textiles

Review

# A Critical Review on Reusable Face Coverings: Mechanism, Development, Factors, and Challenges

**Md Al-Amin [1,*], Md Tanjim Hossain [2], Muneeb Tahir [2], Diana Wyman [2] and S M Fijul Kabir [1,*]**

[1] Department of Plastics Engineering, University of Massachusetts Lowell, Lowell, MA 01854, USA
[2] Wilson College of Textiles, NC State University, Raleigh, NC 27606, USA
* Correspondence: alamintex20@yahoo.com or md_alamin@student.uml.edu (M.A.-A.); smfijul_kabir@uml.edu (S.M.F.K.)

**Abstract:** Textile supply chain challenges due to the COVID-19 pandemic and the Russia–Ukraine war give unique insights into how health crises and geopolitical instability could dry up supplies of vital materials for the smooth functioning of human societies in calamitous times. Coinciding adverse global events or future pandemics could create shortages of traditional face coverings among other vital materials. Reusable face coverings could be a viable relief option in such situations. This review identifies the lack of studies in the existing literature on reusable fabric face coverings available in the market. It focuses on the development, filtration mechanisms, and factors associated with the filtration efficiency of reusable knitted and woven fabric face coverings. The authors identified relevant papers through the *Summon* database. Keeping the focus on readily available fabrics, this paper encompasses the key aspects of reusable face coverings made of knitted and woven fabrics outlining filtration mechanisms and requirements, development, factors affecting filtration performance, challenges, and outcomes of clinical trials. Filtration mechanisms for reusable face coverings include interception and impaction, diffusion, and electrostatic attraction. Face covering development includes the identification of appropriate constituent fibers, yarn characteristics, and base fabric construction. Factors significantly affecting the filtration performance were electrostatic charge, particle size, porosity, layers, and finishes. Reusable face coverings offer several challenges including moisture management, breathing resistance factors, and balancing filtration with breathability. Efficacy of reusable face coverings in comparison to specialized non reusable masks in clinical trials has also been reviewed and discussed. Finally, the authors identified the use of certain finishes on fabrics as a major challenge to making reusable face coverings more effective and accessible to the public. This paper is expected to provide communities and research stakeholders with access to critical knowledge on the reusability of face coverings and their management during periods of global crisis.

**Keywords:** COVID-19; face coverings; masks; reusable masks; woven and knitted fabrics; filtration mechanism; filtration performance; challenges

check for updates

**Citation:** Al-Amin, M.; Hossain, M.T.; Tahir, M.; Wyman, D.; Kabir, S.M.F. A Critical Review on Reusable Face Coverings: Mechanism, Development, Factors, and Challenges. *Textiles* **2023**, 3, 142–162. https://doi.org/10.3390/textiles3010011

Academic Editor: Ivo Grabchev

Received: 25 January 2023
Revised: 23 February 2023
Accepted: 7 March 2023
Published: 9 March 2023



## 1. Introduction

COVID-19 is part of a family of viruses known as coronaviruses. This contagious disease is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [1]. SARS-CoV-2 is a rapidly mutating virus, and the scientific community continues to learn more about various mutated strains of this pathogen over time. There is, however, a mature understanding among epidemiologists that the SARS-CoV-2 pathogen relies primarily on respiratory droplets of various sizes, including aerosols, for its transmission. There is a great deal of discussion but no clear scientific consensus on what size of an infectious respiratory droplet classifies as an aerosol. In this context, the World Health Organization (WHO) has proposed a basic definition to address the ambiguity. According to WHO, droplets of greater than 5-micron diameter classify as respiratory aerosols [2]. Studies have focused on observing the particle size distribution in aerosolization due to various activities including human speech, singing, coughing, sneezing, shouting, exhaling, etc. have produced inconsistent results [3–6]. This variation could be explained by different test methodologies and prevalent ambient conditions for these studies. Particle size distribution has a high degree of variability due to the interplay of factors such as the nature of the transmitted fluid under consideration, relative humidity, the temperature at which the testing is performed, age, health status, and gender of the test subject [2]. Airborne transmission of the pathogen beyond six feet is rare and depends on special circumstances [7]. Large-sized droplets can be blocked by filtration barriers with relative ease; however, more sophisticated processes and defensive mechanisms are required for protection from the contagion-loaded aerosol. In real-life conditions, a diverse set of variables dictate the particle size distribution in droplets that are generated from any form of expiratory exertion [8]. These variables, therefore, influence the chances of transmission among people. Against the backdrop of these variables, it is not realistic to completely eliminate the chances of pathogenic transfer and infection through respiration by adopting the habit of wearing a face covering. However, the use of face coverings is still presented as one of the most significant risk-mitigation strategies considering emergent epidemiological evidence [9]. In response to the SARS-CoV-2 pandemic, the use of fabric face coverings by the public is recommended by various governments and intergovernmental agencies to reduce transmission of the virus. The US Center for Disease Control and Prevention (CDC) issued a public advisory to wear face coverings in public gatherings, where social distancing was difficult to observe during the initial days of the COVID-19 pandemic. As this global health crisis has evolved, a voluminous body of independent research has continued to emerge that links the prevalence of face-covering use with reduced infection rates [10–12]. Therefore, it has become vital for global efforts to mitigate the health challenges posed by airborne or aerosol-based contagious pathogens such as SARS-CoV-2 and understand the protection mechanism of face coverings. [13–15]

There are three main types of face coverings available to reduce the spread or contraction of COVID-19. These types are fabric face coverings (woven, knitted, woven nonwoven/knitted nonwoven hybrids), surgical masks, and professional-grade medical respirators (N95). With limited supplies of personal protection equipment (N95s and surgical masks) for frontline medical workers amid a severe supply-side shock, CDC advised to use available household woven or knitted fabrics to make face coverings [16].

Our globalized world is currently reeling from multiple concurrent crises including the COVID-19 pandemic and the Russia–Ukraine conflict. These crises have spiraled fuel prices upwards and made international shipping cost prohibitive in many cases. Likewise, the global textile supply chain has been battered hard by simultaneous demand and supply shocks [17]. These uncertain times provide an opportunity to think about how future global health crises can be better managed via the utilization of alternative strategies such as the employment of reusable face coverings to combat scarcity [18]. This review paper focuses on readily available knit and woven fabrics used in reusable (launderable) face coverings for daily use by the public. There is a considerable gap in the research literature that informs scholastic understanding of the interactions between textile fibers and the viral load carrying droplets at the micro-level. Much of the existing scholarship about textile-based protection from pathogenic agents revolves around fabric construction parameters, fit, and types of apparel-sourced face-covering materials. To be viable and comfortable, face coverings need to be sufficiently breathable in addition to being efficient at blocking particles. Knitted face coverings can be good alternatives to disposable medical masks in critical coronavirus outbreak situations when communities are facing shortages of more "specialized," single-use face coverings. Knitted face covers are cost-effective, environmentally friendly, and reusable. However, the research found that knitted fabrics show lower droplet-blocking efficiency compared to woven fabrics even when both fabrics have the same porosity [19].

For this review paper, the authors identified relevant papers through the Summon database of North Carolina State University. Some additional literature was availed from the public domain due to pandemic response policies. An extensive collection of SARS-CoV-2 literature was available online through the National Library of Medicine [20]. Because of the huge volume of research available, papers that did not provide unique insight or lend themselves to a more informed selection of fabric face covering were not included in the review. It is likely additional research has been published between the time when this review began and ended. In addition to academic research, guidance, and specifications of various governmental and inter-governmental agencies were also considered. This type of guidance is generally more visible and accessible to the public than peer-reviewed publications, so it is important to consider how policy is related to the most current scientific conclusions.

## 2. Mechanisms of Face Coverings

The filtration function provided by fabric face coverings is not necessarily based upon sieving out larger particles that attempt to pass through to the other side of the fibrous assembly, rather, it is delineated by aerodynamic, electrostatic, and molecular interactions [21]. Therefore, textile-based face coverings use various means to offer protection against the virions riding atop respiratory droplets from reaching the respiratory tract. Woven or knitted fabric face coverings employ the same filtration mechanisms as N95 and surgical masks that might not be accessible to many economically vulnerable population segments around the world [22], albeit at a lower efficiency [23]. At least four papers reviewed include useful explanations of filtration mechanisms and how textile face-covering materials utilize these mechanisms [13,24–26]. No conflict was found among these explanations, and they provide context for data from other papers as well.

### *2.1. Interception and Impaction*

Air curves around the fibers or yarns in textile structures; droplets are unable to follow the air's trajectory and collide with the textile fibers instead (Figure 1). Interception and impaction mechanisms are relevant to fabric face coverings because viruses typically travel on droplets that are large enough to be stopped by contact with textile fibers. Droplet sizes of 0.1–1 micron are stopped by interception. Droplets larger than 1 micron experience impaction [13,25,26].

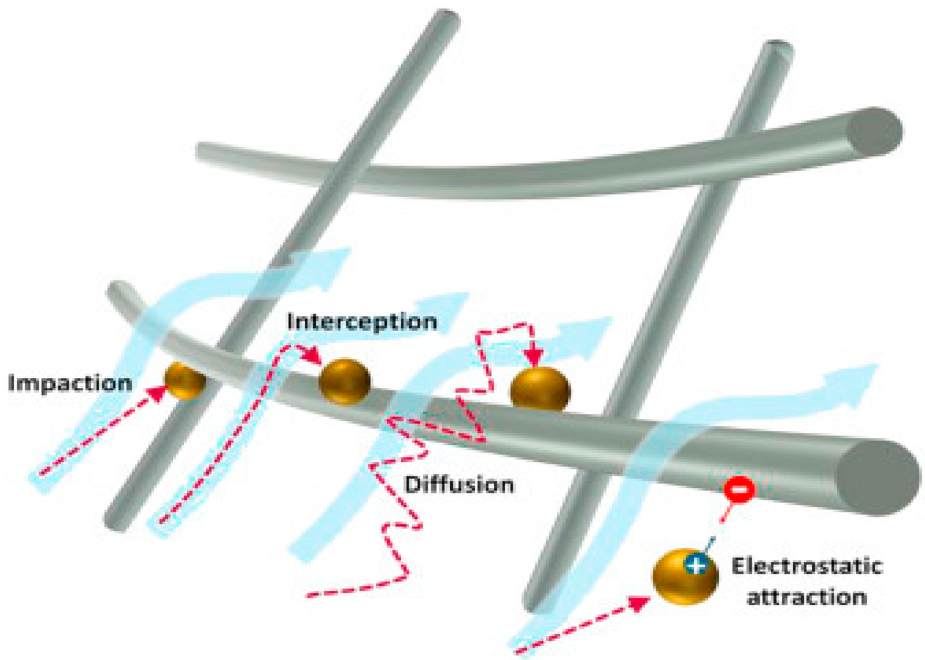


**Figure 1.** Filtration mechanism of face coverings [27].

### 2.2. Diffusion

At the submicron scale, pathogenic particles collide with the air molecules in a process called diffusion. Collisions with gaseous molecules cause these particles to slam into the fibers instead of following normal trajectories through the inter-fiber or inter-yarn voids (Figure 1) [25,26]. Filtration by diffusion requires very fine microfibers to trap very small particles. This mechanism is less commonly employed by woven and knitted face-covering fabrics [13].

