# Size Matters

Caoimhín P. Connell

April 14, 2020


In a previous discussion, I addressed people's misconceptions about the validity of wearing "masks" and "respirators" to protect themselves from contracting viruses. But now, I'm seeing a different kind of misconception arising - and that is the actual nature of "masks."

To begin with, for the purposes of this discussion, I'm going to keep the nomenclature simple and refer to all items that people are using to cover their mouths and noses as "masks" (I've addressed the differences in a previous discussion).

In the world of respiratory protection, we have a term called the "protection factor" (PF). The PF is calculated by measuring the ratio of the concentration of the contaminant outside the mask, to the concentration of the contaminant behind the mask (the upstream/downstream ratio). The PF is expressed as a unitless ratio. PFs are listed as "default" or "determined." Default PFs are known as "Assigned Protection Factors." The difference has nothing to do with the mask itself but, rather, is based on whether the person wearing the mask was subjected to a "qualitative fit test" (QLFT), or a "quantitative fit test" (QNFT). Where no fit test is given, the PF of the mask can be assumed to have a PF of zero.

So for example, if a mask has an APF of 10, (the person has been given a QLFT), and *diligently* wore that mask, and the concentration of the contaminant in the air was 1,450 parts per million (ppm), the presumed exposure for that person to that contaminant would be 145 ppm. The very same mask, however, fitted with a QNFT may have a determined PF of, say 2,395. As such, that same person wearing that same mask in the same atmosphere would have a presumed exposure to the contaminant of 0.6 ppm.

The PF, in a practical sense, is a continuum ranging from *virtually* zero, to infinity. That is, ALL masks will, in theory, provide some degree of protection; therefore, even placing your hand in front of your mouth while inhaling, in theory, will afford *some* protection on that continuum. BUT, at what point is the protection so low as to be meaningless? Worse still, as I described elsewhere, when does wearing a mask actually increase the wearer's risk?

Virtually none of the masks presently being used by the general public are *practically* effective. Meaning, the PF is so remarkable low that there is really no point in wearing the mask at all (except when worn by an infectious person to prevent spreading the contagion), and because of the poor practices of the wearer, the mask may actually increase that person's exposure, and they would be better off not wearing ANY mask.

## PARTICLES

For the purposes of this discussion, we are only interested in particles. That is because the issue is the SARS CoV-2 virus, which is a nonliving particle. And I'm going to qualify this further and define "particle" as a "unit mass" particle. Airborne particles may be "monodispersed" (meaning a single, isolated particle), or more commonly, it may be aggregated on droplets, and attached to motes that increase the effective size of the aggregated airborne suspension.

At its two extremes, the virus may be present in "Flügge particles" which are very large, easily visible, aerosolized droplets that are expelled from a person when we speak, cough, sneeze etc. A single Flügge particle could contain thousands of virus particles. At the other end of the spectrum, the virus may be as a monodispersed particle whose diameter is probably somewhere between 60 to 140 nanometers (0.06 to 0.14 micrometers, µm).

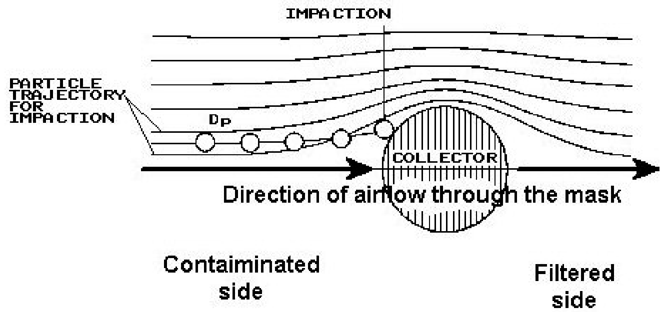
The ability of a filter material to trap and retain particles is based on three modes of capture: 1) Impaction, 2) Interception, 3) Brownian motion.

Each of these modes of capture are based on the size of the aggregated or monodispersed particle in question.

### *Impaction*

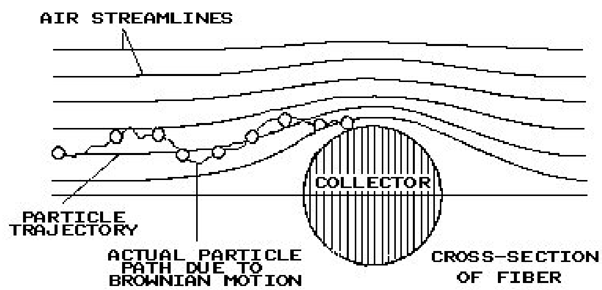
Masks are made from fibrous materials. Therefore, if we look at each fibril under the microscope, we can think of the cross section of the fibril as an idealized circle, as represented in the graphics below as the "collector" (after Kowalski, et al).

As air moves through the filter medium, it curves around each of the fibril in the fabric material. Very large particles have too much mass and can't "turn the corner" to follow the airstream, and "slam" into the fibril. Large particles are easy to capture.



