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An overview of the attributes of face masks in the new normal

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Abstract
The Coronavirus Disease 2019 (COVID-19) has ravaged the globe, killing a large number of people. Along with the hand hygiene, social distancing, disinfection of surfaces and wearing a mask is an essential precaution since the main mode of transmission is through respiratory droplets.
Masks of various types provide varying degrees of protection to the user. Masks are used as protective equipment to shield the respiratory system from potentially harmful air droplets and aerosols such as viruses and other airborne particles. The filtering efficacy of the various masks against these aerosols varies due to the particles' varying sizes, shapes, and characteristics. As a result, filtration efficiencies must be evaluated, which is important for respiratory virus transmission, in order to reduce penetration percentages in the most extreme situations. Many studies have already shown the efficiency of filtration through various layers and finishing, but there is a gap in showing the difficulties people face while wearing face masks in terms of design, comfort, and fit.
There is limited knowledge available on the performance of different types of commercially available masks. This review discusses the different types of face masks and respiratory masks available in Indian market, literature on their application, their advantages and disadvantages and the comparison of various masks available in the market. Furthermore, the relevant filtration mechanisms of aerosol penetration through masks are explored. It also talks about the technical details of commercial and home-made masks and recent advances in mask performance and quality on the basis of design, comfort and fit.

Keywords: Face Masks, COVID-19, mask types, filtration efficiency, mask design, new normal

Introduction
Since the recent Coronavirus Disease 2019 (COVID-19) epidemic, it's become vital to put in action the precautionary steps to counter COVID-19 transmission from individual to individual. As a result, wearing masks in conjunction with thorough hand hygiene has been proposed as a method of reducing illness transmission, particularly in hospital and open environments.
Agreeing to World Health Organization (WHO), the current data recommends that the two primary modes of transmission of the COVID-19 infection are respiratory droplets and contact. In this manner, face masks and respirators are seemingly the foremost critical piece of PPE (Personal protective equipment). They act as a physical obstruction to respiratory droplets which may enter through the nose and mouth and lead to the ejection of salivary droplets from an infected person. Simultaneously, research into improving the quality and performance of face masks has been accelerated, for example, by introducing properties such as antimicrobial activity, super hydrophobicity, studying the technical details of commercial and homemade masks, recent advances in mask engineering, disinfection, materials, and sustainability. There are various types of face masks and respirators available in the market that provide different levels of protection to users as filtration capacity varies with changing material, design & structure. Also, the contaminants in the air differ in size, the coronavirus has a round or elliptical and often pleomorphic form with a diameter ranging from 65-125 nm (Goh, *et al.*, 2020) [8]. As a result, masks and respirators with bigger pore diameters will be able to filter these viruses or tiny virus-laden droplets effectively. The main difference between a respirator and a mask is the fit, since face masks have a loose fit compared to respirators, which have a seal, allowing leaking around the edge of the mask when the user inhales, limiting the filtration capacity of the face mask in contrast to respirators.

As a result, face mask design should be enhanced, and numerous aspects such as effectiveness, design, fit, comfort, and filtering mechanism should be considered while creating face masks.

Types of Face Masks

Masks can be classified into the following types: -

Cloth face Mask

Overview

The general population often wears fabric/cloth masks. These are manufactured from pleated or non-pleated dual-layer textile fabric and can be hand produced (Kumar, Bhattacharjee, Sangeetha, Subramanian, & Venkatraman, Evaluation of filtration effectiveness of various types of facemasks following with different sterilization methods, 2021) [19, 20]. Though these homemade masks are less economical, easier to clean, more comfortable, and are accessible in a variety of colors and styles, they differ in structural design and are less effective than surgical masks or respirators. Cotton materials, silk, tissue paper, pillowcases, and tea cloths are commonly used to make these masks. Tightly woven or multilayer textile fabric will give higher protection than loosely woven textile fabric.

Measuring the performance of cloth masks

The design, the material, the velocity, the fit to the wearer's face, the comfort of breathing, and the qualities of the particles to which it will be subjected all have a role in the overall performance of a homemade mask (Goh, *et al*., 2020) [8]. Also as per (Goh, *et al*., 2020) [8], the synergistic effect of mechanical and electrostatic filtration was observed when various commonly available fabrics, such as cotton-silk, cotton-chiffon, and cotton-flannel, were combined. Filtration efficiency for particles 300 nm and >300 nm was found to be as high as >80% and >90%, respectively. The basic fabric mask is shown in Figure 1.

Fig 1: Cloth mask (Tcharkhtchi, *et al*., 2021) [31]

As a result, when constructed from appropriate quality materials (high-grade cotton, hybrid, and multilayer) and have good fit, fabric face covers are helpful in limiting viral transmission. Here's a table that compares the filtering efficiency of several types of face masks:

As per WHO guidelines, (World Health Organization, 2020) [33] the following characteristics of nonmedical masks should be considered:

- The number of layers of fabric/tissue used
- The material's breathability
- Water repulsion/hydrophobic properties
- Mask design/structure
- Proper fit

3-Ply Surgical Masks

Overview

These blue-colored, fluid-resistant masks cover the user's mouth and nose and act as a physical barrier to particulate substances, as well as preventing the wearer from transferring infectious droplets to others. Surgical masks are categorized as Class II medical equipment by the Food and Drug Administration. These masks meet the standards for fluid barrier protection and flammability (which is, Class I or Class II, per 16 CFR 1610.4) (Food and Drug Administration, 2021) [6]. They are generally considered a better option than cotton masks, but they do not provide a consistent level of protection from airborne particles due to the loose fit between the mask's surface and the wearer's face.

