharan, S., Manibharathi, A., Show, P. L., Chong, C.T. and Ngamcharussrivichai, C. 2021. The COVID-19 pandemic face mask waste: A blooming threat to the marine environment. *Chemosphere.* 272 : 129601.

Okuku, E., Kiteresi, L., Owato, G., Otieno, K., Mwalugha, C., Mbuche, M. and Omire, J. 2021. The impacts of COVID-19 pandemic on marine litter pollution along the Kenyan Coast: A synthesis after 100 days following the first reported case in Kenya. *Marine Pollution Bulletin.* 162 : 111840.

Saadat, S., Rawtani, D. and Hussain, C. M. 2020. Environmental perspective of COVID-19. *Science of The Total Environment.* 138870.

Cordova, M. R., Nurhati, I. S., Riani, E. and Iswari, M. Y. 2021. Unprecedented plastic-made personal protective equipment (PPE) debris in river outlets into Jakarta Bay during COVID-19 pandemic. *Chemosphere.* 268 : 129360.

Aragaw, T. A. 2020. Surgical face masks as a potential source for microplastic pollution in the COVID-19 scenario. *Marine Pollution Bulletin*. 159 : 111517.

Tamir, Y. 2019. Composite Material From Waste and at Least One Element of Vulcanized Rubber and Tire Cords. (U.S. Patent No. 10:246:578).

Silva, A. L. P., Prata, J. C., Walker, T. R., Duarte, A. C., Ouyang, W., Barcelò, D. and Rocha-Santos, T. 2020. Increased plastic pollution due to COVID-19 pandemic: Challenges and recommendations. *Chemical Engineering Journal*. 126683.

UNEP, Fashion's tiny hidden secret. WWW Document. In: Cities and Lifestyle., 2019. URL. https://www.unenvironment.org/news-and-stories/story/fashions-tiny-hidden-secr et. (Accessed on 30 January 2021).

Zambrano-Monserrate, M. A., Ruano, M. A. and Sanchez-Alcalde, L. 2020. Indirect effects of COVID-19 on the environment. *Science of the Total Environment.* 138813.

Klemeš, J. J., Van Fan, Y., Tan, R. R. and Jiang, P. 2020. Minimising the present and future plastic waste, energy and environmental footprints related to COVID-19. *Renewable and Sustainable Energy Reviews. 127*, 109883

Asian Development Bank. Managing Infectious medical Waste during the COVID-19 Pandemic; 2020; ADB;2020 (https://www.adb.org/sites/default/files/publication/578771/managing-medical-waste-covid19.pdf, accessed 21 January 2021).

Hantoko, D., Li, X., Pariatamby, A., Yoshikawa, K., Horttanainen, M. and Yan, M. 2021. Challenges and practices on waste management and disposal during COVID-19 pandemic. *Journal of Environmental Management.* 286 : 112140.

Calma, J. 2020. The COVID-19 Pandemic is Generating Tons of Medical Waste [WWW Document]. *The Verge.*, URL. https://www.theverge.com/2020/3/26/21194647/the-covid-19-pandemic-is-generating-tons-of-medical-waste, accessed 10th March 2021.

Oceans Asia. 2020. COVID-19 Facemasks & Marine Plastic Pollution [WWW Document]. *OceansAsia.* URL https://oceansasia.org/covid-19-facemasks/ (accessed 1.30.21).

Goswami, M., Goswami, P. J., Nautiyal, S. and Prakash, S. 2021. Challenges and actions to the environmental management of Bio-Medical Waste during COVID-19 pandemic in India. *Heliyon*. e06313.

CPCB. 2018. Annual Report 2017-18. Central Pollution Control Board. Ministry of Environment & Forests, GOI.

NGT, 2020a. Before The National Green Tribunal Principal Bench, New Delhi. In reply to: Scientific Disposal of Bio-Medical Waste arising out of Covid-19 treatment- Compliance of BMW Rules 2016. https://greentribunal.gov.in/gen_pdf_test.php?filepath¼ L25ndF9kb2N1b WVudHMvbmd0 L2Nhc2Vkb2 Mvb3JkZXJzL0RFTEhJLzIwMjAtM DctMjAv Y291cn RzLzEv ZGFpbHkvMTU5NTMxOTc1NjEy Njg2OTQ2O Dc1ZjE2YTVj Y2JjMDM5LnBkZg¼¼, (accessed on 10 May 2021)

Shivalli, S. and Sowmyashree, H. 2015. Occupational exposure to infection: a study on healthcare waste handlers of a tertiary care hospital in South India. *The Journal of the Association of Physicians of India*. 63(11) : 24-7.

