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STUDY OF THE AEROSOL PARTICLE FILTRATION EFFICIENCY OF FABRICS USED TO MANUFACTURE NON-MEDICAL FACE MASKS IN LITHUANIA

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The global spread of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) proved to be a challenge for public health. The high demand of medical masks worldwide during the pandemic has led to a critical situation for decision-makers regarding high-quality mask supply. For this period, the World Health Organization has suggested the use of non-medical face masks (also known as 'community' masks) in public places to reduce the airborne spread of SARS-CoV-2. In this study, the filtration efficiency of various fabrics widely used in community masks was determined based on two main mask filtering properties: filtration efficiency (*FE*) and pressure drop (ΔP) according to the recommendations of the CEN Workshop Agreement (CWA) 17553:2020. The combination of *FE* and ΔP parameters must be considered in order to select suitable materials for public masks. The filtration efficiencies for various fabrics ranged from 6 to 100%. It was found that the composite materials have the highest *FE* equivalent to the requirements of a medical mask (*FE* > 95%), that is confirmed by high-quality parameters 16–30 kPa^{-1}. The study found that fabrics of natural fibres (100% cotton) have a higher *FE* with Ag coating (18–40% before and 29–40% after coating) in the 0.54–1.50 μm particle size range.

Keywords: COVID-19, safety, cloth masks, aerosol particles

1. Introduction

Since the beginning of the pandemic in Wuhan, China, public health authorities around the world have been working to curb the spread of the infection. More than 496 million confirmed cases and almost 6 million deaths are currently reported worldwide (12th April 2022) [1]. The coronavirus disease outbreak has challenged not only public health and safety but also public policies, education systems and the economy of the world. In the absence of an effective vaccine or antiviral drug at the onset of the pandemic, most countries have implemented non-pharmaceutical interventions [2] to curb the spread of COVID-19. This includes methods of preventing a close contact – social isolation (2 m distance between persons), using of face mask protections, indoor ventilation and complete quarantine. In order to stop the spread of a pandemic, it is necessary to find effective methods for the prevention of the respiratory virus, the success of which depends on an understanding of the transmission characteristics of SARS-CoV-2.

The main routes of transmission of COVID-19 virus are secretory aerosolized droplets with an aerodynamic diameter D greater than 5 μm and fine aerosol particles, otherwise known as droplet nuclei with an aerodynamic diameter D less than

5 μm [3, 4]. It should be noted that the discussion on the aerosol particle size threshold between aerosol and droplet and the importance of air transmission for SARS-CoV-2 is ongoing. Studies have shown that early-stage patients with the virus secrete large amounts of SARS-CoV-2 virus particles by breathing, coughing, speaking, or sneezing [5]. By breathing or sneezing humans emit droplets in a very diverse range from 0.1 to 1000 μm [4]. According to their size, it is possible to determine how long the particles will remain in the air without settling on the surface and how long they can lose weight due to evaporation. It has been established that large particles (up to 1000 μm) do not exist in the air for a long time under the influence of gravitational forces; they can cover a distance of 1 m to the ground in 0.3 s [6]. However, particles with a diameter smaller than 100 μm partially evaporate before reaching the surface. Meanwhile, the evaporated aerosol residue remains suspended in the air for a longer time, e.g. a particle of about 1 μm can remain in the air for up to 8 h. Also, particles of this size in the air can travel longer distances within a turbulent gas cloud, that could trap and transport the accumulations of droplets in it. As a result of this, cloud movement, pathogenic droplets can travel distances from 7 to 8 m [7]. Thus, the respiratory virus has two main routes of transmission: contact (direct or indirect between humans and contaminated surfaces) and airborne.

Given the global crisis in the production and supply of personal protective equipment at the beginning of the pandemic, when demand for respiratory protective equipment far exceeded supply, the only alternative to meet public demand was the use of fabric masks. Face masks can be traced as far back as Middle Ages when they were used by sanitarians that in a popular culture are known as a 'beak-doctors', during the 17th century plagues, 1918 influenza pandemic and, more recently, the SARS epidemic in 2003 [8]. Decades of research have proven the effectiveness of medical surgical masks and respirators against airborne transmission [9, 10]. Although, significant differences in filtration efficiency due to the fabric material and composition have already been demonstrated [11–16]. New research explains that even fabric face masks provide some protection against the virus and effectively reduce its spread in society [17–19]. In various studies, fabric masks were examined in terms of filtration efficiency (*FE*), pressure difference (ΔP), quality parameter (*QF*), and fabric design parameters – threads per square inch (TPI). Most of studies [13, 14] showed a complex relationship between tissue type, fibre weave and threads, and nanometre-sized aerosol particle filtration. It was demonstrated that cotton, natural silk and chiffon can provide a good protection, typically above 50% in the entire 10 nm to 6.0 μm range, provided they have a tight weave. Higher threads per inch cotton with tighter weaves resulted in better filtration efficiencies. For instance, a 600 TPI cotton sheet can provide average filtration efficiencies of ~79% (in the 10 to 300 nm range) and ~ 98% (in the 300 nm to 6 μm range) [13]. Although the exact effectiveness of fabric face masks varies depending on the fabric characteristics, the number of layers and masks fitting, it has been reported that even fabric masks made at home from 4–5 layers of kitchen paper and textiles can filter out more than 95% of the virus in aerosol particles up to 5 μm [20]. Combining the wearing of masks with social isolation, hygiene, vaccines, and other means of stopping the spread of the virus may be an effective strategy to combat the virus [2, 21]. Aydin et al. (2020) [15] found that high-velocity droplets (e.g. excreted by sneezing, coughing and singing) can be effectively blocked using masks made of 2–3 layers of T-shirt fabric, i. e. in terms of effectiveness can be equivalent to a medical mask. Drops with a low velocity (e.g. excreted in speech) are blocked much more effectively than faster ones. Thus, by combining layers of tissue, infection with the respiratory virus could be effectively prevented.

