Filters and HVAC Selection Webinar

September 10, 2020

Hosted by the McIlvaine Company

The Challenge of Small Aerosols

A large amount of the virus is being transmitted by small aerosols either directly or after a stop on an inefficient mask, filter, or other surface.

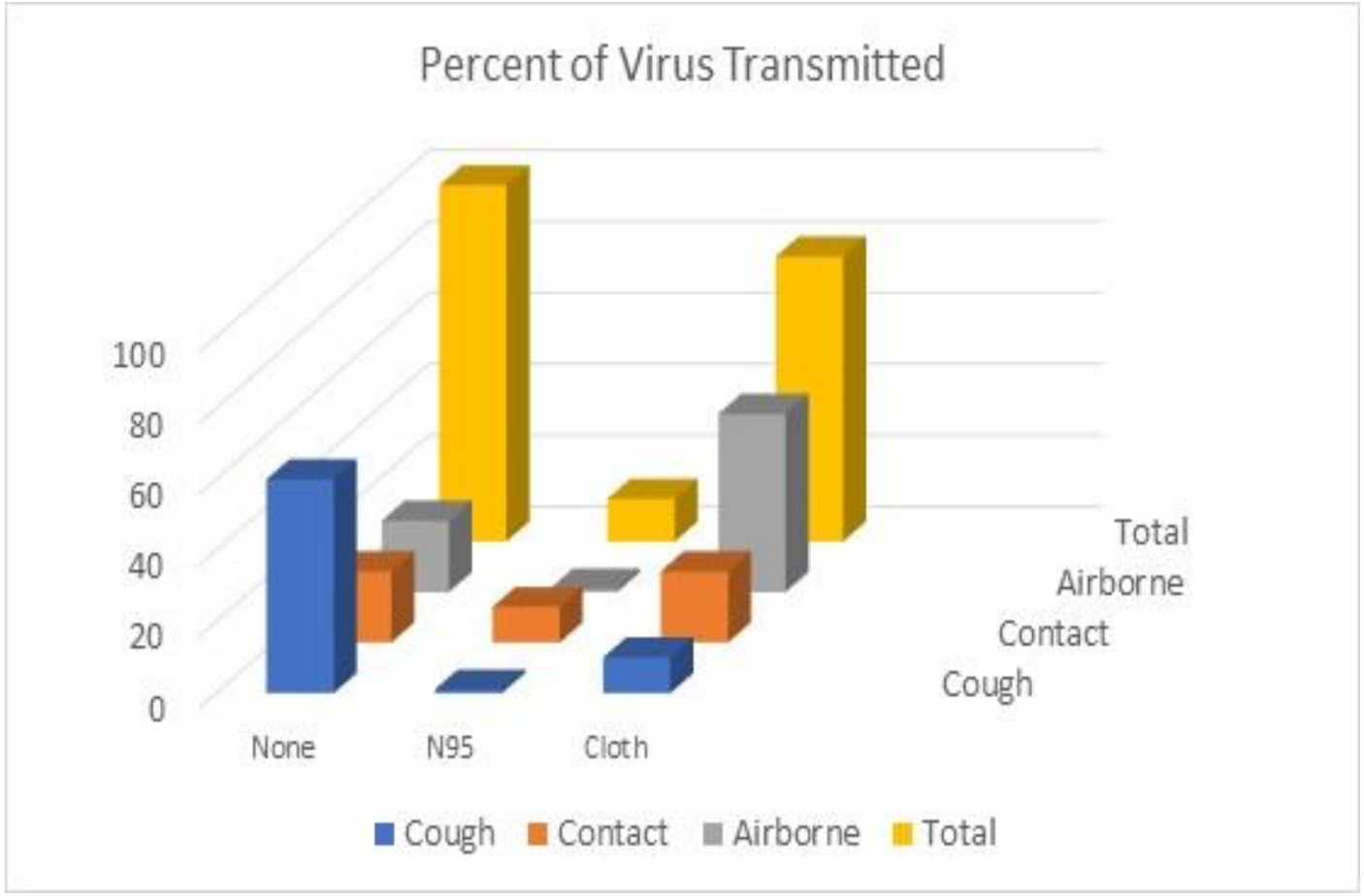
McILVAINE

Filters Challenged by Aerosol Generation from Cloth Masks

New research shows that small aerosol transmission is the major source of COVID. But even if 60% was originally in cough droplets captured on cloth masks there is the potential for the droplets to be converted to aerosols.

The result is that cloth masks are not effective in preventing virus transmission to others and are even more ineffective in preventing infection of the wearer.

Aerosol generation is also occurring from droplets captured on MERV 8 and even MERV 13 filters.