Specific performance criteria for authorized surgical masks

The following criteria are stated by (Food and Drug Administration, 2021) [6] which includes the following details:

- ASTM F1862: Standard Test Method for Resistance of Medical Face Masks to Penetration by Synthetic Blood specifies the fluid resistance (liquid barrier performance) standards (Horizontal Projection of Fixed Volume at a Known Velocity).
- Flammability performance in compliance with 16 CFR Part 1610's definitions of Class 1 and Class 2 textiles.
- ASTM F2100: Standard Specification for the Performance of Materials Used in Medical Face Masks specifies the particle filtration efficiency standards.
- Airflow resistance (i.e. breathability) criteria for differential pressure (delta P) testing using a 6 mm H2O/cm2 acceptance criterion in accordance with ASTM F2100: For masks with four or more layers, there is a Standard Performance Specification for Materials Used in Medical Face Masks.

The materials of manufacture are either

- Non-cytotoxic, non-sensitizing and non-irritating, consistent with the recommendations in the FDA's guidance, "Use of International Standard ISO 10993-1, 'Biological evaluation of medical equipment – Part 1: Evaluation and testing within a risk management process"10 or,
- Conform to the following biocompatibility standards:
- ISO 10993-1: Medical device biological evaluation – Part 1: Testing and evaluating within a risk management process
- ISO 10993-5: Medical device biological evaluation – Part 5: *In vitro* cytotoxicity test
- ISO 10993-10: Medical device biological evaluation – Part 10: Irritation and skin sensitization test

Fig 2: Surgical face mask (Tcharkhtchi, *et al*., 2021) [31]

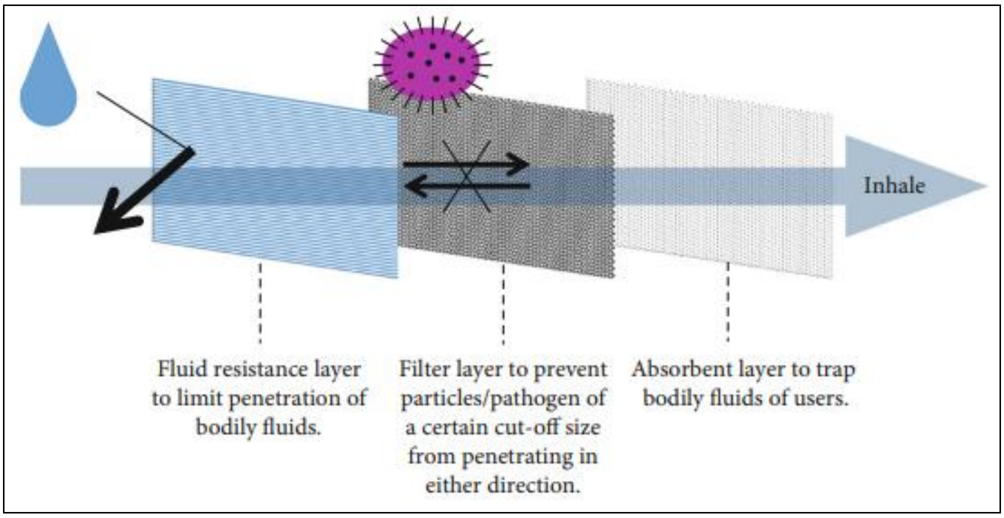


Fig 3: Illustration showing the function of each individual layers of a 3-ply surgical mask (Goh, *et al*., 2020) [8]

Three layers of nonwoven fabric make up the 3-ply surgical mask, each having its specific function. The waterproof outer layer (typically blue) repels fluid such as mucosalivary droplets. The intermediate filter inhibits particles or germs of a certain size from flowing through in either direction. The absorbent polymers in the innermost layer catch mucosalivary droplets from the operator. This layer also absorbs moisture from exhaled air, allowing users to breathe easier. By preventing particle and pathogen transmission in both directions, these three layers efficiently safeguard both the user and the people around them.

Material for making Surgical masks

Surgical masks are frequently made from nonwoven materials. Fibers are bonded together including heat, chemical, or mechanical techniques to make nonwoven fabrics. The two most prevalent processes of creating nonwoven material for surgical masks are spun bond and melt-blown (Goh, *et al*., 2020) [8]. Polypropylene, with a density of 20 or 25 grams per square meter (GSM), is the most frequent material used to manufacture them. Polystyrene, polycarbonate, polyethylene, and polyester can all be used to make masks.

Process of making surgical mask

Surgical masks are multi-layered arrangements that are normally made by covering a layer of textile with non-woven bonded fabric on both sides. Non-woven fabrics have three or four layers that are less expensive to manufacture due to their disposable nature. These disposable masks typically have two filter layers that can filter out particles larger than 1 millimeter in size, such as germs. The fibre, how it is formed, the construction of the web, and the cross-sectional configuration of the fibre, on the other hand, determine the filtration level of a mask. Masks are made on a machine that arranges nonwovens from bobbins, ultrasonically fuses the layers together, and stamps nose strips, ear loops, and other features onto the masks (Thomasnet, 2021) [32].

Table 1: Description of surgical masks, standards and filtration effectiveness (Kumar, Bhattacharjee, Sangeetha, Subramanian, & Venkataraman, Evaluation of filtration effectiveness of various types of facemasks following with different sterilization methods, 2021) [19, 20]

Mask Type	Standards	Filtration effectiveness		
Single-Use Face Masks 	China: YY/T0969	3.0 micron: >=95% 0.1 micron: X		
Surgical Masks 	China: YY 0469	3.0 micron: >=95% 0.1 micron: >= 30%		
	USA: ASTM F2100	Level 1 3.0 micron: >=95% 0.1 micron: >=95%	Level 2 3.0 micron: >= 98% 0.1 micron: >= 98%	Level 3 3.0 micron: >= o98% 0.1 micron: >= 98%
	Europe: EN14683	Type 1 3.0 micron: >=95% 0.1 micron: X	Type 2 3.0 micron: >=98% 0.1 micron: X	Type 3 3.0 micron: >= 98% 0.1 micron: X

