



# Investigation The Bacterial Filtration Efficiency Of Medical Masks From Polyethylene Terephthalate (PET) Fabric

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(First received 31 January 2022 and in final form 24 March 2022)

(DOI: 10.31590/ejosat.1065823)

**ATIF/REFERENCE:** Sipahi, N. & Öztoprak, M. (2022). Investigation The Bacterial Filtration Efficiency Of Medical Masks From Polyethylene Terephthalate (PET) Fabric. *European Journal of Science and Technology*, (35), 142-147.

## ABSTRACT

The Covid-19 pandemic period caused attention to the importance of medical masks. Various studies show that mask fabrics should not be ordinary. Uncontrollably produced masks with poor quality have become an important problem in the market. Based on the idea that viruses spread by binding themselves to environmental bacteria and water droplets, it is assumed that the basic filtering efficiency of masks is of primary importance and requires the use of masks with a certain filtering ability. The purpose of the present study was to produce fabric masks from Polyethylene Terephthalate (PET), and to investigate the filtration efficiency. Masks were produced from the developed PET fabric and widely used Meltblown (MB) fabric, which is known to have a high filtration rate and their filtration efficiencies were compared. EN 14683 BFE methods was used in laboratory setting to measure the filtration efficiency of the masks. It was found that the MB/3-layer mask had 99.7% (SD±0.2) capacity of filtering microorganisms and the 3-layer ART/Mask in the developed PET structure was capable of filtering microorganisms at a rate of 96.8% (SD±2.7). When the filtration efficiency of the masks detected for each microorganism was compared separately, no statistically significant differences were detected (p>0.05). The tested mask was found to have a similar high microbial filtration rate to the mask made of meltblown fabric. This suggests that it will reduce the spread of viruses by attaching themselves to bacteria from sick individuals. It is also it can has protective effect for nosocomial infections.

**Keywords:** Bacterial filtration efficiency, Covid-19, Mask, Pandemic, Polyethylene terephthalate

## Polietilen tereftalat (PET) kumaştan elde edilen tıbbi maskenin bakteri filtrasyon verimliliğinin araştırılması

### Öz

Covid-19 pandemi dönemi tıbbi maskelerin önemine dikkat çekmiştir. Araştırmalar, üretilen maskelerin herhangi bir kumaştan olmaması, belirli özelliklerinin olması gerektiğini göstermektedir. Ancak kontrolsüz olarak üretilen kalitesiz maskeler piyasada önemli bir sorun haline gelmiştir. Virüslerin çevredeki bakteri ve su damlacıklarına tutunarak yayıldığı fikri, maskelerin temel filtreleme etkinliğinin belirli bir düzeyde olması gerektiğini zorunlu kılmaktadır. Bu çalışmada polietilen tereftalattan (PET) kumaştan maske üretilmesi ve filtrasyon etkinliğinin araştırılması amaçlanmıştır. Geliştirilen PET kumaştan ve yaygın olarak kullanılan yüksek filtrasyon verimliliği olduğu bilinen Meltblown (MB) kumaştan maskeler üretilmiş ve filtrasyon verimlilikleri karşılaştırılmıştır. Maskelerin filtrasyon verimliliğini ölçmek için laboratuvar ortamında EN 14683 BFE test standardı prosedürleri uygulanmıştır. MB/3 katmanlı maskenin mikroorganizmaları %99,7 (SD±0.2) filtreleme kapasitesine sahip olduğu ve geliştirilen PET yapısındaki 3 katmanlı ART/Maske'nin mikroorganizmaları %96,8(SD±2.7) oranında filtreleyebildiği tespit edilmiştir. Her bir mikroorganizma için tespit edilen maskelerin filtrasyon verimlilikleri ayrı ayrı karşılaştırıldığında, istatistiksel olarak anlamlı bir farklılık tespit edilmemiştir. (p>0,05). Test edilen maskenin meltblown kumaştan üretilen maskeyle benzer oranda yüksek mikrobiyal filtrasyona sahip olduğu bulunmuştur. Bu durum hasta bireylerden bakterilere bağlanarak yayılan virüslerin çevreye bulaş oranını azaltacağını düşündürmektedir. Ayrıca PET'ten üretilen maskelerin hastane enfeksiyonlarına karşı koruyucu etkisi olabileceği öngörülmektedir.