Several European countries have defined scientific standards for commercially made fabric face masks. For example, in France, specifications were drawn up by the General Directorate of Armaments of the Ministry of the Armed Forces (DGA, 2020), and in Switzerland by the Swiss Federal Laboratories for Materials Science and Technology (Federal Office of Public Health, 2020; NCS-TF, 2020). Finally, the European Committee for Standardization have made available the CEN Workshop Agreement (CWA) 17553:2020 applying to community masks.

This work aims to evaluate the filtration efficiency (according to CWA 17553:2020) of the most widely used fabric in cloth masks in Lithuania.

2. Methods

2.1. Fabric samples

In this research, 20 various natural and synthetic textile fabrics were tested (Fig. 1). All samples have been selected as potential raw materials for the production of protective face masks in Lithuania. The textile fabrics used in the investigation were classified according to the method of production: woven or knitted [22], examined using a digital microscope equipped with a 200× magnification lens and the computer analysis software, Motic Images Plus 3.0. Multilayer and mixed fabrics of an unknown structure were classified as composite. A high-resolution scanning electron microscope (SEM) FESEM Su-70 *Hitachi* with a resolution of 1 nm and an acceleration voltage of 0.5 to 30 kV was used to monitor the surface condition and structure of the materials before and after Ag-containing coating.

2.2. Experimental setup

A schematic of the experimental setup is shown in Fig. 2. The experimental setup consists of modules for aerosol particle generation, transfer, dilution, fabric *FE* testing and particle sizing. The particle suspension from a 2.0% sodium chloride solution was placed into a nebulizer (manufactured by *PARI*, model BOY mobile S) and aerosolized by 7.70 L/min of dried air passing through a diffusion dryer filled with silica gel. As the initial amount of aerosol particles depends on the pressure applied to the air nozzle and the amount of liquid, the following parameters were selected for each experiment: the airflow pressure ranged from 0.31 to 0.48 bar, and the liquid level ranged from 5.0 to 6.0 mL. In the mixing chamber, the flow of aerosol particles was diluted with an intense flow of clean air. A larger portion of the aerosol stream was interrupted by the air collection line, and

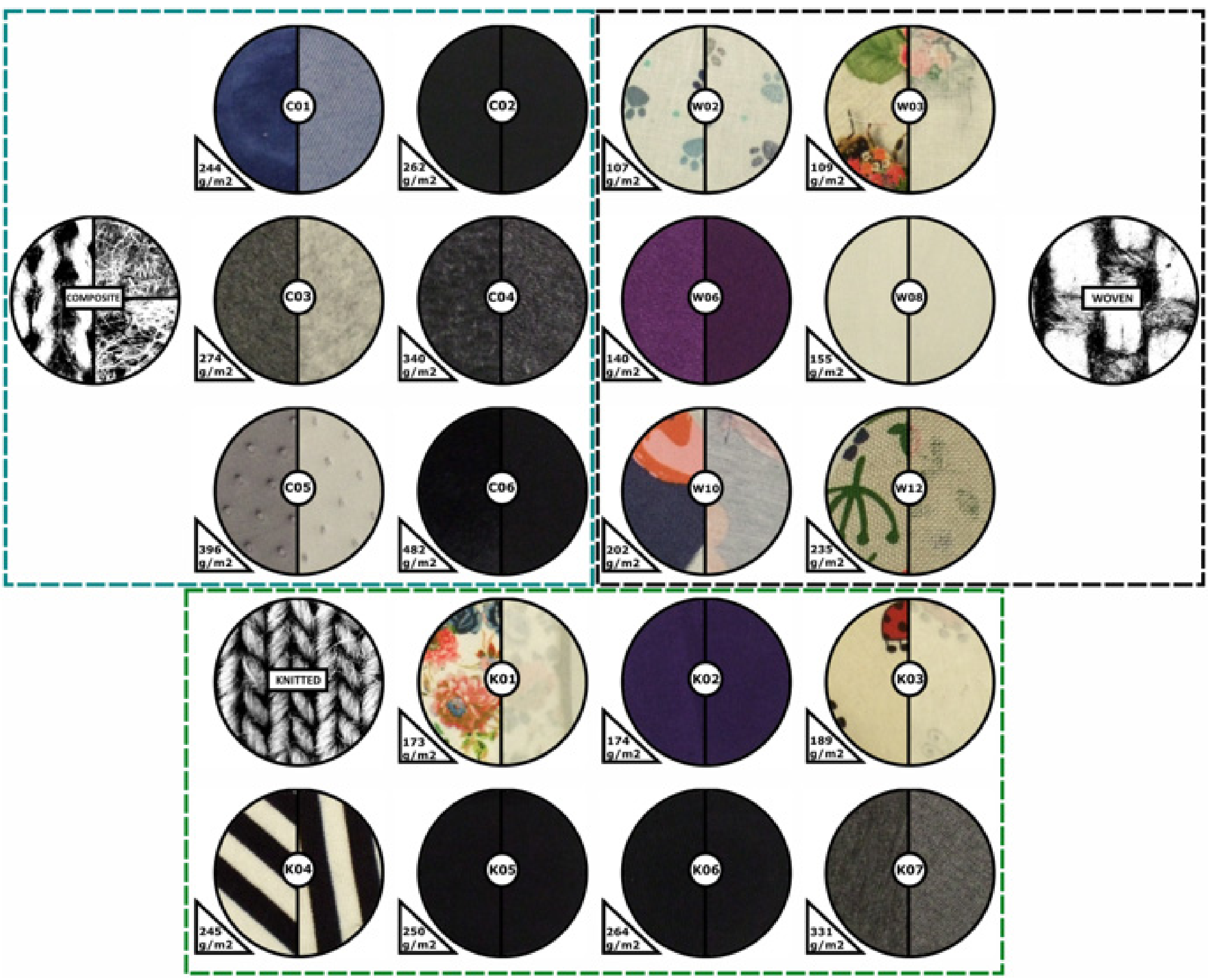

Fig. 1. The mask materials: composite (C), woven (W) and knitted (K). The circle of tested materials shown represent photographs from both sides of the fabric.

