Journal of Composites and Compounds 3 (2021) 218-229

Available online at www.jourcc.com

Journal homepage: www.JOURCC.com

Journal of Composites and Compounds

Recent progress on filtration technologies for the fabrication of effective COVID masks: A review

Rupinder Singh [a], Zahra Rabiei Dolatabadi [b], Nalini Tripathi [c], Shamim Mukhtar [d], Dhastagir Sultan Sheriff [e], Fernando G. Morais [f], Parisa Shafiee [g]*

[a] *Department of Mechanical Engineering, UIE, Chandigarh University, Mohali, Punjab, India*

[b] *Anatomical Sciences Department, Afzalipour School of Medicine, Kerman University of Medical Sciences, Kerman, Iran*

[c] *Scientist-C, Department of Community Medicine, VMMC & Safdarjung Hospital, New Delhi, India 110029*

[d] *College of Earth & Environmental Sciences, University of the Punjab, Lahore, Pakistan*

[e] *American University of Sovereign Nations (AUSN), Los Angeles, USA*

[f] *Institute of Physics, University of São Paulo, Rua do Matão 1371, CEP 05508-090, São Paulo, Brazil*

[g] *Catalyst and Nano Material Research Laboratory (CNMRL), School of Chemical, Petroleum and Gas Engineering, Iran University of Science and Technology, Tehran, Iran*

A B S T R A C T

In the current pandemic COVID-19, which started in late 2019, humans throughout the globe are living in a situation, where all aspects of their lives either social, economic, or emotional have been affected. To inhibit the COVID-19 spread, using face masks in addition to social distancing and hand sanitation is suggested. In this survey, the idea of injecting natural agents that are biologically active into textile nanofibers is presented. Furthermore, we present recent trends which, affect the filtration efficiency of mask material. There is a wide variety of electro spinners on the market, which are easy to consume, secure, battery-powered, and handy that can be utilized to achieve the electrospun nanofiber mattresses without difficulty. The appropriate electrospun filter mats can be applied in the fully made mask. Choosing the right voltage, the right concentration, and the space in the middle of the syringe needle and the holding gatherer is of significant importance for the synthesis of uniform nanofibers.

A R T I C L E I N F O R M A T I O N

Article history:
Received 11 August 2021
Received in revised form 27 October 2021
Accepted 24 December 2021

Keywords:
COVID-19
Facemasks
Filtration
Electrospinning
Nanofiber-Based
Filter Media

Table of contents

1. Introduction

In the current pandemic COVID-19, which started in late 2019, humans throughout the globe are living in a situation, where all aspects of their lives either social, economic, or emotional have been affected. The pathogens of this airborne disease can be transmitted from an infected person to other people while speaking, coughing, or sneezing, which has increased the use of a face mask. It becomes quite important for front-line health workers to wear facemasks to protect themselves and mitigate its spread. Wearing face masks is widely recommended by health agencies and responsible governments ministries throughout the world as an obstacle between the surrounding contaminated environment and

* *Corresponding author: Parisa Shafiee; E-mail: Parisashafiee603@gmail.com*

https://doi.org/10.52547/jcc.3.4.3

the respiratory system. Based on the transmission route, most guidelines recommend a mask to prevent aerosol release and droplet transfer [1, 2]. Face masks that cover the wearer's both mouth and nose are used as physical obstacles to both particulate matter and liquids through a filtration performance [3, 4]. Masks can play at least two roles in preventing the spread of the virus to the general population. Firstly, masks can have a role in the spread of respiratory pathogens and the formation of turbulent gas clouds [5]. Investigations show that masks can obstruct rapidly bursting jets produced through coughing or direct the jets in very less harmful ways to control the air infection [6]. Secondly, the mask material can filter out viral particles like droplets and airborne particles [7]. In addition, infected people without any visible symptoms can decrease the risk of contaminating others by properly worn facemasks.

There are several types of face masks. The basic fabric face mask is the most common mask that can be utilized for a long duration of time. In this pandemic, people may have to wear cloth facemasks for respiratory protection due to the unavailability or scarcity of N95 masks [8]. N95 masks can filter 95% or more of tiny 0.3-mm particles. Although, cloth masks have the ability to filter the viral particles during coughing at about 50-100% of the filtration yield of surgical masks [9, 10]. These masks are low-cost and lightweight masks that consist of a full-length transparent polymer case and elastic headbands. It acts as a shield for protecting parts of the face from direct contact with splashes of infectious fluids while coughing, talking and, sneezing [11, 12]. Wearing a face mask primarily protects others by reducing the number of aerosol particles and exhaled droplets that may contain Covid-19. But, using a mask is not enough to create a sufficient level of safety. Other actions such as hand sanitation and social distance should be taken [13]. It is the most severe of the three coronavirus epidemics in the previous two decades after SARS-CoV-induced viral respiratory illnesses over 2002 till 2003 and the MERS-CoV (Middle East Respiratory Syndrome) by 2012 [14]. Wearing masks has been obligated in some European countries and also other countries apply this law to different degrees. Several countries have been obligated to use masks in shops and on public transports such as Germany and, the Czech Republic, whereas countries such as Spain have also been obligated to use masks out of the home. The Center for Disease Control and Prevention in America, suggests using masks if social distancing is not observed and not using breathing and surgical masks [15]. A surge in the usage of facial masks and other protecting supplies also caused a universal scarcity of raw materials and facial masks [16]. The shortage of N95 respirators has led medical workers to reuse their breathing masks for a long period. Consequently, healthcare workers are looking for alternative filter materials to protect against respiration, and this has inspired a similar curiosity in proving the effectiveness of various products, even those which were not initially designed to keep safe your lungs from being infected by SARS-CoV [17]. The current need for acceptable materials for use in face masks used by medical staff and the general population is unprecedented. These materials must sufficiently filter exhaled droplets and airborne particles that may contain the COVID-19 agent, thereby decreasing the COVID-19 emission. Optimal materials possess good breathability, have high particle filtration efficiencies, and - ideally - are comfortable and, washable without filter damage [18]. A mask filtration efficiency indicates the holding capacity of viruses and particles that exist in the air and is defined as the efficiency rate and includes the time of use, the particle size and, the amount of filtered air[11]. At the moment, there is neither profitable antiviral therapy nor approved vaccine to protect individuals against the COVID-19 agent.

As a result, urgent and significant efforts must be made extensively to evolve reliable treatments. About 100 clusters around the world are now involved in particular clinical trials and investigations [19]. Owing to the significant impact of external parameters on the filtering performance, determining the filtration mechanism has a high position. Only by understanding and clarifying these processes, it will be possible to improve and increase the mask filtration and design [20]. Explaining how particles enter and investigating the mechanism has been one of the points of attraction in this term. The filtration of a mask depends on various techniques that include thermal return, the inertial impact of gravitational deposition, electrostatic enticement, obstruction, and emission [21].

Determination of the total efficiency of filtering is calculated via adding the effect of distinctive filtering processes to efficiency. Thus, separate particle purification mechanisms function should be considered as the initial action [20]. On the other part, either explaining or designing the bio aerosols penetration process into the mask is of great significance [22-25]. This is significant when microorganisms and infected particles arrive at the external layer of the mask. If it does not eradicate either the microorganisms or the virus which have been attached to it, the infected particles can pierce the face mask through capillaries and other diverse methods [26]. In addition, a face mask generally alters to a collection of viruses over repetitive respiratory activity, especially owing to the exposure of the external layer to infected drops [27, 28]. Considering that either bacteria or viruses remain in the masks and on the surface during prolonged use, it is clearly undesirable and dangerous if they are capable to remain active and survive in the hot, damp microenvironments contained in the masks. Owing to the mask conditions and temperature and the high humidity created in the breathing cycle, it leads to the production of water evaporation in the face mask, and this procedure accelerates the process of piercing and more quickly emission of bacteria to the interior layers of the face mask. Numerical investigations in addition to simulations have taken this fact into account as a physical mechanism in mass transmission and transmission of heat in permeable materials [20]. To prevent these abnormalities, it is crucial to examine the particles and bioparticles transport mechanisms in the face mask and to check the model and usage of the mask according to such processes [29].

The purpose of this study is to review the particle filtration processes via face mask and to study the effective factors like unstable or fixed flow pattern, airflow or facial velocity, respiration frequency, relative humidity, particle load status, temperature, and loading time of the efficient mask filter. In addition, in this paper, we present recent trends which affect the mask materials' filtration efficiency.

2. Characteristics and transmission routes of COVID-19

The size of the corona virus is 60 to 140 nanometers, and there are nanorods 9 to 12 nanometers in size on its viral spherical capsid [30]. Both Middle East Respiratory Syndrome (MERS) and Severe Acute Respiratory Syndrome (SARS) are also parts of the coronavirus class. The SARS virus size is about 81 ± 11 nm [31, 32]with at least 15 spikes [31]. MERs surface area is 16 to 21 nm and the spherical shape is 118 to 136 nm in diameter. Virus spikes are present as a January 30of its image under a scanning electron microscope [30]. Virus spikes (mainly proteins) act as anchors to host cells and virus-carrying. Some viruses, like coronaviruses, possess more spikes than others [33]. Coronaviruses like SARS-CoV-2, SARS-CoV, and MERS-CoV, are capsulated viruses with positive single-chain RNA genes. Particles of the SARS-CoV-2 virus (Fig 1) range from 65 to 125 nm in size and are spherical to pleomorphic. In the particle, viral RNA of 29811 nucleotides is firmly wrapped and covered by nucleocapsid (N) protein. Membrane (M), envelope (E), and three glycoproteins, called spike(S) embed into the external lipid membrane. Spike proteins make homotimers that stick out of the lipid lining and shape the "corona" characteristic. Spike proteins bind to the enzyme angiotensin 2 (ACE2), which represents the cells of the expiratory tract, mediating the entrance of the virus to host cells [34]. When these parts

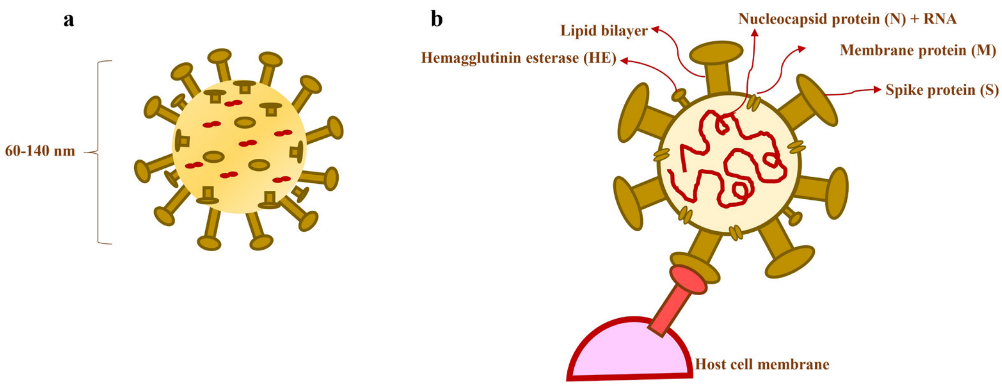

Fig. 1. SARS-CoV-2 viral particles; a) Size, b) Components.