**Anahtar Kelimeler:** Bakteriye filtrasyon verimliliği, Covid-19, Maske, Pandemi, Polietilen tereftalat

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## 1. Introduction

The viral outbreak that appeared in Wuhan Province, China was named as Covid-19 pandemic by the World Health Organization. Although the causing agent first appeared in December 2019 in China, more than 118.000 cases of Covid-19 were detected in 114 countries as of March 11, 2020 (WHO, 2020; Kartal, 2021). Also, it was announced on the same date by the Ministry of Health of Turkey that the novel coronavirus type entered the country for the first time (TÜBA, 2020).

Today, Covid-19, which is still spreading rapidly (as of November 2021), is a novel acute respiratory syndrome, which can become complicated with severe pneumonia (O'Neill et al., 2020). This virus, which is identified as SARS-CoV 2, is an RNA virus that is associated with pneumonia, such as SARS-CoV and MERS-CoV. The virus, which has high infection rates with relatively high mortality, can easily spread through respiration. It was reported that the virus infects healthy people from sick individuals after contact with droplets scattered through coughing, sneezing and with surfaces where the respiratory secretions of patients come into contact (Wu et al., 2020; Zheng et al., 2020). According to researchers, this virus can survive maximum 4-5 days on different materials, such as aluminum, wood, paper, plastic and glass (TÜBA, 2020; Shoenfeld, 2020). The speed of the pandemic and its strong infection routes brought precautionary decisions to the forefront to avoid or stop the pandemic worldwide and in Turkey. The use of personal protective equipment, such as masks, has become mandatory to protect against infection. For this reason, there has been a great demand for masks, gloves and similar equipment in the community.

Experts emphasize social distancing and mask use to protect against Covid-19. On the other hand increased mask use with Covid-19 raised the use of masks independent of coronavirus infection. In fact, "is it necessary to use masks at all times in many infectious diseases, especially in hospital infections?" is a current question. With all these, several companies and factories switched to mask production to meet the demands of the community. In this process, masks produced by people who are not experienced have also found place in the market. Because Covid-19 also caused a shortage in this area. However, masks produced in terms of public health must meet some criteria. It is important especially for health to produce masks in line with ASTM standards, which are widely accepted all over the world (Bayersdorfer et al., 2020). However, the high consumption rates in Turkey and the intensity in limited places performing routine analyses in the first pandemic period, the willingness of companies to produce too many products with insufficient testing and infrastructure to provide ideas for product development appeared as a problem. Although the use of fabric masks is still a matter of debate in Covid-19, it is recommended increasingly (Eikenberry et al., 2020). As it is already known, the cost and supply of masks such as advanced specific N95 cannot be easily delivered to all segments of society. The general opinion of experts is that masks with a certain microbial filtration efficiency that are produced under aseptic conditions can be protective in moderate risk settings. Also, viruses are considered to spread by attaching themselves to environmental bacteria and water droplets (Rodriguez et al., 2020). For this reason, it is important that masks that have certain filtration capabilities and easy-to-deliver to all segments of society find place in the market. moreover, masks today and in the

future should not only protect against coronavirus infection, but also protect against all kinds of microorganisms. The fabric, which came to the forefront in this sense, is Meltblown (MB). As it is known, Meltblowing is a unique one-step process to produce non-woven membranes with self-adhesive fiber (Hassan et al., 2013). However, the MB fabric was very costly, and it was therefore difficult to obtain them in adequate levels during the pandemic period (Tekeoğlu, 2020). For this reason, masks were produced by using a different material (Polyethylene Terephthalate) and EN 14683 BFE (Bacterial Filtration Efficiency) Test Standard was applied in laboratory setting to measure the filtration efficiency of the developed mask.