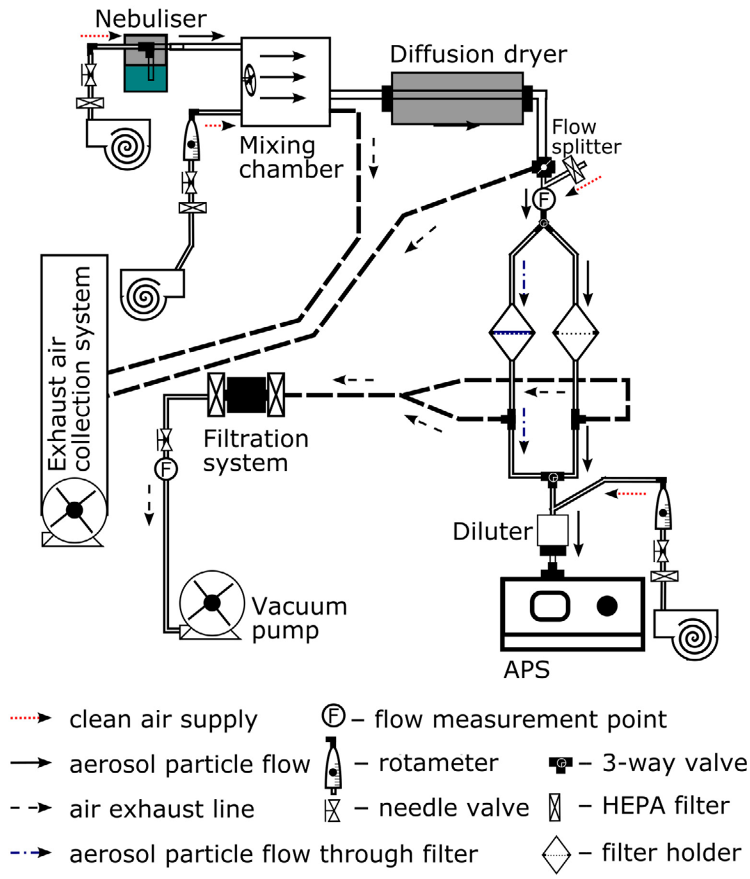

Fig. 2. Experimental setup used for measuring filtration efficiencies.

only a smaller part of the aerosol stream would enter the material filtration efficiency test line. The aerosol particle concentration required for the experiment was chosen so that the concentration recorded on an aerodynamic particle sizer (APS) after the final dilution did not exceed 1500 ppm. The aerosol particles were released through the filter media after 3 min from the beginning of particle generation. Each measurement was recorded every 30 s and repeated 5 times. During the experiment, test aerosol particles were fed into a section of the test sample with an area of 17.4 cm^2. The airflow through the open clipping area (12.6 cm^2) was 7.70 L/min, converted to a flow rate of 10.3 cm/s. The aerosol stream was diluted 1:20 with fresh air before entering the APS.

The aerodynamic particle size distribution of the generated aerosol particles was measured with the Aerodynamic Particle Sizer® (TSI model 3321) which provides high resolution, real-time aerodynamic measurements of particles from 0.5 to 20 μm and light-scattering intensity in the equivalent optical size range of 0.37 to 20 μm. During operation, the total airflow from the outside (5.00 L/min) entered the inlet of the device, where it was divided into two circuits: the flow of aerosol particles (1.00 L/min), that travelled further to the inner inlet, and the jacketed airflow (4.00 L/min), which was cleared through filters. Afterwards, the concentrated stream of aerosol particles inside the device combined with the cleaned stream of enveloped air, and the formed total stream entered a partial vacuum, after which, due to the expansion of the gas flow, the aerosol particles were accelerated. Aerosol particles of different masses (and diameters) – assuming a spherical shape and a density of 1.00 g/cm^3 – acquire different velocities during acceleration: the larger aerosol particles the smaller velocities. In the optical sector of the device, there are two overlapping laser beams perpendicular to the trajectory of the aerosol particles (laser diode power 30 mW, wavelength = 655 nm). Aerosol particle passing through both beams of light generates two pulses of scattered light, and the time between pulses is related to the velocity of the particle and hence the aerodynamic diameter. After the particle has passed through two overlapping laser beams, the scattered light is recorded in the photomultiplier tube as a single pulse of scattered light having two peaks with a time difference between the particle's flight time t, proportional to the particle's aerodynamic diameter D:

$$t \sim \sqrt{D}. \quad (1)$$

Aerosol particles were registered only if the scatter signal showed exactly two peaks in the time taken for the particle to pass through the laser beams. Rejected particles fall into three categories:

1. Only one peak and a low scatter signal – the particle too small or the first beam omitted;
2. Only one peak and a low scatter signal – the particle too small or the second beam omitted;
3. More than two peaks – overlapping particles.

In this way, the number of rejected particles in each category is calculated so that statistical corrections can be applied if necessary.