### 2.3. Electrostatic Attraction

Particles are attracted to oppositely charged fibers. While air curves around the fibers, the particles adhere by electrostatic attraction, preventing them from reaching the respiratory tract (Figure 1) [13,25,26].

## 3. Consideration for Developing Face Coverings

### 3.1. Moisture Management

Fabric hydrophilicity/hydrophobicity came into focus as another key factor in face-covering comfort and effectiveness. As previously discussed, the hydrophobicity of synthetic fibers can have a direct impact on filtration efficiency related to electrostatic interactions. Knitted and woven fabrics that contain hydrophilic fibers have an affinity to droplets [19]. More often, hydrophobicity is considered a comfort factor for wearers of fabric face coverings. WHO (2020) [28] recommends a moisture-absorbing inner layer. An absorbent inner layer moves moisture away from direct contact with the wearer's face. Although holding droplets may increase the droplet-blocking performance, knitted fabrics can also hold viruses and must be decontaminated by washing. Fiber hairiness and low porosity both have a positive effect on filtration efficiency but may negatively impact moisture management and wearing comfort [29]. Increasing fabric cover due to increasing fiber hairiness could undermine the moisture management function down to the fibrous scale [30]. WHO (2020) suggests using water-resistant fabrics for the outer layer of face coverings [28]. The assumption is that the layer will keep infectious droplets in the environment from passing through the face covering and infecting the wearer. Another study found that hydrophobic surfaces pose a greater risk because droplets remain intact, infectious, and liable to spread through touch; droplets on an absorbent surface dry quickly, and thus viruses become inactive [31]. Iqbal et al. developed moisture management of woolen cloth masks using moisture-responsive wool fibers along with an electret polypropylene non-woven layer [32,33]. They found that due to the existence of moisture-responsive wool fibers, the developed cloth mask showed significant moisture management properties compared to commercial 3-ply masks. Parlin et al. studied the hydrophobicity of cotton, polyester, and silk fabrics in single and multiple layers [34]. They found that compared to cotton and polyester, drops of water on silk had a significantly higher contact angle (cotton: 43°; polyester: 61°; unwashed silk: 120°; washed silk: 107°) and lower spreading when wetting occurred (cotton: 87 $mm^2$; polyester: 25 $mm^2$; unwashed silk: 12 $mm^2$; washed silk: 5 $mm^2$). Cotton fiber consists of more than 95% cellulose, and the abundance of OH groups in the cellulose structure is responsible for the hydrophilic behavior of cotton [35]. Other tests, including resistance to aerosolized droplets, showed similar results. Based on the hydrophobicity and lack of capillary action exhibited in the lab, the researchers suggest silk face coverings should be studied in a clinical setting. They also cite the advantages of their lightweight and breathability although they did not measure breathing resistance, and the one reference cited for this claim has been called into question by other authors [34]. Polypropylene is also an attractive fiber choice for the construction of face coverings due to its moisture-wicking function [36], which allows polypropylene to wick moisture away from an area of high concentration to a lower concentration area. In a high cover factor fabric, the ability to wick moisture to prevent uncomfortable moisture build-up is a considerable advantage. Wearing comfort is critical to ensure that wearers are not fatigued by the difficulty in breathing through the face covering. Fatigue could promote lax attitudes towards the face covering wearing etiquette [37].

### *3.2. Breathing Resistance Factors*

A common theme in several of the papers reviewed is the importance of balancing high filtration efficiency with low breathing resistance [13]. Filtration alone is relatively easy to achieve by adding material layers or minimizing porosity, but it is obvious that completely stopping droplets or viruses from passing through the fabric will also significantly limit air from being inhaled or exhaled through the material, and the same could be said for the moisture exchange. Although product design is not addressed in this paper, it is well-documented that air will take the path of least resistance [38]. In use, a fabric or fabric assembly with high breathing resistance requires a well-fitted face covering design to prevent breath from bypassing the material and entering/exiting through gaps at sides, top, bottom, or even through seams.

Davies et al. conclude that based on filtration efficiency and breathability, a pillowcase or cotton T-shirt is the most appropriate household material for an improvised face covering. As noted above, the tea towel (and vacuum cleaner bag) provided higher filtration, but it was deemed unsuitable due to poor breathability. It is interesting to note that the authors recommend the T-shirt for its stretchy quality, suggesting that it would likely provide a better fit [39]. Other publications, including the WHO guidance [28], recommend against stretch fabrics because porosity can increase under tension. Pores of knitted fabrics are generated on each loop and interlacing point. The breathability of the fabric is strongly correlated with porosity. When knitted fabrics are stretched, pore sizes are also enlarged easily, which enables water vapor and air to pass through the fabrics easily [40]. Therefore, knitted fabrics are more breathable compared to woven fabrics if both fabrics are fitted on dynamic objects using the same yarn and density [41].

In a letter to the editor regarding a paper by Konda et al., researchers analyze the relationship between flow rate and breathing resistance [42]. They also note that flow rate has direct and significant implications for particle filtration conclusions. The authors re-analyzed the data reported by Konda et al. and attempted to replicate the results themselves. They found an expected linear relationship between pressure drop and both face velocity and the number of fabric layers for all fabrics tested. The original data by Konda et al. did not show this trend. At standard face velocity (10 cm/s) and area (150 $cm^2$), the pressure drops across even a single layer of 625 threads per inch cotton fabric would fail the breathing criteria for N95 respirators. The fabric pressure drop is 335 Pa, while the respirator requires less than 245 Pa for exhalation and less than 343 Pa for inhalation. A four-layer construction had a pressure drop of 1246 Pa. The letter estimates that to create the pressure drop reported in the original paper, the face velocity would have to be 0.075 cm/s, orders of magnitude less than typically used for testing. Further, the writers explain how very low velocities can present experimental challenges as evaporation over the long air exchange leads to an overestimation of filtration efficiency. Rather than very low face velocity, the Konda data could be explained by very high area, but again, it would have to be orders of magnitude larger than normal [43].

### *3.3. Balancing between Filtration and Breathability*

Breathing resistance is less vigorously analyzed than filtration for fabric face coverings because most common fabrics provide sufficiently low breathing resistance. As previously noted, balance is required, so breathing resistance becomes more critical as high filtration is achieved. Filtration and breathability resistance tests are crucial for reusable fabric face coverings as coverings remain in close contact to skin for a long period of time [44]. The tea towel in the Davies paper that performed so well in filtration was rejected due to breathing resistance [39]. Therefore, an optimum balance between requisite ventilation and filtration function is pivotal. Aydin et. al. evaluated the performance of four knitted face coverings prepared from household fabrics while considering a medical mask as a benchmark [19].

Breathability (air permeability), water absorption properties, and filtration efficiency of these face coverings were assessed to explain the relationships among breathability, porosity, flow rate, and filtration efficiency. To investigate the performance of face coverings against high-velocity droplets, droplets are released from 25 mm away from a nozzle to replicate sneezing and coughing (Table 1).

**Table 1.** Sample details and performance parameters of face coverings reproduced from [19].

| Sample | No. of Layer | Fiber Content | Weight (g/m$^2$) | Porosity% Mean ± SD n = 9 | Blocking Efficiency (%) at 25 mm High Momentum Droplet) | | | Breathability (mm/pa-s); Mean ± SD, n = 3 |
|---|---|---|---|---|---|---|---|---|
| | | | | | Minimum | Medium | Maximum | |
| Medical mask | - | Polypropylene | 53.9 | n/a | 96.4 | 98.5 | 99.9 | 1.83 ± 0.15 |
| Used shirt | 1 | 100% cotton | 114.2 | 0.7 ± 1 | 87.9 | 96.8 | 99.8 | 1.37 ± 0.06 |
| Used undershirt | 1 | 100% cotton | 111.5 | 4.5 ± 1 | 41.1 | 81.9 | 95.2 | 10.7 ± 0.66 |
| Used undershirt | 2 | 100% cotton | - | - | 78.3 | 94.1 | 98.3 | 5.53 ± 0.35 |
| Used undershirt | 3 | 100% cotton | - | - | 96.8 | 98.9 | 99.8 | 3.77 ± 0.06 |
| New t-shirt | 1 | 60/40% cotton/poly | 183.2 | 1.1 ± 0.3 | 42 | 83.1 | 98.3 | 7.23 ± 0.55 |
| New t-shirt | 2 | 60/40% cotton/poly | - | - | 94 | 98.1 | 99.6 | 3.87 ± 0.06 |
| New t-shirt | 3 | 60/40% cotton/poly | - | - | - | >98.1 | - | 2.63 ± 0.06 |

It is found that a single layer of most knitted home fabrics can block droplets reasonably at various velocities. Blocking efficiency is close to that of medical masks maintaining the same or higher breathability when two or three layers are used. Droplet blocking efficiency and breathability of the medical mask is 98.5% (minimum filtration efficiency 96.4%) and 1.83 mm/Pa s, respectively. The performance of a single-layer used knitted shirt was evaluated first. The median blocking efficiency and breathability of the fabric were 96.8% and 1.37 mm/Pa s, respectively. It should be noted that the minimum filtration efficiency of this face covering is 87.9%. The face covering prepared from a 100% cotton, new undershirt shows weaker performance compared to the face covering prepared from a used knitted shirt. Although it has higher breathability (10.7 mm/Pa s), the median filtration efficiency was 81.9% (minimum filtration efficiency is 41.1%). The filtration efficiency increases significantly with the increase in the number of layers. The median filtration efficiency of this face covering increased to 94.1 and 98.9% for two and three layers, respectively. However, additional layers reduced the breathability of the covering drastically. The breathability of three-layer coverings decreased to 4 mm/Pa s. A face covering was also prepared from a new knitted T-shirt of 60/40% cotton/polyester to investigate the effect of fiber composition. Droplet blocking efficiency and breathability of single-layer fabric were 83.1% (minimum filtration efficiency 42%) and 7.23 mm/Pa s, respectively. The filtration efficiency of this face covering increased to more than 98.1%, and breathability decreased to 2.8 mm/Pa s for three layers. Knitted face coverings were also effective against low-momentum droplets when droplets were released from 300 mm away through a nozzle mimicking release of droplets from a nearby person while talking. The velocity and size of droplets decreased while traveling through the air [45,46]. At lower velocity, the median filtration efficiency of the 60/40% cotton/polyester T-shirt fabric was 94.2% (minimum filtration efficiency is 82.5%). For the same velocity, median filtration efficiency increased to more than 94.2% for two layers of fabric. Zangmeister et al. report that air permeability, extension, and breathing resistance are related to yarn count, fabric mass, and weave pattern [47].