## 2. Material and Method

### 2.1. Structure of the Fabric

A fabric with Polyethylene (PE)-Terephthalate (PET) was produced as 25 gsm hydrophilic (ART) in the present study. The features of the test fabric that was developed according to ERT 40.3-90 and ERT 20.2-89 Standard are given in Table 1. The ready-made fabric that was produced as Meltblown (MB) was used for comparison.

### 2.2. Mask Features

ART and MB fabrics were placed between the 25gr/m<sup>2</sup> ront, and 15g/m<sup>2</sup> final spun bond as filtration fabric, and the 3-layer masks were produced with ultrasonic stitching and wires and rubber (Figure 1). The masks, which were produced as 17.5 cm wide, were designed to be triple-fold to wrap the jaw and nose fully. With the masks produced by using MB fabric and strong hydrophobic spun bond fabric, products that were suitable for the use of the healthcare sector (dentists, healthcare employees who carry out surgical applications, emergency and intensive care employees, etc.) were developed. The purpose was to develop a more comfortable mask by using hydrophilic ART fabric with higher air permeability and higher BFE values instead of MB in daily use.

### 2.3. Test Agents

*Staphylococcus aureus* ATCC 25923, *Klebsiella pneumoniae* subsp *pneumonia* ATCC 700603, *Candida albicans* ATCC 64548, *Escherichia coli* ATCC 35218 strains were used in the study. Bacteria were cultured in nutrient broth (NB, Merck) while potato dextrose broth (PDB, Merck) was used for yeast cells. All of test agents were incubated for 24 hours at 37°C.

### 2.4. Microbial Filtration Efficiency Test

The test that was determined for Bacterial Filtration Efficiency (BFE) in EN 14683. The testing standard was modified and analyzed. Each microorganism was prepared with a density of 1.7-2.7X10<sup>3</sup> in the experiment. The test was performed at an ambient temperature of 20-25°C and relative humidity rate of 55±5%. The MMD 3.7 µm (Mesilife M102) nebulizer was used in the study. The debit of the device was fixed at 29.4 L/min, and each sample was subjected to aerosol microorganism for 1 minute. Agar growth media that were exposed to filtered air (Nutrient agar for bacteria, Merck; Potato dextrose agar for yeast, Merck) were incubated for 24 hours at 37°C. The filtration rate was calculated by counting the colonies formed on the agar according to the Control Group. The test setting is given in Figure 2. The test was done with 3 repetitions for each microorganism, and the entire

experimental system and test material were sterilized under UV before each testing.

evaluation of the data. The comparison of the filtration efficiencies of the masks was evaluated for each microorganism with the Mann Whitney U-test.

### 2.5. Statistical Analysis

The mean filtration efficiencies of the masks are given as  $\%(\pm SD)$ . The SPSS 15.0 Program was used for statistical

Table 1. Comparative Features of the Fabric Developed

Sample name	Elongation (% , MD)	Tenacity (N/5cm, MD)	Basic weight	Width (M)	Material	Image
ART fabric	14	26	25	0,175	%100 PE/PET	White, Soft
MB fabric	16,2	13,8	25	0,175	Meltblown	Natural White

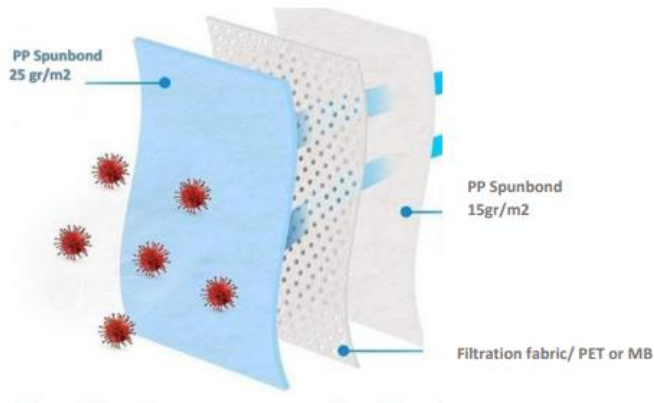


Figure 1. Structure of 3-Layer Mask: There are two different 3-layer masks produced. The ART fabric in PET structure was used in one of these, and MB fabric, which was purchased as ready-made, was used in the other.