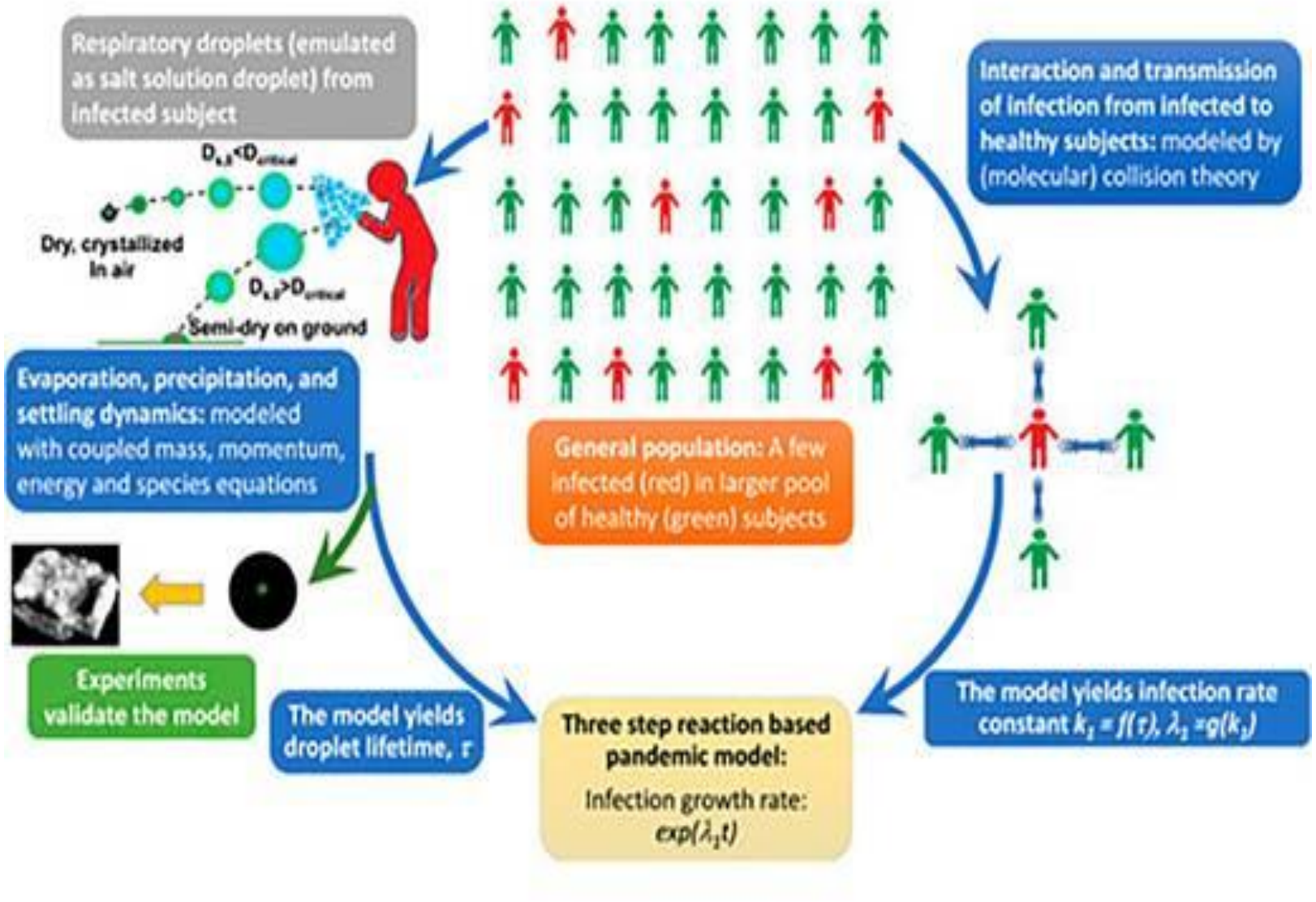


Indoor air quality is important for many reasons in addition to COVID WFI just held a webinar on the subject which can be viewed at [Open Educational Webinar]

What Happens to Virus in Cough Droplets?

Droplet evaporation and modeling is discussed in a McIlvaine interview with Abhishek Saha, a professor of mechanical engineering at the University of California San Diego.

The model can also be used to calculate aerosol generation from cough droplets on mask interiors.



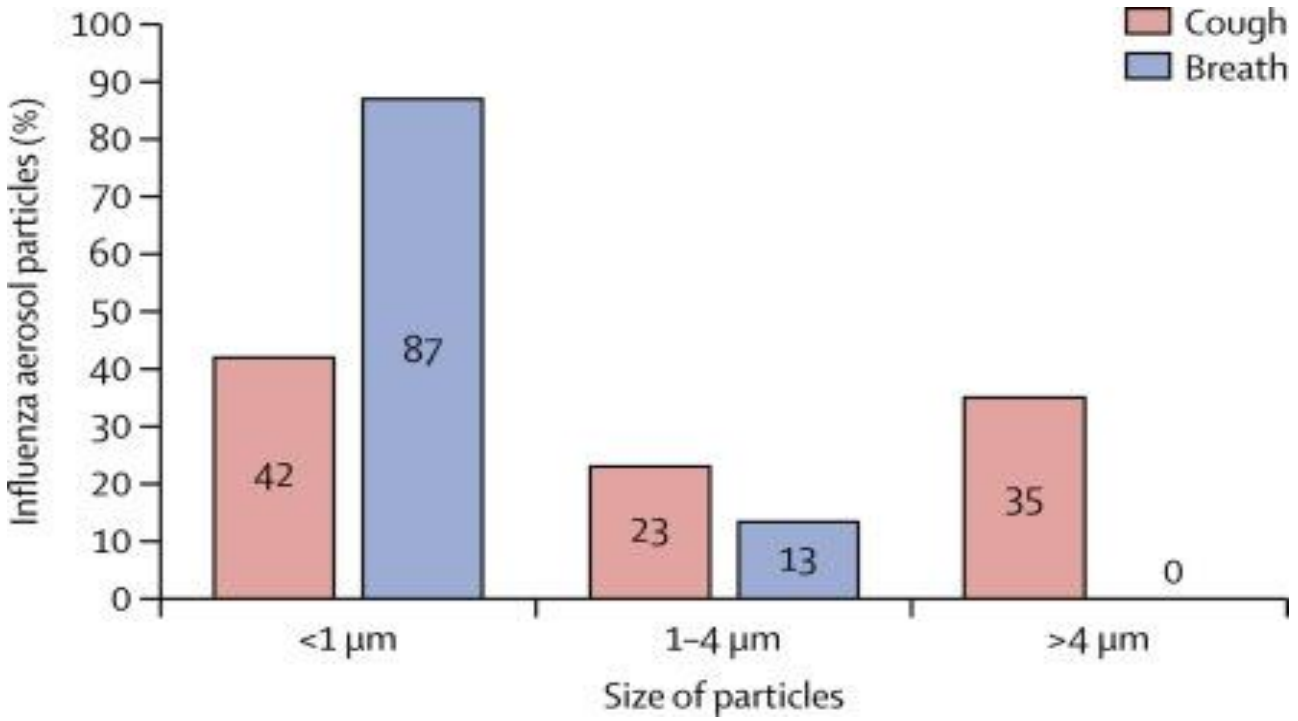
McILVAINE

New Research Indicates That Cough Droplets Are Small Enough To Easily Penetrate Cloth Masks and Inefficient Filters

