The Myth that "Viruses" are Too Small to Be Captured by HEPA Filters

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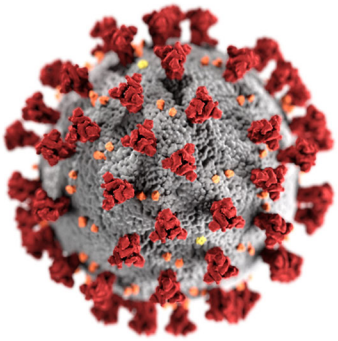

COVID 19 Virion (Source: Wikipedia)

Vs.

HEPA Filter with Stick embedded in it

A Look at COVID 19 in Terms of: 11. HEPA Filters & Virions:
The Myth that "Viruses" are Too Small to Be Captured by HEPA Filters

Andrew A. "Tony" Havics, CIH, PE
pH2, LLC
5250 E US Highway 36, Suite 830
Avon, IN 46123
(317) 7218-7020 Office
(317) 409-3238 Cell

Introduction

This is a continuation of a series of papers on COVID 19 with respect to health & safety. It focuses on the myth that viruses (more accurately called virions) are too small to be captured by High Efficiency Particulate Air (HEPA) filters. Like the other papers, this paper is intended to provide the facts and research support where available, and then draw from that as well as the author's experience to provide recommendations based on the weighting of the evidence. The data provided here, and the conclusions, cannot be maintained in a vacuum, thus other COVID 19 topical papers are intended to follow this one, but each will hopefully be sufficiently self-contained to be useful and reliable. The intended audience of this paper is professionals. This includes industrial hygienists, occupational and public health professionals, health and safety practitioners, and medical personnel. It is not intended for the general public, though many individuals may benefit from reading it.

Virus Size and HEPA Capture Efficiency

The author has heard or read a number of individuals that they are concerned that viruses are smaller than 0.3 µm in size and thus High Efficiency Particulate Air (HEPA) filters will not efficiently capture them. This was stated in the article by Dietz[(1)]. Viruses (actually virions as particles) are typically 20-180 nm (0.02-0.18 µm) in size. COVID 19 (SARs-CoV-2) is in the range of 78-90 nm (0.078-0.09 µm)[(2, 3)]. HEPA filters, used in respirators and air filtration devices, are tested to be 99.97% efficiency at 0.3 µm aerosol size because the most penetrable particle (MPP) size is nearer 0.3 µm (in the range of 0.1-0.45

µm), depending on the filter media characteristics and the flow rate. The efficiency both below and above that most penetrable particle size is better than 99.97%. This is because there are multiple capture mechanisms (interception, inertial impaction, diffusion, gravitational settling, electrostatic attraction) and each has its own capture efficiency. The sum of these produces a capture curve that has a shape like that in Figure 1 (Figure after Vincent[4]).

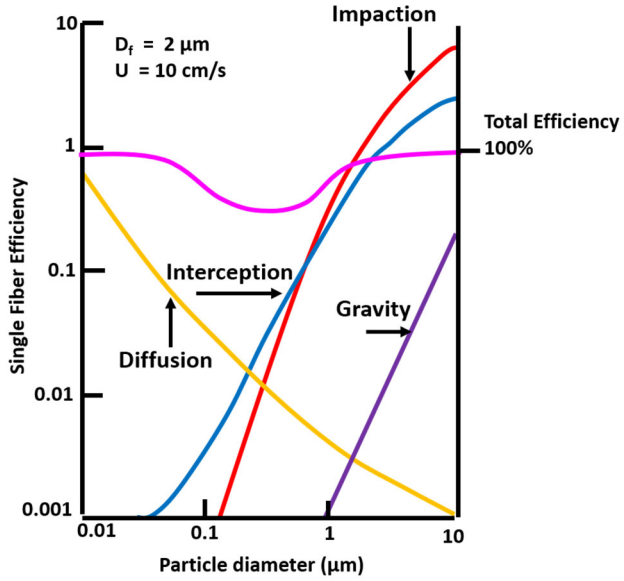

Figure 1. Filtration Mechanisms & Combined Efficiency (after Vincent, 1995)

In terms of viral penetration, M2 Phage was tested on a single HEPA layer at various flow rates and found to have lowest efficiencies of 99.92-99.97% at the MPP size of 100-200 nm (0.1-0.2 µm)[5]. M2 Phage was also used to test P100 filters by electrosprayed aerosol by Eninger[6] in the range of 10-100 nm (0.01-0.1 µm) and found to have a 99.39% efficiency.