Respirators

Overview

NIOSH-approved filtering face piece respirators such as the N99, N100, P95, P99, P100, R95, R99, and R100 are among the medical masks available, and they provide the same or better protection than the frequently used N95 masks. They're face masks that shield the nose and mouth from dust, infectious particles, gases, and vapors in the air. It helps to purify the air, reducing the danger of contamination for the wearer in polluted environments. Most workplaces choose filter face piece respirators because of their great filtration effectiveness (FFRs). Various investigations have approved the FFR filtration acceptability threshold for monodisperse and polydisperse particles greater than 20 nm in size (An overview of filtration efficiency through the masks: Mechanisms of the aerosols penetration, 2021).

a) NIOSH-Approved Standard N95 Respirators

A wearer must acquire and appropriately utilise a government-certified respirator, such as N95 filtering face piece particulate respirator endorsed by the United States National Institute for Occupational Safety and Health (NIOSH), if they want to reduce inhalation of tiny particles in addition to acting as a barrier. The letter N in NIOSH indicates that the substance is not resistant to oil-based particle. Particulate respirators are designed to decrease the user's exposure to airborne particulate threats like viruses and germs. In the United States, the National Institute of Occupational Safety and Health (NIOSH) evaluate and certify respirators. Respirators are tested and certified by the National Institute of Standards and Technology (NIOSH) based on their physical and performance qualities, including filtration efficiency. N95-rated filtering face piece respirators, for instance, have a filtration efficiency of at minimum 95% against non-oily particles when evaluated under NIOSH criteria. The particles employed in the filtration tests are the smallest and most penetrating. As a result of the testing techniques, the filter media could filter particles with an effectiveness of at least 95% (3M Company, 2021) [1].

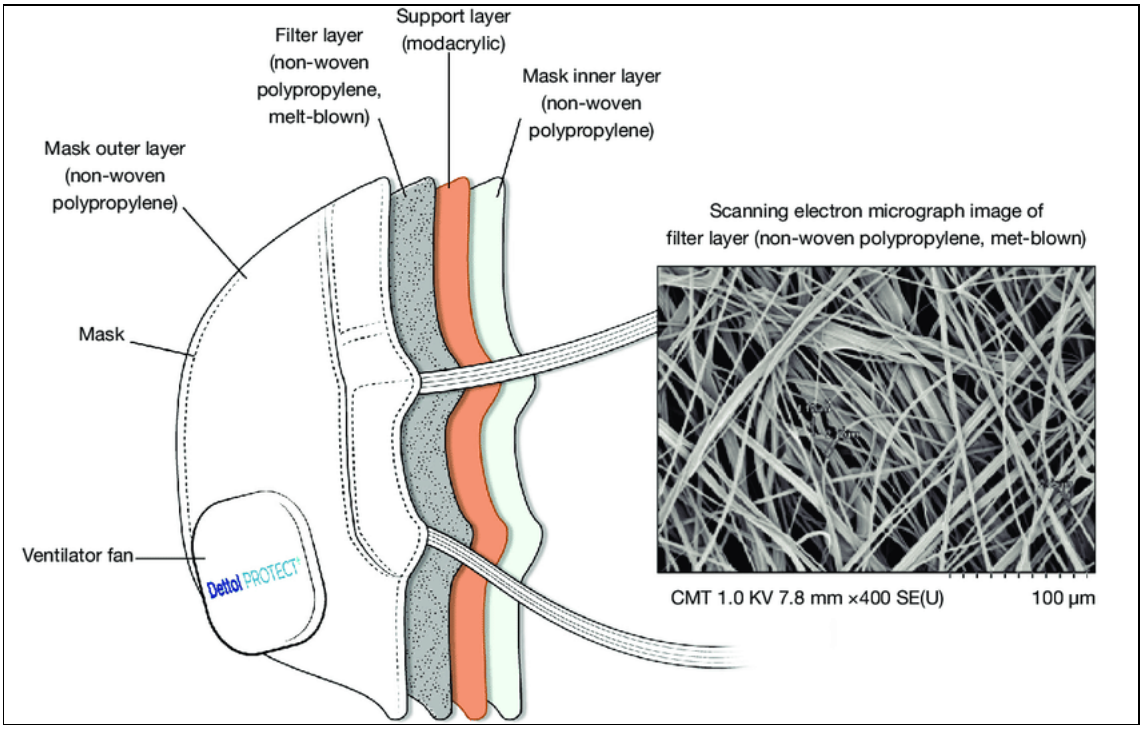


Fig 4: Schematic diagram of N95 masks and the structure design (Zhou, Lukula, Chiossone, & Nims)

Advantages of N95 Masks

N95 respirators have two main advantages over surgical masks or plain fabric: they eliminate more than 95% of 0.3 micrometer molecules (smaller than the 5 micrometer size of wide particles generated by speech, coughing, and sneezing that normally transmit influenza) and they are inspected to ensure contagious droplets and pollutants do not actually leak across the mask (G, Leslie, & M.P., 2020) [7]. Regardless of the fact that N95 filtering for avian influenza is unnecessary, the N95 suit provides the advantage of preventing leakage over the mouth when compared to a loose-fitting surgical mask. These respirator devices are simple to use and require minimal care. These are comfortable and most importantly user-friendly. The valve helps in decreasing temperature build-up and offers a cooling effect, making the wearer's experience even more pleasant. This extends the time that spectacles and eyeglasses can be worn continuously and minimizes the possibility of fogging. (Maclntyre, *et al*., 2013) [23]. During the COVID19 pandemic, it can be utilized as a personal protective strategy.

Table 2: Description and types of respirators (Kumar, Bhattacharjee, Sangeetha, Subramanian, & Venkataraman, Evaluation of filtration effectiveness of various types of facemasks following with different sterilization methods, 2021) [19, 20]

Mask Type	Description of facemask	Image of facemasks
Certified disposable facemask (N-95 equivalent)	Type: pouch/duckbill, make: Magnum (NIOS N95 TC- 84A-6969), three layers (outer, filter and inner), outer and inner layer is made of spun-bond polypropylene fiber; filter layer is made of melt-blown polypropylene fiber	

	Type: Cup shaped, make: Magnum (Formogaurd), three layers (outer, filter and inner), outer layer is made of spun-bond polypropylene fiber, filter layer is made of melt-blown polypropylene fiber, and inner is made of modacrylic fiber.	
	Type: pouch/duckbill, make: Venus (NIOSH TC-84-812 26), Four layers (outer, filter, middle and inner), outer and inner layer is made of spun-bond polypropylene fibre, filter layer is made of melt-blown polypropylene fiber, and middle layer is made of modacrylic fiber.	

