Analysis of the Optimal Use of Fabric Masks and Disposable Medical Masks During the COVID-19

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Abstract. Medical waste is one of the biggest concerns today due to the need to prevent COVID-19. How to properly handle the large amount of discarded disposable medical masks generated during and after the epidemic, fully understand the need for recycling and disposal of discarded masks, and accelerate the development of new technologies for value-added use have become important issues arising from the new crown epidemic and other respiratory infectious diseases, as well as an urgent requirement to protect the ecological environment. This paper outlines the materials of disposable medical masks and cloth masks, and analyses their impact on society and the environment from the perspective of their own characteristics, so as to give advice on how to choose masks. This paper compares cloth masks and traditional disposable medical masks, discussing the similarities and differences between them in terms of epidemic prevention, the environment, the economics of the product, the psychological burden on the public and the production of the company. The recommendations are based on the effectiveness of the two types of masks and their different handling methods. Finally, the challenges associated with the current use of masks are outlined and a personal view on the replacement of disposable medical masks with cloth masks is given. In the future, the government should expand the use of cloth masks by raising public awareness of the use of sustainable masks, in order to save resources and protect the environment. The aim of this paper is to reduce the environmental and socio-economic impact of masks by discussing the effectiveness, social and economic impact of the two types of masks, so that more people will be guided to use cloth masks.

Keywords: Face coverings, COVID-19, disposable medical masks, fabric masks.

1. Introduction

The outbreak of the new crown epidemic has led to a rapid increase in the global demand for masks. However, the disposal of discarded masks is seriously influencing the planet in many ways. Thus, “how to reduce the ecological impact of masks” becomes a hot topic today. Globally, 3 million masks are used every minute, and 3.4 billion masks or face shields are discarded every day. In Asia, 1.8 billion marks in total are discarded every day. Of these, China, the most populous country in the world, can discard nearly 702 million masks every day. By the end of April 2020, the average daily production of disposable medical masks in China reached 200 million, with each weighing approximately 5g. At the same time, the country will soon be faced with about 1,000 tonnes of discarded disposable medical masks every day [1]. How to properly handle the large number of discarded disposable medical masks produced during and after the epidemic, fully understand the need for recycling and treatment of discarded masks, and accelerate the development of new technologies for value-added use have become not only an important issue arising from the COVID-19 epidemic and other respiratory infectious diseases, but also an urgent requirement to protect the ecological environment. At present, tons of wastes are waiting to be disposed of properly, otherwise they will end up in the ocean and the chemicals they contain will cause the greatest harm to marine life and ultimately to people and the planet. It is of great necessity to reduce the negative ecological impact of masks and ensure the basic need for protection against epidemics. In the West, there is a preference for cloth masks, which not only reduces the number of masks used, but also recycles the structure of more masks used, thus fulfilling the need of environmental protection.

Of course, the use of different types of masks can have different degrees of environmental, economic and social impact. Cao Suzhen et al. studied the protective behaviour of Chinese residents in wearing masks during the COVID-19 pandemic and explored the differences in the behavioural patterns of mask wearing among different potentially at-risk groups. In a study conducted by Lu Wei et al. at the Key Laboratory of Environment and Health, Tongji Medical College, Huazhong University of Science and Technology, 12 subjects were selected under different working environments in summer and winter, and the bacteria concentration on the inner and outer surfaces of the masks and the bacteria concentration in the ambient air were measured for 1 h. The differences in the protective effects of different masks were analysed, and the filtration efficiency of different masks was compared by the filtration efficiency test. The average filtration efficiency of the masks was 91.53% at a flow rate of 20 L/min, which was statistically significant ($p<0.01$).

This paper aims to analyse the materials used in disposable medical masks and cloth masks, and examine the social and environmental impacts of both in terms of their own characteristics, in order to give advices on how people should choose their masks.

2. Masks

2.1. Disposable medical masks

Disposable medical masks (DMMs) mainly consist of a waterproof layer (spunbond nonwoven), a filter layer (meltblown nonwoven), ear straps, nose strips, and other components [1]. The structure is shown in Fig. 1. In terms of both the waterproof layer and the filter layer, they take PP non-woven microfibre as the core materials, accounting for more than 90% of the DMMs.