N95 filter Efficiency

P100 filters are the typical HEPA filter designation for use in respirators. Other HEPA filter types, N100 and R100 filters are also 99.97% efficient, but are Not (N) Oil Resistance, or are Oil Resistant (R), but not Oil-Proof (P) as in P100. This means that their (N100 & R100) filtration efficiency may degrade in certain oil-aerosol environments, including at the MPP size of around 0.3 µm. On the other hand, N95 Filtering facepieces (N95 FFs) tend to have a maximum penetration between 0.040-0.200 µm[7-13] (See Figure 2 below from Eshbaugh[11]) and are also affected in oil-aerosol environments. N95 efficiency curves are also similar to the HEPA in that the efficiency increases at both less than and more than the most penetrating particle (MPP) size.

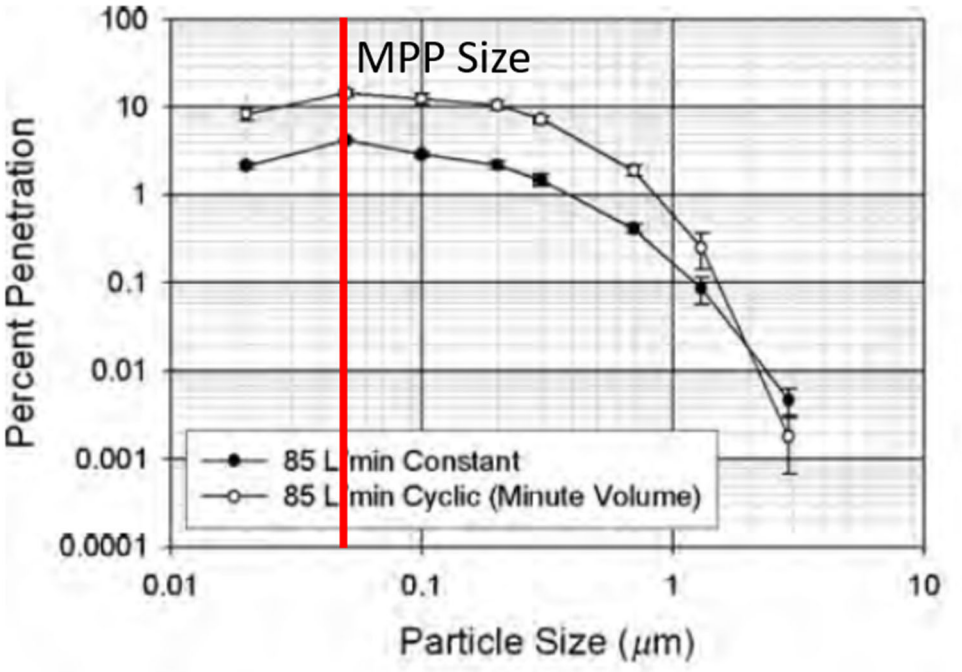

Figure 2. MPP for N95 (from Eshbaugh, 2008)

N95 FFs have smaller MPP sizes than HEPAs and lower efficiencies than HEPAs (a minimum 95% at the MPP versus 99.97% at the MPP for HEPAs). Despite a lower efficiency than HEPAs, N95 FFs perform well in terms of having an electrostatic collection potential. However, for NIOSH testing, the test particles (small Sodium Chloride [NaCl] salt particles) are charge neutralized in an attempt to get worst case conditions. In the real world, these filters should perform better as most particles do not have their charges neutralized. The difference between positively charged, negatively charge and neutralized charged particles can be seen in Figure 3 (from Han[12]). The relatively good collection efficiency for N95 FFs is not typically present for surgical masks. The weight of the evidence clearly indicates poor performance by surgical masks, but generally sufficient performance for N95 FFs when worn properly[14].

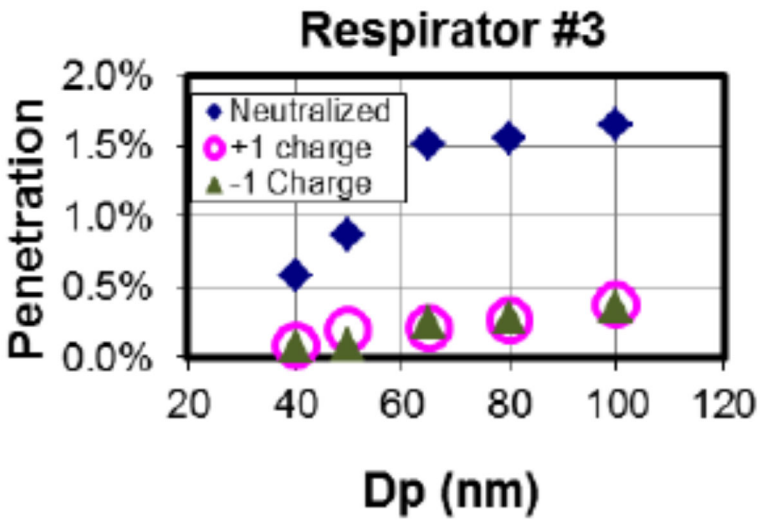

Figure 3. Effect of charge on particle penetration (From Han, 2012)

Filter Efficiency of Minimum Efficiency Rating Value (MERV) rated Filters

An efficiency curve with an MPP size also occurs for MERV rated filters (see Figure 4 below from El Orch as found in NAS[15]). Efficiencies both above and below about 0.3 µm increase rapidly for all MERV ratings[16], and MERV ratings of 13 -16 are reasonably effective to very effective at reducing virions, based on singular size alone[17-19].