convert their structural organization and special settings, inactivation can lead to virus inactivation [19]. It is recommended by the World Health Organization (WHO) that the main routes of the COVID-19 agent transfer are being in touch with tainted surfaces and individual to individual transfer (i.e., droplet emission). The virus fast spread besides diverse investigations [35], for example, demonstrating at distances greater than 1 to 2 m, though, it is recommended that different forms of spread suchlike airborne spread perform a significant role [36, 37] [36, 38, 39] [36-38, 40]. But, the relevant details are still unclear. Drop transfer is based on respiratory droplets that possess a diameter (dp) of 5 mm and bigger in accordance with the WHO council [41, 42]. Transmission of contact (or fomite) can happen through the virus-holding respiratory droplets deposition on surfaces when physically contacted by an individual who later touches their eyes, nose, or mouth. In airborne (or aerosol) transfer, the virus is transmitted through smaller aerosol particles (dp ≤5 mm) or droplet nuclei hanging in the air, which are able to remain hanging in the atmosphere for a long time. Spread through the air needs that the virus stays in the nuclei of infectious droplets for a long time. This is recognized to be the pathogen of measles, pulmonary tuberculosis or chickenpox but, the survival of SARSCoV-2 in airborne particles for more than one hour has also been shown [37]. Airborne particles and respiratory fluids are the primary routes of COVID-19 infection in asymptomatic persons who can subconsciously transmit the virus while talking or breathing [43]. The droplets dimensions change the way of contamination, large droplets (more than 20 micrometers) fall on things easier in comparison with smaller droplets owing to the gravity of earth, while small droplets (<5-10 micrometers) vaporize into the air and the possibility provide airborne transmission [44]. Drops as small as 1 micrometer have been reported to be able to remain in the air for more than 12 hours with a strong sneeze or cough that can transmit these particles to more than 20 feet [43]. Particle spread is associated with loudness while speaking or other vocal activities [45]. An analysis of cases in Wuhan presented that 86% of people contaminated with Covid-19 were asymptomatic, however, more than half of them were infectious (55%). These contagious people led to 79% of new infections [46]. The epidemic was announced a universal health crisis by the WHO on January 30, 2020, and the corona virus was officially named COVID-19 on February 11, 2020, by the director-general of the WHO [47]. As of December 11, 2021, 250,000,000 cases have been announced universal, of which 5.3 million have died. It is the most dangerous among three coronavirus epidemics in two previous decades after SARS-CoV-induced viral respiratory illnesses from 2002 to 2003 and MERS-CoV (Middle East Respiratory Syndrome) by 2012 [14]. On March 19, guidelines were announced by WHO to obstruct COVID-19 infection. They suggested that medical employees utilize face masks while taking care of doubtful sick people, and also they cover their mouths while sneezing or coughing or utilize masks [47]. To obstruct COVID-19 spread, wearing a face mask is recommended as well as physical distance and proper hand hygiene (e.g. WHO 2020b; Leopardine – German National Academy of Sciences 2020) [48].

3. Face masks principles

Face masks usage has a long history. The first reported usage of medical masks was publicized in 1897 by Polish surgeon Jan Mikulic Radki and his colleague, and the next year how these masks were able to decrease the release of droplets from a wearer's nose and mouth [49]. The face mask consisted of a gauze layer covering the nose and the mouth [50]. In 1898 it was mentioned that the increase of gas layers increased the mask protecting characteristic [50]. In the year 1899, Flüge produced face masks in which roller gas strips covered the mouth [51]. Mouth guards' usage was evolved in 1905 to impede the transmission of tuberculosis by preventing sputum drops [52]. In the 1930s, special equipment was produced for face masks; (1) cover the nose and mouth and be comfortable, and do not create fog in the glasses, (2) should not allow transmission, and (3) be cheap and washable. During this period, lightweight deflection masks started to be developed using diverse kinds of materials located between the gases to reinforce the mask [50].

With more improvement of paper-based masks and filter masks, the new mask based on filter became more efficient. Biodegradable face masks were made in the 1960s as a molding frame [53] and then face masks including fiberglass filters or polypropylene was made. This transformation in disposable masks was reinforced in the 1970s when three out of four of all face masks utilized were biodegradable. Nowadays, gas masks or muslin are rarely used. Each mask has three main layers, which are: I) PP spun-bond fabric, 2) middle layer with molten PP fabric, and 3) outer layer with PP band spun fabric like the first layer. The median layer has tiny holes in comparison with the internal and the external layers and performs like a filter and prevents hurtful particles from entering the body [15]. Respirators and masks are undoubtedly the most significant part of PPE. Face masks are a physical obstruction to expiratory aerosols which might come in by the mouth and nose and expel mucus saliva droplets from contagious persons [54, 55]. Masks' function might be especially significant during the COVID-19 pandemic, where contagious people can shed the virus while presymptomatic or asymptomatic [56-58]. There are various kinds of respirators and face masks that provide diverse stages of protection to wearers [9, 15, 59-61]. With the advent of an epidemic that has remarkably raised the extreme need for masks, there is a universal scarcity of access to surgical face masks.

In this situation, it is suggested by the Centers for Disease Control and Prevention (CDC) that the general citizens wear fabric masks in public places to avoid the Covid-19 emission [15]. It has also caused both usage and improvement of fabric masks by a considerable part of the community [8].

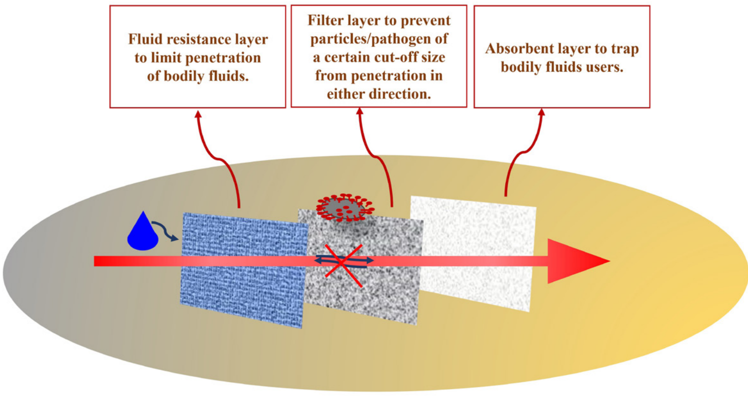

Fig. 2. Picture demonstrating the performance of every singular layer of a 3-ply face mask.

Multiple reforms have been made to the Health Care Center (HPSC) guidelines by The National Public Health Emergency Team (NPHET) for the usage of face masks on April 22, 2020, in response to the epidemic of the Covid-19. After wearing the masks, lowering and raising them on the mouth and nose is not advised. In addition, the safe elimination of masks should be practiced [15]. The major goal of mask usage is to inhibit breathing or trapping of both biological organisms (prions, bacteria, fungi and, viruses) and floating particles (man-made or natural) [22, 62, 63]. Mandatory masks usage has been implemented in several European countries and different countries apply diverse stages [15]. It has also been demonstrated that using a mask protects people who communicate with a stricken individual. Through an examination on five hospitals in Hong Kong during SARS, hospital workers had to answer questions relating to the protection devices they used and the data were relevant to if they were contaminated with the Covid-19. It was discovered that using a mask was only the most significant protecting device to decrease the risk of infection (0 = 0001) and individuals who used N95 face masks or surgical face masks were not among the eleven contaminated employees [64]. Recently, Eikenberry et al. carried out modeling research based on the infection of COVID-19 information achieved in Washington and New York City showed that widespread use of facial masks by the general public could remarkably decrease the mortality rate and community transmission [65]. According to information from February 20 to March 30, cumulative mortality is expected to decrease further as more individuals use the mask over the next two months. Hence, this research concludes that the acceptance of face masks at the community level has great capability to assist reduce the general public spread and the cost of COVID-19 epidemics.

Wearing masks, besides other non-pharmacological interventions, can be an efficient control measure in a pandemic. A physical barrier that inhibits the user to touch the face, the face mask can cause superior hand sanitation [66]. The opposite is also correct - people who use it have an enhanced inclination to touch their face, as when wearing a mask [67]. Also with the appropriate face mask, if droplets pass into the eye, individuals who wear it can still become contaminated, therefore highlighting the significance of extra protection [68].

The three-layer face mask is frequently utilized in the epidemic of COVID-19. The three-layer face mask consists of three various layers of non-woven fabric, each layer plays a particular role, like what is exhibited in Fig 2. The external layer (usually blue) is water-resistant and assists in expelling droplets like mucus saliva drops. The filter is the median part that avoids the entrance of pathogens or particles of a specific size in any route. The innermost layer of absorbent material is produced to trap mucus saliva droplets from the wearer. It also absorbs damp during exhalation, consequently becomes more comfortable.

The above three layers together preserve the wearer and individuals surrounding them via restricting the entrance of pathogens and particles in either direction [1].

Morteza H. Bagheri et al. analyzed either breathability or the filtration efficiency (FE) of multiple and single layers of various materials. Since masks intended for general use must be washable and resistant, 100% cotton fabric was selected for the outer and inner layers. Suitable weight, a large number of threads and, a firm texture are the characteristics of a cotton mask that is efficient in either respiration or particle purification. The cotton fabric was examined as both a double layer and a single layer. The Morteza H. Bagheri et al. suggests a composite of materials that contains a hydrophobic middle and external layer and a hydrophilic internal layer. ("When and how to use masks" n.d.). Hydrophilic layers can absorb water droplets better, whereas hydrophobic layers are capable of raising comfort and protecting the liquid barrier [18].

Facial masks are composed of tiny invisible sieves that are the operative layers of the face mask's working process. The tiny invisible sieve consists of interwoven mattresses made of tiny fibers which can produce complex paths that air must pass through with every particle or virus and bacteria inhaled during usage. While a mask is used, three various kinds of particles can be prevented from reaching the user by four distinct procedures. These particles are categorized into three dimensions, micro, Nano, and macro (Fig 3). Additionally charged particles have been added up to three kinds of particles. Larger particles (over 600 nm) generally larger than the size of pore in the mattress are not able to pass via the filters and are directly obstructed out of the masks by the tracing process. For small particles (about 300 to 600 nanometers), these particles can probably pass through the opaque holes of the mask sieve, however, they are more likely to fall (just like every object moving in an indirect direction at high speed) on the fibrous walls in their path via the entanglement of the fibers. It is strongly mentioned by the velocity and mass of the particles, thus preventing the particle from ever reaching the user. This mechanism is named collision /impact. Nano-sized particles (below 300 nm), have very little dimensions, so these can pass without difficulty via the holes without hitting the hole barriers with the assistance of air, however are bombarded by the surrounding atmosphere particles without difficulty. To adsorb such-like particles, an adsorption process based on diffusion is continued, which occurs only in branched nanofibers and nanometer-sized fibers. Electrospun nanofibers are more capable on this occasion. But, particles exist only in the range of micro and Nano (~ 300 nm), they scarcely respect the impact/ collision process and the diffusion-based recording process, and therefore filtering in many facial masks is difficult. However, particles exist only between the micro and nano ranges at ~ 300 nm, they hardly obey the diffusion-based recording mechanism and the collision/impact mechanism, and therefore filtering in many face masks is difficult. However, particles exist only between the micro and Nano ranges at ~ 300 nm, they scarcely value the diffusion-based recording process and the collision/impact process, and therefore filtering in many facial masks is difficult.