Comparison between a face covering and valved filtering face piece respirator

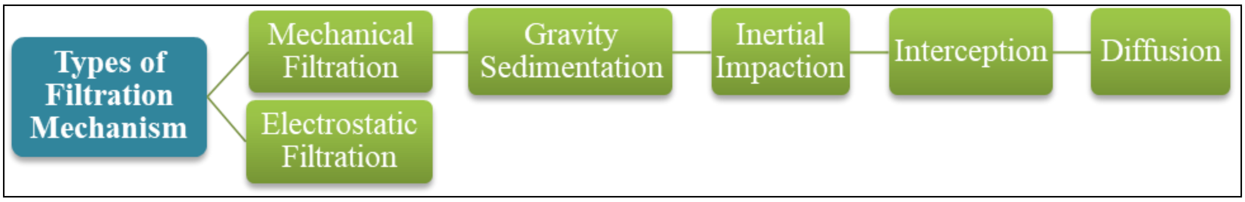
Face masks are not meant to fit tightly around the face and feature gaps around the borders. Air can seep through the gaps as the wearer breaths in and out, and exhaled air may comprise particulates that were evacuated. Particles may be released from mouth coverings and valved respirators as a result, though the path of exhaled airflow differs depending on the configuration (downward/forward for exhalation valve, around the edges for face covering).

When comparing whether valved filtering face piece respirators provide source control to surgical masks, procedure masks, or cloth face coverings, a latest NIOSH study revealed that filtering face piece respirators with an exhalation nozzle offer respiratory protection to the user and can also reduce particle emissions to similar levels or greater than those provided by procedure masks, surgical masks, or cloth face coverings.

Mechanisms of filtration

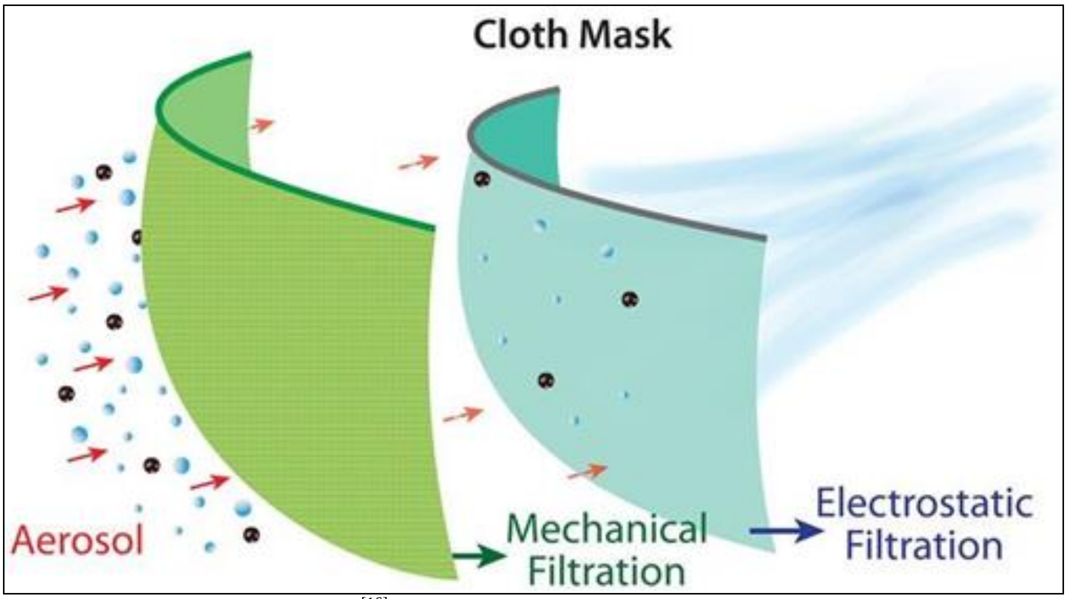
The majority of masks have a filtration system. It's essential to understand the difference between a mask filter and a strainer. As a result, the Particle Filtration Efficiency (PFE) of the mask is not primarily governed by its pore size. In general, mask filtration technologies include both mechanical and electrostatic filtration.