## 4. Development of Face Coverings

### *4.1. Fiber and Yarn Construction*

Correlation between increasing yarn twist, increasing yarn compactness, and reduced porosity is well established [48]. A study by Zhang et al. concluded that in addition to differences in the fabric construction parameters, the inter-fiber spaces in the yarns for polyester, polypropylene, silk, and nylon were also a factor in filtration efficiency [26]. Nonwoven materials take advantage of nanofibers to provide high surface area for good filtration efficiency. Most woven and knitted fabrics do not utilize such fine fibers, but "hairiness" can increase the surface area of yarns. As noted by Zangmesiter et al., raised fibers increase filtration efficiency [47]. Hairiness, i.e., fibers protruding out of the yarn's body, increases the possibility of successful pathogenic particle interception before these reach the respiratory canal [49]. Hairiness can be created through the selection of yarn spinning technology and pile construction in the fabric or by mechanical finishing of the fabric surface. In contrast, it must be considered that pulling too many fibers from the interlaced structure can create voids in the base fabric, which will reduce filtration efficiency. Fabrics that have a high tendency to form pills or that have been subjected to severe mechanical processes may not have a long useful life, though they still provide longer use than disposable surgical masks [50].

## *4.2. Fabric Construction*

### 4.2.1. Knit Fabric Construction

Face coverings having higher breathability show lower leakage around the sides of the face covering as more air passes through the covering material, which is designed to block contagion-carrying droplets [19]. Higher air permeability may also reduce droplet-blocking efficiency, so it is important to maintain a proper balance between breathability and viral particle-blocking efficiency in developing knitted face coverings [51,52]. Air permeability of knitted face coverings depends on several factors including fabric thickness, density, fabric structure, material types, fiber diameter, and finishing processes [41]. Porosity and structure vary based on the stitch length and machine gauge while knitting [53]. This means that fabric with the same construction but different weights, looseness, porosity, or thickness could be compared to determine the effect of these properties on aerosol filtration efficiency. Knitted fabrics deform or stretch more than woven fabric or nonwoven medical masks. This leads to higher porosity and lower filtration efficiency against droplets. High-speed impact of droplets causes higher deformation of knitted fabric samples while medical mask materials do not bend much (Figure 2) [19]. Both transmission control and infection prevention functions of knitted fabrics are affected by their relatively low dimensional stability.

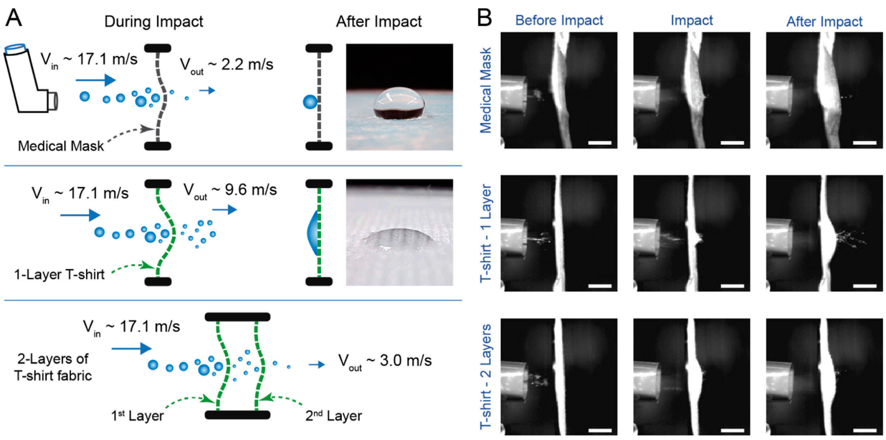


**Figure 2.** Comparative performance analysis between medical masks and knitted sample against high-impact droplets. (**A**) Schematic presentation of the impact of a high-speed droplet on the medical mask and knitted sample. (**B**) Impact response on medical masks and knitted samples [19].

Neupane and colleagues also reported a loss of filtration efficiency due to repeated washing and drying of reusable knitted face coverings. These cycles increased the fabric void sizes and morphed their shapes (Figure 3) [54]. Other sources warn against the use of stretchy materials because of the tendency for voids to increase in size [13,55].

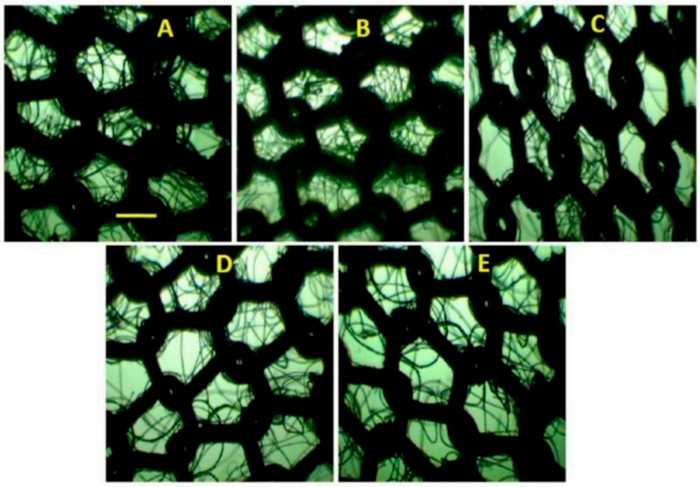


**Figure 3.** Effect of washing and drying cycles on the fabric porosity. (**A**) bright field microscopic images of unwashed CM9, and after (**B**) first, (**C**) second, (**D**) third, and (**E**) fourth washing and drying cycles [54].

4.2.2. Woven Fabric Construction

Bhattacharjee et al. provide a list of factors to consider in designing an optimal woven face covering. These include filtration efficiency, breathing resistance, filter material, water resistance of the outer layer, high surface area, number of layers, thread count and fineness of weave, fabric thickness, and fabric pore size. High filtration efficiency, low breathing resistance, and the need to balance these are highlighted in several studies [13,24]. High thread count cottons are commonly recommended as a readily available option for home-made face coverings [56]. One paper specifically recommends a density of 300–350 threads per inch [13]. Hao et al. acknowledge the potential impact of fiber diameter, thickness, permeability, and fiber material on filtration performance, but use thread count as the parameter to study the filtration potential of fabrics in their research. This choice was confirmed by testing three pillowcase fabrics from the same manufacturer. The pillowcases had 1000, 600, and 400 threads per inch and 55.0%, 44.6%, and 19.9% filtration efficiency, respectively. No other fabric parameters were reported [24]. Several studies include tea towels. Davies reported a filtration efficiency of 83.24% for a single layer of a tea towel and 96.71% for two layers [39]. This was higher than for any other common textile item tested and comparable to results for a nonwoven surgical mask and a vacuum cleaner bag. Filtration testing utilized a Henderson apparatus to generate microbial aerosols and a downstream air sampling device to collect microorganisms that penetrated the test material and those from a control stream with no filtration. The method measures actual bacterial particles similar in size to influenza virus particles rather than latex or NaCl proxies [39]. This could increase the relevance of the data, but the unique testing protocol makes it difficult to compare results with those of other studies. Rengasamy et al. also found towels to be one of the most effective filters among common household textiles, though it is not clear if the towels tested were tea towels, or something closer to bath towels [57].

In many of the papers reviewed, complete fabric descriptions are not included. It would not be fair to assume, based on the data reported by Davies et al., that any tea towel will provide superior filtration to fabric from a scarf or pillowcase. Without more descriptive detail, it is also impossible to identify a trend that might provide guidance in optimizing fabric construction for filtration. Clase et al. reviewed 25 papers and similarly lamented the lack of details required for reproducibility [14]. Despite expressed skepticism about the value of fabric face coverings for general use, the World Health Organization [28] provides a more nuanced view of fabric construction, noting that the filtration efficiency of woven fabrics is also dependent on the tightness of the weave and fiber or thread diameter. Zhao et al. found that base weight and density are not clearly related to filtration efficiency;

however, they recommended that cotton woven or knit fabric for face coverings should be of high density or used in multiple layers [58]. Such conflicting statements only serve to confuse an already complicated issue. Higher thread counts can be expected to provide higher filtration efficiency if all other factors are equal. However, all other factors are rarely equal. Fabrics that are commercially available to the public and even to most non-vertically integrated manufacturers will have additional variables. Research at Florida Atlantic University more strongly emphasizes that thread count alone is not sufficient to guarantee better filtration [59]; however, this conclusion is based not just on fabric construction but on face covering design. The authors of the study cited the example of a bandana with a high thread count performing more poorly than fitted face coverings of lower thread count fabric.

Clase et al. [14] reviewed the study of Zhao et al. [58], where 25 available articles were studied, and found that expected fabric details were not provided in most studies and some recommendations were offered based on the limited data. Two layers of 600 thread count cotton and a combination of 600-count cotton and 90-count flannel reportedly performed well, while two layers of 80-count cotton did not. From this, the authors recommend cotton or flannel at least 100 threads per inch with a minimum of 2 layers to get better filtration efficiency with minimal breathing resistance [14]. The calculation that led to the 100 threads per inch recommendation is unclear, and neither "cotton" nor "flannel" is an adequate description for sourcing suitable fabric. In the current environment, making such a recommendation is dangerous not only in terms of academic reputation but also for the health and safety of those who take the advice. The review by Clase et al. did include a well-researched and organized table of available information from the reviewed literature. It also concludes by returning to the theme of incomplete evidence in the discussion of clinical studies [14]. A paper by Zangmeister et al. (2020) clearly explained the fallacy of correlating cover factors directly to filtration. Cover factor expresses the area covered by the yarns of a fabric. There are holes through the yarns as well as between them, which leads to underestimating fabric porosity. The authors list other relevant factors as yarn mass, fabric texture, and fabric composition [47]. The group specifically set out to establish relationships among fabric parameters, filtration efficiency, and breathing resistance. They systematically selected and characterized fabrics by fiber, thread count, weave pattern, and mass [47]. The research is well-documented and organized. The authors report a 'complex interplay' of fabric parameters with filtration efficiency. Counter to conventional wisdom, the best-performing fabrics had moderate thread count and visible raised fibers [47].

## 5. Factors Affecting Filtration Performance

Several factors govern the performance of face coverings as pointed out in Figure 4. Factors that are related to knitted and woven fabrics have been reviewed in the following sections.

