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Disposable face/cloth masks during COVID-19 pandemic: a precursor for the synthesis of valuable bioproducts for Environment.

Máscaras faciales/de tela desechables durante la pandemia de COVID-19: un precursor para la síntesis de bioproductos valiosos para el medio ambiente.

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ABSTRACT

Different surgical, cloth, and disposable face masks have become required personal protective equipment for preventing the COVID-19 pandemic. Disposable face masks are produced using thermoplastic polymers, and because they may be quickly transformed into useful bioproducts and because their use has significantly increased, their detrimental environmental effects are a very severe subject of worry. The most often utilised interventions for respiratory protection and other airborne transmission are face masks and respirators. This review article highlighted numerous methods and opportunities for contaminated masks, as well as how to turn waste into the most useful byproducts. With these methods, it is important to completely stop the COVID-19 virus from spreading through the air.

Keywords: COVID-19, Disposable face masks, Bioproducts, Pyrolysis

RESUMEN

Diferentes mascarillas quirúrgicas, de tela y desechables se han convertido en equipos de protección personal obligatorios para prevenir la pandemia de COVID-19. Las máscaras faciales desechables se fabrican con polímeros termoplásticos, y debido a que pueden transformarse rápidamente en bioproductos útiles y debido a que su uso ha aumentado significativamente, sus efectos ambientales perjudiciales son un tema de preocupación muy grave. Las intervenciones utilizadas con mayor frecuencia para la protección respiratoria y otra transmisión aérea son las máscaras faciales y los respiradores. Este artículo de revisión destacó numerosos métodos y oportunidades para máscaras contaminadas, así como también cómo convertir los desechos en los subproductos más útiles. Con estos métodos, es importante detener por completo la propagación del virus COVID-19 por el aire.

Palabras clave: COVID-19, Mascarillas desechables, Bioproductos, Pirólisis

INTRODUCTION

The COVID-19 pandemic is anticipated to last for the foreseeable future until a reliable vaccination is accessible. Masks and respirators are significant non-pharmaceutical interventions that can reduce the risk of infection by 85% and are used by medical professionals, the general public, and ill patients during pandemics. RPGs protect healthy wearers and act as source control in public situations, but for healthcare workers (HCWs), their primary utility is personal safety. A medical or surgical mask's water resistance is regulated, and it is made to protect the wearer from splash or spray. The Ministry of Health and Family Welfare Data Tracker reports that there have been 27.1 million verified COVID-19 cases in India, and there have been a total of 1.8 million fatalities with total death of 5,24,803 Prevention (2021) while the total cases worldwide stand at 542,599,590 and a total death toll of 6,336,895 as of June 09, 2022 (Worldometer 2022). While the roll out of vaccines are underway to help combat this pandemic, both the ways i.e. World Health Organization (WHO) and the US Centers for Disease Control and Prevention have recommended preventive measures such as social distancing, hand sanitizers, frequent handwashing, and the use of face masks respectively. Face mask usage has significantly increased as a result of the recent rise in COVID-19 infections overall and the spread of coronavirus outbreaks throughout India. For instance, a survey by Pew Research Center found that, between June and August 2020, the usage of face masks by US people in the West North Central, West South Central, East South Central, and Mountain areas increased by 23%, 27%, 28%, and 33%, respectively (Kramer 2020). According to a survey related to this study, more Indian adults and teenagers—regardless of their political views and affiliations—now view face masks as useful protective gear. Face masks have been characterised by all public health and medical officials as a straightforward barrier that stops respiratory droplets and other airborne transmission from reaching others, significantly slowing down the spread of the coronavirus. Healthcare Infection Control Practices Advisory Committee (HICPAC) (2022). The use of face masks has increased dramatically due to the pandemic scenario during the past two years, and there are worries about the safe disposal of these waste materials (Nzediegwu and Chang 2020). In particular, the disposal of trash disposable face masks will exacerbate the current environmental issues brought on by the quantity of plastics that are dumped in water bodies. It is pertinent to mention that the extreme use of the disposable face masks which are made from polymers such as polypropylene $(C_3H_6)_n$, polyurethane $C_3H_7NO_2$, polyacrylonitrile $(C_3H_3N)_n$, polystyrene $(C_8H_8)_n$, polycarbonate $C_{15}H_{16}O_2$, polyethylene $(C_2H_4)_n$, or polyester $(C_{10}H_8O_4)_n$ (Fadare and Okoffo 2020; Potluri and Needham 2005) and they are not biodegradable. Fadare and Okoffo (Fadare and Okoffo 2020) in the research articles stated that the high rate of single use of disposable face masks will emerge as a new source of microplastic fibers in the environment. Nzediewu and Chang (Nzediegwu and Chang 2020) stated that improper handling of waste COVID-19 preventive gears can increase the spread of COVID-19 in developing countries. If the disposal of these waste materials is not properly managed, it can ultimately result in public health risks such as secondary transmission from contaminated used face masks.