Hence, this needs several layers of the mattress to postpone suchlike particles and allow them to follow one of the procedures. The existence

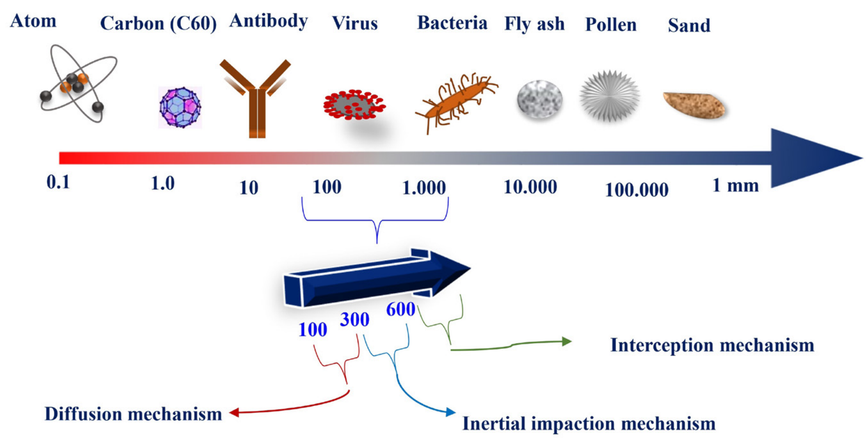

Fig. 3. The main concept of different particle length scales in the environment and the technique related to filters of face masks when filtering them.

of several filtration layers causes a new difficulty of different engineering in the respiration of the ultimate product. Hence, it is significant for an engineer to respond to two opponent requests of air either breathability or filtration to meet a face mask perfect performance. Electrospun nanofibers supply the required stability of appropriate mechanism supervision through electrospinning. The latest technique is electrostatic filtration, in which the filter consists of charged mattresses that can absorb opposing loaded particles to prevent them from reaching the user.

It is significant to mention that the facial mask must meet definite standards. To illustrate, the MIL-M-36954 C: ΔP Respiratory Test, which verifies resistance quantity of the face mask to airflow, the ASTM F1862 which evaluates the face mask resistance to the entrance of liquid, the particle filtration test determines the ASTM F2299. Which estimates the filtration ability of the face mask, ASTM F2101. Bacterial Filtration Test - which verifies the volume of bacteria bigger than 3000 nm that possibly can be filtrated by the face mask, 16 CFR Flammability Test Part 1610: Expansion of flame. Which evaluates the flame resistance of the face mask properties. In addition, other significant regular examinations can be performed, including; toxicity, biocidal efficacy, antiviral efficacy, skin sensitivity, allergies, and more [13].

4. Essential parameters for filtration of masks

The effectiveness of a respirator or a face mask determines by two important factors, fit (leakage of the facepiece) and filtration efficiency [69]. The efficiency of a filter determines how much the mask filtrates particles in certain dimensions that contains sub-micron particles and viruses, while fitting determines the way that respirator or mask obstructs leakage surrounding the face [15]. Leakage between the skin and the mask material allows air to move via the mask material without being filtered. However, it was demonstrated by these estimations that very few leaks of about one percent of the entire sample surface region could significantly decrease the total filtration efficiency of the mask by fifty percent or even less than its material importance. Hence, the leak area must be minimized [48].

The mask filtration efficiency, which represents the mask material adsorption efficiency is based on the concentration of particles (particles cm-3) downstream and upstream (i.e. after and before the particles move through the filter) [15] :

$$Efficiency\ (\%) = [1 - \frac{Downstream \quad concentration}{Upstream \quad concentration}] \times 100 \tag{1}$$

The volume of filter and therefore the rank of protecting against pathogens and contaminants relies upon the engineering design and materials used [9, 59-61, 70]. Many factors such as particle and flow velocities (charge, size distribution and, concentration) besides the mask material properties (packing density, chemical composition, diameters of fibers, electrostatic charge and, mask thickness) can impact the filtration efficiency of a particular material (see Huang et al., and Tcharkhtchi et al. for more details)[11, 71]. Air pollutants vary greatly in dimensions (Fig 1). The size of SARS-CoV-2 is between 60 and 140 nm [72], smaller than pollen, bacteria, and particles. Accordingly, both respirators and face masks were produced by materials with greater pore dimensions, like synthetic fabrics and cotton, which cannot efficiently filtrate these fine virus-loaded droplets or viruses in comparison with masks were produced by materials with much smaller pore dimensions. In the same way, respirators and masks produced from or enveloped with water-proof materials are more efficient facing great respiratory droplets filled with virus and fluid leakage [73]. Membrane filtration efficiency depends on packing density, the structure (fiber organization, pore size), fiber load, fiber diameter, and thickness, etc. of the material. It is concluded that fibers with large surface area and small diameter, which create small holes in comparison with long fibers, result in increased filter efficiency.

Numerous investigations have been performed to clarify the theory of the filtration process via impaction and electrostatic enticement by the fibrous conditions [15, 74-76]. The United States first advanced materials for fiberglass filters and patented them in 1940. Then, high-efficiency glass-fiber air filters emerged as filter materials and were utilized to purify the room atmosphere. Filters with high efficiency produced from very fine glass fibers with an optimal diameter of less than 0.3 mm are utilized to more improve filtrating performance, and the efficiency of the filter for particles equal to or larger than 0.3 m arrives at 99.998%. Subsequently, Japan produced a filter with ultra-high efficiency, with a particle filtrating efficiency of 0.1 m to 99.9955%. Utilizing an electrostatic process, the obtained ultra-thin PMAA (poly (methacrylic acid)) hydrogel can keep its cationic antimicrobial feature [77]. Also, an initial investigation resulted in that electret filters (non-woven fibers) have an elevated efficiency of filtering with inadequate resistance to air and high particle holding space in comparison with traditional fiber filters [78]. Filtrating is determined by the electrostatic gravitational forces between the aerosol particles and the mask matrix and relies upon the material dielectric feature. Therefore, polymeric materials that electrically have high stability and resistance, like polyacrylonitrile (PAN), polypropylene (PP), polyethylene, and so on are the most excellent options for both respirators and face masks [78]. But, the hydrophilicity feature of these polymer surfaces must be advanced for filtering aqueous particles and effective trapping [15]. Three masks with various airflow resistance, filtration efficiencies and, porosity, were compared recently in an investigation, Mask A has a filter plate, Mask B has two filters, and C is a washable fabric Mask [79]. It has resulted in that mask B provides the finest filtrating due to the highest filter efficiency and the lowest porosity.

Mask A had large cavities that decreased filter efficiency, while mask C possessed the top resistance to airflow, which can cause respiratory problems.

Currently, different researches have been done for improving the effectiveness of masks and respirators against very small particles like different pathogens and viruses. These contain the use of qualified filter materials like nanofiber webs and nanofibers. Additionally, the antiseptic ability of the virus can be advanced by purifying the surfaces of the filter using substances that have antimicrobial features. The usage of iodine [80, 81] silver nanoparticles (AgNPs), titanium oxide (TiO_2) [82], and copper oxide [83], etc. have previously been reported in recent decades. The development and fabrication of nanomaterials have improved considerably owing to the rapid growth of nanotechnology. Electrospinning techniques are commonly used to make nanofibers [84]. It was shown by Skaria et al. that surgical masks containing nanofiber filters in comparison with existing commercial masks, reduce airflow resistance and improve filtration efficiency [85]. The maintenance of the electrostatic charge was improved by combining other layers of filter material with electrostatic fibers and thus improved the total filtration efficiency. A very light binary structure of 6-polyacrylonitrile (N6-PAN NNB) nylon nanofiber net was manufactured by Wang et al. for the increased adsorption of tiny particles with a diameter of 2.5 μm or less (PM 2.5) [86]. N6-PAN NNB was synthesized from polyamide 6-15 (PA6-15) together with polyacrylonitrile (PAN) nanofibers via multi-jet rotation. Compared to commercially available fibers, the compound showed 99.99% filtrating efficiency and presented a deep bed filtration template as opposed to the conventional fiber surface filtrating template. A three-dimensional simulation of the construction was also planned and a model of airflow resistance was developed based on the observed experimental information.

More investigations were performed on the strong composition of nanostructures on nanofibers for improving filtration efficiency, decreasing pressure drop while maintaining three-dimensional structure. A hierarchical fluidized bed filter was fabricated with agglomerated CNTs for filtering aerosol particles [87]. It was discovered that the produced material in comparison with conventional filters had a high-quality factor (QF) and an increased waterproof property. In addition, a fiber membrane of the polyether-silica electrode (PEI-SiO_2) was fabricated by an electrospinning mechanism [88]. A filtrating efficiency of 99.992% was achieved via superior self-cleaning properties. This has been suggested that constant SiO_2 bipolar orientation presents an opportunity to absorb target particles and more pathogens, helps to trap more loads, and provides more stability. NIOSH performs several validation tests before legalizing the use of a respirator or mask. These contain inhalation/exhalation tests, NaCl aerosol challenge, dioctyl phthalate (DOP) testing, and valve leakage to confirm standards). In the NaCl aerosol examination, the examples are exposed to aerosolized NaCl, and the volume of NaCl that moves through the sample evaluates the efficiency of filtering. Airflow resistance and particle permeability are evaluated by the DOP test where specimens are tested with particles in the most permeable size series (0.3 μm) [15]. In the following, the efficiency and the essential features of the filter, and the impact of exterior factors on the filtering process are investigated. Table 1 is presented as a summary for this part to review and compare the various factors of external conditions [11]. The filtering process is an important aspect of efficiency and filter media accuracy. Particle filtration is done via five sets of processes: (1) obstruction, (2) inertial latency, (3) spread, (4) gravity-related deposition, and (5) electrostatic enticement. On the other part, deep filtering with longer life and low proficiency takes place when microfiber is utilized, while nanofibers can cause surface filtration process, shorter life and, elevated efficiency. The use of vertebrate nanofibers is suggested for high efficiency, shorter time and, deep filtration process.

Also, Akduman provided a layer of nanofiber containing polyvinylidene fluoride (PVDF) and cellulose acetate (CA) with 100% mechanical filtering for respirators and face masks able to meet the characteristic of N95 masks. The impact of pore size, thickness, and diameter of nanofiber matte on filtering efficiency was compared [89, 90]. The average PVDF nanofibers (236.50 nm) diameter was smaller than the CA nanofibers (319.02 nm) diameter. Thus, CA nanofibers demonstrated superior filtration efficiency [90]. The application of soluble blowing spinning nanofibers (SBS) is an important stage in the development of compound masks [91, 92]. Noel et al. (2019) utilized the SBS nanofiber technique in composite multilayer filter masks and arranged three various kinds of nanofiber materials, PVDF, cellulose acetate (CA) and, polyacrylonitrile (PAN). They showed that the existence of functions of various molecules in electrospun nanofibers has a serious impact on the efficiency of a filter, for example, PAN nanofibers have the greatest filtration efficiency (0.05 Pa^{-1}) with good air condition and permeability, while among the whole of nanofibers investigated, the quality of air filtering by PVDF with the quality coefficient (0.02 Pa^{-1}) was the lowest [93].