2.3. Estimation of the differential pressure, filtration efficiency and quality of cloth masks

The pressure drop (ΔP) was measured using the method described in LST EN 14683: 2019 + AC: 2019. The apparatus measured the differential pressure required to pass air through the measured surface area at a constant flow. A differential pressure gauge MM1K (manufacturer *HK Industries*, measuring range 0–1000 Pa, error 10 Pa) was used to measure the differential pressure. A flow model TSI 4040 was used to measure the airflow, measuring range: 0–200 L/min, with a 2.0% error of the measured value. At the test aperture, the air was drawn in by a diaphragm vacuum pump ME 4R NT (manufactured by *Vacuubrand*), and the airflow was regulated using a needle valve. According to LST EN 14683: 2019 + AC: 2019, the airflow was adjusted to correspond to 8.0 L/min or a linear flow rate of 27.2 cm/s through the material. When testing a material area of 4.52 cm^2, a linear velocity of 7.4 L/min corresponded to a linear velocity of 27.2 m/s through the material. The differential pressure ΔP is calculated according to the empirical formula

$$\Delta P = \frac{X_{\mathrm{m1}} - X_{\mathrm{m2}}}{4.52}, \quad (2)$$

where X_{m1} is the pressure measured with the manometer on the low-pressure side of the material, X_{m2} is the pressure measured with a manometer on the high-pressure side of the material, and 4.52 cm^2 is the area of the test substance.

Evaluation of the materials for filtration efficiency was calculated according to Eq. 3, that represents the capture efficiency of mask fabric and based on the particle concentration upstream and downstream (i.e. before and after particles pass through the filter/mask),

$$FE = \frac{C_{\mathrm{U}} - C_{\mathrm{D}}}{C_{\mathrm{U}}}, \quad (3)$$

where FE is the filtration efficiency, C_{U} is the particle number concentration upstream, and C_{D} is the particle number concentration downstream.

A common criterion for comparing the filtration quality of different materials is the quality factor [23–25]

$$Q = \frac{\ln\left(1 - \frac{FE}{100}\right)}{\Delta P}. \quad (4)$$

Appropriate respiratory protection must ensure a high filtration efficiency of aerosol particles while keeping the pressure drop to a minimum.

3. Results and discussion

3.1. Filtration efficiency of different fabrics

The filtration efficiency of a particular fabric as a function of particle size by measuring the concentration of the particles upstream and the concentration of the particle downstream is presented in Fig. 3. The filtration efficiency based on the number concentration of aerosol particles (0.54–5.00 μm) varied between 90 and 100%. The knitted fabrics K03, K05, K07 and K01 showed the highest filtration efficiency (Fig. 3) (sample codes are presented in the descending order of FE). The most efficient fabric (K03 sample) FE values ranged from 26 to 98%. The woven fabrics showed significant differences in FE. Higher FE results were obtained for the W08 (26–86%) and W10 (35–91%) samples. For the composite the FE within the fine aerosol particle size range was relatively higher for the samples C03 (30%) and C04 (35%). The performance of C03 (98–99%) and C05, C06 (95–97%) composites

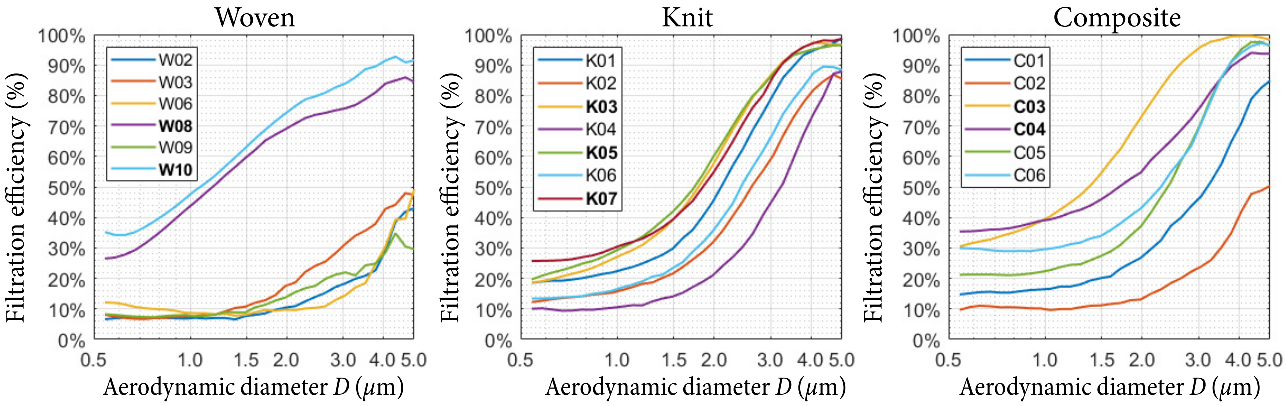

Fig. 3. Filtration efficiency (*FE*) as a function of particle aerodynamic diameter (*D*) for individual fabrics (woven (W), knitted (K) and composite (C)).

offered the best filtration efficiency across the range from 4 to 5 μm. The filtration efficiency was also evaluated using the aerodynamic diameter D50 equivalent (Fig. 5), that indicates the particle size which is filtered out with 50% efficiency. Lower D50 values correspond to a higher filtration efficiency and vice versa. It is recommended that the equivalent D50 values for the two types of masks (as defined in 14683: 2019 + AC) remained D50 < 1.6 μm for type I and D50 < 1.3 μm for type II masks.

The results shown in the bar graph (Fig. 4) were obtained by examining the differential pressure in the sample materials based on the method described in LST EN 14683: 2019 + AC: 2019. The distribution of ΔP varied from 0 to 100 Pa/cm^2 for different test samples. The red line in Fig. 4 shows the pressure drop limit described in the Type I and Type II standards for medical masks, ΔP < 40 Pa/cm^2. The black line represents the limit ΔP < 70 Pa/cm^2 described in the CWA standard. According to the results, these standards were exceeded by the materials tested in W08 and W10, all other samples meet the standard set by the medical mask according to the pressure drop. It can be argued that using W08 and