Figure 2. The image of the apparatus developed for Bacteria Filtration Test

### 3. Results and Discussion

Some features of the masks that were developed by using ART and MB fabrics, such as liquid resistance, mask structure, and flammability were analyzed according to ASTM F2100, and the results are given in Table 2.

The ART/3-layer mask and MB/3-layer mask were tested for BFE according to Modified EN 14683 Standard. Not only the rate of bacterial filtration was tested in the established mechanism, but yeast filtration efficiency was also tested. As a result of the test, the filtration rate was an average of 99.7% (SD±0.2) in all microorganisms for the three-layer MB/Mask. The 3-layer ART/Mask filtered microorganisms at a rate of 96.8% (SD±2.7). The filtration rates of fabric masks according to the microorganisms are given in Table 3. The filtration efficiency of the masks for each microorganism was not at statistically significant levels when compared separately on a species basis ( $p>0.05$ ).

The microorganism filtration rates of masks produced with high-cost MB fabric and the masks produced with ART fabric based on polyethylene terephthalate, which is difficult to supply with increasing demand in the pandemic period, were compared.

Although the importance of using masks is still a matter of debate in the Covid-19 pandemic, it has become increasingly important. Although some experts focus on other health problems caused by the use of masks, a great many experts argue that the use of masks should be mandatory in pandemic period. For the time being, the use of masks is mandatory in public areas almost all over the world. The general opinion is that textile fabrics that have certain filtration rates may be important for the pandemic (Bayersdorfer et al., 2020; Eikenberry et al., 2020). Li et al. (2013) reported that masks decrease potential aerosol transmission in infectious diseases, which do not have an effective vaccine or drug, and that, social distancing is important because of poor quality masks, which find a place in the market due to shortages in production. Cheng et al. (2020) emphasized the importance of masks by arguing that the incidence of Covid-19 was inversely proportional to the use of masks in their comparative and epidemiological analysis in Hong Kong and European Union countries. In another study, researchers pointed out to the importance of proper use of masks that have certain filtration rates during the pandemic period (Azap and Erdinç., 2020). Rodriguez-Palacios et al. (2020) conducted a study and tested the permeability of liquid materials containing *Lactobacillus lactis*, *L. rhamnosus*, *L. plantarum*, *L. casei*, *L. acidophilus*, *Leuconostoc cremoris*, *Bifidobacterium longum*, *B. breve*, *B. lactis*, *Streptococcus diacetylactis*, and *Saccharomyces florentinus*. Because it is considered that viruses spread by attaching to environmental bacteria and water droplets.

A lot of mask consumption emerged worldwide with the spread of mask use (Wang et al., 2020). On the other hand, several organizations started to produce masks regardless of the field of activity in which they were experienced to find a place in the mask production market with the economic problems caused by Covid-19 (Açıkgöz and Günay, 2020; TEB, 2020). Many masks, from those sewn in houses to those without filtration fabric and without resistance to dehydration, found their place in the market. Also, mask filtration tests were done in only a few laboratories in Turkey and the costly tests triggered this problem.

When the mask manufacturing sector is considered, cotton, polyester, nylon, silk fabrics, Polypropylene (PP) and paper-based