### *5.1. Electrostatic Charge*

Charging of surgical masks allows them to take advantage of electrostatic interactions between fibers and environmental particles to provide high filtration efficiency with low breathing resistance. Household air filters use the same mechanism. It is more difficult to impart a permanent charge on reusable, woven or knitted face-covering fabrics [24]. Zhao et al. studied the impact of triboelectric effect on the filtration potential of various fiber-based assemblies [58]. They also observed that latex and nitrile used in fabrication of gloves could be rubbed against polypropylene or other fibers to introduce or reintroduce static charges. Alternatively, fabrics of fibers such as hygroscopic silk, with no electret fibers, can be charged for a short duration by rubbing against polypropylene fabrics [24]. When Zhao et al. rubbed fabric samples with latex gloves to create a triboelectric charge, cotton fabrics showed a decrease in filtration efficiency, but this was attributed to increased pore size due to the mechanical action of rubbing [58]. Other samples showed improved filtration when charged polyester and silk samples lost charge within 30 min, while nylon and polypropylene samples held a charge much longer. This paper does not extend to practical methods of consistent and durable charging for face-covering fabrics, though the authors suggest additional study, including the possibility of interlayer friction for charging a multi-layer assembly [58]. Ghatak et al. suggested an interesting potential application of a triboelectric nanogenerator (TENG) where they recommended a layered face-covering design comprised of four different triboelectrically charged fabrics and an electrocution layer (EL). Under the phenomena of TENG, human activities including breathing, speaking, etc., generate electric charge. This charge on the electrocution layer was supposed to disrupt the protein shell of SARS-CoV-2 virus if the virions encountered the EL [60]. Another study found no significant impact of charge on filtration for the tested textile materials [47]. It was reported that on washing, N95 respirators and surgical masks lose their permanent charges from electret fibers, leading to reduction in their filtration potential. It was also noted that fabric face coverings that do not possess permanent charges do not exhibit a major drop in filtration efficiency after laundering [54]. Zhao and coworkers' study did not explore the effects of laundering on the polypropylene fabric face covering's charge concentration. It would be interesting to find if some charges were retained by the polypropylene fibers after the laundering process. Electrostatic filtration is adversely affected by increasing humidity levels due to poor moisture management in hydrophilic fibers [61]. Zhao et al. reported that hydrophilic nylon fiber, which demonstrated charge build-up in normal relative humidity, began losing its static charge once the humidity levels were increased in the environment [58]. Hydrophobic fibers demonstrate higher levels of static charge build-up and can retain some of that charge even in more humid conditions, which could make them attractive candidates for use in woven and knitted face coverings. On the other hand, hydrophilic cellulosic fibers such as cotton fibers that contain mostly cellulose possess a low charge distribution (Figure 5) [62,63]. Zhao et al. showed that polypropylene provided low filtration efficiency at 85% RH. Hydrophobic polypropylene fiber does not adsorb water, which could completely replace the static charge-carrying capacity [58]. The reduction in the static charge concentration was instead predominantly due to the increased conductivity of humid air that caused leakage of charges from the fiber surface [30].

Ghatak et al. showed that relative humidity in the range of 60–90% did have a pronounced effect on the efficacy of the electrocution mechanism. Increased relative humidity promoted the unwanted flow of charge towards the electrocution layer (EL) [60]. Human breath has been shown to have a relative humidity value in the range of 65–88% in European and Middle Eastern conditions [64]. Therefore, it can be argued that the electrocution function of the EL layer will be weakened by persistent relative humidity levels that repeatedly exhaust charges by channeling them to the EL layer.

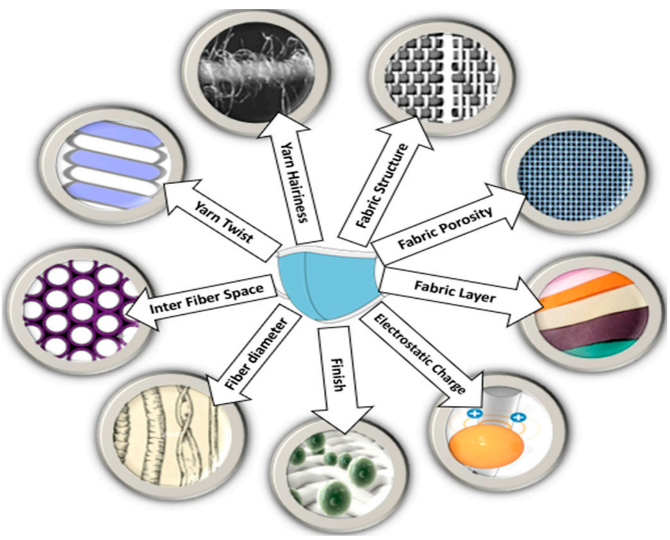


**Figure 4.** Factors affecting the development and filtration performance of reusable face coverings.

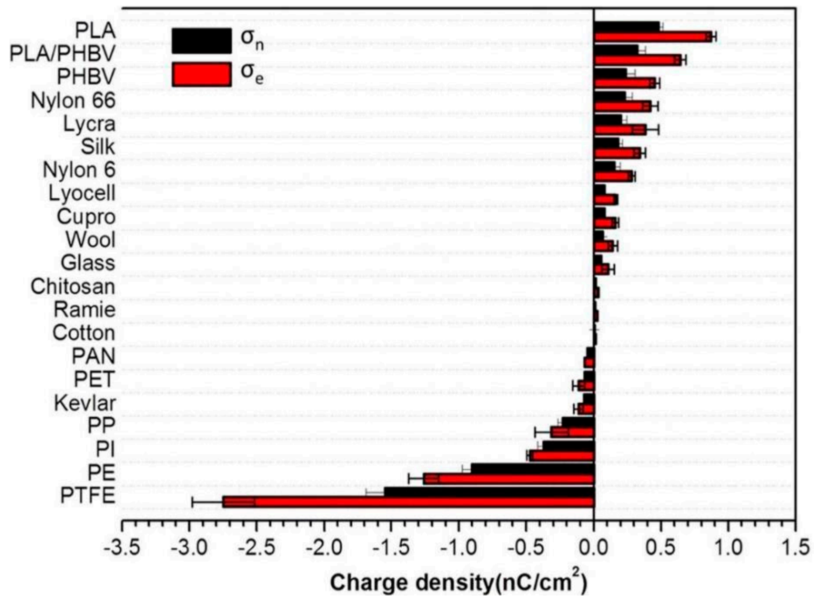


**Figure 5.** Various positive and negative charge densities for textile fibers [65].

## 5.2. Porosity

Porosity, or lack thereof, is a major factor in interception and impaction filtration mechanisms commonly employed by woven and knitted face coverings [66]. As interest in fabric face coverings developed early in the COVID-19 pandemic, advice for achieving effective filtration was based primarily on assumptions about increasing the fabric cover factor. This represents an important transition because cotton gauze was considered successful in reducing infection rates for plague epidemics in the first half of the 20th century [67], though sources that report this historic context do not provide much explanation.

## 5.3. Layers

Multilayer face coverings show improved efficacy. One recommended three-layer system includes a breathable middle layer with an antimicrobial finish. This system was claimed to be effective at filtering the SARS-CoV-2 virus [68]. Two-layered fabric face coverings require high yarn packing, low yarn porosity, and multilayered design to have sufficient aerosol filtering efficiency. The type of fabric also determines the virus filtering efficacy. In the laboratory setting, the efficacy against bacteriophage MS2 has been found to be 50–70% for two-layer fabric face coverings, whereas, for three-ply surgical masks and N95, the efficacy was 95–97% [54]. Sousa-Pinto et al. found that in terms of filtration and breathability, two-layer nonwoven and knitted fabrics perform better. Nonetheless, these performances are found to be wanting compared to the multilayered textile and surgical masks when it comes to high levels of protection from the SARS-CoV-2 virus [69].

Hancock et al. and Mueller et al. conducted particle filtration performance test of at least two-layer coverings made of 5–10 different hand-sewn woven fabrics loosely fitted to the wearer's face [43,70]. At the same time, they tested two types of standard three-layer medical masks. The woven face coverings incorporating a nylon stocking overlayer were also tested to see if the overlayer improved filtration capability. The results indicate that five out of ten woven loose-fitting coverings had high particle filtration efficiency, similar to the performance of three-layer surgical face coverings. Three-layer surgical masks showed 75% filtration efficiency, whereas woven face coverings showed 30–60% filtration efficiency. The authors recommended an extra layer of filter (organic cotton batting, Pellon, or loosely woven cotton muslin) to improve the filtration efficiency of the two-layer woven face coverings. Whiley et al. found that two-layer stretchy cotton denim fabrics showed the highest filtration efficiency (90.90%) among woven fabrics [71]. Figure 6 shows the comparative graphs on the efficacy of increasing layers and flow rate. The ability of home-made (woven and knitted fabric) face covering to filter the ultrafine (0.02–0.1 μm) particles at the velocity (0.5 to 25 cm/s) of coughing and their efficacy in a damp state has been analyzed by O'Kelly et al [23]. The large particles are readily filtered whereas the ultrafine particles decrease the efficiency. The filtration efficiency in a damp or wet state after one laundering cycle reaches a maximum of 45%, which is less than in a dry state. It was recommended that in case of an acute shortage of respirators, people can use the homemade face covering with an extra layer as it gives approximately 90% particle filtration efficiency.

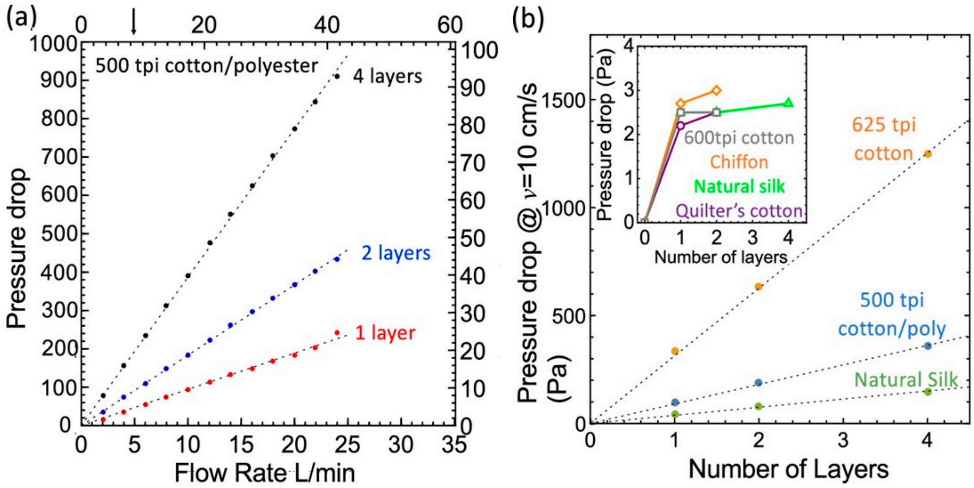


**Figure 6.** (**a**). Pressure drop vs. face velocity for 1, 2, and 4 layers of 500 thread per inch (tpi) cotton/polyester blend, and (**b**) Pressure drop at 10 cm/s face velocity for three materials [43].