5. Effective membrane materials for filtering

The membranes utilized for filtrating particles under the size of micron should also enable the individual to respire and should not be blocked when the particles attach to the outer layer of the face mask [107]. The main techniques applied in the elimination of particles by fibrous media contain gravitational deposition, inertial latency, spread, and electrostatic enticement [108]. Particles are greater than 0.3 μm have been reported to be mainly retained by inertial latency, while particles smaller than 0.2 μm are absorbed by electrostatic enticement and filtration [109]. Important parameters affecting the performance of air filters are permeability of air, the diameter of the fiber, the thickness of the membrane. When the diameter of the fiber is reduced to the nanoscale, the particle elimination efficiency (PM) can be greatly advanced owing to high porosity and the increased surface region, therefore, the thickness of membrane is able to be decreased to reduce the resistance of the air [110].

Of all the nanofiber membrane fabrication techniques, the most widely utilized method is electrospinning which fabricates constant nanofibers from a polymer solution via an electrically charged jet. Due to their extremely interconnected porous web and great particular sur-

Table 1.
Impact of exterior factors on the efficiency of a filter

Exterior factors	The mask filtration efficiency	Ref.
Time of loading	Enhance the time of loading, the efficiency enhancement (but, there is virus gathering risk)	[21, 94]
Temperature and moisture	Enhancing temperature and moisture reduces the efficiency	[94-97]
Breathing frequency	Enhancing frequency reduces the efficiency	[21]
Particle load mode	Efficiency reduces for not loaded particle	[98]
Flow pattern (steady or cyclic)	Efficiency decreases for uncharged particles	[21, 95]
Face velocity (flow rate)	Periodic flow reduces efficiency in comparison with the steady flow	[3, 8, 95]
Shape of particles	Increasing flow rate, decrease efficiency	[99]
Particle size	Decreasing particle size, decrease efficiency (globular shaped particles spread more than rode shaped particles)	[100-106]

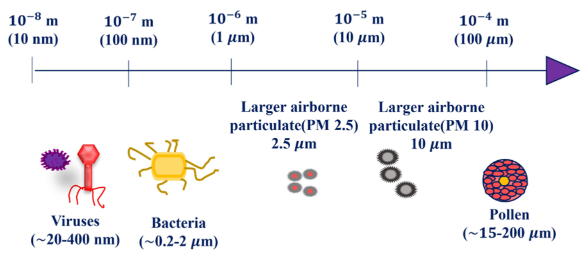

Fig. 4. Chart of relative dimensions of regular microorganisms and air pollutants.

face region, electrospinning membranes have been widely used for energy and biomedical utilization, and water therapy, in recent years, and more currently since Lui et al., Has attracted a lot of attention about electrospinning fibers for air filtration. By electrospinning transparent polyacrylonitrile (PAN) nanofiber membrane of medium fiber diameter of 200 nm produced and estimated for PM2.5 particle adsorption. In comparison with available trading air filters, which are fabricated from dense layers of micron fibers that balance filter function and air resistance, the resulting nanofiber membranes achieve good optical clarity (up till 90%), high filter effectiveness (& GT; 95%), Indicates pressure (up to 132 Pa), and lightweight. Nano nets composed of tiny charged droplets except electrospinning jets beneath the influence of a high electric field have surprising properties such as very small diameter (& Lt; 20nm), a certain great surface region, pore with little size (& Lm; 200 nm), and high porosity, Which makes them desirable candidates for filtering particles.

In the year 2015, Wang's Group made a dual nylon nanofiber of 6-PAN ultra-light nanofibers with a high coating (& GT; 98%) of nylon nanofibers packed with low-density PAN nanofibers. Arranged interconnected membranes show the high efficiency of filtering (99.99%) compared to 300 nm aerosol particles with a low base weight of 2.94 g / m2 and an acceptable quality coefficient (0.1163 Pa^{-1}) beneath a high rate of flow (90 liters per minute) that is considerably greater than trading glass fibers and filtration membranes based on molten polypropylene fibers. The same team introduced a multilayer air filter, which was extremely integrated and consisted of polyamide-6 (~ 20 nm diameter) nanofibers, polysulfide microfiber (diameter ~ 1 μm), and polyacrylonitrile nanofibers (diameter ~ 200 nm), by consecutive electrospinning.

An integrated filter with high porosity and little by little different pore constructions can effectively absorb floating particles in a gradient manner with low resistance (as shown in Fig 4). Currently, Li et al. used the netting /electrospinning mechanism to huge-produce of reusable poly (vinylidene fluoride) nanonet/ nanofiber air filters that showed a 99.985 higher filtration efficiency than PM0.26 and a lower reduction of pressure to 66.7 Pa.

Inactive membranes that adsorb particles with a porous structure, electrostatic air filters can be trapped in effective ways to increase adsorption. Without dependence on the high density of tiny pores, the filter thickness can be decreased and the removal efficiency can be kept under airflow with low reduction of pressure. Electrostatic spinning, triboelectrification, and corona charging are three methods for the fabrication of charged filtration materials. High filtration efficiency (EF) is based on the charging procedures though charge retention is not dependent of although is based on the electrical characteristics of the polymers and also the media structure and the diameter of the fiber. Charged media fabricated using triboelectrification possess a higher charge density. However, FE needs two dissimilar electronegative characteristics of the fibers. Triboelectrification and corona charging both can fabricate bipolar materials. Corona charging has the ability to desirably modify the FE on the uncharged materials of triboelectrification though not so remarkable as via triboelectrification. Corona charging is applied to both fabrics and fibers although it is superb to charge more significant density fabrics than lower density ones. Fibers are charged in the process of electrospinning and this condition can fabricate suitable fibers though the speed of production per spinning nozzle is slow [111]. During the process of electrospinning for making nanofiber membranes, the nanofibers can be charged by introducing load storage amplifiers in electrospinning solutions. In addition to the electrospinning process, corona therapy is the other way to charge fibrous membranes under an extrinsic electrical field.

Zhang et al. concocted nonwoven polypropylene electret as a load booster by blowing melt and then charging the crown with magnesium stearate. After charging at 10 kV for 30 seconds, the non-woven electrostatic precipitator showed a higher filtering efficiency of up to 99.22% towards PM2.5, a low-pressure drop of 92 Pa, and an acceptable QF of 0.054 Pa-1. A new study showed the manufacture of PAN membranes filled with AgNPs, ZnO, and TiO_2, through electrospinning, and the filtering performance was evaluated by NaCl filtration [112]. The TiO_2_F filter showed the topmost efficiency of filtering (_100%), while the Ag_F filter demonstrated the topmost QF (≈0.06 Pa^{-1}). This can be related to the high surface load and the smallest diameter of TiO_2_F, which advances particle adsorption and lowers the drop of air pressure in Ag_F, respectively. TiO_2_F demonstrated the forming of particle agglomerations due to its great particular surface region and high reaction between PAN fibers and TiO_2 nanoparticles [15]. Wang et al [7], developed a suitable integrated environment for a high thermal and respiratory filter containing a sulfone/ barium titanate (PES / $BaTiO_3$ NFM) nanofiber membrane on a non-woven polypropylene substratum. It must be noted that its injection charge energy is optimized and has high porosity. Additionally, the PES / $BaTiO_3$ membrane exhibits moderate water evaporation and good air permeability. Also, PES/ $BaTiO_3$ NFM1.5 electret possesses high filtering efficiency (99.99%) and low drop of pressure after treatment at 200 ° C for 45 minutes [11].

6. Development status of facemask manufacturing

Because the corona virus can be transmitted through particles and airborne drops, breathing masks and N95 face masks are required and need sophisticated certification.

Given this circumstance, the US Centers for Disease Control and Prevention (CDC) suggests that "in places where face masks are not accessible, health care workers may use home masks (like scarves, bandanas) to care for patients with Use Covid-19 as the final resort. Even though droplets and aerosols can be eliminated using a series of fabric fiber filtration mechanisms, their filtration performance has not been accurately evaluated [113].

Civil health mask design requirements vary around the world. China currently updated its standard under the "Chinese Civil Sanitary Mask Design" together published by China Nonwoven and Industrial Textile Association (CNITA), the China National Textile and Garment Council (CNTAC). In this paper, airflow resistance, bacterial filtration efficiency (BFE), flame retardant features, and PFE are the four major requirements applied in the fabrication and design of face masks (Table 2) [114].

6.1. Encapsulation of bioactive agent

Compounds of bioactive causatives are discovered in plants, whole grains, and some foods like nuts, fruits, oils, and vegetables. Indoles, lignin's, lycopene resveratrol and, tannins are examples that exist in bioactive compounds and are being examined by researchers to help treat coronary artery disease, cancers, and other illnesses [115].

Table 2.
Quality requirements for the production and model of civil health mask in the standard group T/CNITA 09104-2020 & T/CNTAC 55-2020 (China)

Test program	Requirements	
	Mask for children	Mask for adult
Detachable carcinogenic aromatic amine dye/(mg/kg)	Prohibited to utilize	
pH	4.0-7.5	4.8-8.5
Formaldehydecontent/(mg/kg)		≤20
Ethylene oxide residue /(μg/g)		≤10
The fastness of dry rubbing/degree	≥4	≥3
Airflow resistance/Pa	≤30	≤49
Inorganic particle filtration efficiency/%		≥90
Bacterial filtration efficiency/%		≥95
Strength of connection between the mask body and mask band/N		≥5
Length of nose clip/ cm	≥5.5	≥8.0
Microbial diagnosis	Necessities	
The whole quantity of fungal colony/(CFU/g)	≤100	
Streptococcus hemolytic	Not found	
Pseudomonas aeruginosa	Not found	
Staphylococcus aureus	Not found	
Escherichia coli	Not found	
The whole quantity of bacterial colony/(CFU/g)	≤200	

There have been several articles on the salient features of these bioactive agents existing in nature which injected from nanomaterials can be used in favor of packaging applications and lesion curing [116-118]. However, no report has been presented on their potential usage in the face mask filter membrane using the bioactive agent. In this study, we summarized and presented opportunities for the use of nanofibers injected with these bioactive causatives for the use of face masks. Sometimes it leads to skin infections and allergies. In this short study, we presented the opinion of injecting bioactive agents existing in nature like moringa and curcumin into textile nanofibers. The proposed masks are known as anti-inflammatory, free of chemical odors and, anti-allergic. In connection with the individual impacts of moringa or curcumin on masks, moringa and curcumin synergistic effects are anticipated to provide the above-mentioned extraordinary features and maintain antiviral function for a long time. The filterability and breathability of nanofibers in face masks are determined by two contrasting morphological features such as fibers surface area and porosity. Engineering the surface area and porosity to an optimal status through the electrospinning method presents a large possibility of a face mask with a bioactive agent. The electrospinning process with changes in technology suchlike force spinning and emulsion or coaxial provide a low-cost process with possible morphological adjustment of the nanofiber surface and mass production capacity [115]. By optimizing the nanofibers collection time, polymer / bioactive causative concentration, and, nozzle position perform a significant function in estimating the surface of the resulting nanofibers in the role of an operative layer of the face mask fabric. It has been recommended that nanofibers with dimensions between 100 to 500 nm, which are arranged perpendicular to each other to prevent the passage of pathogens, form a lattice structure and, provide better respiration [119]. In addition, textiles with a super-hydrophobic nature dry quickly and provide superior resistance to fluid. It is important to notice that the face mask injected with the bioactive agent must comply with commercial standards, including washable (ASTM F2100), Particle Filtration Test (ASTM F2299), flammability test (ISO 4589 Part 2), Breathing Test (MIL-M-36954), Liquid Resistance Test (ASTM F1862), and bacterial filtering test (ASTM F2101). Recently, three-dimensional printing has been significantly applied to produce tailored seal manufacturing for the improvement of mask fit and comfort. The 3D laser scanning can be used for scanning precise facial factors to customize face mask seals, with a customized and tailored face seal N95 template. Anthropometric data of the nose protrusion, nose, and face lengths, jawline, and chin arc measurements can be considered for this customized seal. In an investigation via a Fused Deposition Modeling 3D printer, through prototypes of face seal with Acrylonitrile Butadiene Styrene plastic 3 subjects indicated modified contact pressure in comparison with application of 3M 8210 N95 FFR respirator masks [120].