This NIH Viewpoint suggests that infection control guidelines should be re-evaluated to account for the predominance of small particles within infectious aerosols.

Protective devices available to health-care workers have a range of protection, increasing from surgical masks to filtering facepiece respirators to powered air-purifying respirators. Although these are indicated for close encounters, their limitations highlight the need for improved administrative controls, such as more rapid diagnosis and isolation, and the development of vaccines and treatments.

These data support calls for the recognition of aerosol (i.e., traditional airborne) transmission of SARS-CoV-2.



McIlvaine *Coronavirus Technology Solutions Alert* - July 28, 2020

McILVAINE

Inefficient Media is an Aerosol Generator?

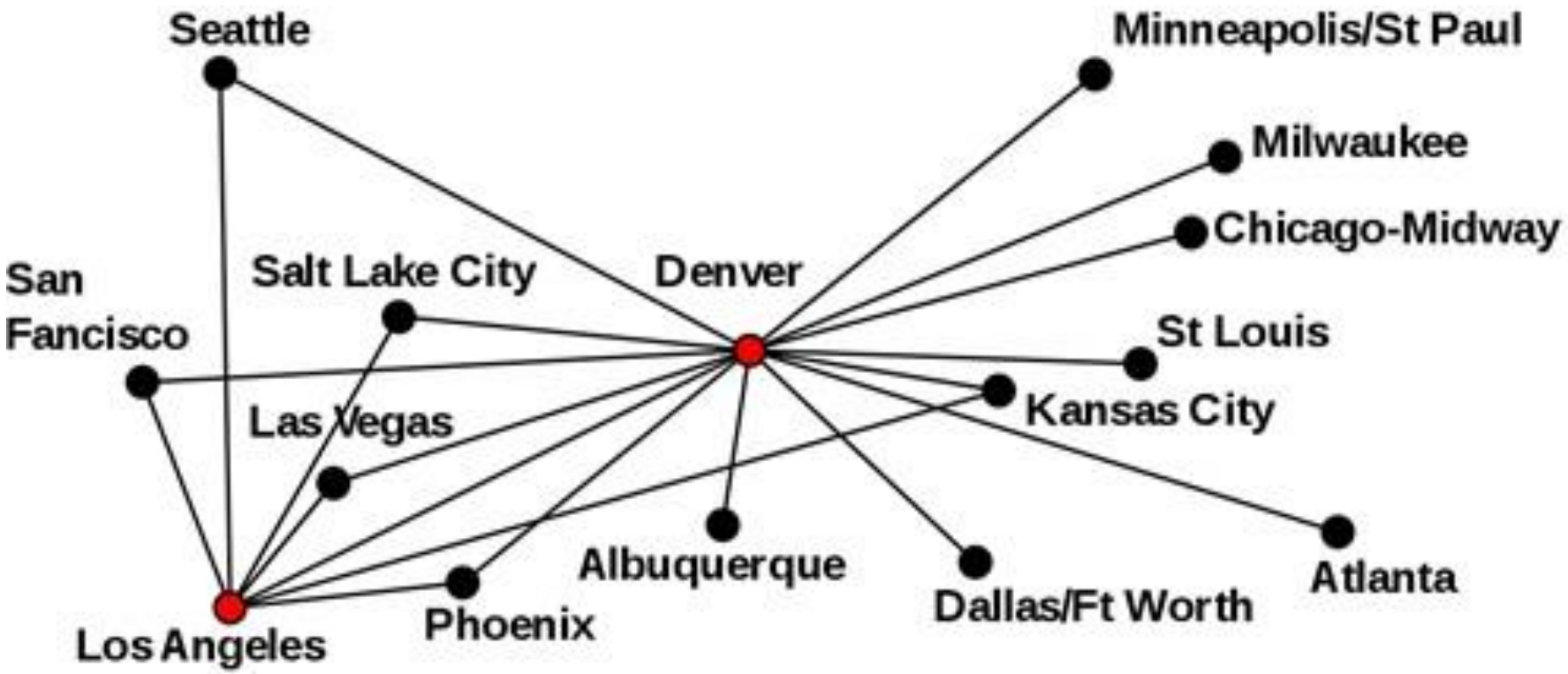
Droplets on an inefficient filter media can be visualized as rain drops on a screen. One difference is that with filter media the droplet will be subjected to many forces. The velocity of inhaled air will be relatively uniform across the mask. But the velocity of exhaled air will be uneven.

The August 18th Alert documents jets of air escaping a loose-fitting mask. In the August 11th Alert Duke documents more droplets being generated with an inefficient mask than with no mask.

Another Alert documents finding more virus outside the mask than inside.