Structural differences between knitted, woven, and nonwoven fabrics influence their filtration potential and air permeability in various ways. This has been taken into consideration by Varallyay et al. They examined the airflow and filtration efficiency of knitted, woven, and nonwoven fabrics available in household and health care centers [72] that complied with the ASTM F2299 Standard [73]. These fabrics had varying numbers of layers and were tested in both wet and dry states. Filtration efficiency was measured using a quantitative fit testing device (TSI, Porta Count Pro Plus. Shoreview, MN) with a standard 40-nm median diameter particle generator. The airflow resistance was measured as pressure drops through the fabric sample using an air compressor with a pressure gauge (EPAuto, Model 1. Walnut, CA). The filtration efficiency was calculated according to the following formula (Equation (1)). The normal rule of thumb is that higher filtration efficiency means lower airflow.

$$Filtration\ efficiency(\%) = \left(1 - \frac{Filtered\ count}{Ambient\ count}\right) \times 100 \quad (1)$$

Sample fabrics with varying base weights of 22–300 g per square meter (GSM) and 1–4 layers were selected. The effect of the layer and washing were also assessed. The results indicate that non-elastic fabrics that are commonly found in households showed very poor filtration and airflow efficiency. The cotton–polyester blended fabric and cotton tea towel of higher GSM showed inferior filtration performance. Thick polyester fleece and microfiber cleaning cloth showed better performance. Polyester-felt nonwoven fabric showed higher performance than any other available household fabric.

*5.4. Finishes*

This paper focuses on the formation of fabric for general-use face coverings and will not fully address the myriad possible finishes for these fabrics. However, a few key points that have surfaced in recent research and recommendations are worth mentioning. To identify readily available materials for homemade face coverings, particularly very early in the pandemic, researchers investigated not only T-shirts and towels but also everything from coffee filters to vacuum cleaner bags. WHO warns that these items that are not intended for clothing may contain materials that are injurious to health when breathed in and should be avoided [28]. This may be due to fiber content as well as finishes. Vacuum bags are typically made of polypropylene, the same material used for surgical masks, but they are not designed or tested for use on the face. In commenting on the high filtration efficiency of vacuum bags, Kahler and Hain acknowledge that these may contain harmful fibers and unhealthy ingredients intended to kill bacteria [38].

Antimicrobial/Antiviral Finishes

Microbes include organisms that are not visible to naked eyes, such as viruses and bacteria [74]. Antimicrobial finishes are imparted to a fabric surface for protection against viruses and bacteria [75–77]. The benefits of antimicrobial/antiviral finishes are debated. Such treatments have the potential to reduce the number of infectious particles on the face covering, but most antimicrobials/antivirals approved for use in textiles are not tested for the viral reduction in a face covering. In its December 2020 mask use guidance, WHO clearly states that antimicrobial-treated fabrics should not contact mucous membranes and should not be used for the inner layer of any face covering. Antimicrobial compounds may cause skin irritation or penetrate through the skin in the case of direct contact with the skin [78]. WHO also expresses concern about antimicrobial claims providing wearers with an unsupported sense of security. Standard tests evaluate bacteriostatic or bactericidal activity over the course of several hours and may be of limited value in determining the efficacy of face coverings in the COVID-19 context, where a face covering has to contend with viral particles [28]. In the case of an outbreak of airborne or aerosol-hopping bacterial infectors, standard tests may have some utility in establishing the efficacy of a face covering. Secondary bacterial infections of the skin due to excessive use of face coverings are another avenue where antimicrobial finishing could be beneficial. There are some commercially available face coverings that can retain antimicrobial properties and high filtration efficiency without an antimicrobial finish such as M-chitosan and copper line face coverings. The M-chitosan face covering is prepared using three layers. The first layer consists of high-density knitted fabric with a very smooth surface. The third layer contains low-density knitted fabric with a chitosan film. The intermediate layer works as the interlining. Chitosan is a derivative of chitin, which is obtained by partial deacetylation of chitin in alkaline conditions or by using enzymatic hydrolysis in the presence of chitin deacetylase [79]. Chitosan is a positively charged hydrophilic antimicrobial polymer, which can neutralize negatively charged bacteria. According to the American Association of Textile Chemist and Colorist (AATCC) test method, this chitosan-containing face covering is effective against 99.9% of bacterial growth even after 100 washes [41]. Commercially available anti-bacterial copper line face coverings are prepared using polyurethane, polyester, and copper. Ionized copper yarn is used to prepare this face covering with antibacterial properties and the capability to eliminate viruses. It is also claimed to be skin-friendly and reduce skin irritation. The *New England Journal of Medicine* recently reported that the SARS-CoV-2 virus is eliminated within a few hours after encountering the copper surface. Ionized copper yarn can kill 50% of bacteria in ten min and 99.5% of bacteria within one hour. The filtration efficiency of the three-layered knitted copper line face covering is increased to 99.9% and 99.6% against viruses and particles, respectively, when an additional disposable filter is inserted. Antibacterial properties of face coverings remain unchanged until 30 washes [41].

### *5.5. Particle Size*

When the droplets hit the fabric surface with a median velocity of approximately 17.1 m/s, few droplets penetrate the fabrics and split into smaller droplets. With more layers, fewer droplets pass through. Penetration depends on the pore size, thickness, and velocity regardless of the impacting droplet diameter [68]. The most penetrating particle size (MPPS) is too small to be effectively captured by interception or impaction and too large to be caught by diffusion or electrostatic interaction. This size has been reported as anywhere between 0.05 and 0.5 µm [13]. Filtration test methods often target this range as representative of a "worst case scenario." The exact MPPS and the method of measuring filtration for general-use face coverings are far from standardized. One of the primary challenges of reviewing research is the heterogeneity of test conditions and protocols, including particle size. These differences, along with frequently incomplete characterization of tested materials make a direct comparison across studies difficult.

The French Association Française de Normalisation (AFNOR) Group [80] was one of the first to publish a specification for general community use face coverings. The AFNOR S76 guide references EN 13274-7 (CEN-2019) with particles up to 3-µm. The particles may be NaCl, or liquid paraffin oil and face coverings must exhibit at least 70% filtration efficiency. Since the AFNOR standard, several other countries and the European Union have published similar documents. The Belgian (NBN) and European (CEN-2020) standards also call for at least 70% filtration of 3-µm particles. The global standard published by AATCC recommends 70% efficiency when testing with 3-µm latex spheres, though this document also notes that smaller particles could also be tested and may be more representative of actual use conditions (AATCC) [81].

More recently, the American Society for Testing and Materials (ASTM) International published a specification including the filtration test method commonly used to evaluate medical respirators. The NaCl aerosol particle has an average diameter of 0.075 µm. The particle size is much smaller than that used in other face covering standards, but only 20% filtration is required [82]. Rengasamy et al. studied improvised fabric face coverings in 2010 in response to influenza (H5N1, H1N1) outbreaks. Fabrics from common consumer items were tested for filtration efficiency using 0.02–1.0 µm particles [57]. The test included two different velocities, and both polydisperse and monodisperse particles and the fabrics were compared with surgical masks, dust masks, and an N95 respirator. Sweatshirts, T-shirts, towels, and scarves, as well as fabric face coverings allowed at least 50% penetration of the particles, with the exception of one poly/cotton sweatshirt with 40% penetration at low velocity. Towels generally provide greater filtration than other apparel items [57]. The paper provides no explanation for this, and the only descriptive information provided about fabrics is fiber content. Most fabrics were cotton or a cotton/polyester blend. Fiber content did not appear to have any direct correlation with filtration. It is likely that the towels had the tightest construction of the fabrics tested; moreover, pile structures in such fabrics could also be responsible for improved chances of contagion impaction. Fabrics in the Rengasamy et al. study were selected for their availability and not optimized for filtration. Nonetheless, the results agree with other studies that common woven and knit textiles are less effective filters as particle size decreases [38,83]. Interestingly, two of the three towels tested showed improved filtration between 0.3 and 1.0 µm. Penetration of other samples continued to increase across the complete range of particle sizes tested [57]. A more recent study by Hao and colleagues found that household textiles had filtration efficiencies below 60%. The average particle size for these tests was 0.3 µm. Size-dependent filtration evaluations were also performed with particles between 0.1 and 0.6 µm [24]. Even the top end of this range is smaller than the particle size that can be effectively filtered by common fabrics, though the results do show an upward trend in efficiency beginning at approximately 0.4 µm [24].

### 5.6. Related Effect

Kähler and Hain approached the question of face-covering filtration from the perspective of fluid dynamics [38]. They began with an investigation of the droplet size and spread of cough or speech. Among the household materials tested, only high-quality vacuum bags provided adequate filtration to protect the wearer from infectious particles in the environment. However, they also conclude that face coverings are quite effective at preventing the spread of the wearer's exhaled air [38]. This aligns with other reports [15,24,59] and the common messages regarding the social contract of wearing a face covering to protect others. The fluid dynamics analysis should inform future testing and evaluation of materials for the general use of face coverings. This may also explain conflicting data between epidemiological evidence that wearing face coverings reduces transmission of SARS-CoV-2 and lab results showing most fabrics to be poor filters. Researchers at Duke University discovered a negative effect of face coverings as a barrier to exhaled air. Their results showed that a fleece gaiter, especially, dispersed large droplets into smaller droplets [84]. Smaller droplets have the potential to travel farther and remain airborne longer, increasing the probability of contact with another person. No hypothesis was offered for why the fleece performed differently from other fabrics, and this phenomenon is not detailed in other papers reviewed [13,19,28–47].

## 6. Clinical Outcomes

There are far fewer studies of clinical outcomes than laboratory analyses. The Nanda review covers much of the relevant work [15]. A publication by MacIntyre et al. found that a randomized group using fabric face coverings had the highest rate of all infections when compared to groups using medical masks or the wearer's usual practice [85]. The usual practice group included individuals wearing medical masks, fabric face coverings, a combination, N95 respirators, and no covering. There was no specific no-covering control. The authors could not conclude whether fabric face coverings simply provided less protection than medical masks due to lower filtration efficiency or if they actually increased the risk of infection. Possible sources of increased risk included self-contamination due to repeated use, donning, doffing, and moisture retention [85]. Some of the same authors collaborated to propose a new set of randomized trials in the community. They also recommended properties for constructing a fabric face covering. Few references are cited for the recommendations, and no explanation is provided. As with other papers offering specific recommendations, there is a risk of the guidance being taken at face value. The imperative statement, "select a fabric that is water resistant", is one example from this paper [67]. Courtney and Bax recently proposed a new perspective on the efficacy of fabric face coverings. Rather than focusing on the ability or inability to filter potentially harmful particles, they suggest that the increased humidity of the respiratory epithelium (cells lining the airway) reduces the severity of illness if the wearer is exposed to infectious particles [86]. If true, this could steer testing from filtration to moisture management and a completely different set of technologies. As noted in the earlier moisture management discussion, too much humidity can lead to discomfort, so balance among properties is still required.

