# EFFECTS OF PHYSICAL PROPERTIES OF A FIBER MEDIA ON PARTICULATE FILTRATION EFFICIENCY (PFE) AND WOB IN BREATHING

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**Abstract** - The outbreak of the 2019 coronavirus pandemic (COVID-19) has led to the recommended routine use of face masks to reduce the risk of exposure. In this study, the increase in work of breathing (WOB) imposed by face masks has been theoretically investigated for both normal subjects and patients with obstructive and restrictive lung diseases at different activity levels. The results show a significant increase in WOB due to face masks, which is more intense at higher activity levels. The added WOB is significant during physical activity and may be intolerable for patients with pre-existing lung disease and may contribute to inspiratory muscle fatigue and dyspnea. Furthermore, in this study, the effects of physical properties of a fiber medium, including thickness, porosity, and fiber diameter, on particulate filtration efficiency (PFE) and added WOB are analyzed. The relationships between the physical properties of the fiber media and the added WOB and PFE are shown in some contour plots as a quick and simple tool to select the desired physical properties for a monolayer filter to ensure that the added WOB is comfortable in While PFE is high enough.

**Keywords** - Filter Face Mask, Most Penetrating Particle Size, Respiratory Protection, Particle Filtration Efficiency, Fiber Diameter

## I. INTRODUCTION

Since the emergence of the coronavirus disease 2019 (COVID-19) pandemic, the routine use of respiratory protective devices (RPDs) has been recommended to reduce the risk of exposure. In addition, the latest World Health Organization recommendations include the use of masks by the general public to reduce the risk and impact of COVID-19. The most widely used RPD among healthcare workers and the general population are surgical face masks (SMs) and face-filtering respirators (FFRs), particularly N95 FFRs.

Consistent use of RPD is critical to personal protection from exposure to contaminated particles or the risk of respiratory infections. Although RPD is mandatory and highly recommended for areas most affected by the COVID-19 pandemic, significant problems have been observed in RPD wearers due to physical symptoms and discomfort.

Major experimental studies have been conducted on PRD comfort. Some researchers used automatic breathing and metabolic simulators (Sinkule EJ, 2013), while others tested the comfort of masks on human subjects (Laird, 2020). due to thermal discomfort (Lim, 2016), CO2 accumulation, oxygen depletion causing headache when wearing N95 FFR [1,6,9], and mechanical factors such as increased respiration. resistance (Lee HP, 2011). A recent study found that panic-prone individuals may be at increased risk of mask-related respiratory distress (Perna, 2020).

An increase in breathing resistance of up to about 300% was previously reported for the N95 FFR. Increased respiratory resistance, combined with CO2 rebreathing while wearing a mask, may promote respiratory fatigue and impair physical work capacity. However, no indication of increased respiratory effort at low workload for a relatively short period was observed by Roberge et al. Hopkins et al. reported that pulmonary function and cardiopulmonary exercise capacity were greatly impaired by N95 FFRs in healthy subjects. to be Later, Hopkins et al. They found some flaws in their work that questioned the validity of the study. The authors argued that since there were no significantly different results for arterial blood gases, heart rate, cardiac output, and blood pressure between masked and unmasked conditions, it should not be taken as a recommendation to avoid mask use during be exercise These different results suggest the use of a mathematical model to investigate the effect of workload level on increasing work of breathing (WOB).

There are various experimental researches in the field of particle filtration efficiency (PFE) of face masks. To achieve aerosol filtration of more than 95% under standard conditions, proper masks are needed. PFE depends on the filter material, fiber properties, including structure, diameter and electrostatic charges, number of layers, shape (surgical style, conical, or duckbill), and face fit. Furthermore, a significant decrease in PFE has been observed during a cyclic cough episode (Dbouk, 2020). Although the main mechanisms of aerosol penetration through masks have been well studied (Tcharkhtchi, 2021), the combined effects of the physical properties of the fibrous medium (including fiber diameter, porosity, and thickness) and wearer activity level on PFE have not been reported.

This study calculates the WOB enhancement applied by the masks through a porous media model. Then, the effects of the physical properties of the fibrous

medium and the wearer's activity level on the added WOB and PFE are investigated.

For simplicity, this study assumes that air flows uniformly over the entire surface of the mask and that there is a uniform pressure in the space between the face and the mask. However, it is not accurate because the maximum flow occurs right in front of the nose. Therefore, fluid dynamics analysis for breathing through a face mask that covers the human face is proposed as an improvement. In addition, we have not calculated the increase in pressure drop due to clogging caused by the continuous use of masks. This can also increase the added WOB of wearers in the long run.