This is corroborated by a study by Kampf et al. (Kampf et al. 2020), which examined the persistence of coronavirus on inanimate surfaces. They found that the human coronavirus can survive infectiously on inanimate surfaces for up to 9 days at room temperature, and that a rise in temperature above 30 °C will cause a reduction in the coronavirus's persistence time. Disposable mask use and management are viewed as environmental challenges, yet all of these waste materials and resources can be transformed into beneficial bioproducts. FTIR technique is being used for the analysis of the disposable masks in which it was reported that the layers of the mask i.e outer and inner layers has a characteristic peak of the polypropylene and high-density polyethylene respectively report on Fadare and Okoffo, 2020. Polypropylene $(C_3H_6)_n$ and high-density polyethylene are thermoplastic hydrocarbon polymers which are produced from the propylene (C_3H_6) and ethylene (C_2H_4) monomers, respectively. It is important to note that because they are hydrocarbons, they can readily be transformed into useful bioproducts like syngas, bio-oil, and biochar. This requirement means that the enormous amount of used disposable face masks can act as a trustworthy feedstock for the synthesis of bioproducts. Disposable face masks made of polymeric materials have been proven to have superior qualities to lignocellulosic feedstocks, including low moisture content (0.00-0.80%), low ash content (0.00-1.40%), and high volatile content (86.83-99.63%). (Jouhara et al. 2018).

Bioproducts which obtained from the thermochemical conversion of disposable face masks will therefore not have physicochemical characteristics inhibiting the direct utilization of lignocellulosic feedstock–derived bioproducts as they have various multifunctional properties as shown in Figure 1.