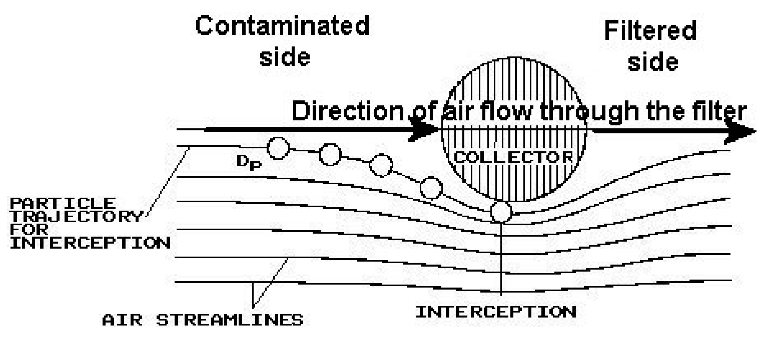

### *Brownian Capture*

Now let's look at the other end of the size spectrum - very small particles. Very small particles move in the airstream in general agreement with the flow, but in the environment of the fabric, the velocities at the interface between particle and collector are low, and the very small particles exhibit a random motion known as "Brownian motion." As the particles "wander" they attach to the collector through a variety of mechanisms including Van der Waals force, etc. Very small particles are EASY to capture.



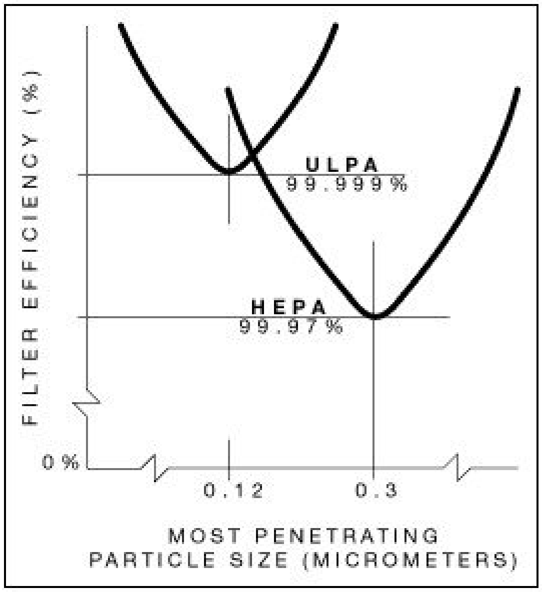

### *Interception*

Now, what about those particles that are small enough to follow the air stream, but too large to be subject to Brownian motion?




As Hamlet said, "Aye, there's the rub." There is certain size of particle that is very difficult to capture when considering just mechanical capture. That size is approximately 0.3 µm. Larger than this: easy to capture; smaller than this: easy to capture.

In fact, if we look at the capture efficiency of a filter material designed to capture particles we see a characteristic capture curve:




The upper curve is for an "Ultra-Low Particulate Air" filter designed to capture and retain 99.999% of monodispersed particulates whose nominal aerodynamic diameter is 0.12 µm.

The lower curve is for an High Efficiency Particulate Air (HEPA) filter which is a filter designed to capture and retain 99.97% of monodispersed particles with a nominal aerodynamic diameter of 0.3 µm.

Now, unfortunately, the SARS CoV-2 virus just happens to be in the range of particle sizes that is the most difficult to capture and retain by fabric filters.

### *Channeling*

As velocity of air flow increases, resistance to that flow also increases in a nonlinear fashion. That means that as the velocity of the air across the filter increases, the resistance to that flow increases disproportionally. The resistance across the filter is known as the "pressure differential" or delta-P ($\Delta P$).