According to Figures 1 and 2, it is impossible to reduce the added WOB while improving the PFE of the face mask by changing the fiber diameter, porosity and thickness of the fiber medium. Therefore, it is suggested that PFE improves the fiber environment with other techniques such as electrical charging of fibers.

**Theoretical**

Considering the perspective of the corona epidemic, the successive emergence of mutated strains in a wide range of the world and the relative and unstable effectiveness of vaccines, it is necessary to take health-oriented measures to deal with this threat; Actions that have a participatory approach and are active and proactive. Until achieving a sustainable solution, in addition to measures such as vaccination, physical precluding is one of these measures. - According to the increasing reduction of the effect of "only" use of the mask, physical barrier should preferably be done through "universal use of the face shield (Face Shield) along with the mask and the appropriate cover under it, while the wide and free distribution of the face shield" take Considering the very high transmission power of some new strains, the lower effectiveness of previous vaccines and "the lower efficiency of using only masks in preventing the spread of disease caused by these strains", using a face shield with the necessary cover underneath it can be a way be effective for the public in normal spaces to deal with the spread of corona infection. An important function of the cover under the face shield, especially reducing the "speed and intensity" of particles exiting the mouth, also considering the "effect of the shield plate placed in front of it" and also "the major role of relatively larger respiratory particles in the transmission of covid - It is 19 But for many, it is not easy to use a face shield and disposable masks that cover both the mouth and especially the nose for a long time. (However, covering only the mouth under the face shield, on the contrary, can facilitate the use of the shield for many.) - Therefore, investigating "a simplified method of simultaneous use of the face shield and mask" is of fundamental importance. Therefore, it is suggested to immediately perform a simple practical test to show the effectiveness of using a face shield with a mask "only on the mouth and not on the nose" under the shield with different masks, as well as with "washable" covers (Ismaili, 1400).



KCC-1 silica nano mesh is of interest due to its features such as adjustable pores, biocompatibility, high stability, low toxicity, and easy synthesis. The purpose of this research is to prepare filters for breathing masks using nanotechnology. In this research, polystyrene fibers and its composite with KCC-1 were used to make filters with high absorption of particles. Conventional masks have the problem of static electricity loss, which loses its filtering efficiency, while fibers do not use static electricity and are suitable for physical removal of particles. Polystyrene fibers and its composite were prepared with KCC-1 by electrospinning method. TGA, FESEM, FITR and EDS techniques were used to determine the structural characteristics of the fiber nanocomposite and its filtration efficiency was investigated (Idrisi, 1401).



Today, health and public health of societies is one of the basic pillars of the human rights system, and having physical, mental health, etc., which should be available to everyone, is the right of all human beings. In recent years, viral infections are one of the important factors in increasing mortality and also a serious threat to public health, one of these pathogenic viruses is the corona virus. The first impact that a widespread disease has on the world is the situation It is the economy, the corona virus has affected many important economic sectors, the textile industry was more affected than other industries. Corona virus may be one of the ways of transmission of corona virus through respiratory droplets by

infected people when they cough, sneeze or talk. Masks and fabric clothes can be very useful to limit the spread of corona, but you should pay attention to the choice of fabric, the number of layers of fabric used and other things. In this review, using textile concepts, we have provided suggestions and recommendations regarding the limited supply of breathing masks and face masks, and according to the findings and collected materials as well as data analysis, we found that most of the fabric have significant blocking efficiency. In particular, bilayers of highly permeable fabrics perform similarly to masks and medical gowns, while being almost twice as breathable, and overall our study shows that fabric-based coverings, especially with multiple layers, are possible. It helps to reduce the transmission of droplets of respiratory infections, in addition, masks and clothes made of materials used in cotton fabrics allow washing and reuse, which can reduce adverse environmental effects and also help lead to economic problems (Mousavi, 2019).



The sudden spread of Covid-19 in the world has attracted everyone's attention. In addition, due to the unknown and lack of definitive treatment methods, the recommendation of the World Health Organization and other medical institutions is to provide non-drug solutions to control this virus. In this regard, one of the proposed methods is to use a mask during this global epidemic as a tool to control the spread of respiratory droplets (Goharian, 1400).

The presence of a wide range of air pollutants in many countries of the world causes the prevalence and mortality rate of respiratory disorders. With the emergence and spread of the Covid19 virus and its respiratory complications, attention to the transmission of various infections through the air has attracted the attention of researchers. One of the most important personal protection methods to prevent the transmission of respiratory infections is to use a face mask. But the type of fiber used in making the mask must be able to remove the highest amount of infectious agents. In this study, while examining the fibers used in the medical industry, the mechanism of removal of respiratory infectious agents (living and non-living) by these textiles has been tried to be identified and evaluated. The results of this study show that the use of non-woven fibers is effective in controlling these factors. In this technology, a type of fabric is produced without weaving, that is, the fibers are mixed together and a connection operation is performed on them. Compared to other fibers, non-woven fabrics have advantages in six cases: mechanical resistance - application in wound dressing - bacterial impermeability - secretion impermeability - flexibility - ease of use (Mahmoudian, 2019).

