



DOI: 10.34658/9788366741751.24

A STUDY ON BARRIER PERFORMANCE OF MEDICAL FACE MASKS

Muhammad Usman Munir^{1(*)} , Daiva Mikučionienė¹ 

¹ Kaunas University of Technology 1, Studentu str. 56-249, LT-51424, Kaunas, Lithuania

(*) Email: muhammad.munir@ktu.edu

ABSTRACT

The sudden outbreak and rapid transmission of SARS-Covid-19 virus has urged people around the world to adopt safety measures to help stop the spread of this infectious disease. Thus, there comes a sudden increase in demand for PPEs such as face masks and gowns. This increase in demand has paved the way for low-quality medical face masks to the public, causing a serious threat to the contamination of the Covid-19 virus. Therefore, to verify the real picture of the performance quality of medical face masks, we carried out a study to check their barrier performance as per the requirements of International Standards EN 14683 and ASTM F2100. We conducted the bacterial filtration efficiency, particle filtration efficiency and differential pressure tests on all the medical face masks samples and found that almost all the masks fall under 95% filtration to bacterial aerosol requirement, 95% filtration efficiency to latex sphere, and had differential pressure in limits. Our study has also concluded a correlation between these performance criteria, and it would be a great help and time saving if we adopted the findings of this research. The out has helped to create public confidence in their quality performance.

KEYWORDS

Covid-19, personal protective equipment, medical face masks, bacterial filtration efficiency, particle filtration efficiency, differential pressure.

MATERIALS AND METHODS

We collected medical face masks from 10 different pharmacies and are treated anonymously. The medical face masks are generally made of polypropylene. The notation of the 10 medical mask samples is as follows: MFM1, MFM2, MFM3, MFM4, MFM5, MFM6, MFM7, MFM8, MFM9 and MFM10. All medical face masks were tested against the performance criteria defined in EN 14683: 2019 and ASTM F2100-19 [1]. As our focus is to check the barrier performance of medical face masks, we have focused only on Bacterial Filtration Efficiency, Particle Filtration Efficiency and Differential pressure of these masks.

Bacterial Filtration Efficiency Test (BFE)

The bacterial filtration of all the collected medical masks was analysed using the Bacterial Filtration Efficiency Tester (QUINSUN, G299), in which it is possible to place the control and sample simultaneously at the same time, avoiding test error and improving the test accuracy. ASTM F2101-2019 [2] was followed, which defines a test method to check the bacterial filtration efficiency (BFE) of medical face mask materials, using a biological aerosol of staphylococcus aureus. The BFE tester uses a ratio of upstream bacterial challenge to downstream residual concentration to determine filtration efficiency of medical face mask materials. The working principle of the tester is in a way that a certain



concentration of bacterial aerosol (*staphylococcus aureus*) occurs at upstream of the mask, entering the aerosol chamber and mixing, the bacterial aerosol enters the two parallel gas path sampling system. One has a test sample for the Anderson sampler, and the other one does not have a sample as a positive quality control (total bacterial count). The ratio between the positive quality control value and the sample test value is the bacterial filtration efficiency of the medical face mask. The filtration efficiency percentage is calculated using the following equation:

$$C - T / C \times 100 = \%age \text{ BFE} \quad [1]$$

where, C is Plate count of control; T is Plate count of test sample.

Particulate Filtration Efficiency Test (PFE)

The submicrometer particulate filtration efficiency of all medical face masks was analysed using a particulate efficiency tester (DRICK, DRK506F Double photometer sensor), which determines the filtration efficiency of latex sphere particles. To carry out this test, ASTM F2299 was followed. The PFE tester measures filtration efficiency by comparing the particle count in the feed stream (upstream) with that in the filtrate (downstream). The PFE utilizes filtered and dry air through an atomizer which is used to produce aerosols containing latex spheres having particle size in the range of 0.1 to 5.0 μm and airflow test velocities of 0.5 to 25 cm/s. Each medical face mask sample was clamped in the fixtures and then mounted on the machine and the test procedure was initiated. The generated aerosol is passed through the sample material, and the photometer detects the Upstream and Downstream counts of aerosol particles and generates report in %age filtration efficiency w.r.t. different sizes of aerosol.