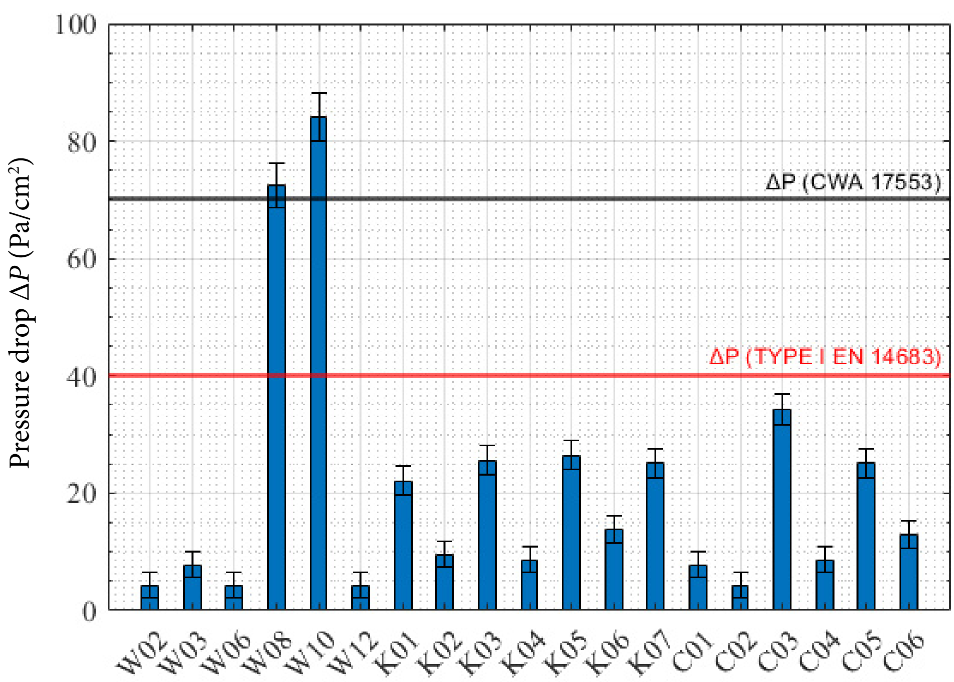

Fig. 4. Pressure drop in the sample materials. Also, ΔP < 40 Pa/cm^2 is the pressure drop limit described in the Type I and Type II standards for medical masks, and ΔP < 70 Pa/cm^2 described in the CWA standard.

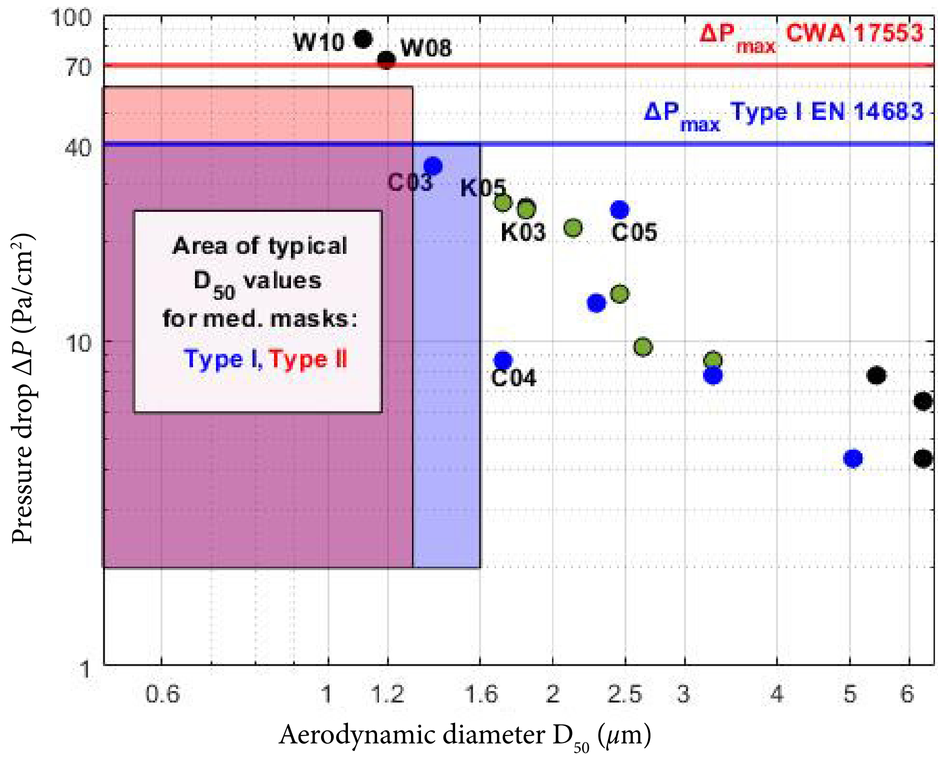

Fig. 5. Dependence of pressure drop through the material ΔP on the aerodynamic diameter D_{50} (black for woven, green for knitted and blue for composite). The graph shows the standards for medical masks LST EN 14683 (ΔP, D_{50}) and non-medical masks CWA 17553 (ΔP).

W10 fabrics for fabric masks would make it difficult to breathe through, as a drop in pressure in excess of the standards would result in an excessive air resistance through the fabric to ensure a normal breathing while wearing the mask. The graph also shows the pressure drop error calculated for each material separately. The errors ΔP are closely related to the errors of the differential manometer used.