## 7. Quality Control

Chemical compliance is an important issue for fabric face coverings. Fabrics are colored with dyes that contain many trace elements, additives, and nanoparticles (Table 2) that can enter the human body through ingestion and inhalation [87]. In a recent study, Bussan et al. found that textiles used in most of the specialized masks contained heavy metals/trace elements that are toxic to the human body [88]. Blevens et al. found significant differences between products with quality labeled and tested and therefore, argued for strict product testing and inhalation regulation for face covering manufacturers [89]. As CDC promotes the use of fabric face coverings, a cytotoxicity test (e.g., ISO-10993) could be included as part of the quality test of fabrics before their dispatch from the manufacturing site to ensure public health safety [90].

**Table 2.** Harmful chemicals used in fabrics [87,91].

| Category of Chemicals Used in Fabrics | Restricted Chemical Compounds |
|---|---|
| Additives/Plasticizers | Flame retardants (polybrominated diphenyl ethers, Phthalates, organophosphate esters, hexabromocyclodecane, and $Sb_2O_3$). |
| Trace Elements | Metal complex dye (cobalt, copper, chromium, and lead), pigments, mordant, antimicrobials (nanoparticles of silver, titanium oxide, and zinc oxide), trace metals (Ag, Al, As, B, Ba, Be, Bi, Cd, Co, Cr, Cu, Fe, Hg, Mg, Mn, Mo, Ni, Pb, Sb, Sc, Se, Sm, Sn, Sr, Ti, Tl, V, and Zn) |
| Dyes | Aromatic Amine (azo), Quinoline and derivatives, bisphenols (BPAs), benzothiazoles (BTHs), and benzotriazoles (BTRs) |
| Nanoparticles | Carbon nanotubes, nanoclays, aluminum oxide, silicon dioxide, zinc oxide, titanium oxide, and silver. |
| Finishing agents | Formaldehydes (anti-creasing), nanoparticles (nano Ag), antimicrobial agents (Ag-coating) |

[28,67,84–86].

## 8. Conclusions and Future Research Direction

A growing body of research is tackling the problem of optimizing the performance of fabric-based face coverings recognizing the reliance of most vulnerable groups on these coverings to protect themselves against the COVID-19 disease [13,14,67]. Moreover, the impact of non-biodegradable single-use personal protection equipment, including face coverings on the ecology of the planet, has started to be documented in various publications now since we have spent multiple years with the COVID-19 pandemic [92–94]. Global health and geopolitical crises and the consequent commodity super cycle have spawned widespread supply chain disruptions. A paucity of resources has given an opportunity to reevaluate response to future public health emergencies in times of global strife and scarcity. Strategies to offset supply bottlenecks during pandemics include the use of immediately available resources such as reusable fabric-based face coverings. Reuse is an important economic and ecological advantage of fabric face coverings, but the area is not well-studied. A better understanding of how use and laundering affect performance is needed. Complete lifecycle analysis of both disposable and reusable face coverings would also be useful. Other areas to explore are the human factors of selection, use, handling, and washing. The current body of research indicates the highest degree of filtration efficiency for N95 respirators followed by surgical masks, while fabric face coverings provide comparatively lower filtration efficiency. Despite the dearth of penetrating discussion on the effects of key construction parameters and how these influence the utility of fabric face covering in terms of blocking contagions, woven face coverings demonstrate better filtration efficiency than knitted face coverings in the available literature. Knitted face coverings are, however, more breathable. Woven face coverings are made of all types of synthetic and natural fibers such as cotton, polyester, cotton-polyester blends, and silk with different count variations. Among these, polypropylene is inexpensive, with excellent antimicrobial behavior, mechanical strength, and chemical resistance. At least one study recommended this as an ideal fiber for use in face coverings [44].

The spread of SARS-CoV-2 is becoming better understood but is not yet replicated by standard laboratory tests. To evaluate the true efficacy of fabric face coverings, more relevant methods are needed both in the field and in the lab. Nanda et al. were quite critical of the existing literature regarding preclinical and clinical studies of face-covering use [85]. They identified 10 of the 12 studies reviewed as having a high risk of bias, with the remaining two having "some concerns." Most of the bias arose due to deviations from the intended intervention [44,85]

Again, WHO describes the main shortfall of existing studies. The report notes that while many materials have been studied, few fabrics or combinations have been systematically evaluated, and "there is no single design, choice of material, layering or shape among non-medical masks that are considered optimal" [28]. The challenge for future studies is similar. There is an unlimited number of fabric combinations, making it impossible to complete an exhaustive evaluation or comparison. Nonetheless, a systematic study of fabrics using consistent methodology could provide some practical insight of value to manufacturers and consumers.

The scope of discussion in most of the available literature has not been expanded to cover the effects of weave or knit types, yarn construction methods, and the selection of fibers. In most of the publications regarding face coverings, no investigation has been conducted to determine the impact of yarn types and fabric types on effectiveness. Very few papers gave the details of yarn count, loop length, or fabric weight of reusable face coverings, although these factors have a significant impact on the performance of face coverings. Fabric weight and thickness depend on the yarn count used during fabric manufacturing, which has a significant impact on filtration efficiency and thermal comfort. For meaningful research developments in the realm of estimating the filtration performances of these face coverings, these parameters and their impact on the filtration function must be exhaustively investigated.

Moreover, compliance in regard to the use of restricted chemicals on fabrics used for constructing reusable face coverings has to be given utmost importance in the wider interest of public health.

**Author Contributions:** Conceptualization, M.T. and D.W.; methodology, M.A.-A.; software, M.A.-A.; validation, M.T.H., S.M.F.K. and M.A.-A.; formal analysis, M.T.; investigation, S.M.F.K.; resources, M.A.-A.; data curation, M.T.H.; writing—original draft preparation, M.A.-A.; writing—review and editing, S.M.F.K.; visualization, D.W.; supervision, Md Al-Amin and M.T.H. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** The data presented in this study are available on request from the corresponding author.

**Conflicts of Interest:** The authors declare no conflict of interest.

## References

1. Krammer, F. SARS-CoV-2 vaccines in development. *Nature* **2020**, *586*, 516–527. [CrossRef] [PubMed]
2. World Health Organization. *Infection Prevention and Control of Epidemic-and Pandemic-Prone Acute Respiratory Infections in Health Care*; World Health Organization: Geneva, Switzerland, 2014.
3. Lindsley, W.G.; Pearce, T.A.; Hudnall, J.B.; Davis, K.A.; Davis, S.M.; Fisher, M.A.; Khakoo, R.; Palmer, J.E.; Clark, K.E.; Celik, I.; et al. Quantity and Size Distribution of Cough-Generated Aerosol Particles Produced by Influenza Patients During and after Illness. *J. Occup. Environ. Hyg.* **2012**, *9*, 443–449. [CrossRef] [PubMed]
4. Asadi, S.; Wexler, A.S.; Cappa, C.D.; Barreda, S.; Bouvier, N.M.; Ristenpart, W.D. Aerosol emission and superemission during human speech increase with voice loudness. *Sci. Rep.* **2019**, *9*, 2348. [CrossRef]
5. Alsved, M.; Matamis, A.; Bohlin, R.; Richter, M.; Bengtsson, P.-E.; Fraenkel, C.-J.; Medstrand, P.; Löndahl, J. Exhaled respiratory particles during singing and talking. *Aerosol Sci. Technol.* **2020**, *54*, 1245–1248. [CrossRef]
6. Zayas, G.; Chiang, M.C.; Wong, E.; Macdonald, F.; Lange, C.F.; Senthilselvan, A.; King, M. Cough aerosol in healthy participants: Fundamental knowledge to optimize droplet-spread infectious respiratory disease management. *BMC Pulm. Med.* **2012**, *12*, 11. [CrossRef]
7. Centers for Disease Control and Prevention. *Coronavirus Disease 2019 (COVID-19)*; Centers for Disease Control and Prevention: Atlanta, GA, USA, 2020.
8. Sickbert-Bennett, E.E.; Samet, J.M.; Clapp, P.W.; Chen, H.; Berntsen, J.; Zeman, K.L.; Tong, H.; Weber, D.J.; Bennett, W.D. Filtration Efficiency of Hospital Face Mask Alternatives Available for Use During the COVID-19 Pandemic. *JAMA Intern. Med.* **2020**, *180*, 1607–1612. [CrossRef]