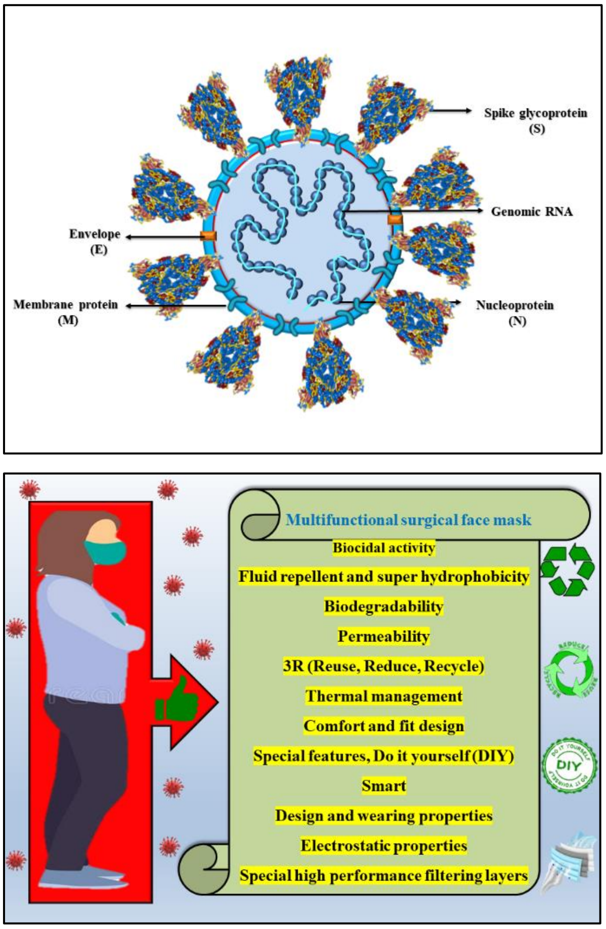

Figure 1. Representation of the multifunctional properties of the face mask

PYROLYSIS TECHNOLOGY

A material is thermally decomposed at a temperature exceeding 500 °C in the absence of oxygen in pyrolysis, a thermochemical conversion process that yields biochar, biooil, and non-condensable gas (Oginni and Singh 2019; Oginni et al. 2017). The conversion of lignocellulosic and non-lignocellulosic feedstocks into bio-oil and biochar has been documented in a number of earlier research literatures. In several studies, the pyrolysis of polypropylene (PP) and high-density polyethylene (HDPE) at temperatures between 250 and 400 °C was reported and examined. Additionally, the best bio-oil yields of 69.82% and 80.88% for PP and HDPE, respectively, were obtained at pyrolysis temperatures of 300 °C and 350 °C (Ahmad et al.,2014). The pyrolysis of waste polypropylene and polyethylene in a fluidized bed reactor at temperatures between 650 and 750 °C was also reported and explored by Jung et al. in 2010. They reported bio-oil yields of 43% and 53% for polypropylene and polyethylene, respectively. According to reports, the bio-oils produced by pyrolyzing polypropylene and polyethylene have calorific values that are nearly as high as those of traditional liquid fuels.

A solid porous carbonaceous material called biochar is produced via pyrolysis (Oginni and Singh 2020). It has been thoroughly investigated for soil amendment, carbon sequestration, water treatment, home heating, catalysis, and energy storage due to its tunable physicochemical properties. The carbonization temperature has a major impact on the use of disposable face masks in the production of biochar. The yield of biochar is often quite low due to the high temperature needed to thermally breakdown thermoplastics and the low fixed carbon content of these materials. During the pyrolysis of a waste plastics mixture made up of 45% polypropylene, 35% low-density polyethylene, and 25% high-density polyethylene, Papuga et al. (Papuga et al. 2015) reported a decrease in biochar yield from 25.46 to 1.23% when the pyrolysis temperature rose from 450 to 525 °C. During the pyrolysis of a plastic combination (40 weight percent polyethylene, 35 weight percent polypropylene, 18 weight percent polystyrene, 4 weight percent PET, and 3% PVC) at a temperature range of 460-600 °C, Lopez et al. (López et al. 2011) observed a very low biochar output of 0.8-1.1%. This suggests that the amount of biochar produced from used face masks may not be as large as the amount of biooil produced.

The use of waste/contaminated disposable face masks as a precursor for the production of bio-oil and biochar will not pose any risk of secondary transmission because the virus will not be able to survive the temperature at which this thermochemical conversion process is taking place because the persistent duration of coronavirus decreases as temperature increases. However, it will be advised that these masks be collected separately, just as plastic bottles and other recyclable waste products are, in order for pyrolysis technology to securely manage waste/contaminated disposable face masks. As a result, it won't be necessary to separate the masks from other trash. According to estimates from the World Health Organization (WHO), 129 billion face masks are used globally each month and thrown away. Thus, face masks contribute to a monthly global waste stream of 651.5 billion grammes of both disposable and non-disposable garbage. It is projected that a total of 194.2-361.2 billion grammes of bio-oil can be produced monthly from these used face masks worldwide based on the bio-oil yield range (43-80%) that has been documented in the previous research literatures during the pyrolysis of plastics trash. This shows that, despite the fact that the disposal of discarded face masks first appeared to be a kind of environmental pollution, they may really be safely transformed into beneficial and valuable bioproducts (Figure 2).