In addition, examinations with phytochemicals collected from natural resources have demonstrated that bioactive compositions have previously been capable of killing pathogens or boosting the immune system against coronaviruses, which has attracted little attention as a substitute resource of medicines with fewer side effects [119, 121, 122]. In this relation, Nano flora--nanoparticles enhancing biological improvement in biological compounds was reported to increase the non-soluble phytochemicals delivery, adapting antimicrobial drugs [123-125], including therapeutic methods opposed to coronaviruses (CoVs) [126, 127] and viruses [128-130].

6.2. Green Electrospun Nanofibers

On the market, there is a wide range of easy-to-use, movable, battery-powered, and secure electro spinners that can be utilized easily utilized to attain electrified nanofiber mattresses [131]. Thus, after attaining the correct electrospun filter mattresses, they can be used if placed in a completely collected face mask. To get a functional face mask, A DO-IT-YOURSELF (DIY) method is offered that can be followed at home.

Electrospinning is a new method for producing nanofibers because it offers a low-cost, fast process and, exact control of nanofiber compounds and geometric features. In electrospinning, high electrical forces are applied to molten or polymer solution droplets to produce very fine fibers with a diameter between 40 and 2000 nm and to eliminate the surface tension of the liquid [132]. Choosing the space between the holding collectors, the right solution concentration, the syringe tip and, the right voltage, are of considerable importance to the synthesis of steady nanofibers. As the main section of this technology, filter media based on nanofiber are key parts to increase filtering efficiency [133-137]. Electrospun filter media based on nanofiber possess good bonding of cavities, high surface/volume ratio, controllable morphology and bonding and, a low-pressure drop which makes them desirable for excellent filtration. Due to their fragility, electrospun nanofibers cannot be used separately in the filter medium; they must be placed on a substrate, usually a nonwoven fabric. Nylon, glass, cellulose and, polyester are common materials utilized as a supporter for electrospun nanofibers. The substrate must have great mechanical features to allow filter construction, toughness and, arrangement in use [138]. To suggest filtration, substrates are chosen for durability in usage, stratification, filter sanitizing and, filter fabrication. The use of nanofibers in respirators and masks is better than commercial masks. Productive filters utilized in trading respirators and face masks currently use PP fibers with a small diameter of about 500 to 1000 nm, these filters are attained with the assistance of steady electricity. The pore dimensions reduce when the diameter of the fiber reduces and the distribution of fiber per unit area gets denser. Melt blowing with the help of electrostatics improves the quality of filtration via producing a small load on the textile that enhances the absorbency of the fabric. Several patents and studies have been recognized on nanofibers in various respiratory and face mask applications [139-141]. Munzarová created nanofibers fabrics barrier by electrospinning to be laminated on face masks. This preserves against the penetration of allergens, microorganisms and, particles [142].

Skaria and Smaldone developed the first filter mask based on nanofiber in comparison with the N95 face mask. They recognized that the prototype considerably decreased resistance to airflow, which led to better adaptation of the face mask and enhanced the efficiency of filtering, like that achieved during the N95 face mask usage [85]. Lee and Gong with a little different perspective, reported the improvement of polysulfide-based nanofibers for mask filtration, using electrospinning to coat non-woven PP, to prevent the inhalation of detrimental contaminants into the foggy air. The thickness of the nanofiber mat was reformed during different periods of mass preparation (15 minutes <30 minutes <60 minutes) and these three nanofiber-based face masks were compared with Ito PM2.5, non-woven disposable face masks, R95 and N95 masks and, non-woven operating room masks. It was found that electrospun nanofiber face masks may be effective infiltration of PM2.5 particles while maintaining good respiration [143]. Also, Akduman provided a nanofiber layer of polyvinylidene fluoride (PVDF) and cellulose acetate (CA) with 100% mechanical filtration for respirators and face masks able to meet the N95 face masks specifications. The impact of pore size, the thickness of nanofiber mat and, the diameter of nanofiber on the efficiency of filtering was compared [89, 90]. The average diameter of CA nanofibers (319.02 nm) was bigger than the diameter of PVDF nanofibers (236.50 nm). Thus, CA nanofibers demonstrated greater efficiency of filtering [90].

7. Conclusions and future aspects

The goal of this research was to examine the particle filtration mechanisms by face mask and to evaluate the effective factors such as efficient mask filter loading time, respiration frequency, unstable or fixed flow pattern, relevant temperature and humidity, particle load status, and airflow or facial velocity.

In addition, in this article, we introduce new trends that will be effective for future investigations on the filtration efficiency of mask materials. Membrane filtration efficiency depends on fiber diameter and thickness, the structure (fiber organization, pore size), packing density, fiber diameter, and thickness, etc. of the material. It is concluded that fibers with large surface area and small diameter, which create small holes in comparison with long fibers, lead to increased filter efficiency. The mechanism of filtrating is an important feature in terms of the efficiency and accuracy of the filter media. Particle filtration is done via five sets of procedures: (1) interception, (2) inertial latency, (3) spread, (4) gravitation deposition, and (5) electrostatic enticement.

On the other part, deep filtering with a longer lifetime and lower efficiency happens when microfiber is applied, whereas nanofibers cause shorter life, surface filtration process, and high efficiency. The use of vertebrate nanofibers is suggested for high efficiency, shorter time, and deep filtration process. The main parameters affecting the performance of air filters are membrane thickness, air permeability, and diameter of the fiber. When the diameter of fibers is reduced to the nanoscale, the particle elimination efficiency (PM) can be significantly advanced owing to high porosity and the increase in specific surface area, and therefore, the thickness of the membrane can be decreased to make certain low resistance of the air. Electrospinning is the most widely utilized technique among all approaches to make nanofiber membranes that manufacture continuous nanofibers from a polymer solution via an electrically charged jet. Electrospinning membranes present a highly interconnected porous network and large specific surface area, therefore they have been widely applied for biomedicine, energy-related applications, and water treatment in recent decades. Filterability and breathability nanofibers in face masks are determined by two contrasting morphological features such as fiber surface area and porosity. Engineering the surface area and porosity to an optimal level through the electrospinning method presents a large possibility of a face mask with a bioactive agent. Electrospinning is a new method for producing nanofibers because it presents a low-cost, fast, accurate control of nanofiber compounds and geometric features. It was reported by Lee and Gong that polysulfide-based nanofibers developed for filtration of a mask, using electrospinning to coat non-woven PP, to prevent from breathing in detrimental contaminants in the foggy atmosphere. The thickness of the nanofiber mat was reformed during various periods of mass preparation (15 minutes <30 minutes <60 minutes) and these three nanofiber face masks were compared with Ito PM2.5, non-woven operating room masks, R95 and N95 masks, and non-woven disposable face masks. It was identified that electrospun nanofiber face masks may be capable of PM2.5 particles filtering while maintaining good respiration.

REFERENCES

[1] M.H. Chua, W. Cheng, S.S. Goh, J. Kong, B. Li, J.Y.C. Lim, L. Mao, S. Wang, K. Xue, L. Yang, E. Ye, K. Zhang, W.C.D. Cheong, B.H. Tan, Z. Li, B.H. Tan, X.J. Loh, Face Masks in the New COVID-19 Normal: Materials, Testing, and Perspectives, Research (Washington, D.C.) 2020 (2020) 7286735.

[2] J. Howard, A. Huang, Z. Li, Z. Tufekci, V. Zdimal, H.-M. van der Westhuizen, A. von Delft, A. Price, L. Fridman, L.-H. Tang, An evidence review of face masks against COVID-19, Proceedings of the National Academy of Sciences 118(4) (2021).

[3] S. Rengasamy, B. Eimer, R.E. Shaffer, Simple respiratory protection—evaluation of the filtration performance of cloth masks and common fabric materials against 20–1000 nm size particles, Annals of occupational hygiene 54(7) (2010) 789-798.

[4] N.H. Leung, D.K. Chu, E.Y. Shiu, K.-H. Chan, J.J. McDevitt, B.J. Hau, H.-L. Yen, Y. Li, D.K. Ip, J.M. Peiris, Respiratory virus shedding in exhaled breath and efficacy of face masks, Nature medicine 26(5) (2020) 676-680.

[5] J.W. Tang, T.J. Liebner, B.A. Craven, G.S. Settles, A schlieren optical study of the human cough with and without wearing masks for aerosol infection control, Journal of the Royal Society Interface 6(suppl_6) (2009) S727-S736.

[6] D. Kharaghani, M.Q. Khan, A. Shahrzad, Y. Inoue, T. Yamamoto, S. Rozet, Y. Tamada, I.S. Kim, Preparation and In-Vitro Assessment of Hierarchal Organized Antibacterial Breath Mask Based on Polyacrylonitrile/Silver (PAN/AgNPs) Nanofiber, Nanomaterials (Basel, Switzerland) 8(7) (2018).

[7] N. Wang, M. Cai, X. Yang, Y. Yang, Electret nanofibrous membrane with enhanced filtration performance and wearing comfortability for face mask, Journal of colloid and interface science 530 (2018) 695-703.

[8] A. Konda, A. Prakash, G.A. Moss, M. Schmoldt, G.D. Grant, S. Guha, Aerosol Filtration Efficiency of Common Fabrics Used in Respiratory Cloth Masks, ACS Nano 14(5) (2020) 6339-6347.

[9] A. Davies, K.-A. Thompson, K. Giri, G. Kafatos, J. Walker, A. Bennett, Testing the efficacy of homemade masks: would they protect in an influenza pandemic?, Disaster medicine and public health preparedness 7(4) (2013) 413-418.

[10] C.M. Dugdale, R.P. Walensky, Filtration efficiency, effectiveness, and availability of N95 face masks for COVID-19 prevention, JAMA Internal Medicine 180(12) (2020) 1612-1613.

[11] A. Tcharkhtchi, N. Abbasnezhad, M. Zarbini Seydani, N. Zirak, S. Farzaneh, M. Shirinbayan, An overview of filtration efficiency through the masks: Mechanisms of the aerosols penetration, Bioactive Materials 6(1) (2021) 106-122.

[12] A. Mostaghimi, M.J. Antonini, D. Plana, P.D. Anderson, B. Beller, E.W. Boyer, A. Fannin, J. Freake, R. Oakley, M.S. Sinha, L. Smith, C. Van, H. Yang, P.K. Sorger, N.R. LeBoeuf, S.H. Yu, Regulatory and Safety Considerations in Deploying a Locally Fabricated, Reusable Face Shield in a Hospital Responding to the COVID-19 Pandemic, Med (New York, N.Y.) 1(1) (2020) 139-151.e4.