It can be seen in Fig. 5 that the woven materials showed two extreme situations: 1) a poor filtration efficiency and a low-pressure drop, 2) a good filtration efficiency and an extreme pressure drop, that exceeded the limit described in the CWA standard. Higher pressure drop is associated with a better filtration efficiency (lower D50). None of the investigated woven fabrics showed an intermediate combination

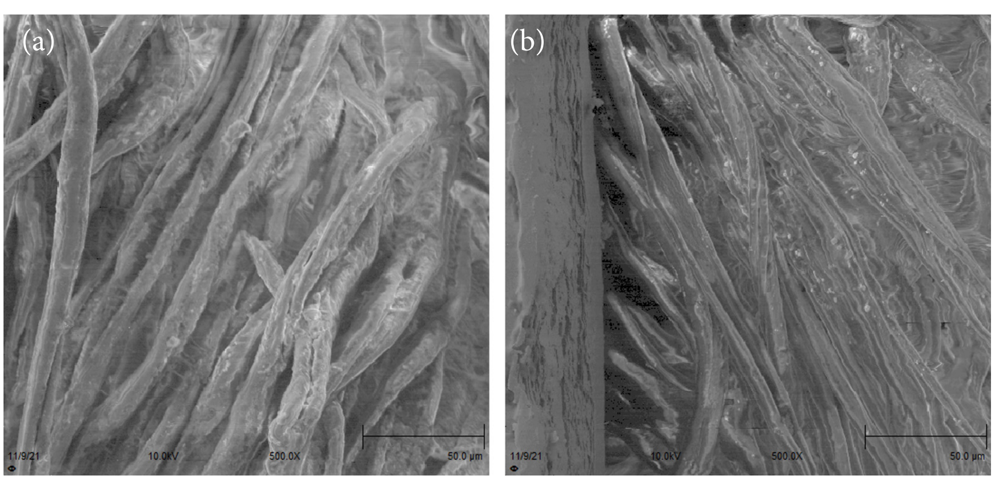

Fig. 6. SEM image: (a) K03 sample without Ag coating, (b) K03 sample with Ag coating.

of filtration efficiency and pressure drop values. The D50 of knitted fabrics ranged from 1.8 to 3.2 μm. The composite materials also showed significant differences in D50 values, but there was no clear model that could associate a larger material pressure drop with a better filtration efficiency. It can be assumed that the composite materials have different structures and are usually combined with different layers of material, thus no clear correlation was observed between ΔP and *FE*. Several composite materials C03 (D50 = 1.34 μm) and C04 (D50 = 1.71 μm) showed a good FE comparable with quality standards used for medical masks: D50 < 1.6 μm for type I and D50 < 1.3 μm for type II.

Several materials selected for the study (C03, C04, C05, K03 and K07) were coated with an

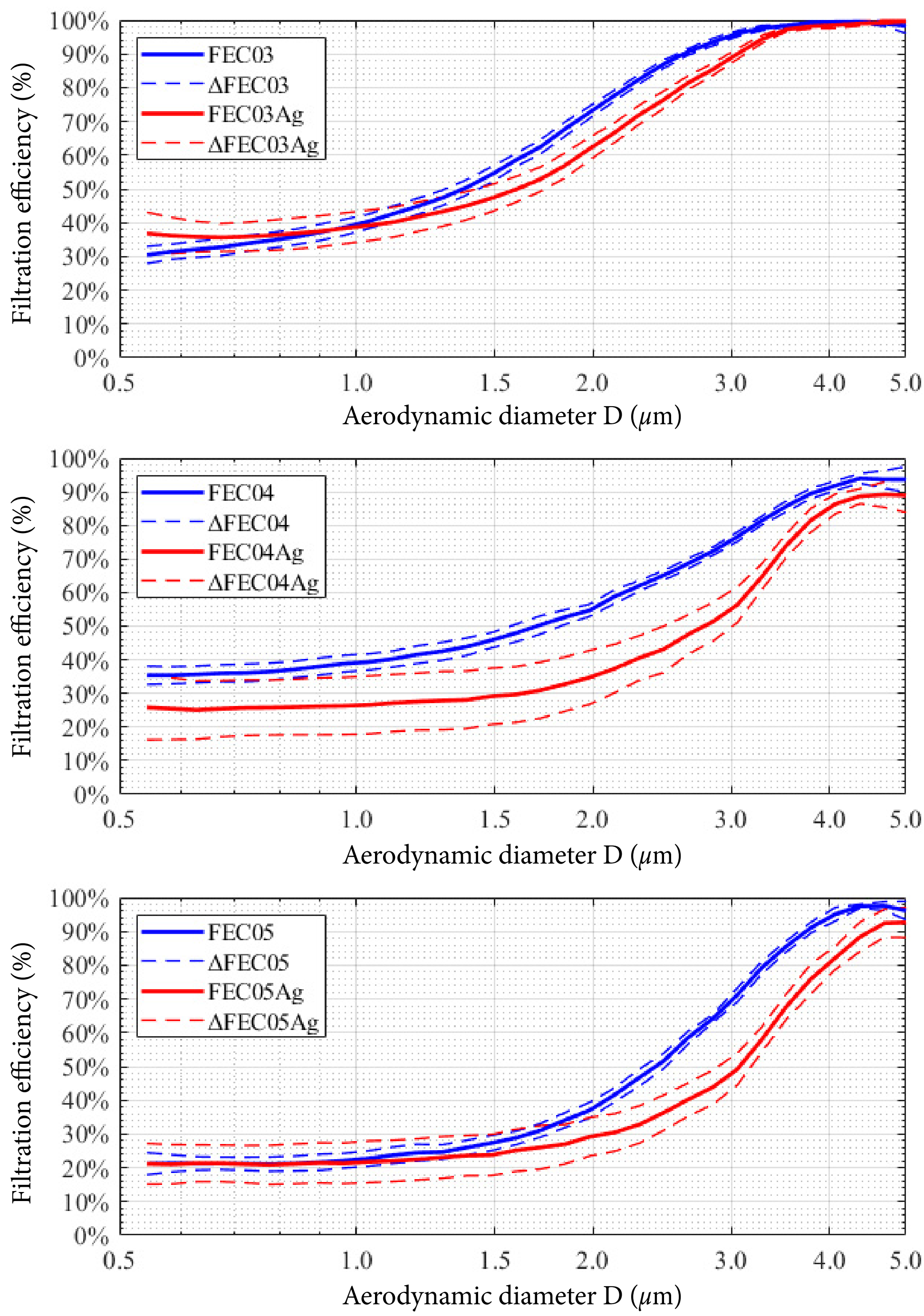

Fig. 7. Filtration efficiency of aerosol particles in composite fabrics with silver nanoparticles and without silver nanoparticles.