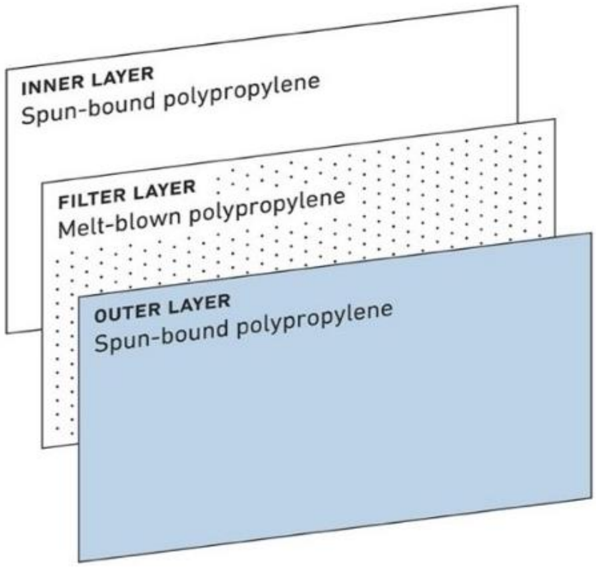

Figure 1. Layers layout of disposable medical mask.

The earbands are made of polyethylene terephthalate (PET) and polyurethane (PU). In addition, the nose strips are made of PP/galvanised iron wire, PE/galvanised iron wire or aluminium strips. The PP ultra-fine fibres of the filter layer are approximately 2 μm in diameter and are prepared by a meltblown process, whereby the molten PP extruded by a screw is blown with a high speed and high-temperature airflow, causing the molten fine stream to be stretched at a high rate and forming ultra-fine short fibres. Furthermore, they are stacked onto a curtain of condensed mesh to form a continuous network of short fibres, which are then prepared by a self-adhesive effect or other reinforcement process, and then by a high voltage corona charging technique to produce a large electrostatic charge. Firstly, the small diameter of the microfibres gives them a very high specific surface area. Secondly, the high surface resistance of the PP material (1016 ~ 1018 Ω) makes it very easy to generate a large electrostatic charge on the surface of the microfibres. Therefore, when the droplets with bacteria or viruses are close to the microfibre, they will be firmly adsorbed by the electrostatic charge on the surface of the microfibre, so that the purpose of blocking bacteria or viruses can be achieved. As the electrostatic force on the surface of the microfibre is strong, bacteria or viruses cannot be removed by simple washing, and washing will also greatly reduce the electrostatic force on the surface of the microfibre. Therefore, these masks are mostly for single use. It is noteworthy that the bacteria or viruses are adsorbed on the mask surface but are not killed, which brings a particular inconvenience in the recycling process of disposed DMMs.

2.2. Cloth mask

Cloth masks also consist of three layers: an inner layer of absorbent material such as cotton, a middle layer that acts as a filter or barrier and is made of a non-woven material such as polypropylene, and an outer layer of non-absorbent material such as polyester or polyester blends [2]. Although cloth masks offer a lower level of protection, the design changes can be effective in increasing their protective capacity. Currently, the most effective designs are multi-layer masks that fit snugly over the face with no dead space between the user and the mask. In addition, low air resistance insert filters and surgical mask liners can provide the maximum protection [3]. In fabric masks, however, the loops on the knitted fabric form an 'omega' shape with interwoven fabric structures, and the structure of woven fabrics uses warp yarns intersecting with weft yarns, mainly in a straight line. Due to their different structural configurations, woven fabrics can be packed together more tightly and often have a higher degree of dimensional stability. Another area of concern is the creation of pores at each loop and intersection point of the knitted fabric. While the pore sizes of knitted and knitted fabrics may appear similar under static conditions, knitted fabrics can easily increase in size when stretched, allowing more air and water vapour to pass through. Therefore, when knitted fabrics are mounted on dynamic objects using the same yarn and density, knitted fabrics are usually more breathable than woven fabrics, meaning that cloth masks contain materials with good water vapour permeability, they can transfer heat and moisture from the body quickly and are less susceptible to moisture and deterioration, and such masks are usually more comfortable for people to wear.

3. Characteristic

3.1. Protective effect

The COVID-19 outbreak has resulted in a shortage of personal protective equipment (PPE) throughout the world. This shortage has resulted in an increase in production of PPE to meet the demand, and as a result, several substandard equipment has entered the market [4]. With face masks and respirators now beginning to see widespread use throughout the world, the standards and test with which they are required to undertake have become points of interest [5]. The mask is effective in preventing the spread of airborne viruses, as shown in Fig. 2; the protective capacity of the mask, i.e., its ability to stop particles from penetrating the inside of the mask, depends primarily on the filtering capacity of its material and the adaptability of the mask to the wearer.