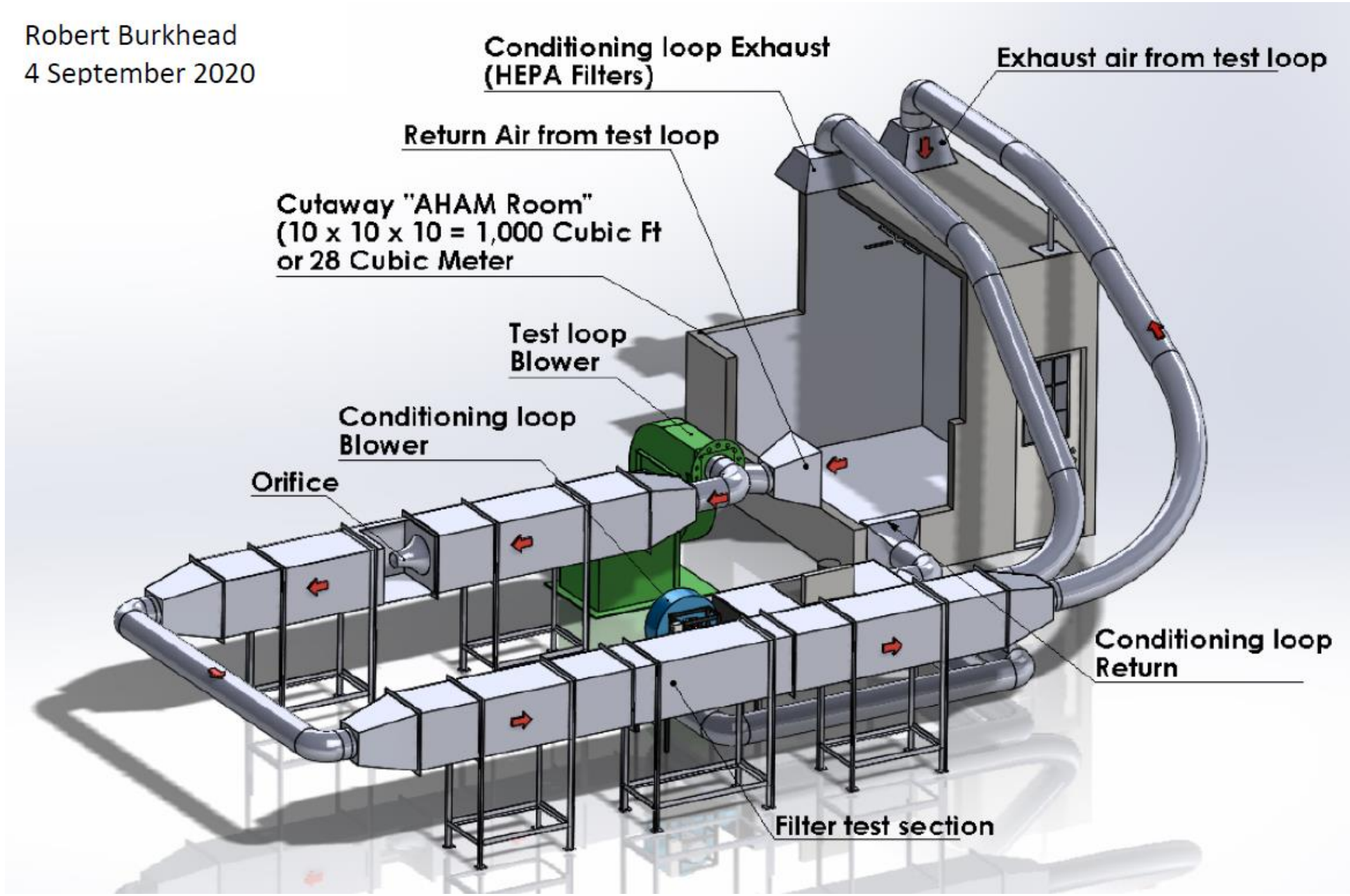
The continuous air flow across an inefficient filter will evaporate droplets and transport small droplets and nonvolatile residues.

To measure the potential virus transmission of airline travelers from Seattle to Atlanta you need to take into account one stop as well as direct flights. The same is true for masks and filters. We need a new testing protocol.



McILVAINE

Robert Burkhead
4 September 2020



Cabin Air

Freudenberg says “Contaminated particles inside a vehicle cabin rarely pass directly into the air filtration system. Initially, they are much more likely to settle on and around the air vents or on the upholstery and other surfaces. They remain actively infectious in such places for anything from a few hours to several days. At the same time, even if they are not passed on by touching, they will become airborne again in regular cycles as a result of wind disturbance, changing humidity levels, wiping or simply the vibration of the vehicle.”

This can be extended to the masks worn by the Uber driver and his passengers. If they are wearing cloth masks, then the breathing will be a much more effective aerosol generator than the vibration of the vehicle.

If the cabin air filter is H-13 or higher it should prevent most aerosol generation from the filter media.

In the case of the Freudenberg three phase system once the filter captures the virus, it is deactivated through an approach based on natural fruit extracts which prevents secondary contamination. The virus interacts with the fruit extract’s acid environment. The reaction causes the rendering or denaturation of the virus’ protein structure, giving a harmless pathogen unable to infect human cells.