antimicrobial Ag-enriched coating for prolonged mask wearing. Figure 6 shows a SEM image of the fabric sample K03 without (a) and with (b) a coating of silver nanoparticles. On Fig. 6(b) small white dot-like granules densely scattered on the fibre filaments represent the Ag nanoparticles detected on the fibres. The results of filtration efficiency of aerosol particles in a size range from 0.54 to 5.00 μm for materials with and without a silver-enriched coating are presented in Fig. 7(composite materials) and Fig. 8 (knitted materials). The highest *FE* results were shown by the C03Ag fabric – the *FE* of this sample increased by 1–6% compared to that of C03 in the particle size range up to 1 μm. The FE of C03Ag for particles from 1.0 to 3.5 μm decreased compared to that of C03, while for the particles from 3.5 to 5.0 μm the *FE* values were equal to those of C03. The fabric sample K03Ag also showed good FE results: for the particles of 0.53–1.50 μm, the *FE* increased up to 10%. The tested samples of C03Ag and K03Ag fabrics showed that a coating with high-quality silver nanoparticles can provide a better filtration efficiency in the small particle size range, namely in the range of aerosol particles that are critical according to filtration theory. The coating did not affect the *FE* for the most of samples but it affected the FE negatively for the samples K07Ag, C04Ag and C05Ag. *FE* of the C05Ag sample was not affected withing the small particles ($D < 1$ μm) range and was negatively affected for the particles larger than 2 μm. It is also seen that *FE* was negatively affected for the C04Ag sample that suggests that the coating would reduce the effectiveness of a face mask made from such fabrics.

3.2. The quality of cloth mask

In order to compare the combination of both *FE* and ΔP, the quality factor Q (Eq. 4) was determined

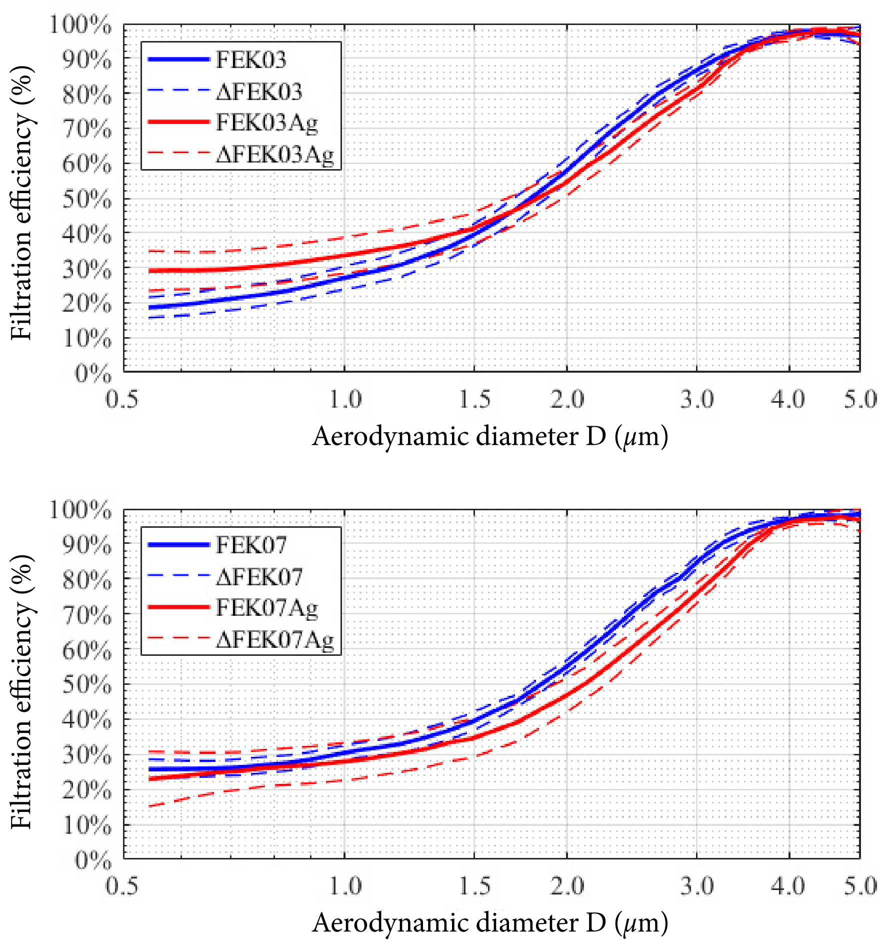

Fig. 8. Filtration efficiency of aerosol particles in knitted fabrics with silver nanoparticles and without silver nanoparticles.

for all investigated samples. It was found (Table 1) that the standard of public masks (CWA) $FE > 70\%$, with an aerosol particle size of $2.5 < D < 3.5$ μm, is met by the samples C03, C04, K03 and K07, but with an additional coating, two substances of those, i.e. C03Ag and K03Ag, meet the standard. According to the pressure drop, all materials meet the standard of both CWA and medical masks. The requirements of the standard for public and medical masks are also provided in Table 1.

Considering the quality factor, the C04 sample had the highest value (31 kPa^{-1}). However, *FE* was negatively affected by coating with Ag nanoparticles. The quality factor alone does not determine the suitability of the material for face masks. The results show that the quality factor for all fabrics coated with an additional silver coating decreased; however, the limit of $Q > 3$ kPa^{-1} set by the WHO recommendations was met.