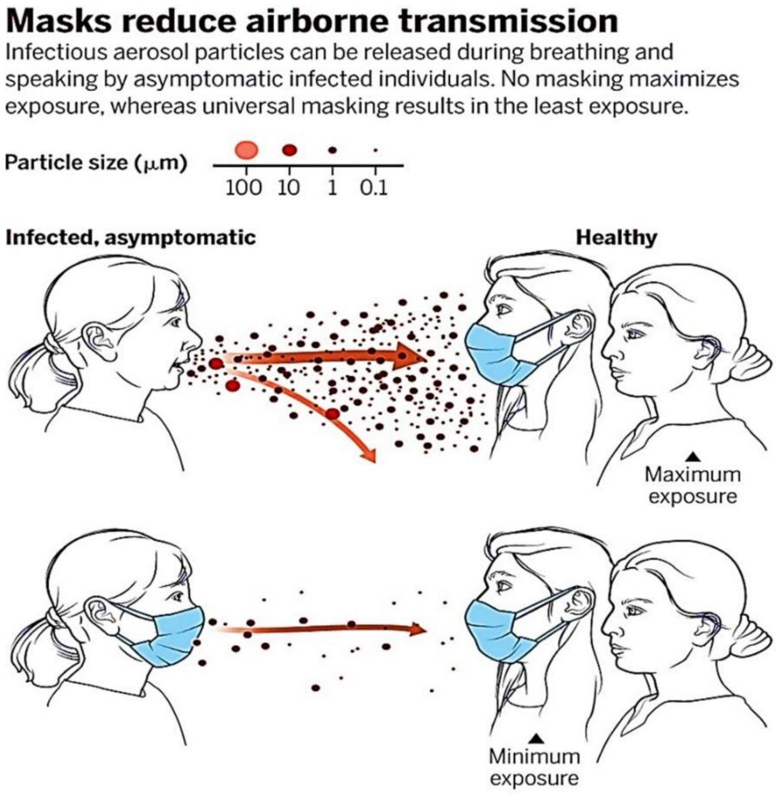

Figure 2. Mask prevention of transmission of the airborne virus [6].

In a study conducted by Lu Wei and other students from the Tongji School of Medicine, Huazhong University of Science and Technology, the average filtration efficiency of medical masks for bacteria was 91.53% at a flow rate of 20 L/min after 1 h of testing under different working conditions in summer and winter, with a statistically significant difference ($p<0.01$). The results show that disposable medical masks are effective in reducing the risk of viral infections in people. Furthermore, the WHO considers that medical surgical masks are more effective than single-use medical masks and recommends them to be worn by suspected cases, public transport drivers and service workers in public places.

Translated with www.DeepL.com/Translator (free version) Although fabric masks will never provide the same protection as disposable medical masks, fabric masks nevertheless meet the need for protection at a social distance between people. For the wearer, fabric masks limit the number of particles that can penetrate the inside of the mask, thus reducing the likelihood of harmful particles affecting the wearer. Although fabric masks offer a lower level of protection, their ability to protect increases significantly with design changes. The most effective designs are multi-layer masks that fit closely to the face, and the results of a study by Eugenia O'Kelly et al. suggest that there is significant heterogeneity in the protection offered by different fabric masks, and that some design features may enhance the protection offered by these masks. A variety of ways to improve the protection of fabric masks are being widely used and promoted, for example: fabric masks often come with a pocket into which a replaceable filter can be inserted; and the use of high filtration materials such as particulate matter (PM2.5) or HEPA (High Efficiency Particulate Air Filter) in an attempt to increase the protective effect of fabric masks. The results of the study by Eugenia O'Kelly et al. showed that the protection offered by fabric masks can be significantly adjusted according to fit and construction, with the best masks tested offering five times the amount of protection of lower performing masks. The most protective masks tested were those with very close-fitting multiple layers. Low air resistance filters can be inserted into fabric masks to increase protection. Alternatively, surgical masks can be worn under a tight-fitting fabric mask to significantly improve protection. Although fabric masks do not offer the same level of protection as N95 masks, much can and should be done to improve the protection they offer [3]. The study by Harriet Whiley et al. demonstrated that typically available fabric masks have at least a 50% viral filtration efficiency and this can be increased through the use of everyday items (vacuum cleaner bag and baby wipes) as an alternative to disposable pocket filters or through designing fabric masks to have three layers of different fabrics. This research supports the use of fabric masks in community settings to prevent the spread of new coronaviruses. Future research will need to investigate fabric mask designs that allow for optimal fit, examine the effects of different flow rates, and determine the availability and cost of materials needed to manufacture effective masks [7].