Types of Filtration Mechanism



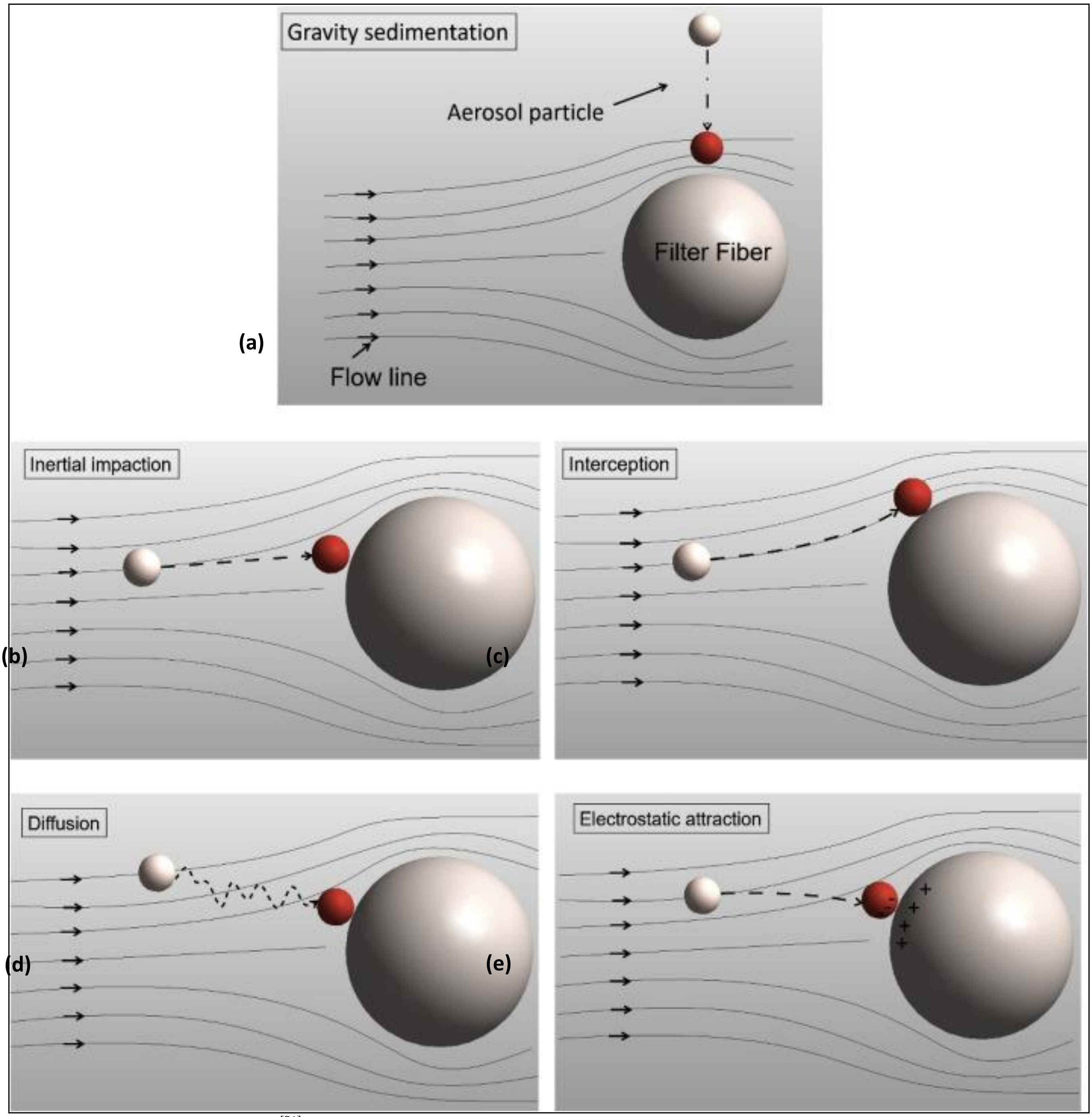
Source: Author

Fig 5: Types of Filtration Mechanism



Source: (Ju, Boisvert, & Zuo, 2021) [16]

Fig 6: Filtration Mechanisms of Mask



Source: (Tcharkhtchi, *et al*., 2021) [31]

Fig 7: Types of Filtration Mechanism

i) Mechanical Filtration

Non-charged fibres are used in mechanical filtration to trap particles by inertial impaction, gravitational sedimentation, interception, and Brownian diffusion (Tcharkhtchi, *et al*., 2021) [31], (Ju, Boisvert, & Zuo, 2021) [16].

- **Gravity Sedimentation**

Gravity sedimentation plays an important role when aerosol particles range from 1 μm-10 μm because gravity forces or ballistic energy have an early effect on the large exhaled droplets (Tcharkhtchi, *et al*., 2021) [31].

- **Inertial Impaction**

Inertial impact happens when the particles' inertia is too strong, prompting alterations in the direction of movement of the particles in the airflow (Hinds, 1999) [12], (Tcharkhtchi, *et al*., 2021) [31]. Particles with larger sizes, higher face velocities, and densities have higher inertia, allowing them to be trapped more easily. However, due to their high inertia, such particles are unable to circulate around the respirator fibres. Moreover, instead of passing through the material filtration system, particles with larger sizes drift from the air streamlines, strike with the fibres, and stick to them (Bailar, Burke, Brosseau, Cohen, & Gallagher, 2006) [3], (Tcharkhtchi, *et al*., 2021) [31]. Brownian motion has a significant impact on microscopic particles. The predominant aggregation process for particles smaller than 0.2 m is diffusion, whereas particles larger than 0.2 m are governed by detection and inertial impaction (Hinds, 1999) [12], (Brown, 1993) [4], (Lee & Liu, 1980), (Tcharkhtchi, *et al*., 2021) [31].

- **Interception**

Interception happens when a particle follows the primary streamline, allowing interaction of particle and filter media within one particle width of the fibre surface (Hinds, 1999) [12], (Tcharkhtchi, *et al*., 2021) [31]. Although particle velocity does not directly influence interception, it does become more apparent as particle size decreases (Mahdavi, 2013) [24, 25], (Tcharkhtchi, *et al*., 2021) [31]. (Konda, *et al*., 2020) [17] mentioned that diffusion by Brownian motion along with particle mechanical interception by filter fibres are the primary mechanisms when reducing size of aerosol in the region of 100 nm to 1 m.

- **Brownian diffusion**

It is the most efficient technique for gathering particles of size less than 0.2 m as it is based on the random particles' Brownian motion bouncing into the filter material (Janssen, 2003) [15]. In a streamline that doesn't intercept, irregular particle motion increases the chances of particle-fiber collision (Hinds, 1999) [12], (Tcharkhtchi, *et al*., 2021) [31]. Diffusion of very small particles including ultrafine and nanoparticles becomes more important than interception. As size of particles or facial velocity declines, the rate of diffusion is more noticeable. Because filter media increases particle residence time at lower speeds, the likelihood of particles and filter media collisions increases significantly (Qian, Willeke, Grinshpun, Donnelly, & Coffey, 1998), (Tcharkhtchi, *et al*., 2021) [31].