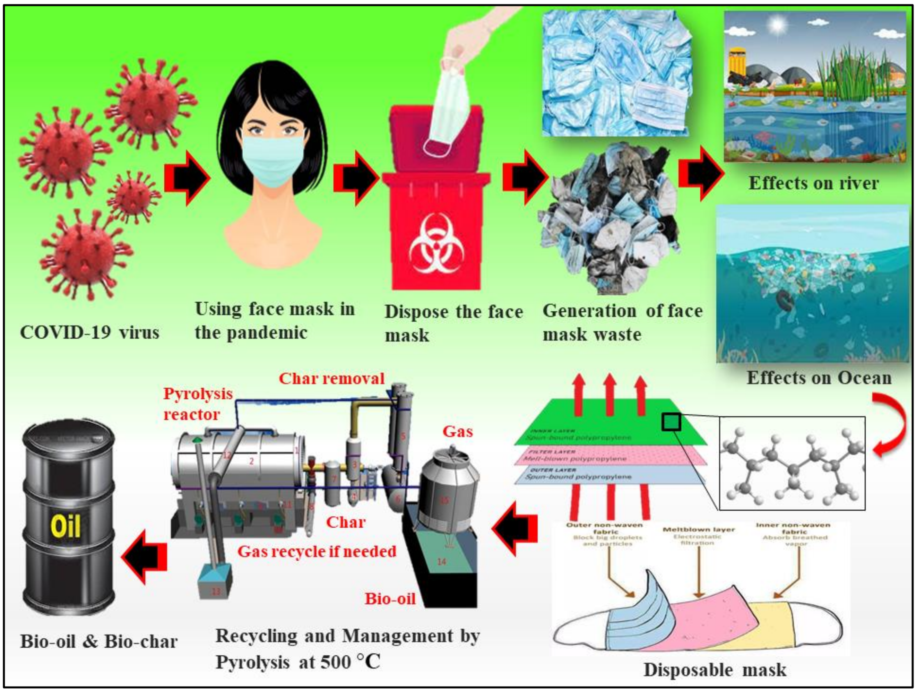

Figure 2. Representation of the technique into beneficial and valuable bioproducts

FILTRATION MECHANISMS

There are several contaminants in the environment, all of which come in different sizes. [Eshbaugh, 2008] It takes both physical and electrostatic filtration to successfully trap pollutants in a filter. RPGs eliminate microorganisms and pollutant particles using electrostatic, diffusion, interception, and impaction methods. [Eshbaugh, 2008] While the other filtration processes are effective for bigger particle sizes, electrostatic filtration predominates for negatively charged tiny particles (like viruses and bacteria). Figure 3 shows various filtration techniques utilised by frequently seen RPGs.