3.2. Environmental impact of disposable medical mask

It is well-known that mask pollution can directly affect wildlife (e.g., via ingestion and entanglement), regardless of their habitat, physiology, behavioural patterns. Disposable medical mask can directly affect animals and the environment like more than 200 species, including marine mammals, turtles, and seabirds, are entangled, or ingested by mask. Feeding and entanglement may limit the mobility and feeding ability of organisms, which is unfavorable to the survival and reproduction of organisms [8]. It is reported that the death of an adult Magellanic Penguin (sphenicus magellanicus) found in Juquehy Beach in São Sebastião, Brazil may be related to the intake of disposable medical masks. This mask appears in the stomach of penguins, which may limit the feeding activities of organisms and lead to hunger [9].

Because the disposable medical mask is composed of high molecular weight Petrochemical polymers, the mask is not easy to biodegrade in an open environment [10]. Very thin polypropylene it turns into microplastics and microfibers, which see into the soil and into the water. This is not only harm to animals but also to human body. Due to the material characteristics of masks, it is difficult to degrade naturally, and it requires a lot of energy and money to intervene by human means.

The World Health Organization (WHO) call people wearing fabric face masks (cloth masks) in public spaces where social distancing isn't possible. In order to reduce the impact of disposable medical mask on the environment, researchers defined filtration efficiency, air permeability and environmental impact index as the main standards when looking for materials to replace disposable masks. Cotton finally stands out and meets the material properties required by WHO. In addition, due to the natural degradation of cotton, there is no impact on the environment.

3.3. mic impact of disposable medical masks

The sudden outbreak of COVID-19 has caused a large demand for masks so that the selling price of 1 disposable mask rose from 0.5 yuan to 5 yuan, and N95 mask also rose from 3 yuan to 40 yuan, with masks being snapped up and even out of stock in pharmacies for a time. In addition to the extreme shortage of mask, meltblown cloth as an important raw material for mask also issued an emergency signal. The market price of 1-ton meltblown cloth went from 18,000 yuan before COVID-19 to 400,000 yuan today, 20 times increase in price within two months.

Compared with the price of disposable mask, cloth mask is more expensive, but they can be reused and on average are more cost-effective than disposable mask. Considering the same reliable protection, economically cloth masks are more suitable for daily life protection.

3.4. Enterprises to transfer production

From the perspective of the impact on the business, the data from Ministry of Industry shows that the high demand for disposable medical masks has forced many companies to transform into mask makers. Then, its capacity has climbed rapidly, which will cause the company to suffer financial losses. However, the cloth mask is recyclable, and people's demand for it will be reduced. For some masks that only need to replace filter cartridges, they require fewer parts to be produced, and companies can meet the supply demand easily, which will reduce the probability of other industries switching to the production of masks. From this point of view, cloth masks to replace the traditional disposable medical masks have a certain significance and should be promoted.

3.5. Psychological burden on the public

From the perspective of people's mental health, when people wear masks, their mouths are covered, which leads to misunderstandings when people communicate with their eyes. In addition, the memory of horrific events such as 9/11 has caused unconscious fear in the public and there is a certain resistance to the use of cover-ups.

In contrast, cloth masks may pose less psychological pressure, firstly, because their recyclability somewhat reduces the financial outlay of households on masks. At the same time, the various patterns on cloth masks will distract people and reduce the fear of covering the face. In addition, the comfort of skin contact will make children more likely to wear cloth masks. In addition, cloth masks contain materials with good water vapour permeability, they can quickly transfer heat and moisture from the body and are therefore less susceptible to moisture and deterioration, and such masks are usually more comfortable to wear. Disposable medical masks are the most common type of mask used to prevent respiratory infections. However, they may allow air and microbial leakage or cause a feeling of suffocation due to a choking sensation. They are also not the most environmentally friendly and cost-effective option in the current situation. Many manufacturers and investors have therefore taken the opportunity to develop reusable and washable masks to meet market demand.

3.6. Environmentally friendly

From the perspective of environmental awareness, many people may not be aware of what disposable medical masks are made of and what harm they can do. Because of its low price, people usually do not cherish low-priced goods. Its non-recyclable characteristics also lead people to consume them recklessly, making it difficult for people to generate environmental awareness. The Covid-19 pandemic has led to widespread environmental contamination of plastics, including polypropylene medical masks. In large scale or highly specific environments, the cost of disposable masks is lower than the cost of recycled polypropylene, which may not be a viable economic goal due to the small weight/volume of each mask, its infectiousness risk and the lack of available recycling circuits. However, at the end of the mask's life, the ecological costs will be more expensive. The rational reuse of medical masks and their end-of-life management is crucial, especially in times of pandemics, when a decisive shift can be taken. Reuse is the first step in the recycling process.