ii) Electrostatic Filtration

In electrostatic filtration, charged fibres called as electrets with a quasi-permanent electric field are used to electrostatically attract and filter particles (Ju, Boisvert, & Zuo, 2021) [16], (Hao, *et al*., 2020) [10]. Charged particles, including those smaller than that of the pore size of a filter, can be attracted by electrets with the opposite charge (Ju, Boisvert, & Zuo, 2021) [16]. At the nanoscale level, particles can slide between the gaps in the web of filter fibres; low mass particles are eliminated by electrostatic attraction, and hence electrostatic filters can be useful at low velocity, such as when breathing through a facemask (Konda, *et al*., 2020) [17]. According to the research, mechanical and electret filters absorb particles in the nanoscale range in distinct ways. Particles with a size of 300 nm are perhaps the most penetrating for mechanical filters (non-charged); nevertheless, particles with a diameter smaller than this diminish the efficiency of electret filters (charged) (Tcharkhtchi, *et al*., 2021) [31]. It's worth mentioning that fibre charges don't last permanently, and if the filter is sufficiently loaded with particles, the electrostatic forces will progressively weaken over time, eventually returning to those of a typical mechanical filter (Ju, Boisvert, & Zuo, 2021) [16].

Influence of different parameters on the penetration

The ability of a mask to hold particles and viruses in the air is expressed as an efficiency ratio that includes particle size, the amount of filtrated air, and the amount of time spent using it (Tcharkhtchi, *et al*., 2021) [31]. Fluid mechanics considers flow rates, aerosol size, gaps size between facial profiles and surgical masks or N95s, and the corresponding resistance of flowing fluid through gaps against the persistence of flow across N95s or surgical masks (Tcharkhtchi, *et al*., 2021) [31].

I) External condition parameters

i) Particle size and shape

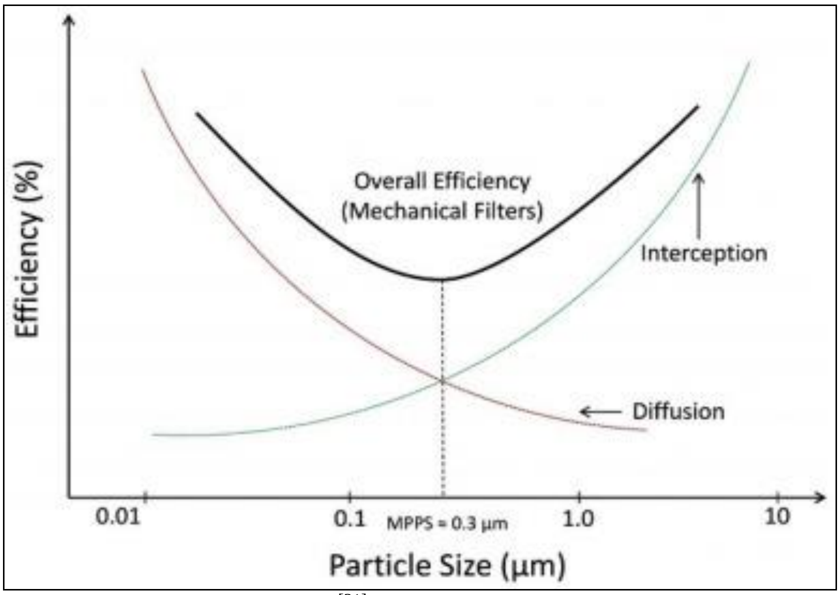
The word "nanoparticle" refers to particles with a diameter of less than 100 nanometers. Toxicological investigations reveal that a given substance is more deadly at the nano-metric size level relative to micro-metric size level for the same mass. This is due to the surface reactivity, large particle surface area, and number concentration (Tcharkhtchi, *et al*., 2021) [31].

As particle size declines beneath an absolute value, the mean thermal velocity due to Brownian motion has been demonstrated to increase the capture rate, increasing the danger of particle separation from the filter surface (Hinds, 1999) [12], (Tcharkhtchi, *et al*., 2021) [31].

(Hinds, 1999) [12], (Tcharkhtchi, *et al*., 2021) [31] Brown's observations indicated that due to their nano-sized dimensions, which are close to molecular clusters, they act more like molecules, while the paper stated that particles of small size would have less adhesion to the filter's surface. As a result, they will not stick to the filter surface when they come in contact with it.

The effect of thermal rebound on particle transmission through filters has been studied in several researches. (Hwa-ChiWang & Kasper, 1991) [14] developed a filter efficiency model for nanometer-sized particles that takes into account the effect of particle rebound off the filter surface as a result of their thermal velocity. The particle size below which efficiency of filter begins to deteriorate is sensitive to particle-surface adhesion force and temperature, as well as other filter characteristics.

(Heim, Mullins, & Kasper, 2007) [11] reported that the thermal rebound for sodium chloride particles between 4 and 30 nm range was not detected. As a result, it appears that the results are also influenced by the particle type utilized in the experiment. The most important methods for sub-micrometer particles filtered using mechanical filters are interception and diffusion. Figure 6 represents the percentage of contribution of all of these mechanisms in relationship to penetrating particle size (Qian, Willeke, Grinshpun, Donnelly, & Coffey, Performance of N95 respirators: filtration efficiency for airborne microbial and inert particles, 2010) [28].



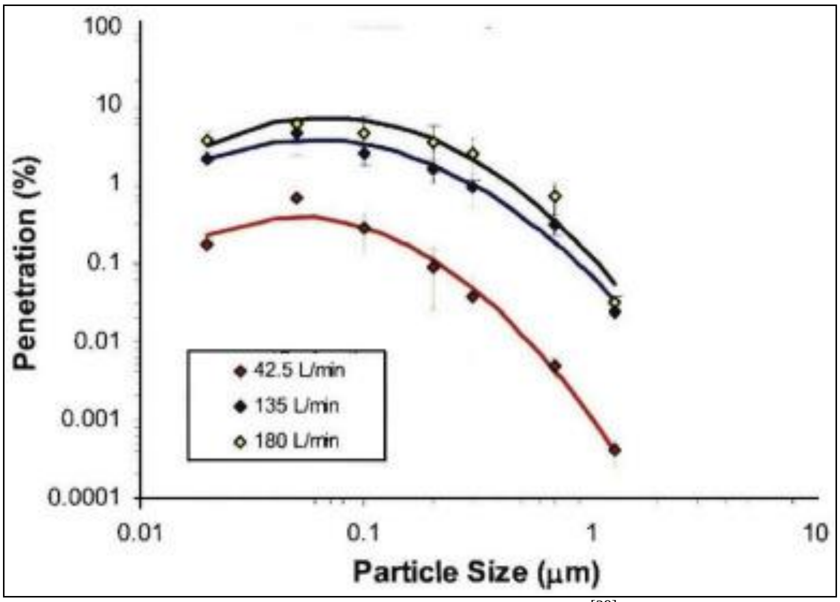
Source: (Tcharkhtchi, *et al*., 2021) [31]