9. Howard, J.; Huang, A.; Li, Z.; Tufekci, Z.; Zdimal, V.; van der Westhuizen, H.-M.; von Delft, A.; Price, A.; Fridman, L.; Tang, L.-H.; et al. An evidence review of face masks against COVID-19. *Proc. Natl. Acad. Sci. USA* **2021**, *118*, e2014564118. [CrossRef]
10. Gallaway, M.S.; Rigler, J.; Robinson, S.; Herrick, K.; Livar, E.; Komatsu, K.K.; Brady, S.; Cunico, J.; Christ, C.M. Trends in COVID-19 incidence after implementation of mitigation measures—Arizona, January 22–August 7, 2020. *Morb. Mortal. Wkly. Rep.* **2020**, *69*, 1460. [CrossRef]
11. Van Dyke, M.E.; Rogers, T.M.; Pevzner, E.; Satterwhite, C.L.; Shah, H.B.; Beckman, W.J.; Ahmed, F.; Hunt, C.; Rule, J. Trends in county-level COVID-19 incidence in counties with and without a mask mandate—Kansas, June 1–August 23, 2020. *Morb. Mortal. Wkly. Rep.* **2020**, *69*, 1777. [CrossRef]
12. Mitze, T.; Kosfeld, R.; Rode, J.; Wälde, K. Face masks considerably reduce COVID-19 cases in Germany. *Proc. Natl. Acad. Sci. USA* **2020**, *117*, 32293–32301. [CrossRef]
13. Bhattacharjee, S.; Bahl, P.; Chughtai, A.A.; MacIntyre, C.R. Last-resort strategies during mask shortages: Optimal design features of cloth masks and decontamination of disposable masks during the COVID-19 pandemic. *BMJ Open Respir. Res.* **2020**, *7*, e000698. [CrossRef] [PubMed]
14. Clase, C.M.; Fu, E.L.; Ashur, A.; Beale, R.C.; Clase, I.A.; Dolovich, M.B.; Jardine, M.J.; Joseph, M.; Kansiime, G.; Mann, J.F.; et al. Forgotten Technology in the COVID-19 Pandemic: Filtration Properties of Cloth and Cloth Masks—A Narrative Review. *Mayo Clin. Proc.* **2020**, *95*, 2204–2224. [CrossRef] [PubMed]
15. Nanda, A.; Hung, I.; Kwong, A.; Man VC, M.; Roy, P.; Davies, L.; Douek, M. Efficacy of surgical masks or cloth masks in the prevention of viral transmission: Systematic review, meta-analysis, and proposal for future trial. *J. Evid. Based Med.* **2021**, *14*, 97–111. [CrossRef]
16. Mahase, E. COVID-19: What is the evidence for cloth masks? *BMJ* **2020**, *369*, m14222020. [CrossRef]
17. Milewska, B. The Impact of Instability in the Business Environment on the Competitiveness of Enterprises Using the Example of the Apparel Industry. *Sustainability* **2022**, *14*, 14673. [CrossRef]
18. Shruti, V.; Pérez-Guevara, F.; Elizalde-Martínez, I.; Kutralam-Muniasamy, G. Reusable masks for COVID-19: A missing piece of the microplastic problem during the global health crisis. *Mar. Pollut. Bull.* **2020**, *161*, 111777. [CrossRef]
19. Aydin, O.; Emon, B.; Cheng, S.; Hong, L.; Chamorro, L.P.; Saif, M.T.A. Performance of fabrics for home-made masks against the spread of COVID-19 through droplets: A quantitative mechanistic study. *Extreme Mech. Lett.* **2020**, *40*, 100924. [CrossRef]
20. SARS-CoV-2 Resources—NCBI. Available online: https://www.ncbi.nlm.nih.gov/sars-cov-2/ (accessed on 15 January 2023).
21. Luisetto, M.; Nili, B.; Khaled, E.; Mashori, G.; Rafa, A.Y.; Latishev, O.Y. Bioaerosols and Corona Virus Diffusion, Transmission, Carriers, Viral Size, Surfaces Properties and other Factor Involved. *Int. J. Med. Healthc. Reports* **2021**, *1*, 1004.
22. Tucho, G.T.; Kumsa, D.M. Universal Use of Face Masks and Related Challenges During COVID-19 in Developing Countries. *Risk Manag. Healthc. Policy* **2021**, *14*, 511–517. [CrossRef]
23. O'Kelly, E.; Pirog, S.; Ward, J.; Clarkson, P.J. Ability of fabric face mask materials to filter ultrafine particles at coughing velocity. *BMJ Open* **2020**, *10*, e039424. [CrossRef]
24. Hao, W.; Parasch, A.; Williams, S.; Li, J.; Ma, H.; Burken, J.; Wang, Y. Filtration performances of non-medical materials as candidates for manufacturing facemasks and respirators. *Int. J. Hyg. Environ. Health* **2020**, *229*, 113582. [CrossRef] [PubMed]
25. Gandhi, M.; Marr, L.C. Uniting Infectious Disease and Physical Science Principles on the Importance of Face Masks for COVID-19. *Med* **2020**, *2*, 29–32. [CrossRef] [PubMed]
26. Zhang, Z.; Ji, D.; He, H.; Ramakrishna, S. Electrospun ultrafine fibers for advanced face masks. *Mater. Sci. Eng. R Rep.* **2020**, *143*, 100594. [CrossRef] [PubMed]
27. Han, S.; Kim, J.; Ko, S. Advances in air filtration technologies: Structure-based and interaction-based approaches. *Mater. Today Adv.* **2021**, *9*, 100134. [CrossRef]
28. World Health Organization. Advice on the Use of Masks in the Community, during Home Care and in Healthcare Settings in the Context of the Novel Coronavirus (COVID-19) Outbreak. Available online: https://www.who.int/publications/i/item/advice-on-the-use-of-masks-in-the-community-during-home-care-and-in-healthcare-settings-in-the-context-of-the-novel-coronavirus-(2019-ncov)-outbreak (accessed on 15 January 2023).
29. Zieliński, J.; Przybylski, J. How much water is lost during breathing? *Pneumonol. Alergol. Polska* **2012**, *80*, 339–342.
30. Wardiningsih, W.; Troynikov, O. Influence of cover factor on liquid moisture transport performance of bamboo knitted fabrics. *J. Text. Inst.* **2012**, *103*, 89–98. [CrossRef]
31. Lai, M.Y.Y.; Cheng, P.K.C.; Lim, W.W.L. Survival of Severe Acute Respiratory Syndrome Coronavirus. *Clin. Infect. Dis.* **2005**, *41*, e67–e71. [CrossRef]
32. Iqbal, M.I. Adaptive Textiles for Thermal Management Using Wool Fibers. 2021. Available online: https://theses.lib.polyu.edu.hk/handle/200/11310 (accessed on 20 February 2023).
33. Iqbal, M.I.; Shuo, S.; Jiang, Y.; Fei, B.; Xia, Q.; Wang, X.; Hu, W.; Hu, J. Woolen Respirators for Thermal Management. *Adv. Mater. Technol.* **2021**, *6*, 2100201. [CrossRef]
34. Parlin, A.F.; Stratton, S.M.; Culley, T.M.; Guerra, P.A. A laboratory-based study examining the properties of silk fabric to evaluate its potential as a protective barrier for personal protective equipment and as a functional material for face coverings during the COVID-19 pandemic. *PLoS ONE* **2020**, *15*, e0239531. [CrossRef]
35. Parajuli, P.; Acharya, S.; Rumi, S.S.; Hossain, M.T.; Abidi, N. Regenerated cellulose in textiles: Rayon, lyocell, modal and other fibres. In *Fundamentals of Natural Fibres and Textiles*; Elsevier: Amsterdam, The Netherlands, 2021; pp. 87–110.

36. Durur, G.; Öner, E. The Comfort Properties of the Terry Towels Made of Cotton and Polypropylene Yarns. *J. Eng. Fibers Fabr.* **2013**, *8*, 155892501300800201. [CrossRef]
37. Syed, Q.; Sopwith, W.; Regan, M.; Bellis, M.A. Behind the mask. Journey through an epidemic: Some observations of contrasting public health responses to SARS. *J. Epidemiol. Community Health* **2003**, *57*, 855–856. [CrossRef]
38. Kähler, C.J.; Hain, R. Fundamental protective mechanisms of face masks against droplet infections. *J. Aerosol Sci.* **2020**, *148*, 105617. [CrossRef] [PubMed]
39. Davies, A.; Thompson, K.-A.; Giri, K.; Kafatos, G.; Walker, J.; Bennett, A. Testing the Efficacy of Homemade Masks: Would They Protect in an Influenza Pandemic? *Disaster Med. Public Health Prep.* **2013**, *7*, 413–418. [CrossRef] [PubMed]
40. Iqbal, M.I.; Sun, F.; Fei, B.; Xia, Q.; Wang, X.; Hu, J. Knit Architecture for Water-Actuating Woolen Knitwear and Its Personalized Thermal Management. *ACS Appl. Mater. Interfaces* **2021**, *13*, 6298–6308. [CrossRef] [PubMed]
41. Lee, K.-P.; Yip, J.; Kan, C.-W.; Chiou, J.-C.; Yung, K.-F. Reusable Face Masks as Alternative for Disposable Medical Masks: Factors that Affect their Wear-Comfort. *Int. J. Environ. Res. Public Health* **2020**, *17*, 6623. [CrossRef]
42. Konda, A.; Prakash, A.; Moss, G.A.; Schmoldt, M.; Grant, G.D.; Guha, S. Aerosol filtration efficiency of common fabrics used in respiratory cloth masks. *ACS Nano* **2020**, *14*, 6339–6347. [CrossRef]
43. Hancock, J.N.; Plumley, M.J.; Schilling, K.; Sheets, D.; Wilen, L. Comment on "Aerosol Filtration Efficiency of Common Fabrics Used in Respiratory Cloth Masks". *ACS Nano* **2020**, *14*, 10758–10763. [CrossRef]
44. Liao, M.; Liu, H.; Wang, X.; Hu, X.; Huang, Y.; Liu, X.; Brenan, K.; Mecha, J.; Nirmalan, M.; Lu, J.R. A technical review of face mask wearing in preventing respiratory COVID-19 transmission. *Curr. Opin. Colloid Interface Sci.* **2021**, *52*, 101417. [CrossRef]
45. Bourouiba, L.; Dehandschoewercker, E.; Bush, J.W.M. Violent expiratory events: On coughing and sneezing. *J. Fluid Mech.* **2014**, *745*, 537–563. [CrossRef]
46. Wei, J.; Li, Y. Human Cough as a Two-Stage Jet and Its Role in Particle Transport. *PLoS ONE* **2017**, *12*, e0169235. [CrossRef]
47. Zangmeister, C.D.; Radney, J.G.; Vicenzi, E.P.; Weaver, J.L. Filtration efficiencies of nanoscale aerosol by cloth mask materials used to slow the spread of SARS-CoV-2. *ACS Nano* **2020**, *14*, 9188–9200. [CrossRef] [PubMed]
48. Tahvildar, A.; Ezazshahabi, N.; Mousazadegan, F. Appearance and comfort properties considering yarn-spinning system and weave structure in worsted woven fabrics. *J. Eng. Fibers Fabr.* **2019**, *14*, 1558925019845978. [CrossRef]
49. Nguyen, M.; Donalson, G.; Bradley, N.; Templeton, T.; Verma, M.; Aldridge, A.; Spalding, S. Evaluation of the Efficacy of Fabric Face Masks on the Number of Wash during the Outbreak of Coronavirus (COVID-19). 2021. Available online: https://ursa.mercer.edu/handle/10898/12658 (accessed on 21 January 2023).
50. Haleem, N.; Wang, X. Recent research and developments on yarn hairiness. *Text. Res. J.* **2014**, *85*, 211–224. [CrossRef]
51. Al-Amin, M. *A Comparative Study of Mechanical Performance Characteristics Between Treated and Untreated Ham Nets*; Mississippi State University: Mississippi State, MS, USA, 2020; Available online: https://scholarsjunction.msstate.edu/cgi/viewcontent.cgi?article=1057&context=td (accessed on 8 February 2023).
52. Cheng, S.; Hao, W.; Wang, Y.; Wang, Y.; Yang, S. Commercial Janus Fabrics as Reusable Facemask Materials: A Balance of Water Repellency, Filtration Efficiency, Breathability, and Reusability. *ACS Appl. Mater Interfaces* **2022**, *14*, 32579–32589. [CrossRef]
53. Ogulata, R.T.; Mavruz, S. Investigation of Porosity and Air Permeability Values of Plain Knitted Fabrics. *FIBRES TEXTILES East. Eur.* **2010**, *18*, 71–75.
54. Neupane, B.B.; Mainali, S.; Sharma, A.; Giri, B. Optical microscopic study of surface morphology and filtering efficiency of face masks. *PeerJ* **2019**, *7*, e7142. [CrossRef]
55. World Health Organization. *Mask Use in the Context of COVID-19: Interim Guidance, 1 December 2020*; World Health Organization: Geneva, Switzerland, 2020.
56. CDC. Science Briefs | CDC. 2020. Available online: https://www.cdc.gov/coronavirus/2019-ncov/science/science-briefs/ (accessed on 15 January 2023).
57. Rengasamy, S.; Eimer, B.; Shaffer, R. Simple Respiratory Protection—Evaluation of the Filtration Performance of Cloth Masks and Common Fabric Materials Against 20–1000 nm Size Particles. *Ann. Occup. Hyg.* **2010**, *54*, 789–798. [CrossRef]
58. Zhao, M.; Liao, L.; Xiao, W.; Yu, X.; Wang, H.; Wang, Q.; Lin, Y.L.; Kilinc-Balci, F.S.; Price, A.; Chu, L.; et al. Household Materials Selection for Homemade Cloth Face Coverings and Their Filtration Efficiency Enhancement with Triboelectric Charging. *Nano Lett.* **2020**, *20*, 5544–5552. [CrossRef]
59. Verma, S.; Dhanak, M.; Frankenfield, J. Visualizing the effectiveness of face masks in obstructing respiratory jets. *Phys. Fluids* **2020**, *32*, 061708. [CrossRef]
60. Ghatak, B.; Banerjee, S.; Ali, S.B.; Bandyopadhyay, R.; Das, N.; Mandal, D.; Tudu, B. Design of a self-powered triboelectric face mask. *Nano Energy* **2020**, *79*, 105387. [CrossRef]
61. Das, A.; Alagirusamy, R. Improving tactile comfort in fabrics and clothing. In *Improving Comfort in Clothing*; Song, G., Ed.; Elsevier Masson SAS: Oxford, UK, 2011; pp. 216–244. [CrossRef]
62. Sear, R.P.L.; de Anda, I.R.; Wilkins, J.W.; Robinson, J.F.; Royall, C.P. Modelling the Filltration Efficiency of a Woven Fabric: The Role of Multiple Lengthscales. *Phys. Fluids*. Available online: https://openresearch.surrey.ac.uk/esploro/outputs/journalArticle/Modelling-the-filltration-efficiency-of-a/99628465402346?institution=44SUR_INST (accessed on 22 January 2023).
63. Hossain, T.; Liyanage, S.; Abidi, N. FTIR microspectroscopic approach to investigate macromolecular distribution in seed coat cross-sections. *Vib. Spectrosc.* **2022**, *120*, 103376. [CrossRef]