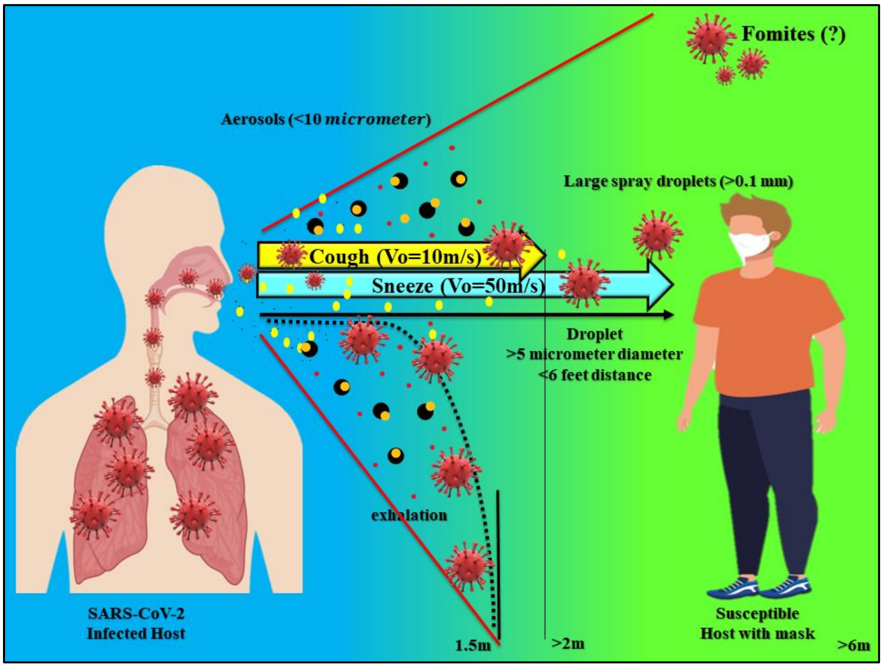

Figure 3: Representation shows various filtration techniques utilised by frequently seen RPGs.

ELECTROSTATIC FILTRATION

This is the mechanism that surgical masks and respirators most frequently employ. A positive charge is applied to the filter medium during electrostatic filtering. When microorganisms and negatively charged dust particles pass through the filter, positively charged filter material attracts them and binds them to the mask. As the negatively charged particles are trapped over time, the electrostatic charge of the filter is neutralised, which causes a rapid decrease in filtration efficiency. [McCullough, 1997]

GRAVITY SEDIMENTATION

Gravity sedimentation has been reported to have a crucial role for aerosols particulate matter in the 1 m–10 m range because ballistic energy or gravity forces have an immediate impact on the big inhaled droplets. [McCullough, 1997]. It has been projected that the aerosol with the smallest size, which is polystyrene latex spherical (0.5 m), has the most penetrating capacity for the size of particles (0.5>m), with inertia and gravity being the possible dominant mechanisms. [McCullough, 1997]

INTERTIAL IMPACTION

When a particle's inertia exceeds a certain threshold, changes in the direction of the particle's motion in the airflow result [Bailar, 2006]. Larger particles have higher inertia due to their higher face velocities, densities, and diameters, which makes them easier to catch. Due to their inertia, these particles cannot pass around the fibres of the respirator. Furthermore, bigger particles deviate from air streamlines, clash with fibres, and can attach to them rather than passing through the material filter [Hinds, 1999]. Overall, this method may be effective in removing particles that are 1 m or larger [Eshbaugh, 2008]. However, it plays a minor role in the systems that capture nanoparticles. The effectiveness of this method for catching Ultrafine.

DIFFUSION

Due to Brownian (random) motion, airborne particles come into contact with the fibre during the diffusion process. Another particle moves to the open space to be captured when one is captured on the fabric. Increasing the microfibre concentration is necessary to increase the likelihood of this event. With longer exposure to particles in the capture zone, there is a greater chance that a particle will be captured. [Hutten, 2016]

INTERCEPTION

In the interception technique, a particle is collected as it approaches the fibre surface from behind a streamline at a distance of one particle radius. The particle thus comes into contact with the fibre and is caught. Because the particles are so tiny, only those that follow the streamline and are close to the fibre are observed in this situation. [Hutten, 2016] see Figure 4.