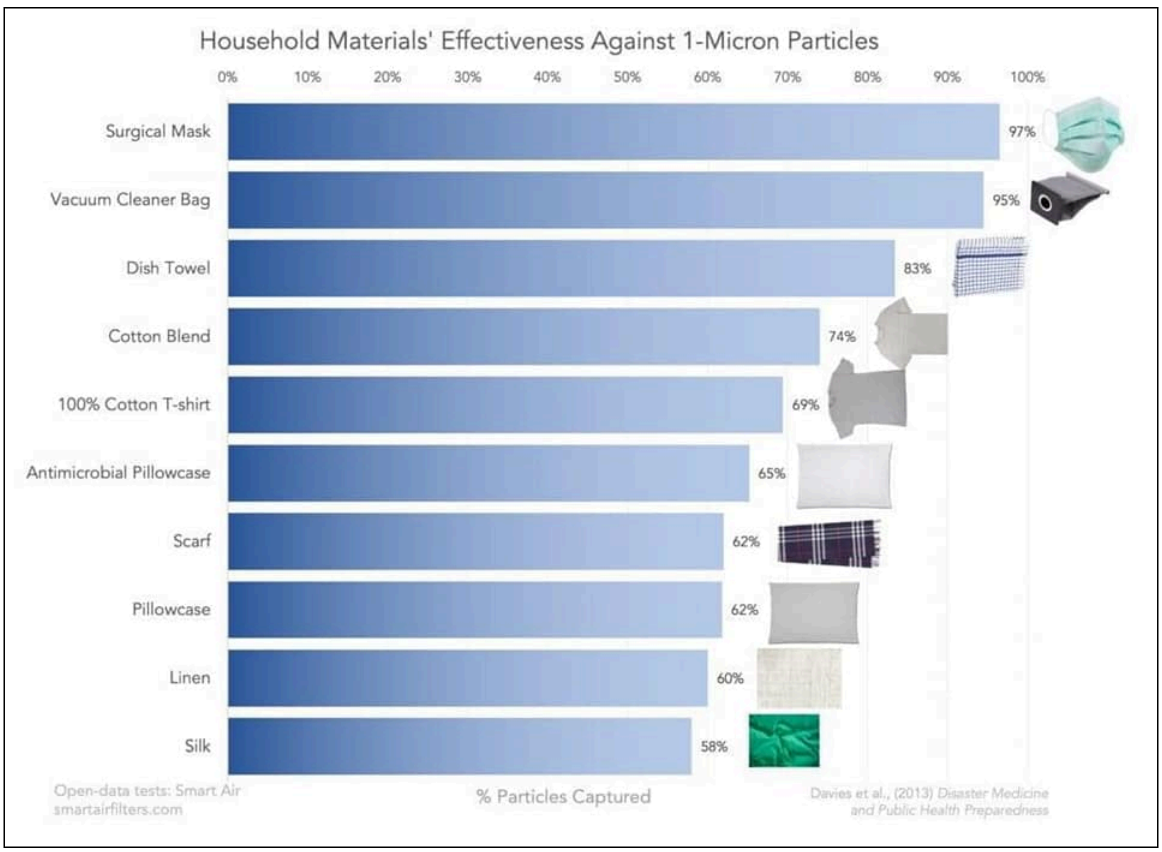
Air, being a formless fluid, moves from high pressure to low pressure along the path of least resistance. As the resistance to flow through the filter increases, the air will seek ways to flow to the low pressure side without going through the filter. That is, the particle laden air will go around the filter material, this is known as "channeling."

Obviously when this happens, the air is not filtered. Channeling occurs in ALL lose fitting masks such as surgical masks, bandanas, and all other masks. Therefore, even if one has a *material* identified as an HEPA designed material, unless the material forms a sealed assembly that decouples the outside air from the filtered side air, channeling occurs and the air is not optimally filtered.

Channeling is just one of the many reasons that the homemade masks, bandanas and other non-NIOSH approved respirators/masks have vanishingly low PFs and therefore afford virtually no protection. Imagine that it takes only ten virus particles to result in an infection and the person is wearing an home-made mask with a PF of 1.01 (a realistic PF). That person walks through an aerosol of 10,000 virus particles resulting from a single sneeze from an infected person. The mask has filtered out 1% of those particles. That person has inhaled 9,900 virus particles. Has that mask provided the individual with any practical protection? No - the resulting exposure is still 990 times greater than that needed to result in an infection.

When we see a "NIOSH Approved" device, and that device has a "TC Number," that device AS AN ENTIRE ASSEMBLY, meets the criteria for that certification - not just the material.

**Filtering Materials**
What prompted this particular discussion was a post I saw today (April 14, 2020) on FaceBook. That post had a graphic of various materials and their supposed capture efficiency - perhaps you've seen it:




The post is very misleading for a variety of reasons. The first reason is that the graphic seems to indicate something that the original authors (1) never intended.

When these materials were tested, the materials were fitted in a frame such that the system was air-tight. That is, there was no channeling and the air was forced through the filtering medium. The second aspect of the study looked at how well the homemade mask prevented the dispersion of aerosolized emission FROM the wearer into the occupied space - NOT how well the homemade device protected the wearer from contaminant already inside the occupied space. Furthermore, the results were expressed as particles of unit mass, nominal 1 µm.

Not included with the graphic circulating on Facebook, is the author's recognition that

> "*Although any material may provide a physical barrier to an infection, if as a mask it does not fit well around the nose and mouth, or the material freely allows infectious aerosols to pass through it, then it will be of no benefit.*"

Remember our spectrum of protection discussed above.

The ultimate conclusions from the authors responsible for the data used in the graphic is:

> "*Our findings suggest that a homemade mask should only be considered as a last resort TO PREVENT DROPLET TRANSMISSION from infected individuals, but it would be better than no protection.* "

Importantly, again, the study from which the circulating graphic is taken looks at how the mask reduces the contaminant COMING FROM an "infected" person, NOT how well the mask PROTECTS the person wearing the mask.

So, however unpopular the opinion is, based on my personal observations of people wearing a variety of "masks" in public during this outbreak, it is my professional opinion that those people would be better off NOT wearing any mask, and instead, adopting good personal hygiene.

The above statement has as much to do with the practices of wearing the masks as it has to do with the actual devices themselves.

In conclusion:

Bad devices + bad practices = increased risk.
Excellent devices + bad practices = no benefit
Excellent devices + good practices = very good benefit
Excellent practices in the absence of any devices = very good benefit

References:
1) Davies A, Thompson K, Giri K, et al, *Testing the efficacy of homemade masks: would they protect in an influenza pandemic?* Disaster Med Public Health Prep. 2013 Aug;7(4):413-8. doi: 10.1017/dmp.2013.43.