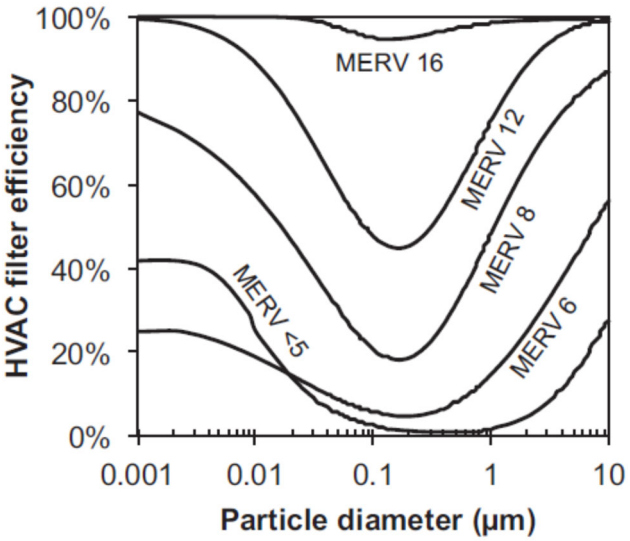

Figure 4. Filtration efficiency for MERV ratings (from El Orch, 2014).

As singular bioaerosols, viruses, bacteria, fungi, and pollen cover fairly specific ranges. However, in general, one finds a broad-based range of sizes that includes aggregates and microbial fragments (see Figure 5 below from NAS[15]); many are larger than 0.3 µm. Thus, from a practical sense, higher rated

MERV filters (13-16) will work well on many particles and even MERV 12 will perform well on a variety of practical particles sizes.

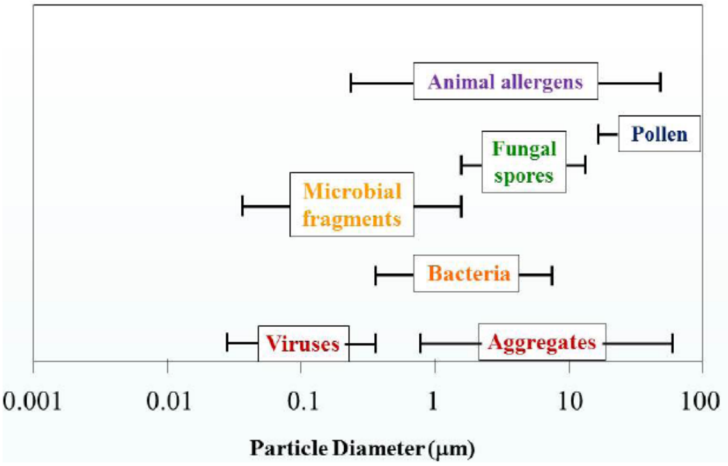

Figure 5. Bioaerosol sizes (from NAS, 2016)

Particle Generation & Sizes for Coughs & Sneezes

One must also consider real conditions for viral aerosols. One expects these aerosols to be created/emitted by coughing and sneezing of symptomatic individuals as well as aerosol generating medical procedures (AGMP)[20] involving these symptomatic persons. These AGMPs might include: intubation, ventilation, suctioning, manipulation of oxygen mask, cardiopulmonary resuscitation, and bronchoscopy[21, 22]. These AGMPs are expected to produce similar patterns to coughs and sneezes.

Coughing and sneezing produce a wide variety of aerosol sizes depending on the action, the person, and the age of infection[23-31]. Although, coughs and aerosolization actions produce droplets < 100 nm (<0.1 µm), the bulk of droplets are > 100 nm (>0.1 µm)[23, 25], even though the source of the aerosol can be associated with the concentration[31]. See Figure 6 below showing particle production per cough and sneeze by size based on a combination of references cited above.