CPCB, 2020a. Guidelines for Handling, Treatment, and Disposal of Waste Generated during Treatment/Diagnosis/Quarantine of COVID-19 Patients - Rev. 4. Central Pollution Control Board. Government of India. https://cpcb.nic.in/uploads/Projects /Bio-Medical-Waste/BMW-GUIDELINES-COVID_1.pdf. (accessed on 13 March 2021)

Anastopoulos, I. and Pashalidis, I. 2021. Single-use surgical face masks, as a potential source of microplastics: Do they act as pollutant carriers?. *Journal of Molecular Liquids.* 326 : 115-247.

Strasser, B. J. and Schlich, T. 2020. A history of the medical mask and the rise of throwaway culture. *The Lancet*.

MacIntyre, C. R., Seale, H., Dung, T. C., Hien, N. T., Nga, P. T., Chughtai, A. A. and Wang, Q. 2015. A cluster randomised trial of cloth masks compared with medical masks in healthcare workers. *BMJ open.* 5(4): e006577.

World Health Organization, R*ational use of personal protective equipment (PPE) for coronavirus disease (COVID-19): interim guidance, 19 March 2020* (No. WHO/2019-nCoV/IPC PPE_use/2020.2). World Health Organization.

Tirupathi, R., Bharathidasan, K., Palabindala, V., Salim, S. A. and Al-Tawfiq, J. A. 2020. Comprehensive review of mask utility and challenges during the COVID-19 pandemic. *Infez Med*. 28(suppl 1) : 57-63.

Liao, L., Xiao, W., Zhao, M., Yu, X., Wang, H., Wang, Q. and Cui, Y. 2020. Can N95 respirators be reused after disinfection? How many times?. *ACS nano.* 14(5) : 6348-6356.

Livingston, E., Desai, A. and Berkwits, M. 2020. Sourcing personal protective equipment during the COVID-19 pandemic. *Jama.* 323(19) : 1912-1914.

West, R., Michie, S., Rubin, G. J. and Amlôt, R. 2020. Applying principles of behaviour change to reduce SARS-CoV-2 transmission. *Nature Human Behaviour.* 1-9.

Cheng, V. C., Wong, S. C., Chuang, V. W., So, S. Y., Chen,

J. H., Sridhar, S. and Yuen, K. Y. 2020. The role of community-wide wearing of face mask for control of coronavirus disease 2019 (COVID-19) epidemic due to SARS-CoV-2. *Journal of Infection*.

Javid, B., Weekes, M. P. and Matheson, N. J. 2020. Covid-19: should the public wear face masks?

Leung, C. C., Lam, T. H. and Cheng, K. K. 2020. Mass masking in the COVID-19 epidemic: people need guidance. *Lancet.* 395(10228) : 945.

Ministry of Environment, Forest and Climate Change. Biomedical waste management rules;2016 (http://www.cpcbenvis.nic.in/pdf/BMW_Rules_2016.pdf, accessed on 15 June 2020).

Supehia, S., Singh, V., Sharma, T., Khapre, M. and Gupta, P. K. 2020. Rational use of face mask in a tertiary care hospital setting during COVID-19 pandemic: An observational study. *Indian Journal of Public Health.* 64 (6) : 225.

Wang, J., Shen, J., Ye, D., Yan, X., Zhang, Y., Yang, W. and Pan, L. 2020. Disinfection technology of hospital wastes and wastewater: Suggestions for disinfection strategy during coronavirus Disease 2019 (COVID-19) pandemic in China. *Environmental Pollution.* 114665.

World Health Organization, *Advice on the use of masks in the context of COVID-19: interim guidance, 5 June 2020* (No. WHO/2019-nCov/IPC_Masks/2020.4). World Health Organization.

Wu, H. L., Huang, J., Zhang, C. J., He, Z. and Ming, W. K. 2020. Facemask shortage and the novel coronavirus disease (COVID-19) outbreak: Reflections on public health measures. *EClinical Medicine.* 100329.

Yordanova, D., Angelova, S., Kyoseva, V. and Dombalov, I. 2014. Household Medical Waste-Threat to The Environment And Human Health. *Journal of Chemical Technology and Metallurgy.* 49(2) : 185-188.