Differential Pressure (DF)

Air permeability of medical face masks was determined by Differential Pressure Tester. (QUINSUN, G285, designed for medical face masks) Following EN 14683 test method, air is drawn at a rate of 8 L/min to a measured area (25 mm in dia or 4.9 cm^2) of medical face mask and the differential pressure was measured in Pa/cm^2 .

RESULTS AND DISCUSSION

Bacterial Filtration Efficiency

All medical face mask samples were first conditioned at 21 °C and 85 % relative humidity for 4 hours and then subjected to test for their bacterial filtration efficiency according to the ASTM F2101:19 test method ASTM F2101 [2]. The results of the bacterial filtration efficiency of all medical face mask samples are shown in Table 1.

Table 1. DF, BFE, PFE of medical face masks.

Samples	DF Pa/cm²	BFE %age	PFE %age
MFM1	29.8	95.2	94.6
MFM2	36.8	96.5	95.8
MFM3	36.0	96.0	95.5
MFM4	65.4	100.0	99.5
MFM5	47.6	99.0	98.0
MFM6	25.6	95.0	93.5
MFM7	38.8	97.0	96.0
MFM8	59.2	99.25	98.5
MFM9	44.8	98.7	98.2
MFM10	34.0	95.8	95.0

The Bacterial Filtration efficiency of all samples was measured against control samples, as it contains no sample in it and all the bacteria from aerosol chamber got their way to this control Petri dish. It has been observed that all medical face masks tested have BFE in limits defined by EN 14683:2019 and ASTM F2100:20 i.e. $\geq 95\%$, ranging from low values of 95% to maximum BFE of 100%. None of the medical face mask samples under testing exhibits poor BFE, which shows a higher filtration efficiency of these medical face masks available to the public. We must remember that the aerosol size used in the BFE is about (2.1~3.3) μm that is only judged from the Anderson column used for its testing. The BFE testing machine does not have a photosensor to measure the aerosol size generated in the aerosol chamber. This also makes this test difficult and time consuming, as to test the BFE of 1 medical face mask, we need to carefully prepare media in 6 Petri dishes for the control Anderson chamber and 6 Petri dishes for the sample Anderson chamber. In addition, results are obtained after 24 hours of incubation, and if any contamination is found after 24 hours of incubation, the test should be repeated in a clean environment. Bacterial Filtration Efficiency is the requirement of medical type of face masks and is defined in ISO and ASTM standards, but to check the filtration against Covid-19, which has a particle size of 0.1 micrometres, we need to test the medical face masks against the particles having size in range of 0.1 μm .

Particle Filtration Efficiency Test

For the particle filtration efficiency test, each medical face mask was preconditioned under test conduit conditions at a relative humidity of 30-50 % at a temperature of 21 °C for 4 hours. After conditioning, all face masks were tested according to the test method defined in ASTM F2299 [3]. As the Particle filtration efficiency tester generates latex sphere within the range of 0.1 to 5.0 microns, so to check the filtration to the size of the Covid-19 virus i.e., 0.1 microns, we only focused on the filtration efficiency of medical face masks against this size.

According to Table 1, most of the face masks under testing exhibit good PFE at 0.1 micron particle size. MFM4 showed the highest PFE of 99.5% and we can denote it as a Type III medical face mask. Only MFM1 and MFM6 failed this barrier performance test with PFE values of 94.6% and 93.5% against the minimum requirement of 95% PFE. We have also found a correlation of BFE and PFE, by comparing the results of BFE and PFE a medical face mask with highest BFE of 100% also shows a highest PFE of 99.5%. The PFE of MFM4 is lower compared to its BFE; this can be explained by the fact that in PFE we have a particle size of 0.1 microns, so more particles get their way through MFM4, and thus the filtration efficiency is lower. In contrast to this in BFE we have particle size of 3 microns, so more of the bacterial aerosol is filtered, resulting in 100 % BFE for MFM4. Also considering the results of BFE and PFE we can conclude with confidence that, if we need a face mask against Covid-19 spread; PFE is the main test that can depict a filtration performance against particle size of 0.1 micron, same as the size of Covid-19 virus. A correlation between BFE and PFE was observed by Whyte et al. [4], but their study was not specific to the size of Covid-19 particles.

Differential Pressure

It can be observed from Table 1, that the differential pressure tests in which most medical face masks have differential pressure values within acceptable limits also define what type of category they fall into. Type I and Type II medical face masks require differential pressure to be greater than 40 Pa/cm² and Type II medical face mask requires values to be less than 60 Pa/cm².