[13] M. Tebyetekerwa, Z. Xu, S. Yang, S. Ramakrishna, Electrospun nanofibers-based face masks, Advanced Fiber Materials 2(3) (2020) 161-166.

[14] G. Qiu, Z. Gai, Y. Tao, J. Schmitt, G.A. Kullak-Ublick, J. Wang, Dual-functional plasmonic photothermal biosensors for highly accurate severe acute respiratory syndrome coronavirus 2 detection, ACS nano 14(5) (2020) 5268-5277.

[15] K. O'Dowd, K.M. Nair, P. Forouzandeh, S. Mathew, J. Grant, R. Moran, J. Bartlett, J. Bird, S.C. Pillai, Face Masks and Respirators in the Fight Against the COVID-19 Pandemic: A Review of Current Materials, Advances and Future Perspectives, Materials 13(15) (2020).

[16] J. Phua, L. Weng, L. Ling, M. Egi, C.-M. Lim, J.V. Divatia, B.R. Shrestha,

Y.M. Arabi, J. Ng, C.D. Gomersall, M. Nishimura, Y. Koh, B. Du, Intensive care management of coronavirus disease 2019 (COVID-19): challenges and recommendations, The Lancet Respiratory Medicine 8(5) (2020) 506-517.
[17] S. Sousan, N. Garcia, A. White, J.A. Balanay, Filtration efficiency of surgical sterilization fabric for respiratory protection during COVID-19 pandemic, American Journal of Infection Control 49(1) (2021) 1-7.
[18] M.H. Bagheri, I. Khalaji, A. Azizi, R.T. Loibl, N. Basualdo, S. Manzo, M.L. Gorrepati, S. Mehendale, C. Mohr, S.N. Schiffres, Filtration efficiency, breathability, and reusability of improvised materials for face masks, Aerosol Science and Technology 55(7) (2021) 817-827.
[19] E. Ruiz-Hitzky, M. Darder, B. Wicklein, C. Ruiz-Garcia, R. Martín-Sampedro, G. Del Real, P. Aranda, Nanotechnology responses to COVID-19, Advanced healthcare materials 9(19) (2020) 2000979.
[20] L. Yi, L. Fengzhi, Z. Qingyong, Numerical simulation of virus diffusion in facemask during breathing cycles, Int J Heat Mass Transf 48(19) (2005) 4229-4242.
[21] A. Mahdavi, Efficiency measurement of N95 filtering facepiece respirators against ultrafine particles under cyclic and constant flows, Concordia University, 2013.
[22] D. Bunyan, L. Ritchie, D. Jenkins, J.E. Coia, Respiratory and facial protection: a critical review of recent literature, The Journal of hospital infection 85(3) (2013) 165-9.
[23] C.J. Kähler, R. Hain, Fundamental protective mechanisms of face masks against droplet infections, Journal of Aerosol Science 148 (2020) 105617 DOI: https://doi.org/10.1016/j.jaerosci.2020.105617.
[24] S. Adanur, A. Jayswal, Filtration mechanisms and manufacturing methods of face masks: An overview, Journal of Industrial Textiles (2020) 1528083720980169.
[25] F. Sharifianjazi, A. Esmaeilkhanian, L. Bazli, S. Eskandarinezhad, S. Khaksar, P. Shafiee, M. Yusuf, B. Abdullah, P. Salahshour, F. Sadeghi, A review on recent advances in dry reforming of methane over Ni-and Co-based nanocatalysts, International Journal of Hydrogen Energy (2021).
[26] C.B. Hiragond, A.S. Kshirsagar, V.V. Dhapte, T. Khanna, P. Joshi, P.V. More, Enhanced anti-microbial response of commercial face mask using colloidal silver nanoparticles, Vacuum 156 (2018) 475.
[27] Y. Li, P. Leung, L. Yao, Q.W. Song, E. Newton, Antimicrobial effect of surgical masks coated with nanoparticles, The Journal of hospital infection 62(1) (2006) 58-63.
[28] M. Hashmi, S. Ullah, I.S. Kim, Copper oxide (CuO) loaded polyacrylonitrile (PAN) nanofiber membranes for antimicrobial breath mask applications, Current Research in Biotechnology 1 (2019) 1-10.
[29] E.O. Ogunsona, R. Muthuraj, E. Ojogbo, O. Valerio, T.H. Mekonnen, Engineered nanomaterials for antimicrobial applications: A review, Applied Materials Today 18 (2020) 100473.
[30] C.Y.H. Chao, M.P. Wan, L. Morawska, G.R. Johnson, Z.D. Ristovski, M. Hargreaves, K. Mengersen, S. Corbett, Y. Li, X. Xie, D. Katoshevski, Characterization of expiration air jets and droplet size distributions immediately at the mouth opening, Journal of Aerosol Science 40(2) (2009) 122-133.
[31] S. Lin, C.-K. Lee, S.-Y. Lee, C.-L. Kao, C.-W. Lin, A.-B. Wang, S.-M. Hsu, L.-S. Huang, Surface ultrastructure of SARS coronavirus revealed by atomic force microscopy, Cell Microbiol 7(12) (2005) 1763-1770.
[32] C.S. Goldsmith, K.M. Tatti, T.G. Ksiazek, P.E. Rollin, J.A. Comer, W.W. Lee, P.A. Rota, B. Bankamp, W.J. Bellini, S.R. Zaki, Ultrastructural characterization of SARS coronavirus, Emerg Infect Dis 10(2) (2004) 320-326.
[33] M. Zeraati, R. Pourmohamad, B. Baghchi, N.P. Singh Chauhan, G. Sargazi, Optimization and predictive modelling for the diameter of nylon-6,6 nanofibers via electrospinning for coronavirus face masks, Journal of Saudi Chemical Society 25(11) (2021) 101348.
[34] H. Huang, C. Fan, M. Li, H.-L. Nie, F.-B. Wang, H. Wang, R. Wang, J. Xia, X. Zheng, X. Zuo, J. Huang, COVID-19: A Call for Physical Scientists and Engineers, ACS Nano 14(4) (2020) 3747-3754.
[35] Y. Li, H. Qian, J. Hang, X. Chen, L. Hong, P. Liang, J. Li, S. Xiao, J. Wei, L. Liu, M. Kang, Evidence for probable aerosol transmission of SARS-CoV-2 in a poorly ventilated restaurant, medRxiv (2020) 2020.04.16.20067728.
[36] M. Hadei, P.K. Hopke, A. Jonidi, A. Shahsavani, A Letter about the Airborne Transmission of SARS-CoV-2 Based on the Current Evidence, Aerosol and Air Quality Research 20(5) (2020) 911-914.
[37] N. van Doremalen, T. Bushmaker, D.H. Morris, M.G. Holbrook, A. Gamble, B.N. Williamson, A. Tamin, J.L. Harcourt, N.J. Thornburg, S.I. Gerber, J.O. Lloyd-Smith, E. de Wit, V.J. Munster, Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1, N Engl J Med 382(16) (2020) 1564-1567.
[38] R. Zhang, Y. Li, A.L. Zhang, Y. Wang, M.J. Molina, Identifying airborne transmission as the dominant route for the spread of COVID-19, Proceedings of the National Academy of Sciences of the United States of America 117(26) (2020) 14857-14863.
[39] M. Klompas, M.A. Baker, C. Rhee, Airborne Transmission of SARS-CoV-2: Theoretical Considerations and Available Evidence, JAMA 324(5) (2020) 441-442.
[40] L. Morawska, D.K. Milton, It Is Time to Address Airborne Transmission of Coronavirus Disease 2019 (COVID-19), Clin Infect Dis 71(9) (2020) 2311-2313.
[41] J. Gralton, E. Tovey, M.L. McLaws, W.D. Rawlinson, The role of particle size in aerosolised pathogen transmission: a review, The Journal of infection 62(1) (2011) 1-13.
[42] J.S. Kutter, M.I. Spronken, P.L. Fraaij, R.A. Fouchier, S. Herfst, Transmission routes of respiratory viruses among humans, Current opinion in virology 28 (2018) 142-151.
[43] K.A. Prather, C.C. Wang, R.T. Schooley, Reducing transmission of SARS-CoV-2, Science 368(6498) (2020) 1422-1424.
[44] E.L. Anderson, P. Turnham, J.R. Griffin, C.C. Clarke, Consideration of the Aerosol Transmission for COVID-19 and Public Health, Risk analysis : an official publication of the Society for Risk Analysis 40(5) (2020) 902-907.
[45] W.E. Wei, Z. Li, C.J. Chiew, S.E. Yong, M.P. Toh, V.J. Lee, Presymptomatic Transmission of SARS-CoV-2 - Singapore, January 23-March 16, 2020, MMWR Morb Mortal Wkly Rep 69(14) (2020) 411-415.
[46] R. Li, S. Pei, B. Chen, Y. Song, T. Zhang, W. Yang, J. Shaman, Substantial undocumented infection facilitates the rapid dissemination of novel coronavirus (SARS-CoV-2), Science 368(6490) (2020) 489-493.
[47] J. Howarda, Z.L. Austin Huangb, Z. Tufekcim, Z. Vladimire, H.-M. van der Westhuizenf, A. von Delfto, A. Pricen, L. Fridmand, L.-H. Tangi, V. Tangl, Face masks against COVID-19: an evidence, Review An Evidence Review. Preprints 2020040203 (2020).
[48] F. Drewnick, J. Pikmann, F. Fachinger, L. Moormann, F. Sprang, S. Borrmann, Aerosol filtration efficiency of household materials for homemade face masks: Influence of material properties, particle size, particle electrical charge, face velocity, and leaks, Aerosol Science and Technology 55(1) (2021) 63-79.
[49] T.G. Tunevall, Postoperative wound infections and surgical face masks: a controlled study, World journal of surgery 15(3) (1991) 383-7; discussion 387-8.
[50] J.L. Spooner, History of surgical face masks, AORN J 5(1) (1967) 76-80.
[51] C.A. Rockwood, Jr., D.H. O'Donoghue, The surgical mask: its development, usage, and efficiency. A review of the literature, and new experimental studies, Archives of surgery (Chicago, Ill. : 1960) 80 (1960) 963-71.
[52] N.L. Belkin, The evolution of the surgical mask: filtering efficiency versus effectiveness, Infection control and hospital epidemiology 18(1) (1997) 49-57.
[53] E.S. Schrader, From apron to gown: a history of OR attire, AORN J 24(1) (1976) 52-67.
[54] J.W. Tang, T.J. Liebner, B.A. Craven, G.S. Settles, A schlieren optical study of the human cough with and without wearing masks for aerosol infection control, J R Soc Interface 6 Suppl 6(Suppl 6) (2009) S727-S736.
[55] C.C. Leung, T.H. Lam, K.K. Cheng, Mass masking in the COVID-19 epidemic: people need guidance, Lancet 395(10228) (2020) 945-945.
[56] K. Zhou, Y. Zhao, X. Sun, Z. Yuan, G. Zheng, K. Dai, L. Mi, C. Pan, C. Liu, C. Shen, Ultra-stretchable triboelectric nanogenerator as high-sensitive and self-powered electronic skins for energy harvesting and tactile sensing, Nano Energy 70 (2020) 104546.
[57] M. Gandhi, D.S. Yokoe, D.V. Havlir, Asymptomatic Transmission, the Achilles' Heel of Current Strategies to Control Covid-19, New England Journal of Medicine 382(22) (2020) 2158-2160.
[58] Z. Gao, Y. Xu, C. Sun, X. Wang, Y. Guo, S. Qiu, K. Ma, A systematic review of asymptomatic infections with COVID-19, Journal of Microbiology, Immunology and Infection 54(1) (2021) 12-16.
[59] Y. Long, T. Hu, L. Liu, R. Chen, Q. Guo, L. Yang, Y. Cheng, J. Huang, L. Du, Effectiveness of N95 respirators versus surgical masks against influenza: A systematic review and meta-analysis, Journal of Evidence-Based Medicine 13(2) (2020) 93-101.
[60] A.V. Mueller, M.J. Eden, J.M. Oakes, C. Bellini, L.A. Fernandez, Quantitative Method for Comparative Assessment of Particle Filtration Efficiency of Fabric Masks as Alternatives to Standard Surgical Masks for PPE, medRxiv (2020) 2020.04.17.20069567.
[61] M. van der Sande, P. Teunis, R. Sabel, Professional and Home-Made Face Masks Reduce Exposure to Respiratory Infections among the General Population, PLOS ONE 3(7) (2008) e2618.
[62] F. McDonald, C.J. Horwell, R. Wecker, L. Dominelli, M. Loh, R. Kamanyire, C. Ugarte, Facemask use for community protection from air pollution disasters: An ethical overview and framework to guide agency decision making, International Journal of Disaster Risk Reduction 43 (2020) 101376.