64. Mansour, E.; Vishinkin, R.; Rihet, S.; Saliba, W.; Fish, F.; Sarfati, P.; Haick, H. Measurement of temperature and relative humidity in exhaled breath. *Sens. Actuators B Chem.* **2019**, *304*, 127371. [CrossRef]
65. Liu, S.; Zheng, W.; Yang, B.; Tao, X. Triboelectric charge density of porous and deformable fabrics made from polymer fibers. *Nano Energy* **2018**, *53*, 383–390. [CrossRef]
66. Application Note ITI-041. Mechanisms of Filtration for High Efficiency Fibrous. Available online: https://tsi.com/getmedia/d8a4412d-3050-41c8-9e89-bc3a20ffda4d/ITI-041?ext=.pdf (accessed on 2 January 2023).
67. Chughtai, A.A.; Seale, H.; MacIntyre, C.R. Effectiveness of Cloth Masks for Protection Against Severe Acute Respiratory Syndrome Coronavirus 2. *Emerg. Infect. Dis.* **2020**, *26*, e200948. [CrossRef] [PubMed]
68. Sharma, S.; Mishra, M.; Mudgal, S. Efficacy of cloth face mask in prevention of novel coronavirus infection transmission: A systematic review and meta-analysis. *J. Educ. Health Promot.* **2020**, *9*, 192. [CrossRef]
69. Sousa-Pinto, B.; Fonte, A.P.; Eng, A.A.L.; Oliveira, B.M.; Fonseca, J.A.; Costa-Pereira, A.; Correia, O. Face masks for community use: An awareness call to the differences in materials. *Respirology* **2020**, *25*, 894–895. [CrossRef]
70. Mueller, A.V.; Eden, M.J.; Oakes, J.M.; Bellini, C.; Fernandez, L.A. Quantitative Method for Comparative Assessment of Particle Removal Efficiency of Fabric Masks as Alternatives to Standard Surgical Masks for PPE. *Matter* **2020**, *3*, 950–962. [CrossRef]
71. Whiley, H.; Keerthirathne, T.P.; Nisar, M.A.; White, M.A.F.; Ross, K.E. Viral Filtration Efficiency of Fabric Masks Compared with Surgical and N95 Masks. *Pathogens* **2020**, *9*, 762. [CrossRef]
72. Varallyay, C.; Li, N.; Case, B.; Wolf, B. Material Suitability Testing for Nonmedical Grade Community Face Masks to Decrease Viral Transmission During a Pandemic. *Disaster Med. Public Health Prep.* **2020**, *15*, e26–e32. [CrossRef]
73. Standard Test Method for Determining the Initial Efficiency of Materials Used in Medical Face Masks to Penetration by Particulates Using Latex Spheres. Available online: https://www.astm.org/f2299_f2299m-03r17.html (accessed on 9 February 2023).
74. What Are Microbes?—InformedHealth.org—NCBI Bookshelf. Available online: https://www.ncbi.nlm.nih.gov/books/NBK279387/ (accessed on 11 February 2023).
75. Kalaycı, S.; Iyigundogdu, Z.U.; Yazici, M.M.; Asutay, A.B.; Demir, O.; Sahin, F. Evaluation of Antimicrobial and Antiviral Activities of Different Venoms. *Infect. Disord.-Drug Targets* **2016**, *16*, 44–53. [CrossRef]
76. Balasubramaniam, B.; Prateek; Ranjan, S.; Saraf, M.; Kar, P.; Singh, S.P.; Thakur, V.K.; Singh, A.; Gupta, R.K. Antibacterial and Antiviral Functional Materials: Chemistry and Biological Activity toward Tackling COVID-19-like Pandemics. *ACS Pharmacol. Transl. Sci.* **2020**, *4*, 8–54. [CrossRef]
77. Pollard, Z.A.; Karod, M.; Goldfarb, J.L. Metal leaching from antimicrobial cloth face masks intended to slow the spread of COVID-19. *Sci. Rep.* **2021**, *11*, 19216. [CrossRef] [PubMed]
78. Liyanage, S.; Parajuli, P.; Hossain, M.T.; Chaudhari, H.; Abidi, N. Antimicrobials for protective clothing. In *Antimicrobial Textiles from Natural Resources*; Elsevier: Amsterdam, The Netherlands, 2021; pp. 349–376.
79. Jayakumar, R.; Menon, D.; Manzoor, K.; Nair, S.; Tamura, H. Biomedical applications of chitin and chitosan based nanomaterials—A short review. *Carbohydr. Polym.* **2010**, *82*, 227–232. [CrossRef]
80. AFNOR. Barrier Masks___Guide to Minimum Requirements, Methods of Testing, Making and Use Serial Manufacture and Artisanal Making (or DIY). 2020. Available online: www.veritaszim.net (accessed on 15 January 2023).
81. AATCC. AATCC-AATCC. 2020. Available online: https://members.aatcc.org/store/m014/3085/ (accessed on 15 January 2023).
82. ASTM. Standard Test Method for Evaluating the Bacterial Filtration Efficiency (BFE) of Medical Face Mask Materials, Using a Biological Aerosol of Staphylococcus aureus. 2020. Available online: https://www.astm.org/f2101-22.html (accessed on 15 January 2023).
83. Van Der Sande, M.; Teunis, P.; Sabel, R. Professional and Home-Made Face Masks Reduce Exposure to Respiratory Infections among the General Population. *PLoS ONE* **2008**, *3*, e2618. [CrossRef]
84. Fischer, E.P.; Fischer, M.C.; Grass, D.; Henrion, I.; Warren, W.S.; Westman, E. Low-cost measurement of face mask efficacy for filtering expelled droplets during speech. *Sci. Adv.* **2020**, *6*, eabd3083. [CrossRef]
85. MacIntyre, C.R.; Seale, H.; Dung, T.C.; Hien, N.T.; Nga, P.T.; Chughtai, A.A.; Rahman, B.; Dwyer, D.E.; Wang, Q. A cluster randomised trial of cloth masks compared with medical masks in healthcare workers. *BMJ Open* **2015**, *5*, e006577. [CrossRef] [PubMed]
86. Courtney, J.M.; Bax, A. Hydrating the respiratory tract: An alternative explanation why masks lower severity of COVID-19. *Biophys. J.* **2021**, *120*, 994–1000. [CrossRef] [PubMed]
87. Rovira, J.; Domingo, J.L. Human health risks due to exposure to inorganic and organic chemicals from textiles: A review. *Environ. Res.* **2018**, *168*, 62–69. [CrossRef]
88. Bussan, D.D.; Snaychuk, L.; Bartzas, G.; Douvris, C. Quantification of trace elements in surgical and KN95 face masks widely used during the SARS-COVID-19 pandemic. *Sci. Total Environ.* **2021**, *814*, 151924. [CrossRef] [PubMed]
89. Blevens, M.S.; Pastrana, H.F.; Mazzotta, H.C.; Tsai, C.S.-J. Cloth Face Masks Containing Silver: Evaluating the Status. *ACS Chem. Health Saf.* **2021**, *28*, 171–182. [CrossRef]
90. Tuñón-Molina, A.; Takayama, K.; Redwan, E.M.; Uversky, V.N.; Andrés, J.; Serrano-Aroca, Á. Protective Face Masks: Current Status and Future Trends. *ACS Appl Mater Interfaces* **2021**, *13*, 56725–56751. [CrossRef] [PubMed]
91. Saleem, H.; Zaidi, S.J. Sustainable Use of Nanomaterials in Textiles and Their Environmental Impact. *Materials* **2020**, *13*, 5134. [CrossRef] [PubMed]

92. Okuku, E.; Kiteresi, L.; Owato, G.; Otieno, K.; Mwalugha, C.; Mbuche, M.; Gwada, B.; Nelson, A.; Chepkemboi, P.; Achieng, Q.; et al. The impacts of COVID-19 pandemic on marine litter pollution along the Kenyan Coast: A synthesis after 100 days following the first reported case in Kenya. *Mar. Pollut. Bull.* **2020**, *162*, 111840. [CrossRef]
93. Dharmaraj, S.; Ashokkumar, V.; Hariharan, S.; Manibharathi, A.; Show, P.L.; Chong, C.T.; Ngamcharussrivichai, C. The COVID-19 pandemic face mask waste: A blooming threat to the marine environment. *Chemosphere* **2021**, *272*, 129601. [CrossRef]
94. De-La-Torre, G.E.; Aragaw, T.A. What we need to know about PPE associated with the COVID-19 pandemic in the marine environment. *Mar. Pollut. Bull.* **2020**, *163*, 111879. [CrossRef]