Fig 8: Contribution of interception and diffusion mechanisms in accordance with the particle size

i) Face Velocity or Airflow

People breathe at various rates in different situations, therefore studying airflow and face velocity is significant in many ways. Increased flow flow rate rate improves penetration, and flow rate variations are not just a factor that suggests a higher risk of infection because the actual infectious or lethal dose a a person takes in is comparable to the overall breathing flow rate (Guha, McCaffrey, Hariharan, & Myers, 2016) [9], (Tcharkhtchi, *et al*., 2021) [31]. (Mahdavi A., 2013) [24, 25] reported that peak inhalation flow (PIF) fluctuations accounted for the majority of penetration enhancement from low to high respiratory efforts, while frequency variations accounted for only a small amount The maximum penetrations under constant flow surpassed the maximum penetrations (MIF) under cyclic flow at higher flow rates (Konda, *et al*., 2020) [17] mentioned that increasing the flow rate from high flow (3.2 CFM (cubic feet per minute)) reduces the filtration efficiency (Qian, Willeke, Grinshpun, Donnelly, & Coffey, Performance of N95 respirators: filtration efficiency for airborne microbial and inert particles, 1998) [27] compared the filtration efficiency of unloaded N95 particulate respirators to those of dust/fume/mist (DFM) and dust/mist (DM) respirators that were approved under the previous regulations (30 CFR Part 11). The findings show that using a low flow rate improves filtration effectiveness because the time it takes for the respirators electrostatically charged fibres to remove sub-micrometer particles is prolonged. Second, when particle dispersion takes longer, more particles are removed.

(Richardson, Eshbaugh, Hofacre, & Gardner, 2006) [29] analyzed the influence of the flow rate at a steady flow on the percentage of penetration for a multitude of particles for N95 Cartridge style of mask. Figure 2 displays the results of this experiment, which demonstrate that as the flow rate increases; penetration also increases, indicating that airflow rate has a significant effect on particle penetration through filter face-piece respirators.



Source: (Richardson, Eshbaugh, Hofacre, & Gardner, 2006) [29]

Fig 9: Effect of particle size and constant flow rate on measured penetration through MSA Flexi-Filter N95 Cartridge

ii) Steady or unsteady pattern of flow

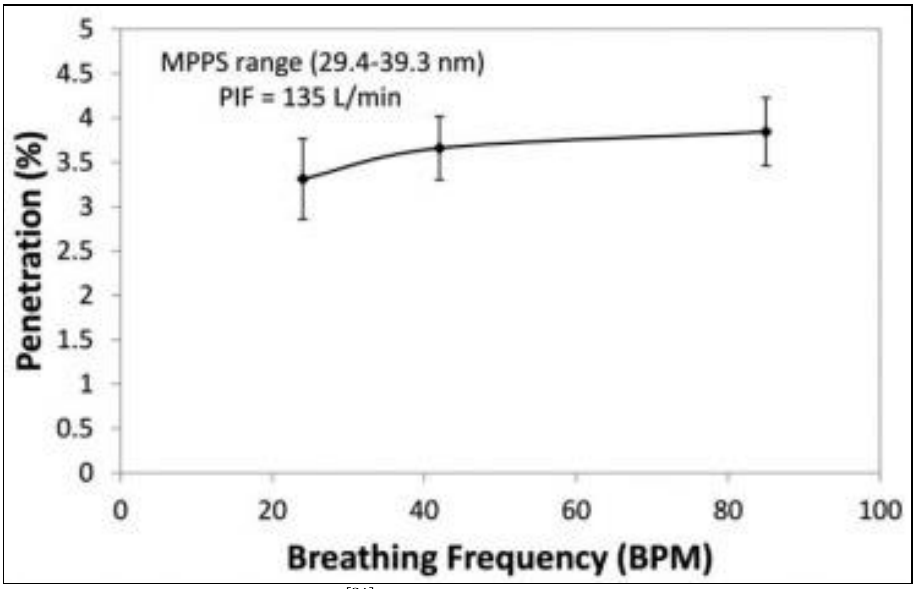
According to certain studies, a steady or unsteady flow pattern is yet another useful criterion; nonetheless, it is less impressive than that of the rate of flow (Tcharkhtchi, *et al*., 2021) [31]. (McCullough, Brosseau, & Vesley, 1997) [26] Put this theory to the test using 85.1 L/min cyclic flows and 32 L/min steady flows. The aerodynamic diameter of non-spherical particles aerosol penetration in such filters may not be the greatest indicator (Qian, Willeke, Grinshpun, Donnelly, & Coffey, Performance of N95 respirators: filtration efficiency for airborne microbial and inert particles, 2010) [28] stated that in comparison to constant flow, cyclic flow had better particle penetration (Richardson, Eshbaugh, Hofacre, & Gardner, 2006) [29] examined the penetration of dioctyl phthalate (DOP) and monodisperse polystyrene latex (PSL) particles at three various cyclic flows of 30, 35, and 53 L/min, as well as a constant flow of 32 L/min (Eshbaugh, Gardner, Richardson, & Hofacre, 2008) [5] investigated the influence of high flow rates on aerosol penetration, as well as the relationship between penetration at constant and cyclic flow rates. Three constant flow flow conditions (85, 270, and 360 L/min) were chosen to match the minute, inhalation peak flows and inhalation mean, of the 4 cyclic flow conditions (40, 85, 115, and 135 L/min), and penetration was observed to increase under increased cyclic and constant flow conditions.