products, which are used widely as fabric, have filtration rates that range from 5% to 25% (Zhao et al., 2020). In the present study, polyethylene terephthalate (PET) was used as an out-of-the-usual fabric material, and surprisingly, the filtration rate was found to be quite high. It was determined in this study that the fabric produced had a microorganism filtration efficiency rate of 96.8% (SD±2.7). An advantage of PET fabric is that it transfers the heat, and is more hygienic in terms of microbial load. No water and wetness occur on the user face in the mask made of PET fabric, it absorbs the moisture of the breath because the material is hydrophilic (Geçkil et al., 2021). On the other hand, polypropylene (PP) hydrophobic, which is used frequently in mask fabrics, has a hydrophobic structure. When PET fabric is compared to Melt Blown, it has much more air permeability (Ullah et al., 2020). In the present study, it was found that ART/3-layer mask had a filtration efficiency of 96% (SD±2.7), and MB/3-layer mask had 99% (SD±0.2) filtration efficiency. According to the statistical analysis, it was found that the difference was not at a significant level ( $p>0.05$ ). For this reason, it is believed that PET fabrics can be used instead of MB in mask production. This was interpreted as pleasing in terms of the study findings. Because, although MB fabrics have very high filtration efficiencies, they are manufactured by a limited number of manufacturers and their sales prices have increased up to 20 times with the increasing demand in pandemic period. Although the purpose was to meet the increasing demands by limiting MB exports, 4-5 months of periods were given, which could not be prevented in the pandemic period (T.C. Ticaret Bakanlığı, 2020). Therefore, it is possible to argue that masks produced with ART fabric are easily available and reduce costs, which causes mask sales prices to decrease by 4 to 1 when compared to MB. Also, the most important advantage of masks produced with PET fabric is that they are safe and comfortable with easy breathing and high BFE values when playing sports, working with tempo at work places, or during hot weather. Also, PET fabrics have become an alternative solution in the shortage caused by Covid-19. Because, although PP fabrics are heavily preferred in mask fabrics, this study brings a new perspective to textile masks. In the present study, it is very important that the ART/3-layer mask that is produced from PET fabric has a high filtration rate. Because the basic filtering efficiency of masks used during the pandemic period has primary importance (Hill et al., 2020). Also, the high BFE values can reduce the viral load spreading with attaching to bacteria from oral and nasal cavity (Rodriguez et al., 2020; Lin et al., 2020). Because the main transmission routes of infectious diseases are air, droplets, aerosol, and contact from human to human.

While only *Staphylococcus aureus* was used as the standard strain in the routine EN 14683 test standard, 4 different strains (*S. aureus*, *K. pneumoniae*, *C. albicans*, *E. coli*) were used in this study. In the study conducted by Lubasova et al. (2014) nanofiber materials were tested with *E. coli* K-12 strain in his own filtration mechanism. Also different from this study, the breath debit is considered to be 28.3 L/min in daily conditions and standard tests (ECS, 2019). The mechanism used in this study; however, had a continuous one-way airflow at 29.4 L/min. There are periods of inspiration that lasts about 2-3 s, and expiration periods that last 6-8 s in normal human respiratory function. For this reason, the ART mask that was tested was considered to have a higher capability to filter bacteria in daily use under normal living conditions. Also these kind of medical masks may have a protective effect for other nosocomial infections.

Table 2. Features of Masks according to ASTM F2100

	MB / 3-Layer Mask	ART/ 3-Layer Mask
<b>Color</b>	White	White
<b>Liquid resistance</b>	160 mmHg	160 mmHg
<b>Flame</b>	Class 1	Class 1
<b>Mask Construction</b>	Earloop	Earloop
<b>Attachment Design</b>	Sonic	Sonic

Table 3. Microorganism Filtration Rates of Fabrics

Microorganism	Filtration Rate		Significance P (%)
	3-Layer ART/Mask % (SD)	3-Layer MB Mask % (SD)	
<i>S. aureus</i>	96 (±0,6)	99 (±0,7)	0,1
<i>K. pneumoniae</i>	98 (±1,2)	99 (±0,7)	0,7
<i>E. coli</i>	93 (±0,5)	99 (±0,4)	0,1
<i>C. albicans</i>	99 (±0,7)	100 (0)	0,1

#### 4. Conclusion

Various studies show that mask fabrics should not be ordinary. In this sense, the filtration efficiency of masks used for medical purposes is an important issue. The mask which is produced by the study has high bacterial filtration efficiency. Moreover, it is produced at a lower cost than other good quality masks. This suggests that it will reduce the spread of viruses by attaching themselves to bacteria from sick individuals. It is also considered that the masks that were made of PET will be an alternative solution in the scarcity caused by Covid-19 and it can have protective effect for other nosocomial infections.

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