[63] V.C.-C. Cheng, S.-C. Wong, V.W.-M. Chuang, S.Y.-C. So, J.H.-K. Chen, S. Sridhar, K.K.-W. To, J.F.-W. Chan, I.F.-N. Hung, P.-L. Ho, K.-Y. Yuen, The role of community-wide wearing of face mask for control of coronavirus disease 2019 (COVID-19) epidemic due to SARS-CoV-2, The Journal of infection 81(1) (2020) 107-114.

[64] W.H. Seto, D. Tsang, R.W. Yung, T.Y. Ching, T.K. Ng, M. Ho, L.M. Ho, J.S. Peiris, Effectiveness of precautions against droplets and contact in prevention of nosocomial transmission of severe acute respiratory syndrome (SARS), Lancet 361(9368) (2003) 1519-20.

[65] S.E. Eikenberry, M. Mancuso, E. Iboi, T. Phan, K. Eikenberry, Y. Kuang, E. Kostelich, A.B. Gumel, To mask or not to mask: Modeling the potential for face mask use by the general public to curtail the COVID-19 pandemic, Infectious Disease Modelling 5 (2020) 293-308.

[66] R. Pung, C.J. Chiew, B.E. Young, S. Chin, M.I. Chen, H.E. Clapham, A.R. Cook, S. Maurer-Stroh, M. Toh, C. Poh, M. Low, J. Lum, V.T.J. Koh, T.M. Mak, L. Cui, R. Lin, D. Heng, Y.S. Leo, D.C. Lye, V.J.M. Lee, Investigation of three clusters of COVID-19 in Singapore: implications for surveillance and response measures, Lancet 395(10229) (2020) 1039-1046.

[67] M. Klompas, C.A. Morris, J. Sinclair, M. Pearson, E.S. Shenoy, Universal Masking in Hospitals in the Covid-19 Era, New England Journal of Medicine 382(21) (2020) e63.

[68] K.H. Chan, K.Y. Yuen, COVID-19 epidemic: disentangling the re-emerging controversy about medical facemasks from an epidemiological perspective, International journal of epidemiology 49(4) (2020) 1063-1066.

[69] T. Oberg, L.M. Brosseau, Surgical mask filter and fit performance, Am J Infect Control 36(4) (2008) 276-82.

[70] S.D. Rubbo, L.R. Abbott, Filtration Efficiency of Surgical Masks: A New Method of Evaluation, The Australian and New Zealand journal of surgery 38(1) (1971) 80-83.

[71] S.-H. Huang, C.-W. Chen, Y.-M. Kuo, C.-Y. Lai, R. McKay, C.-C. Chen, Factors Affecting Filter Penetration and Quality Factor of Particulate Respirators, Aerosol and Air Quality Research 13(1) (2013) 162-171.

[72] N. Zhu, D. Zhang, W. Wang, X. Li, B. Yang, J. Song, X. Zhao, B. Huang, W. Shi, R. Lu, P. Niu, F. Zhan, X. Ma, D. Wang, W. Xu, G. Wu, G.F. Gao, W. Tan, A Novel Coronavirus from Patients with Pneumonia in China, 2019, New England Journal of Medicine 382(8) (2020) 727-733.

[73] M.H. Chua, W. Cheng, S.S. Goh, J. Kong, B. Li, J.Y. Lim, L. Mao, S. Wang, K. Xue, L. Yang, Face masks in the new COVID-19 normal: materials, testing, and perspectives, Research 2020 (2020).

[74] H.F. Kraemer, H.F. Johnstone, Collection of Aerosol Particles in Presence of Electrostatic Fields, Industrial & Engineering Chemistry 47(12) (1955) 2426-2434.

[75] K.W. Lee, B.Y.H. Liu, Theoretical Study of Aerosol Filtration by Fibrous Filters, Aerosol Science and Technology 1(2) (1982) 147-161.

[76] C. Zhu, C.-H. Lin, C.S. Cheung, Inertial impaction-dominated fibrous filtration with rectangular or cylindrical fibers, Powder technology 112(1-2) (2000) 149-162.

[77] L. Séon, P. Lavalle, P. Schaaf, F. Boulmedais, Polyelectrolyte Multilayers: A Versatile Tool for Preparing Antimicrobial Coatings, Langmuir 31(47) (2015) 12856-12872.

[78] M. Lehtimäki, K. Heinonen, Reliability of electret filters, Building and Environment 29(3) (1994) 353-355.

[79] Z. Liu, D. Yu, Y. Ge, L. Wang, J. Zhang, H. Li, F. Liu, Z. Zhai, Understanding the factors involved in determining the bioburdens of surgical masks, Ann Transl Med 7(23) (2019) 754-754.

[80] S. Ratnesar-Shumate, C.-Y. Wu, J. Wander, D. Lundgren, S. Farrah, J.-H. Lee, P. Wanakule, M. Blackburn, M.-F. Lan, Evaluation of Physical Capture Efficiency and Disinfection Capability of an Iodinated Biocidal Filter Medium, Aerosol and Air Quality Research 8(1) (2008) 1-18.

[81] J.H. Lee, C.Y. Wu, K. Wysocki, S. Farrah, J. Wander, Efficacy of iodine-treated biocidal filter media against bacterial spore aerosols, Journal of applied microbiology 105(5) (2008) 1318-1326.

[82] M. Pini, E.I. Cedillo González, P. Neri, C. Siligardi, A.M. Ferrari, Assessment of Environmental Performance of TiO2 Nanoparticles Coated Self-Cleaning Float Glass, Coatings 7(1) (2017) 8.

[83] G. Borkow, S.S. Zhou, T. Page, J. Gabbay, A Novel Anti-Influenza Copper Oxide Containing Respiratory Face Mask, PLOS ONE 5(6) (2010) e11295.

[84] M. Zhu, J. Han, F. Wang, W. Shao, R. Xiong, Q. Zhang, H. Pan, Y. Yang, S.K. Samal, F. Zhang, C. Huang, Electrospun Nanofibers Membranes for Effective Air Filtration, Macromolecular Materials and Engineering 302(1) (2017) 1600353.

[85] S.D. Skaria, G.C. Smaldone, Respiratory source control using surgical masks with nanofiber media, Ann Occup Hyg 58(6) (2014) 771-781.

[86] N. Wang, Y. Yang, S.S. Al-Deyab, M. El-Newehy, J. Yu, B. Ding, Ultra-light 3D nanofibre-nets binary structured nylon 6–polyacrylonitrile membranes for efficient filtration of fine particulate matter, Journal of Materials Chemistry A 3(47) (2015) 23946-23954.

[87] C. Wang, P. Li, Y. Zong, Y. Zhang, S. Li, F. Wei, A high efficiency particulate air filter based on agglomerated carbon nanotube fluidized bed, Carbon 79 (2014) 424-431.

[88] X. Li, N. Wang, G. Fan, J. Yu, J. Gao, G. Sun, B. Ding, Electreted polyetherimide-silica fibrous membranes for enhanced filtration of fine particles, Journal of colloid and interface science 439 (2015) 12-20.

[89] C. Akduman, E.P. Akçakoca Kumbasar, Nanofibers in face masks and respirators to provide better protection, IOP Conference Series: Materials Science and Engineering 460 (2018) 012013.

[90] C. Akduman, Cellulose acetate and polyvinylidene fluoride nanofiber mats for N95 respirators, Journal of Industrial Textiles 50(8) (2019) 1239-1261.

[91] X. Zhuang, X. Yang, L. Shi, B. Cheng, K. Guan, W. Kang, Solution blowing of submicron-scale cellulose fibers, Carbohydrate polymers 90(2) (2012) 982-7.

[92] J.M. Salva, D.D. Gutierrez, L.A. Ching, P.M. Ucab, H. Cascon, N.P. Tan, Solution blow spinning (SBS)-assisted synthesis of well-defined carboxymethyl cellulose (CMC) nanowhiskers, Nanotechnology 29(50) (2018) 50LT01.

[93] N.P.B. Tan, S.S. Paclijan, H.N.M. Ali, C.M.J.S. Hallazgo, C.J.F. Lopez, Y.C. Ebora, Solution blow spinning (SBS) nanofibers for composite air filter masks, ACS Applied Nano Materials 2(4) (2019) 2475-2483.

[94] R. Givehchi, The Effect of Capillary Force on Airborne Nanoparticle Filtration, Journal of Aerosol Science 83 (2015) 12-24.

[95] A.W. Richardson, J.P. Eshbaugh, K.C. Hofacre, P.D. Gardner, Respirator Filter Efficiency Testing Against Particulate and Biological Aerosols Under Moderate to High Flow Rates, 2006.

[96] J.T. Huang, V.I. Huang, Evaluation of the efficiency of medical masks and the creation of new medical masks, The Journal of international medical research 35(2) (2007) 213-23.

[97] X. Xiao, L. Qian, Investigation of humidity-dependent capillary force, Langmuir 16(21) (2000) 8153-8158.

[98] Y. Kousaka, K. Okuyama, M. Shimada, Y. Takii, Development of a method for testing very high-efficiency membrane filters for ultrafine aerosol particles, Journal of Chemical Engineering of Japan 23(5) (1990) 568-574.

[99] K. Willeke, Y. Qian, J. Donnelly, S. Grinshpun, V. Ulevicius, Penetration of airborne microorganisms through a surgical mask and a dust/mist respirator, American Industrial Hygiene Association journal 57(4) (1996) 348-55.

[100] P.K. Kang, D.O. Shah, Filtration of Nanoparticles with Dimethyldioctadecylammonium Bromide Treated Microporous Polypropylene Filters, Langmuir 13 (1997) 1820-1826.