The use of disposable masks in the general population causes them to be consumed in large quantities to help combat highly transmissible mutants, but their reuse up to 10 times will compensate or even reduce their environmental impact. For lower-scale use, the possibility of safely recycling medical masks is cost-effective and an eco-friendly gesture. Ecological consequences must be taken into account: a non-woven mask is easily recycled as it is only composed of pure polypropylene when the nasal bar and the elastic bands are removed. This is not the case for woven masks that often uses a mix of synthetic fibres and has to follow a specific recycling. However, the recycling of domestic usage of medical masks has not been yet envisaged.

However, the unite price of recyclable masks is higher than that of disposable masks, so that people have a concept of valuing higher-priced goods. The awakening of environmental awareness can provoke them to consider the use of other disposable products and to think about whether there is an alternative for other items.

4. Masks Recycling

The raw material used in large quantities in masks is polypropylene material, which is one of the most widely used plastics within the fields of packaging, components and construction furniture, accounting for 19.3% of the total demand for plastics. In 2019, China's imports of polypropylene reached 3.49 million tonnes, and the widespread use of polypropylene also poses the problem of environmental disposal. At present, China does not have a mature capacity to recycle and treat polypropylene plastics, and compared to the average utilisation rate of over 45% for waste plastics in Europe (60% in Germany), the utilisation rate for plastics in China is only 25%. At present, there are four main methods of recycling DMMs. To be specific, the first is the high-temperature incineration, where the masks are mainly made up of highly flammable hydrocarbons. The calorific value of polypropylene, the main component of masks, is known to be 44 MJ/kg. If all masks produced in 2020 were incinerated, 2.68 x 1010 MJ of energy would be generated, an energy content equivalent to 5.9 x 105 tonnes of diesel, 5.86 x 105 tonnes of gasoline fuel, or 5.01 x 105 tonnes of natural gas. Although the incineration of waste masks generates much energy, the carbon dioxide produced during the incineration process cannot be ignored. If all masks produced in 2020 were to be incinerated, 1.43 x 109 kg of carbon dioxide1 would be released [11]. The second method is landfill degradation, which uses microorganisms in the soil to break down the polymer by landfilling waste DMMs. This is a time-consuming process, which also causes secondary contamination of the soil. The third method is mechanical recycling, where the crushed DMMs fraction is blended with other polymers or inorganic fillers using a melt processing method to produce a lower grade product for further use. The fourth method is the chemical recycling. It is a relatively complex and energy-intensive process in which polymers are transformed into small molecules through chemical processes such as pyrolysis or gasification, and then they are reconstituted to form new materials.

5. Challenges and perspectives

The sudden global outbreak of the Newcastle pneumonia epidemic has made the recycling and upcycling of waste DMMs an important issue in the new situation at home and abroad. Chemically selective conversion of waste DMMs into a single product range of related chemicals, fuels and high value-added materials is a fundamental way to add value to the use of waste DMMs. For polyolefin materials such as PP, chemists must develop new methods to selectively and efficiently cleave or functionalise the two most abundant bonds in the molecular chain, namely aliphatic C-C and C-H bonds, which are also the two most resistant systems to existing synthetic methods. The ability to break specific C-C bonds in polymers, and the strategy of introducing functional groups as a result of these cleavage reactions, will greatly facilitate the up-cycling and value-added use of polymers, with energy-saving and environmental implications.

Obviously, if cloth masks are used instead of disposable masks, the number of masks used will be reduced to a large extent, reducing the pressure to recycle. At the same time, the material of cloth masks can be recycled, disinfected and sterilised for secondary use, making them more valuable than disposable medical masks.

6. Conclusion

With the generalisation of the new crown epidemic, the demand for masks will only increase, so the correct choice of mask is a topic worthy of further study. This paper compares cloth masks and traditional disposable medical masks, discussing the similarities and differences between the two in terms of epidemic prevention, the environment, the economics of the product, the psychological burden on the public and the production of the company. The recommendations are based on the effectiveness of the two types of masks and their different handling methods. Finally, the challenges associated with the current use of masks are outlined and a personal view on the replacement of disposable medical masks with cloth masks is given. In the future, the government should expand the use of cloth masks by raising public awareness of the use of sustainable masks, in order to save resources and protect the environment. At the same time, it is hoped that the community will take responsibility for the disposal of masks and that there will be someone to instruct each household on how to properly separate medical waste from household waste. Proper separation will help with the subsequent recycling and removal of waste such as medical waste. The government should monitor the amount of polypropylene throughout the city. The government can search for the amount of polypropylene, the main substance in plastic materials, to effectively reduce its harmful effects on the environment.

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