By this categorization only MFM4 exceeds the threshold of less than 60 Pa/cm² and has a value of differential pressure of 65.4 Pa/cm². Freeman et al. [5] have found the correlation between DF and PFE, but with non-medical face masks. After analysis of the obtained results, a correlation was found between bacterial filtration efficiency, particle filtration efficiency and differential pressure. This correlation is presented in Figure 1 and Figure 2.

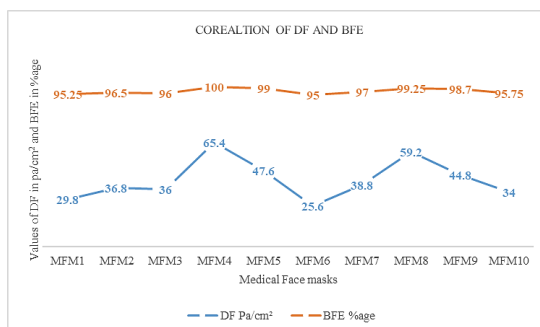


Figure 1. Correlation of DF and BFE of medical face mask.

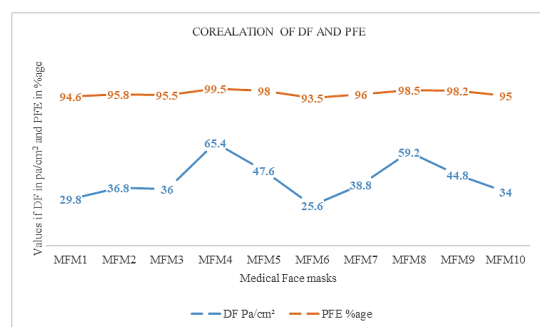


Figure 2. Correlation of DF and PFE of medical face masks.

CONCLUSION

After this study, it has been concluded that almost all the tested medical face masks available on the market exhibit barrier properties as defined in the European and American standards. In addition, a correlation has been found between bacterial filtration efficiency, particle filtration efficiency and differential pressure. If we compare the results of BFE and PFE, we can see that the BFE of a medical face mask is always higher than the PFE, this is because in the BFE test the bacterial aerosol has a size of almost 3 microns and in the PFE the latex sphere aerosol has a particle size of 0.1 microns. Also, if we know the PFE of medical face masks, we can now predict its BFE as it would be some fractions higher than that of PFE and we can skip the long-time taking BFE testing procedure. Also, as the differential pressure increases, the BFE and PFE of the medical face mask also increases, because as the pore size gets smaller the differential pressure increases and more particles of bacterial or latex sphere are filtered, increasing the barrier performance of these medical face masks. Thus, if we know the PFE, we can predict its DF and its BFE.

REFERENCES

- [1] ASTM International: ASTM F2100-19e1 2020. Standard Specification for Performance of Materials Used in Medical Face Masks, <https://doi.org/10.1520/F2100-20.2>.
- [2] American Society for Testing and Materials: ASTM F2101 2019. Standard Test Method for Evaluating the Bacterial Filtration Efficiency (BFE) of Medical Face Mask Materials, Using a Biological Aerosol of Staphylococcus aureus, <https://doi.org/10.1520/F2101-19.2>.
- [3] Particles L., Standard Test Method for Determining the Initial Efficiency of Materials Used in. 03(Reapproved) 2010, pp. 1–8. <https://doi.org/10.1520/F2299>.

- [4] Whyte H. E., Montigaud Y., Audoux E., Verhoeven P., Prier A., Leclerc L., Sarry G., Laurent C., le Coq, L., Joubert A., Pourchez J., *Comparison of bacterial filtration efficiency vs. particle filtration efficiency to assess the performance of non-medical face masks*, Scientific Reports 2022, vol.12, no 1, pp. 1–8. <https://doi.org/10.1038/s41598-022-05245-4>.
- [5] Freeman C., Burch R., Black C., Strawderman L., Rickert J., Wilson J., Saucier D., Smith B., *Filtration efficiency and differential pressure of fabrics used in non-medical masks based on SARS COVID-19 particle size*, Textile Research Journal 2021, vol. 92, no 17-18, <https://doi.org/10.1177/00405175211046056>.