Viral Lung Protection with Filter Masks

Alex Stenzler

With so much in the media and healthcare proclamations surrounding masks for protecting people from the coronavirus, it is important to understand the difference between masks, how they filter, and how to select the mask that serves the desired protection needs. Listening to even scientists on TV about wearing masks reflects the poor understanding of how masks work and the complexity of protecting a person's breathing zone.

Consider masks with valves, which are typically found on many N95 masks. N95 masks can be used for both industrial and medical indications. In most industrial applications where the workers are exposed to harmful particles in the air, N95 masks with valves are frequently preferred. The valve opens only on exhalation, which allows more exhaled heat and moisture to escape the mask, while filtering all of the air that the worker inhales. This makes the mask more comfortable to wear. However, in industries such as the semiconductor industry, where they need to protect the semiconductor from any particles in the worker's breath, they only use N95 masks without valves.

In hospitals, the purpose of a surgical mask or N95 surgical mask is to protect both the healthcare worker from the patient and to protect a patient who is opened on a surgical table from anything in the medical team's exhaled breath. Therefore, these masks don't have exhalation valves. This is reflected in FDA not having approved a surgical mask or N95 surgical mask with an exhalation valve. And therefore, the only indications for use for a surgical mask are for protecting both the patient and the wearer from each other.

In managing patients with COVID-19 or most other diseases outside the operating room, there may be only a need to protect the healthcare worker and therefore, they may use masks with or without valves; however the valved masks are still not FDA cleared. Patients with respiratory infections should only wear masks without valves to protect other people. If the only mask available has a valve, hospital personnel may place a procedure mask over that N95 mask with a valve. Doing this maintains the protection of the healthcare worker and also protects other people from droplets in the exhaled breath passing through the valve.

It's important to appreciate that the biological load that a person is exposed to is important in the body's ability to protect itself. Inhaling a few viral particles will probably not harm a healthy person. Considering that an N95 masks only filters 95% of the particles at 0.3 micron, which means that 5% get past the mask; if the 5% of the particles could kill a person, they would be dead. When considering how infectious the coronavirus is, and how much air is moved through the mask when breathing, one might think there are a lot of viral particles inhaled, even with an N95 mask. However, viruses are much smaller than 0.3 micron. The SARS coronavirus was in the range of 0.100-0.130 micron. The recent Novel Coronavirus (2019-nCoV) has been measured in the range of 0.080-0.140 micron. These are much smaller than the 0.3 micron filtration specification of an N95 mask. But it turns out that masks are better at filtering smaller particles as well as particles larger than 0.3 micron particles.

What makes filter masks so effective is that they are non-woven materials and there is no direct path through the fibers that make

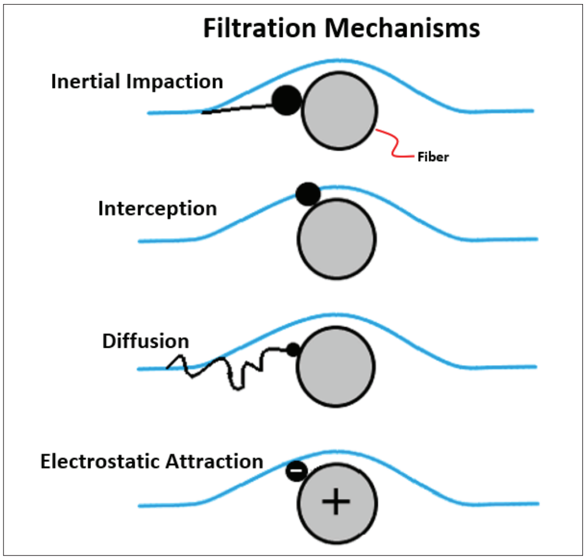

Figure 1. Filtration Mechanisms

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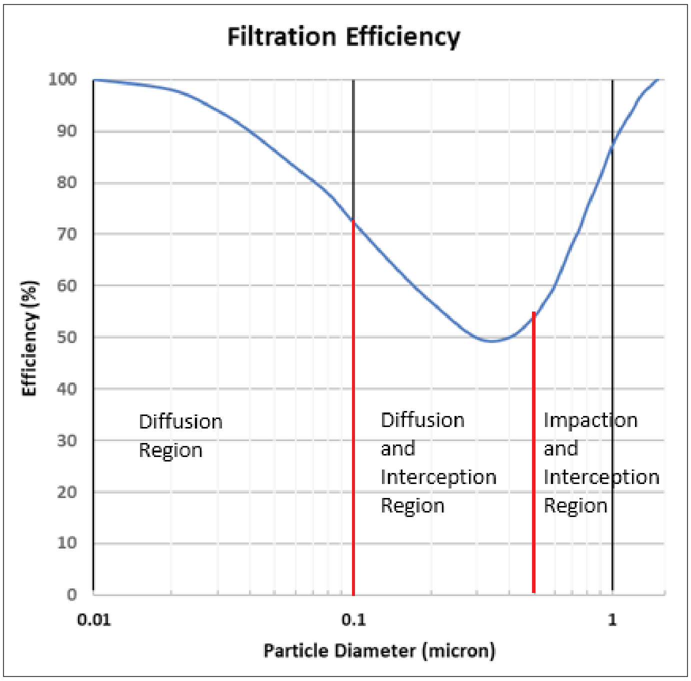