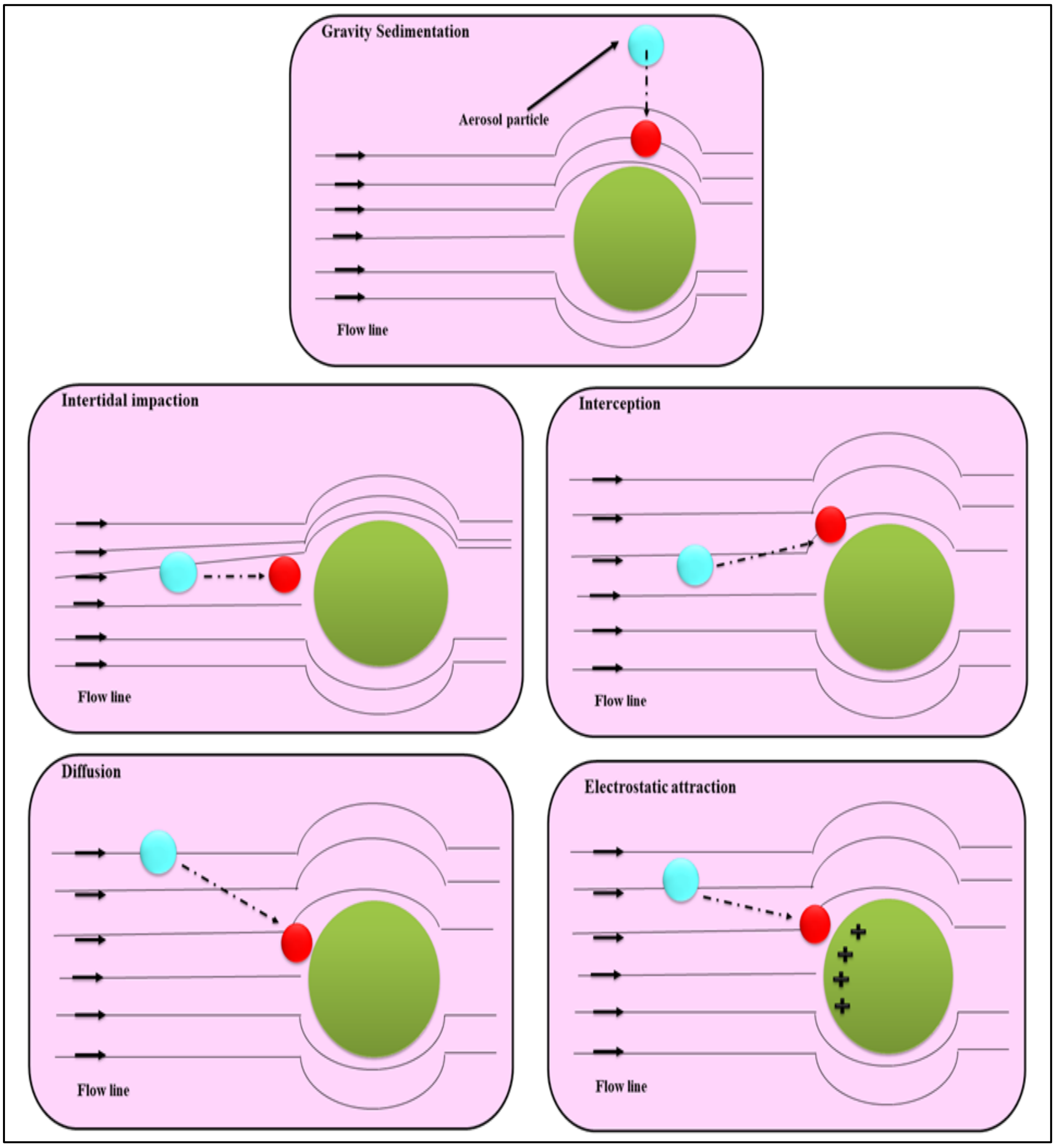

Figure 4. Schematic of the mechanisms of aerosol penetration through the masks.

CONCLUSION

Since the COVID-19 virus cannot survive the operating temperature of this conversion technology, pyrolysis has been identified in this study as a tested conversion method that can be used to convert the contaminated face masks into high-value bioproducts like biochar and bio-oil. To stop the spread of COVID-19, disposable face masks are a recommended piece of personal protective equipment.

AUTHORS CONTRIBUTION

All the review, interpretation, and conclusion were discussed and planned by both the authors. The first author (Dr. Shobhana Ramteke) wrote the first draft of the manuscript and critically re-viewed the whole manuscript for further valuable intellectual content. The second author (Dr. Bharat Lal Sahu) collected all the information, wrote and edited the whole manuscript and meanwhile both the authors have read and agreed to the published version of the manuscript.

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CONFLICTS OF INTEREST

The authors declare that they have no known competing financial interest that could have appeared to influence the work reported in this paper.

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