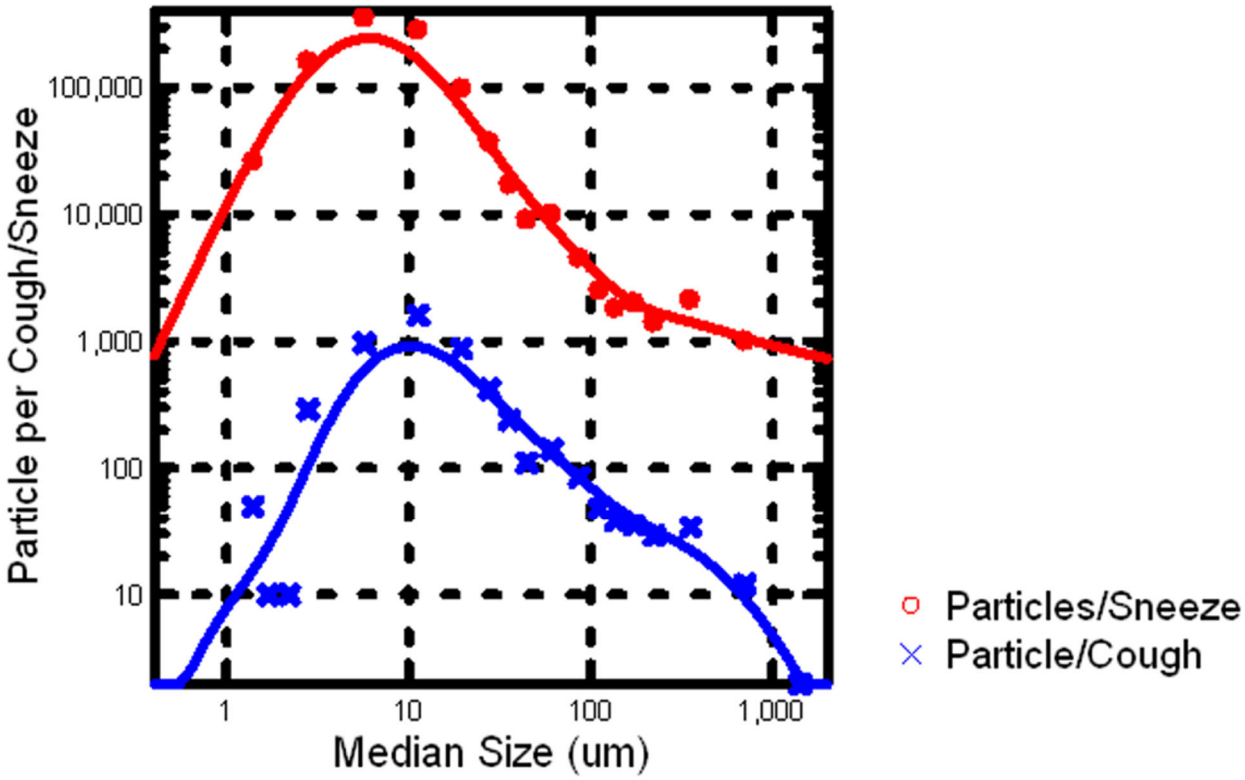

Figure 6. Particles generated/emitted by sneezes and coughs.

Viral Fraction & Survivability

In addition to aerosol sizes, one must consider which fractions contain viable virus material. Virus survivability has been shown to be dependent on virus type and particle size. Survivability of the three animal viruses in large particle size aerosols (300–450 nm) was significantly higher than at particle size aerosols close to the size of the virion (100–200 nm)[23]. MS2 phage aerosol showed a 5% viability at approximately 0.2 µm (aerodynamic size), 50% rate at about 0.5 µm, and a 99% viability at 3 µm and above[32]; thus a greater importance of particles greater than 0.3 µm emitted from infected individuals. M2 phage showed capture efficiency rates of 99.78-99.999+[32] for HEPA filters, indicating good efficiencies on more realistic bioaerosols. Pan[33] too found a steady increase in infectious M2 phage beginning at a particle size 100 nm (0.1 µm) and increasing from there. Eninger[6] noted that while purposefully aerosolizing M2 phage, that "the nebulized particles in the 23–26 nm range were composed primarily of contaminant and solute residues", e.g, the viral material was not found in these smaller particles which is consistent with Pan's data. Thus, again, the focus towards (relatively speaking) larger particles.

In terms of overall aerosols, the "fine" (< 5um) fraction have higher viral content than the "coarse" (>5 µm) fraction of particles expelled[24, 26]. Even though the filters (when used properly[A]) will capture

[A] Respirators with P100 filters, N95 FFs, etc. must be worn properly (good seal, straps positioned correctly, etc.) or they will quickly decrease in effectiveness. The same goes for HEPA filters used for ventilation applications; these must have proper seals in the housing or devices in which they are set. Often, this is not the case in real world applications.

particles smaller than the MPP more effectively, the majority of aerosol sizes will be greater than the MPP and thus will be captured more efficiently.

Conclusion

The bottom line is that HEPA Filters will work well on virions (viruses), and so will N95 FFs. The myth that viruses are too small to be captured by HEPA filters needs to be eradicated.

Acknowledgements

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