Figure 2. Filtration Efficiency vs Particle Size

up the filtration material. Millions of individual fibers are laid down and bonded together with either heat or chemicals into a flat sheet material. Therefore, the airflow and the particles it carries must turn and weave their way through the tortuous path of the filter media. There are several mechanisms for a respirator mask to stop particles from penetrating through the filter while still allowing the air needed to breathe to get into the lungs. Most respirators stop particles by either electrostatic attraction (i.e., the particles stick to the mask) or by inertial impaction (the particles slam into the fibers and get stuck). The other two mechanisms include particle interception and diffusion. (See Figure 1). It takes a combination of these mechanisms to provide the maximum protection. N95 masks are like HEPA filters and the more particles they trap, the more efficient they become.

Very large particles in slow moving airstreams may settle out to the ground due to gravity. However, most respirable particles are too small for this mechanism. Respirable particles above 0.5 um in diameter may be captured by inertial impaction and are usually captured when the particle can't make the turn around a fiber due to its inertia and it impacts on a fiber. In the interception mechanism for these slightly larger particles, the particle holds to the streamline, but that streamline will naturally bring the particle close enough to come in contact with the fiber and it sticks. The random bouncing movement of very small particles (around 0.1 microns in diameter) wandering across streamlines due to Brownian motion, cause them to accidentally come into contact with fibers and get trapped because they are too small to be carried away in the airflow. Therefore, it is not the largest or the smallest particles that are the hardest to trap but the particles that are greater than 0.1 micron and less than 0.5 micron. These particles are large enough to be picked up by the airflow, yet small enough to travel with the airflow around most fibers. Particles of 0.3 microns are therefore considered to be the most difficult particles to trap and the object test size for the most stringent requirements for NIOSH certification of an N95 Respirator.

Figure 2 shows the interaction of the different capture mechanisms on one type of filter media (not N95) for the purpose of illustration. Filtration efficiency is shown as a function of particle diameter. While the filtration efficiencies are not representative of actual filters used in respirators today, which are better, it does demonstrate that most particulate filters have a region of minimum filtration efficiency somewhere between 0.1-0.5 micron. Particles in this range are too large to be effectively pushed around by diffusion and too small to be effectively captured by interception or impaction. Therefore, N95 masks will typically block >99.9% of particles in the virus particle size range, while only capturing 95% of slightly larger particles (0.3 micron).

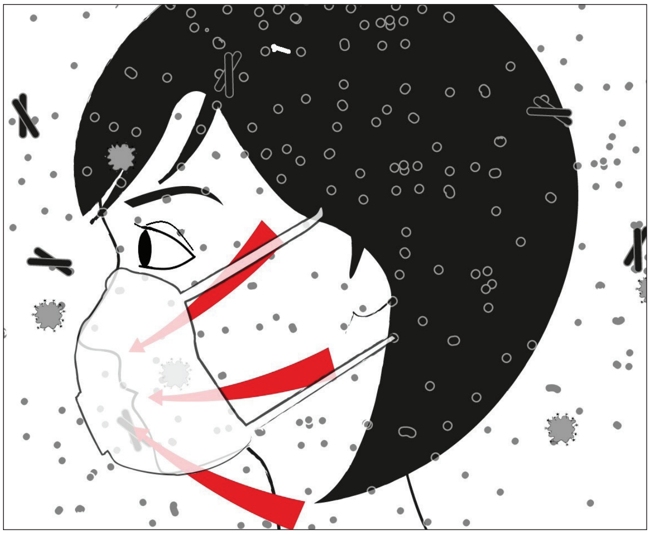

Figure 3. Breathing zone is unprotected when there's a poor facial seal

No matter how good the filter, air always flows through the path of least resistance. If a person is wearing a mask that is not sealed on the edges, the resistance of the filter is higher than the resistance at the edges and they won't be breathing filtered air, but the air coming in the sides (Figure 3). So, the seal to the face is everything. Interestingly, almost all masks will filter 99% of viruses and many pleated surgical masks with ear loops can filter viruses; however, without a facial seal they don't protect the wearer. They still do protect others from large particles exhaled by the wearer. The reason why N95 masks are sought after is not just that they are better filters, but that they are designed to provide a better seal on the face. And this is the reason for fit testing, to assure the facial seal.

Masks for consumers are primarily indicated for people with coronavirus infections (known or asymptomatic) to minimize or eliminate the aerosolization of viral particles in the air from their breath or during coughing. The best protection from inhaling viral particles is to stay away from any environment where there are people with viral infections. Alternatively, if a person must be in that area, wearing a tight, face-fitting mask that filters out fine particles is critical.

Conclusion

While no mask can completely provide lung protection, knowing what particles are in the air and their particle size, can assist in making the right decision to wear the right mask. And independent of the filtration capability of the mask, the facial seal is the most import aspect to assure. Whenever in an environment where other people may have viral infections, everyone should be wearing a mask that can demonstrate that it filters small particles (~0.1 micron) and seals well to the face.