Due to the spread of the corona virus last year, the use of sanitary masks increased sharply. After a few months passed since the start of the virus and the widespread use of masks, the need to change the structure of sanitary masks was felt. According to this need, the product of maintaining the mask cache was designed and manufactured (Rosouli, 2019).

Nowadays, due to the spread of the corona virus, the use of respiratory masks has increased a lot. In this regard, masks prepared with nano technology can increase the efficiency of these products by absorbing more airborne particles. However, the issue of microbial contamination of masks has also caused concerns. Due to the sensitivity of some people, the possibility of using antimicrobial chemicals in the structure of the mask faces limitations. For this reason, preparation of antimicrobial masks with extracts of natural medicinal plants is very important (Sabri, 1400).

The covid-19 pandemic has caused the widespread use of personal protective equipment. In the meantime, masks are one of the most widely used protective devices to prevent the transmission of the virus. However, the mismanagement of such materials threatens the environment with a new form of plastic pollution, so the evaluation of their effects has attracted special attention. The results of the life cycle assessment showed that in the single-use surgical mask, the most harmful environmental effect in all the middle effects of the life cycle is related to the paper and cardboard used in mask packaging, so that more than 92% of global warming, more than 97% of fine particles, more than 96% of land use and more than 97% of fresh water etherification is due to the packaging of this type of mask. In the N95 mask, the most biologically destructive effect is related to the mask packaging paper (more than 1.99% terrestrial environmental toxicity, 6.98% land use and 1.94% human carcinogenic toxicity) and in the next category in some categories with The difference includes the most negative effect related to linen fiber in the body of the mask (acidification of the earth, eutrophication of fresh water and marine eutrophication with values of 47.2%, 24.2% and 95.33%, respectively. From the comparison of disposal scenarios It was also found that both types of masks have the most destructive biological effect related to landfill, which in global warming, etherification of fresh and sea water is 100% and in other parameters with a high percentage as the most destructive disposal scenario (Parsai, 1401).



The recent outbreak of the coronavirus (COVID-19) and the increase in the number of confirmed cases have forced governments to find a way to control the disease. The governments' initial decision was quarantine and social distancing. In addition to these limitations, scientists are trying to develop a suitable vaccine or medicine. However, due to the prolongation of these restrictions and the failure of scientists, the economy has been adversely affected. Therefore, governments have reduced these restrictions and required all people to use face masks in public places to reduce the rate of transmission of the coronavirus (Hieh Chi, 2019).

The borderless corona virus and the spread of this strange disease left a new experience on the way of life of the people of the world, a special experience that has never been seen anywhere in the history of the world with this intensity, quality, speed and pervasiveness, along with disruption and economic and political consequences. , social, cultural and even disruption in interpersonal and social communication has not been recorded. Among them, one of the effects of dealing with the corona disease, which is in the form of using a mask on the face to take care of physical health and prevent the spread and break the chain of this disease in many countries of the world, as a health task and a human and social duty. It has appeared (Maadi, 1400).

Conclusion

This study investigated the effect of face masks on added resistance WOB of mask wearers at four different levels of physical activity. The added WOB at rest was about 3.5% and 11.6% of the healthy lung for SMs and N95 FFRs. While the body of literature reports that this issue is not significant for healthy subjects, the results of the present study suggest that face masks may increase WOB even in healthy subjects during physical activity. Patients with pre-existing lung diseases experience increased dyspnea more than healthy individuals when using a face mask due to an increase in WOB above the tolerance threshold. The study estimated that long-term use of a face mask may increase pressure drop due to congestion.

The simultaneous effects of porosity, fiber diameter and the thickness of the fibrous medium of a fibrous medium were theoretically investigated on the added WOB and PFE. Both porosity and fiber diameter can change the added WOB and PFE of face masks. Assuming a constant fiber diameter, a thin filter with higher porosity will have a lower added WOB and PFE than a dense filter with lower porosity. Furthermore, assuming constant porosity, increasing fiber diameter leads to a decrease in WOB and added PFE. Changing the average fiber thickness is also a double-edged sword. Thicker filters have better PFE but higher added WOB. We present these non-linear relationships in some contour plots as a quick and simple tool to select the desired values of porosity and fiber diameter in the fiber medium to ensure that the added WOB is comfortable while the PFE is sufficiently high. (equation (4)), (17) - (20)).

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