Ford is installing filters with the citric acid proprietary compound from Freudenberg

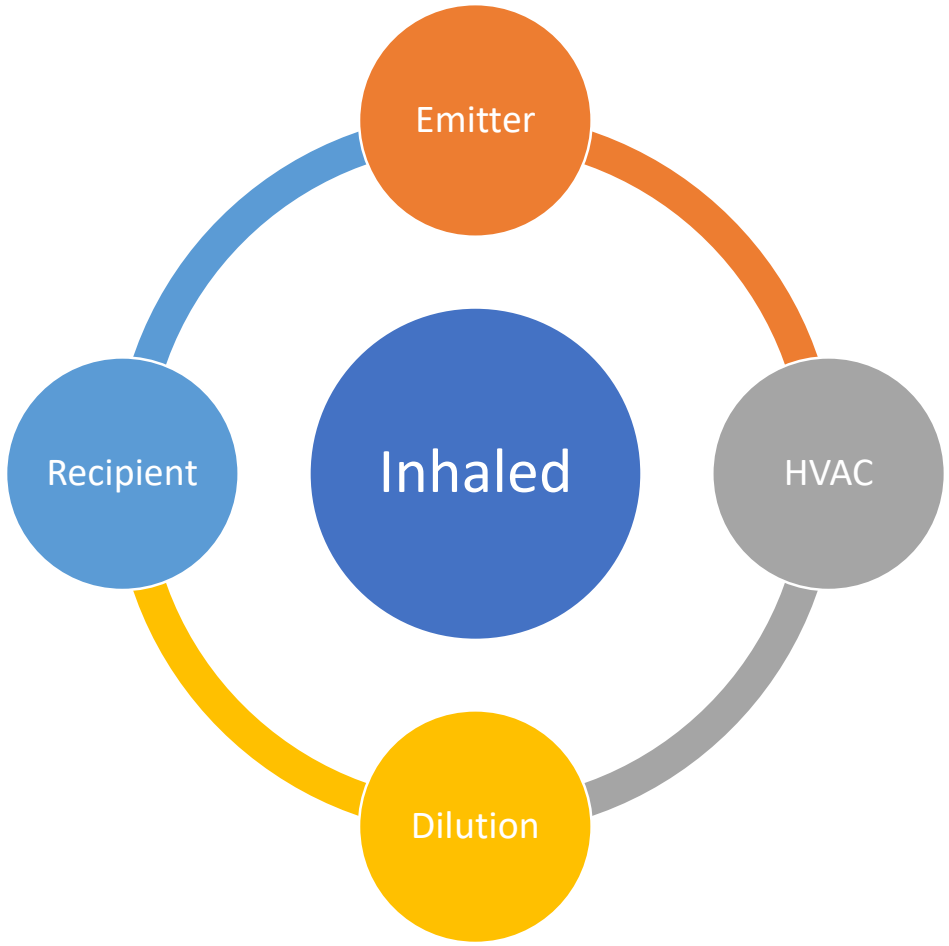
The Ford micronAir proTect is capable of trapping very small particles down to 0.05 microns – less than a thousandth the thickness of a human hair. If mounted on the vehicle's ventilation system, it can dilute the concentration of harmful particles entering the cabin and remove droplets containing viruses as quickly as possible, reducing the possibility of further contamination and infection.
The filter features an activated carbon element designed to offer additional protection against harmful pollution, such as particles and acid gases, and a multilayer microfiber barrier that retains the smallest particles, dust and pollen.
In addition, the filter acts actively against some agents that are located in the passenger compartment, demonstrating a **99.9% effectiveness in inactivating the viruses** that come into contact with the special active layer. (*) These include swine flu (H1N1) and the HCov-229E virus. Current conditions make it too dangerous to test the filter against SARS-CoV-2, the coronavirus that causes COVID-19-related disease, but Freudenberg estimates 99.9% effectiveness in this case too.
Coronaviruses spread in droplets produced when affected people sneeze, cough or breathe and can remain contagious on surfaces for hours or even days. Wind, changes in temperature and humidity can put these particles back into circulation, which, at that point, can be picked up by the filter.

Risk of Infection Compared to Cost of Prevention

In the August 18th Alert the model for assessing infection risk prepared by the U. of Colorado, is discussed. Parameters include infection rate in the population, space conditions, virus release quantity per infected individual and time spent in the space. It includes the mask efficiency of emitter and recipient.

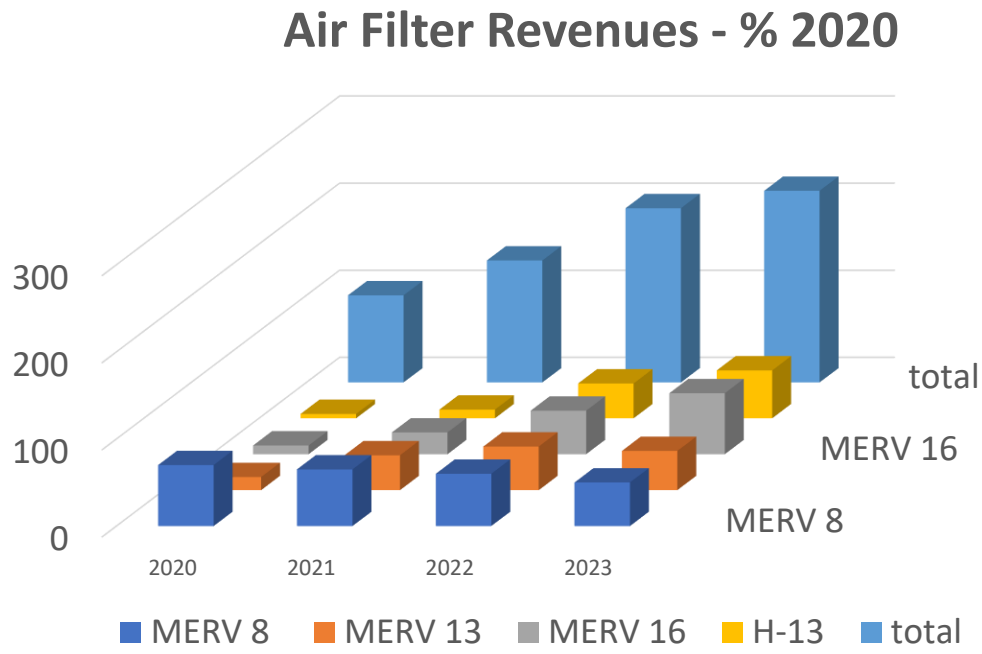
A more sophisticated version should include air flow direction, dilution and HVAC filter efficiency. In the circular example the clockwise flow provides maximum protection whereas counterclockwise provides little protection.