In Table 1, the samples are arranged according to the values of *FE* from the highest to the lowest. Based on the composition of the samples, cotton materials have better filtration efficiency properties, that is evidenced by CO3 and KO3 (80 and 100% cotton-containing). Supporting conclusions about a higher filtration efficiency of materials of more natural origin have been found in previous studies [13, 14]. The filtration efficiency for each sample with and without a coating by silver nanoparticles can also be found in Table 1. Fabrics with a predominance of polyester (C04, C05) had a significant decreasing effect in *FE* when covered with a coating of silver nanoparticles. The reductions of *FE* were 17 and 20% for the fabrics made of 100 and 78% polyester, respectively.

Thus, it can be concluded that synthetic fibres are adversely affected by silver particles. The lowest reduction in *FE* was found for 100% cotton fibre (K03). The filtration efficiency of natural fibres decreased by only 4%, that did not change the *FE* value within a significant level. Meanwhile, for the fabrics containing 80% cotton (C03), the *FE* changed by more than 8%. Therefore, it can be stated that no significant change in *FE* was observed for natural fabrics coated with Ag nanoparticles. The Ag-coated material has superior properties due to its retention of standard *FE* and antimicrobial and hydrophobic properties due to Ag^+ ions. To summarize, the fabric with an Ag coating becomes an unsuitable medium for bacteria to accumulate and stays dry longer, which can prolong the wear time of personal protective coatings.

4. Conclusions

1. The filtration efficiency of aerosol particles of the aerodynamic diameter in a range of 0.54–5.00 μm was found to vary in a wide range between 6 to 100% depending on the aerosol particle size. It was found that the composite materials C03 (D50 = 1.34 μm) and C04 (D50 = 1.71 μm) have the highest filtration efficiency equivalent to the requirements of a medical mask, that is confirmed by high quality factor Q parameters 16 and 30 kPa^{-1}, respectively. Fabric face

Table 1. Comparison of the data for the measured samples C03, C04, C05, K03 and K07.

	Composition	*FE*, %	*FE* with Ag, %	*P*, Pa/cm^2	*Q*, kPa^{-1}	*Q* with Ag, kPa^{-1}
C03	80% cotton, 17% polyester, 3% elastane	91±1	83±2	34±3	16±3	11±3
K03	100% cotton	80±2	76±2	26±2	14±4	12±4
K07	20% cotton, 78% polyester, 2% elastane	78±2	69±3	25±2	13±3	10±4
C04	20% cotton, 78% polyester, 2% elastane	70±1	50±6	9±2	31±4	18±13
C05	100% polyester	60±1	43±5	25±3	8±1	5±3
CWA standard		≥70	≥70	≤70		
Medical mask standard		≥95	≥95	<40		

masks can achieve adequate filtration efficiency over a range of large particle sizes by adding a number of layers, as the filtration efficiency of composite materials is enhanced by the unevenness of their layers, e.g. the material consists of different layers of tissue.

2. Although all textile samples are selected as potential samples for the production of fabric masks (in terms of material composition, strength or thickness), very significant differences are observed between the measured filtration efficiency and pressure drop values. It was estimated that materials (W08, W10) with a good filtration efficiency, filtering more than 70% of particles in the CWA standard in a range of 2.50–3.50 μm, did not meet the minimum requirements for pressure drop, i.e. exceeded 70 Pa/cm^2. The higher the pressure drop the higher the difficulty for the wearer to breathe, so the combination of *FE* and pressure drop parameters must be considered in order to select suitable materials for public masks.

3. The study found that after coating the material with silver nanoparticles, the filtration efficiency in a particle size range of 2.50–3.50 μm (according to the CWA standard for the evaluation of non-medical masks) decreased. The analysis has shown that fabrics with a predominance of natural fibres (80 and 100% cotton in Fig. 7) have a higher *FE* with an Ag coating (18–40% before and 29–40% after coating) in the 0.54–1.50 μm particle size range.

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LIETUVOJE PRIEINAMŲ AUDINIŲ, TINKAMŲ NEMEDICININIŲ VEIDO KAUKIŲ GAMYBAI, AEROZOLIO DALELIŲ FILTRAVIMO EFEKTYVUMO TYRIMAS

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Santrauka

Spartus sunkaus ūminio kvėpavimo takų sindromo koronaviruso (angl. SARS-CoV-2), paprastai žinomo kaip COVID-19, plitimas – iššūkis visuomenės sveikatai nuo pat pirmojo protrūkio 2019 m. gruodžio gale. Staiga išaugęs medicininių kaukių poreikis lėmė neeilinius sprendimus kokybiškoms kaukėms tiekti. Dėl šios priežasties Pasaulio sveikatos organizacija pasiūlė viešosiose vietose naudoti nemedicinines iš įvairaus audinio pagamintas veido kaukes (kitaip žinomas kaip medžiagines ar visuomenines kaukes), siekiant sumažinti SARS-CoV-2 perdavimą oro lašeliniu būdu. Šiame tyrime buvo remtasi CWA 17553:2020 standartu (angl. *CEN Workshop Agreement*), pagal kurį išskirti du pagrindiniai filtravimo parametrai: filtravimo efektyvumas (*FE*) ir slėgio kritimas (ΔP) visame medžiagos plote. Norint parinkti tinkamas medžiagas visuomeninėms kaukėms, reikia atsižvelgti į *FE* ir ΔP parametrų derinį. Nustatyta, kad aerozolio dalelių filtravimo efektyvumas kinta nuo 6 iki 100 % skirtingame aerozolio dalelių dydžio intervale. Didžiausiu filtravimo efektyvumu, prilygstančiu medicininei kaukei (*FE* > 95 %) keliamiems reikalavimams, pasižymi kompozitinės medžiagos. Tai patvirtina aukšti kokybės parametrai: 16–30 kPa^{-1}. Tyrimai parodė, kad medžiagos, kurių sudėtyje vyrauja natūralus pluoštas (80, 100 % medvilnė) po padengimo Ag nanodalelėmis buvo aukštesnio *FE* (18–40 % prieš ir 29–40 % po padengimo) 0,54–1,50 μm dalelių dydžio intervale.