[101] S. Guha, B. McCaffrey, P. Hariharan, M.R. Myers, Quantification of leakage of sub-micron aerosols through surgical masks and facemasks for pediatric use, Journal of occupational and environmental hygiene 14(3) (2017) 214-223.

[102] A. Moradmand, H. Khaloozadeh, An experimental study of modeling and self-tuning regulator design for an electro-hydro servo-system, 2017.

[103] K. Donaldson, V. Stone, A. Clouter, L. Renwick, W. MacNee, Ultrafine particles, Occupational and environmental medicine 58(3) (2001) 211-6, 199.

[104] J.P. Eshbaugh, P.D. Gardner, A.W. Richardson, K.C. Hofacre, N95 and p100 respirator filter efficiency under high constant and cyclic flow, Journal of occupational and environmental hygiene 6(1) (2009) 52-61.

[105] H.-C. Wang, G. Kasper, Filtration efficiency of nanometer-size aerosol particles, Journal of Aerosol Science 22(1) (1991) 31-41.

[106] C.S. Kim, L. Bao, K. Okuyama, M. Shimada, H. Niinuma, Filtration efficiency of a fibrous filter for nanoparticles, Journal of Nanoparticle Research 8(2) (2006) 215-221.

[107] K. Sutherland, G. Chase, Filters and filtration handbook, Elsevier2011.

[108] W.H. Revoir, Respiratory protection handbook, CRC Press1997.

[109] M.J. Schick, Introduction to aerosol science, Parker C. Reist, MacMillan, New York, 1984, 299 pp. Price: $38.00, Journal of Polymer Science: Polymer Letters Edition 23 (1985) 162.

[110] S. Fooladi, S. Matin, A. Mahmoodpoor, Copper as a potential adjunct therapy for critically ill COVID-19 patients, Clinical Nutrition ESPEN 40 (2020) 90-91.

[111] P.P. Tsai, H. Schreuder-Gibson, P. Gibson, Different electrostatic methods for making electret filters, Journal of electrostatics 54(3-4) (2002) 333-341.

[112] A.C. Canalli Bortolassi, V.G. Guerra, M.L. Aguiar, L. Soussan, D. Cornu, P. Miele, M. Bechelany, Composites Based on Nanoparticle and Pan Electrospun Nanofiber Membranes for Air Filtration and Bacterial Removal, Nanomaterials (Basel, Switzerland) 9(12) (2019) 1740.

[113] Z. Zhao, H. Cui, W. Song, X. Ru, W. Zhou, X. Yu, A simple magnetic nanoparticles-based viral RNA extraction method for efficient detection of SARS-

CoV-2, (2020) 2020.02.22.961268.
[114] M. Liao, H. Liu, X. Wang, X. Hu, Y. Huang, X. Liu, K. Brenan, J. Mecha, M. Nirmalan, J.R. Lu, A technical review of face mask wearing in preventing respiratory COVID-19 transmission, Current Opinion in Colloid & Interface Science 52 (2021) 101417.
[115] D. Sundhari, N. Dhineshbabu, S. Sutha, M.R. Saravanan, Encapsulation of bioactive agent (Curcumin, Moringa) in electrospun nanofibers–Some insights into recent research trends, Materials Today: Proceedings (2021).
[116] M.A. Alam, M.H. Asoushe, P. Pourhakkak, L. Gritsch, A. Alipour, S. Mohammadi, Preparation of bioactive polymer-based composite by different techniques and application in tissue engineering: A review, Journal of Composites and Compounds 3(8) (2021) 194-205.
[117] M. Arefian, M. Hojjati, I. Tajzad, A. Mokhtarzade, M. Mazhar, A. Jamavari, A review of Polyvinyl alcohol/Carboxymethyl cellulose (PVA/CMC) composites for various applications, Journal of Composites and Compounds 2(3) (2020) 69-76.
[118] R.N. Azadani, M. Sabbagh, H. Salehi, A. Cheshmi, A. Raza, B. Kumari, G. Erabi, Sol-gel: Uncomplicated, routine and affordable synthesis procedure for utilization of composites in drug delivery, Journal of Composites and Compounds 3(6) (2021) 57-70.
[119] S. Ben-Shabat, L. Yarmolinsky, D. Porat, A. Dahan, Antiviral effect of phytochemicals from medicinal plants: Applications and drug delivery strategies, Drug Delivery and Translational Research 10(2) (2020) 354-367.
[120] M. Cai, H. Li, S. Shen, Y. Wang, Q. Yang, Customized design and 3D printing of face seal for an N95 filtering facepiece respirator, Journal of occupational and environmental hygiene 15(3) (2018) 226-234.
[121] Z.K. Shinwari, M. Qaiser, M.Q. Nasar, A. Ali, Indigenous knowledge based herbal medicine for corona (COVID-19) treatment, Pak J Bot 52(4) (2020) 1427-34.
[122] J.S. Mani, J.B. Johnson, J.C. Steel, D.A. Broszczak, P.M. Neilsen, K.B. Walsh, M. Naiker, Natural product-derived phytochemicals as potential agents against coronaviruses: A review, Virus Research 284 (2020) 197989.
[123] I. Dammak, P.J.d.A. Sobral, A. Aquino, M.A.d. Neves, C.A. Conte-Junior, Nanoemulsions: Using emulsifiers from natural sources replacing synthetic ones—A review, Comprehensive Reviews in Food Science and Food Safety 19(5) (2020) 2721-2746.
[124] S. Banerjee, Nanoparticle-Based Delivery of Phytochemical Compounds Against Major Maladies: Cancer, Diabetes, and Cardiovascular Disease, Plant-derived Bioactives, Springer2020, pp. 591-619.
[125] D. Guzman-Villanueva, I.M. El-Sherbiny, D. Herrera-Ruiz, H.D. Smyth, Design and in vitro evaluation of a new nano-microparticulate system for enhanced aqueous-phase solubility of curcumin, BioMed research international 2013 (2013).
[126] M. Kaur, G. Devi, M. Nagpal, M. Singh, G.A. Dhingra, G. Aggarwal, Antiviral essential oils incorporated in nanocarriers: Strategy for prevention from COVID-19 and future infectious pandemics, Pharmaceutical Nanotechnology 8(6) (2020) 437-451.
[127] N. Mittal, V. Garg, S.K. Bhadada, O.P. Katare, Role of novel drug delivery systems in coronavirus disease-2019 (covid-19): Time to act now, Current Drug Delivery 18(3) (2021) 289-296.
[128] E. Szymańska, P. Orłowski, K. Winnicka, E. Tomaszewska, P. Bąska, G. Celichowski, J. Grobelny, A. Basa, M. Krzyżowska, Multifunctional Tannic Acid/Silver Nanoparticle-Based Mucoadhesive Hydrogel for Improved Local Treatment of HSV Infection: In Vitro and In Vivo Studies, International journal of molecular sciences 19(2) (2018).
[129] A.A. Haroun, H.A. Amin, S.H. Abd El-Alim, Immobilization and In vitro Evaluation of Soyasapogenol B onto Functionalized Multi-Walled Carbon Nanotubes, IRBM 39(1) (2018) 35-42.
[130] R.K. Sharma, K. Cwiklinski, R. Aalinkeel, J.L. Reynolds, D.E. Sykes, E. Quaye, J. Oh, S.D. Mahajan, S.A. Schwartz, Immunomodulatory activities of curcumin-stabilized silver nanoparticles: efficacy as an antiretroviral therapeutic, Immunological investigations 46(8) (2017) 833-846.
[131] J. Xiao, J. Liang, C. Zhang, Y. Tao, G.-W. Ling, Q.-H. Yang, Advanced Materials for Capturing Particulate Matter: Progress and Perspectives, Small Methods 2(7) (2018) 1800012.
[132] D.H. Reneker, I. Chun, Nanometre diameter fibres of polymer, produced by electrospinning, Nanotechnology 7(3) (1996) 216.
[133] J.A. Abbas, I.A.-M. Said, M.A. Mohamed, S. Yasin, Z.A. Ali, I.H. Ahmed, Electrospinning of polyethylene terephthalate (PET) nanofibers: optimization study using taguchi design of experiment, IOP Conference Series: Materials Science and Engineering (2018).
[134] A. Yang, L. Cai, R. Zhang, J. Wang, P.-C. Hsu, H. Wang, G. Zhou, J. Xu, Y. Cui, Thermal management in nanofiber-based face mask, Nano letters 17(6) (2017) 3506-3510.
[135] C. Yang, Aerosol Filtration Application Using Fibrous Media—An Industrial Perspective, Chinese Journal of Chemical Engineering 20(1) (2012) 1-9.
[136] S.A. Yasin, J.A. Abbas, I.A. Saeed, I.H. Ahmed, The application of green synthesis of metal oxide nanoparticles embedded in polyethylene terephthalate nanofibers in the study of the photocatalytic degradation of methylene blue, Polymer Bulletin 77 (2019) 3473-3484.
[137] R.S. Barhate, S. Sundarrajan, D. Pliszka, S. Ramakrishna, Fine chemical processing: The potential of nanofibres in filtration, Filtration & Separation 45(4) (2008) 32-35.
[138] V. Thavasi, G. Singh, S. Ramakrishna, Electrospun nanofibers in energy and environmental applications, Energy & Environmental Science 1(2) (2008) 205-221.
[139] V. Shabafrooz, M. Mozafari, D. Vashaee, L. Tayebi, Electrospun nanofibers: from filtration membranes to highly specialized tissue engineering scaffolds, Journal of nanoscience and nanotechnology 14(1) (2014) 522-34.
[140] D. von Loesecke, B. Murphey, Machinery and processing: An overview of engine filtration, Filtration & Separation 45(7) (2008) 17-19.
[141] G.J. Hofmeyr, A.P. Betrán, M. Singata-Madliki, G. Cormick, S.P. Munjanja, S. Fawcus, S. Mose, D. Hall, A. Ciganda, A.H. Seuc, T.A. Lawrie, E. Bergel, J.M. Roberts, P. von Dadelszen, J.M. Belizán, F. Althabe, J.M. Belizán, E. Bergel, A. Ciganda, G. Cormick, D. Sawchuck, M. Vidler, S. Allie, J. Anthony, K. Frank, A. de Greeff, S. Fawcus, D. Hall, J. Hofmeyr, M. Kovane, P. Kovane, T. Lawrie, S. Mose, N. Mshweshwe, V. Mqikela, P. Njikelana, N. Novikova, A. Oyebajo, C. Parker, A. Phuti, M. Singata-Madliki, E. van Papendorp, X. Williams, A.P. Betrán, T. Dannemann, A. Seuc, L. Magee, P. von Dadelszen, F. Donnay, S. Drebit, J. Roberts, B. Guzha, E. Makaza, S. Manyame, S. Munjanja, E. Tahuringana, Prepregnancy and early pregnancy calcium supplementation among women at high risk of pre-eclampsia: a multicentre, double-blind, randomised, placebo-controlled trial, The Lancet 393(10169) (2019) 330-339.
[142] M. Munzarová, Barrier fabric containing nanofiber layer, Brno, Nanocon (2013) 16-19.
[143] X. Li, Y. Gong, Design of Polymeric Nanofiber Gauze Mask to Prevent Inhaling PM2.5 Particles from Haze Pollution, Journal of Chemistry 2015 (2015) 460392.