The cost of highly efficient masks and filters and good laminar air flow can be compared to the lives saved.



McILVAINE

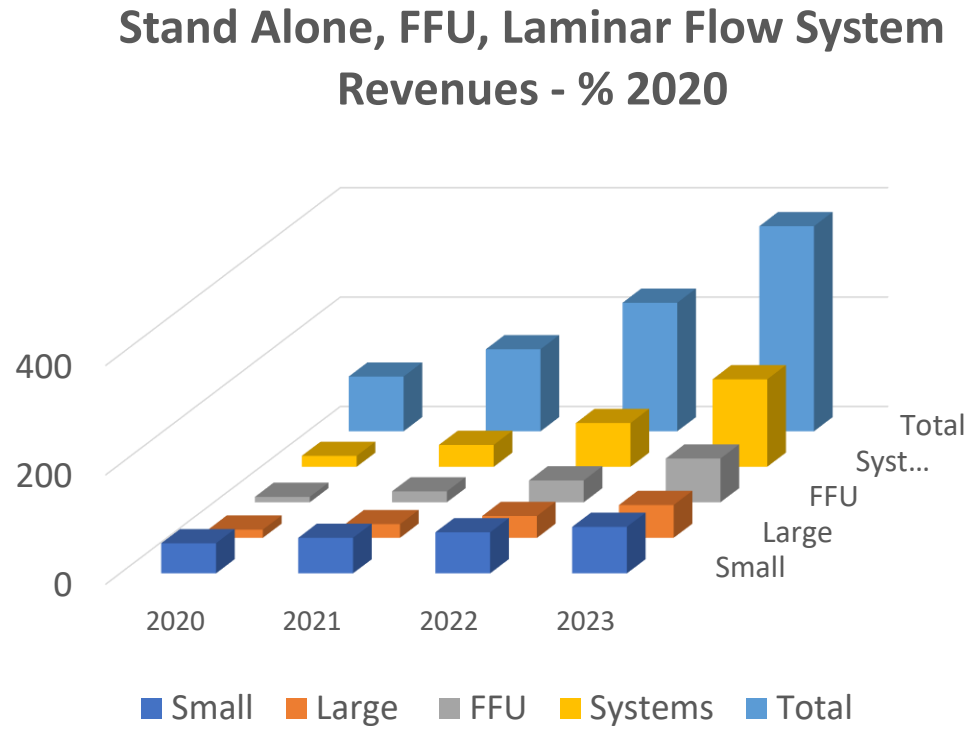
Evidence is growing that highly efficient air filters will be needed to vanquish COVID. A proactive program by filter and media suppliers would greatly reduce COVID and generate very large revenues for suppliers of media and filters.



MERV 8 filters will not remove more than 15% of the viruses. MERV 13 filters will remove about 40% of the virus. The MERV 16 filter will remove close to 70%. The market for high efficiency filters with a proactive supplier program is forecast to grow 10-fold over the next 4 years. The MERV 14-16 market will grow 7-fold.

McILVAINE

Room air purifiers, fan filter units, and laminar flow systems will be critical to preventing the spread of COVID. There is already a market for small air purifiers but growth in larger units will be the trend in the future.



There will be high growth for fan-filter units which will be a better solution than partitions. The best solution is controlled laminar air flow systems with HEPA filtered air. They will find increasing use in nursing homes, meat processors and other applications in addition to their present use in cleanrooms and hospital operating suites.

McILVAINE

Value Rating System

McILVAINE

Value Factors

- The decision to purchase an H 13 vs MERV 8 filter can be justified by the value rating system if properly applied. Quality Enhanced Life Days (QELD) is an important component