iii) Charge state of particle

When it comes to penetration, charged and uncharged particles act differently, and some studies have revealed that uncharged particles are less successful at filtering efficacies than charged particles. It's worth noting that reducing the particle size reduces the difference by accounting for how the other factors influence the results. Particle size is less impacted by increased face velocity because to the shorter residence period (Kousaka, Okuyama, Shimada, & Takii, 1990) [18].

iv) Frequency of respiration

Frequency and Peak inhalation flows (PIF) are essential factors in penetration performance. This concept was assisted in research conducted by (Mahdavi A., 2013) [24, 25]. Figure 9 shows that penetration is always less than 5% for varied frequencies at the given flow rate of 135 L/min. Furthermore, it has been discovered that changing the frequency has little effect on the filtration process. The PIFs, on the other hand, do not have the same variance. When the PIG is increased from 135 to 360 L/min at a frequency of 42 min1, penetration increases by 145 percent (Tcharkhtchi, *et al*., 2021) [31].



Source: (Tcharkhtchi, *et al*., 2021) [31]

Fig 10: Penetration of MPPS at the range of 29.4–39.3 nm for cyclic flows (135 L/min) as PIF versus frequency (24, 42 and 85 BPM) for N95 filtering face piece respirators

II. Filter Characteristic

Respirator and medical mask filters should enable the user to breathe while also avoiding clogging and permitting air to pass through the filter. When enough particles have been captured to block the open pores of woven or nonwoven network, particle adherence to the filter fibre can become a stumbling obstacle. Van der Waals interaction and other forces hold particles that have been trapped by a filter to the fibres, making it difficult for captured particles to escape (Bailar, Burke, Brosseau, Cohen, & Gallagher, 2006) [3], (Tcharkhtchi, *et al*., 2021) [31].

Filter Chemical Composition

Filters in medical masks and respirators are frequently made of nonwoven fibrous materials such as wool felt, fiberglass paper, or polypropylene. In the earliest electrostatic filters, the application of resins to natural wood fibres proved to hold an electrostatic charge (Bailar, Burke, Brosseau, Cohen, & Gallagher, 2006) [3], (Tcharkhtchi, *et al*., 2021) [31]. Polyester woven fabrics can hold a greater static charge than cotton woven materials or natural fibres due to their poorer water absorption capabilities (Konda, *et al*., 2020) [17], (Tcharkhtchi, *et al*., 2021) [31].

Filter thickness and packing density

As the number of layer grows, the masks' performance improves, but this is based on the type of material structures (Konda, *et al*., 2020) [17], (Tcharkhtchi, *et al*., 2021) [31]. Researcher (SHOKRI, *et al*., 2015) [30] reported the physical and microscopic properties of surgical masks used in Iranian hospitals, as well as their submicron particulate filtration efficiency. Domestic surgical masks have a thicker thickness than imported surgical masks, and air pressure drop in domestic surgical masks is greater than that of imported masks, according to an analysis of physical properties of masks. Half-face and surgical masks were tested with aerosols ranging in size from 0.3 to 10 microns and found to have a filtration efficiency of 95% for particles with a diameter of 5 micron or greater. Surgical masks allowed far more virus penetration than N95 masks, implying that surgical masks are poor mechanical filters. The highest and lowest quality factors are Zist filer mask and Blosom, respectively. (Huang, *et al*., 2013) [13] developed a theoretical model to investigate how factors such as fibre diameter, packing density and fibre charge density, filter thickness and face velocity, affect the filtration characteristics of respiratory filters. According to the findings, aerosol penetration through electret filter medium increases with increasing face velocity and fibre diameter, and decreases with increasing packing density, filter thickness, or fibre charge density. The impacts of face velocity and fibre charge density on filter quality are greater than the effects of the other parameters. To recapitulate based on results showing the effect of fibre diameter and packing density on the quality factor, there is no uniform "best" filter (Tcharkhtchi, *et al*., 2021) [31].

Filtration Efficiency

(Li, *et al*., 2006) [22] reported that the N95 respirators had much lower water vapor permeability and air permeability than surgical masks. In-vivo filtration tests showed that the N95 respirators filtered out 97 percent of potassium chloride (KCl) solution while surgical masks filtered out 95 percent of KCl solution. When compared to standard N95 and surgical masks, nano-masks have better water repellency and antibacterial properties, but no variation in usability.

(Guha, McCaffrey, Hariharan, & Myers, 2016) [9] found that in comparison to surgical masks (SMs) and facemasks for paediatric use (FPUs), as the gap size grows, the rise in leakage from surgical respirators is larger, indicating that some SMs and FPUs with electret layers may be preferred to N95s that have not been tested for fit. It further stated that the N95s have the best filtration and, as a result, have the lowest penetration efficiency.

Conclusion

This literature review provides the analysis of available research findings and evidences regarding the adoption of mask-wearing as the most effective method of reducing coronavirus transmission, as well as complementary health measures such as following WHO and other healthcare authorities' guidelines for proper face mask use and regular sanitization. We looked at the several varieties of face masks and respiratory masks prevalent in the Indian markets, as well as the literature on their use, benefits, and downsides, as well as a comparison of the various masks on the market. The essential mechanisms of filtration of aerosol penetration through masks are also explored. It also goes through the technical aspects of commercial and homemade masks, as well as current improvements in mask performance and quality based on design approach, comfort, and fit. As a result, research into enhancing the quality and performance of face masks has been accelerated, for example, by incorporating antimicrobial activity and superhydrophobicity, as well as analysing the technical aspects of commercial and homemade masks, as well as significant advancements in mask engineering, disinfection, materials, and sustainability. This is a dynamic process that will definitely spur more innovation and fill current gaps in antiviral testing and assessment, bringing the features and usefulness of face masks closer to the forefront.

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