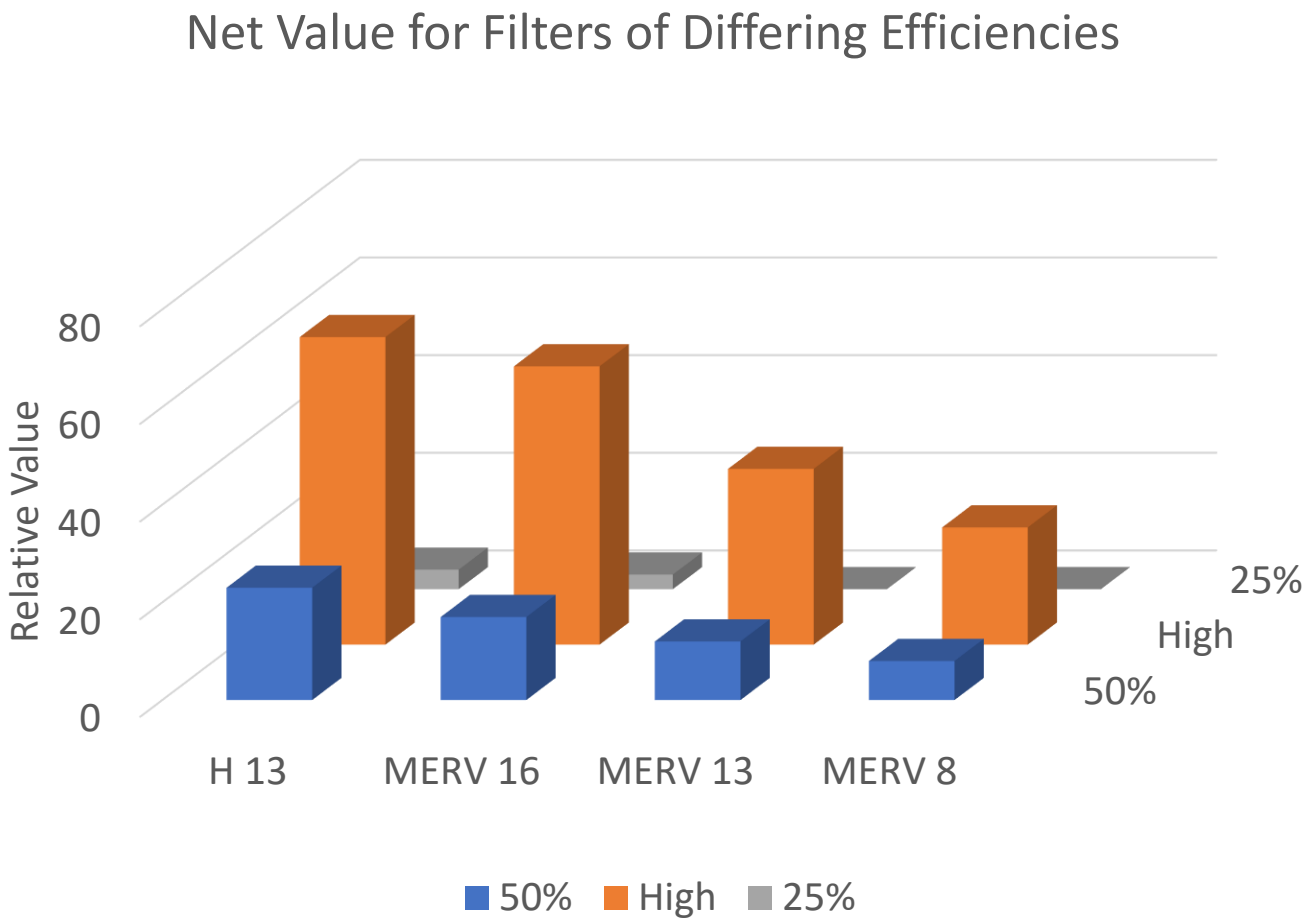
Factor	Description
Value	Lives saved, sickness averted, life quality costs avoided
Effectiveness	Efficiency of the device in removing the virus
Applicability (virus load)	The percentage of the virus load which will enter device
Economic Cost	Capital and operating cost of the device as a % of value
Life Quality Cost	Life Quality Costs as measured by QELD
Net Value	Percentage of total value remaining after reductions

Value x effectiveness x applicability (load) minus economic and life quality costs = net value. However assuming that the virus load is only half as much the net value of the more expensive filters is greatly reduced.

Product	Effect-iveness	High Load	50% Load	25% Load	Econ Cost	Life Qual Cost	Net High	Net 50%	Net 25%
H13	99	80	40	20	16	0	63	23	4
MERV 16 +	90	80	40	20	15	0	57	17	3
MERV 13 +	60	80	40	20	12	0	36	12	0
MERV 8+	40	80	40	20	8	0	24	8	0
Net H 13-MERV 8 Differential							39	15	4

McILVAINE

The cost of COVID is so high compared to the cost of increasing filter efficiency that even at a 25% virus load factor there still is an advantage for the H 13 filter. This value is increased further by the addition of the air pollution control benefits.



Product	Effect-iveness	Applicability	Net\effect	Econ Cost	Life Quality Cost	Net Value
N95 Mask No Valve	95	95	90	-10	-15	65
N95 Mask Valve	85	98	83	-10	-10	63
Cloth Mask	20	100	20	-5	-5	10
MERV 16 +	90	80	72	15	0	57
MERV 13 +	60	80	48	12	0	36
MERV 8+	40	80	32	8	0	24
Lockdown	95	70	66	-30	-30	6
Room Air Purifiers	80	40	32	-15	-3	14
Social Distancing	50	60	30	-5	-15	10

McILVAINE

This net value ranking is completely at odds with what has been advised by CDC and WHO. However, it is consistent with the ranking to fight air pollution or measles. In both cases the assumption is that if there is a source it will be airborne for long distances.

There are some who argue that there is not sufficient proof that the virus will remain viable after being airborne. There has been lots of indirect evidence where other causes were eliminated. Now we are seeing direct evidence where with new sampling methods which do not damage the virus there are viable specimens being captured.

There are some who argue that the small amount of virus conveyed by small droplets is not going to be infectious. New evidence shows that the quantity of virus in small droplets emanating directly from lungs is much higher than in cough droplets which are composed of mucus with diluted virus quantities.

The fact that surfactants make up about 4% of large droplets means that as these droplets evaporate on the mask or filter surface the surfactant concentration will increase and the surface tension be reduced to make the formation of smaller droplets easier.

McILVAINE

Factors Shaping the Market

The following factors are shaping the market and are being continually assessed

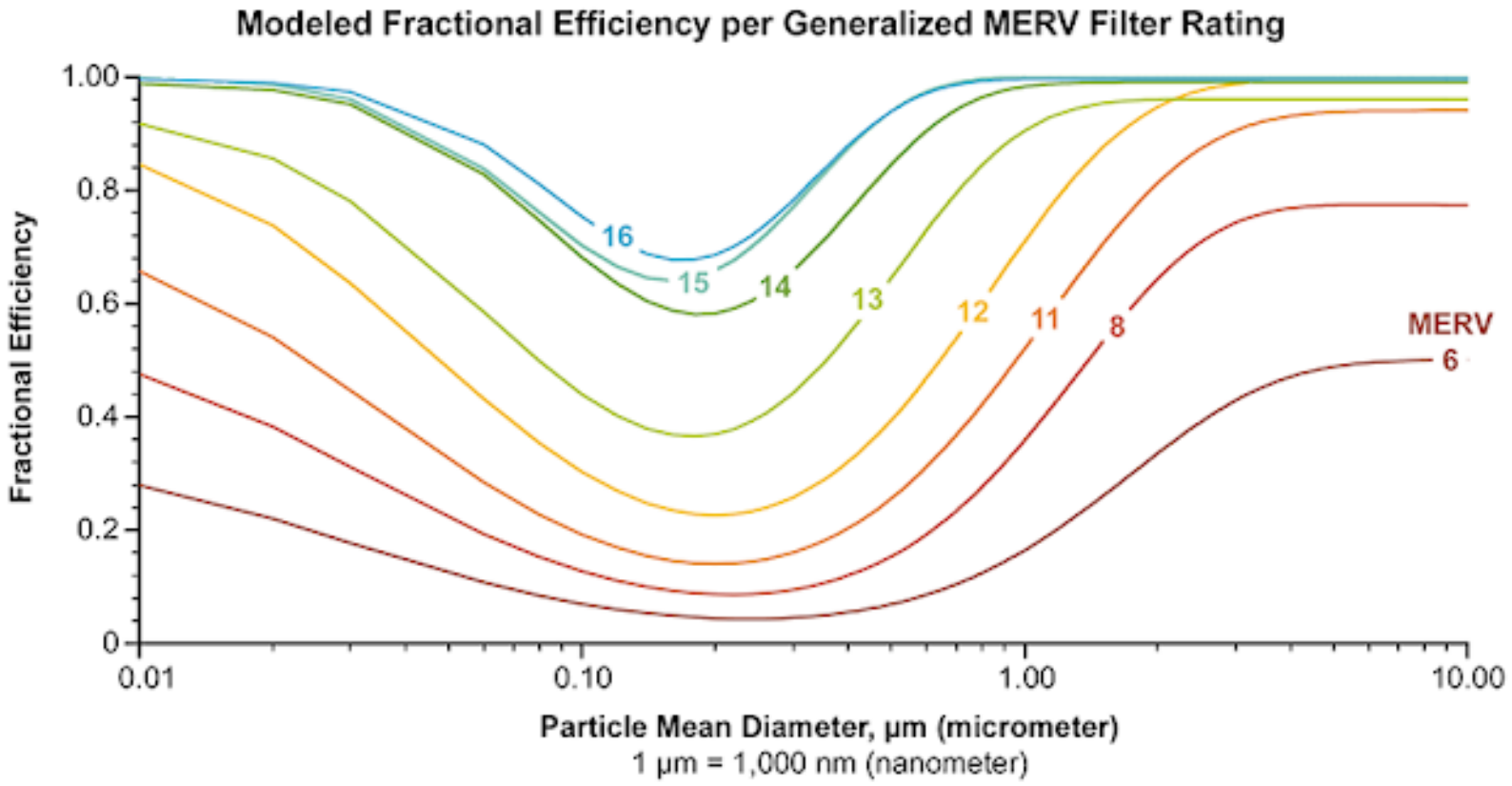
Issue	Aspects
Virus Parameters	Size, quantity, minimum infectious load, life, destruction methods, deposition on duct internal surface, distance traveled
Treatment Types	Filtration, ionization, UV disinfection, precipitators, carbon beds. What is the performance and how widely is each used? Are combinations used and is this a benefit?
Filter Design	Pleated, panel, box, pocket
Filter Media	Membranes vs micro fiberglass for high efficiency, shapes, pleats, and other parameters
Particulate Efficiency	Viral removal performance of the range of MERV and HEPA filters including the efficiency after any electrostatic charge dissipates
Placement	Pre filter or final filter,
Pressure Loss	Filter depth vs filter efficiency and pressure drop
Filter Inventory	How efficient are filters now installed in schools, nursing homes, meat processors, etc. What about buildings without HVAC?

McILVAINE

Expense	How costly will it be to install more efficient filters?
Air Quantity	How many air changes per hour are needed? How much outside air should be introduced? How is this limited cost wise by outdoor temperature and humidity?
Air Direction	How is air directed so that the maximum amount flows from transmitter to the HVAC system and then is diluted prior to reaching the recipient? Where are partitions and diffusers beneficial?
Room Air Purifiers	When and where should they be used and what volume and efficiency is needed?
Fan Filter Units	Where should they be used rather than partitions or in conjunction with partitions?
Isolators, Modules	Where are isolators and modular cleanrooms the best choice?
Pollution Combination	Use of filters to eliminate air pollutants and viruses in outdoor spaces such as traffic intersections?
Indoor Air	Benefits of purifying indoor air to remove pollutants as well as viruses; a common metric to measure all harm and good
Processes	Rooms, elevators, reception, cashier counters, industrial processing, machinery rooms, individual AC units
Facilities	Residential, commercial, hotel, nursing homes, hospitals, dental, meat processing, schools, gyms, transportation

Efficiency Comparisons

If one assumes that the capture of COVID on a % basis is equivalent to the MERV efficiency at 0.3 microns, the MERV 8 filters installed in most schools are removing only 10%. They may be capturing 75% of the 10-micron cough droplets but if these droplets evaporate then 90% of the virus in these droplets will pass through the filter.



Source: W.J. Kowalski and W.P. Bahnfleth, "MERV Filter Models for Aerobiological Applications" (2002)

Children wearing masks will be generating small aerosols. A MERV 16 filter will remove only 70% of the virus. A vaccine vial in a pharmaceutical cleanroom is protected by a 99.999 % removal of any potential virus in the air. It would therefore be a priority to do better than 70% to protect children and teachers.

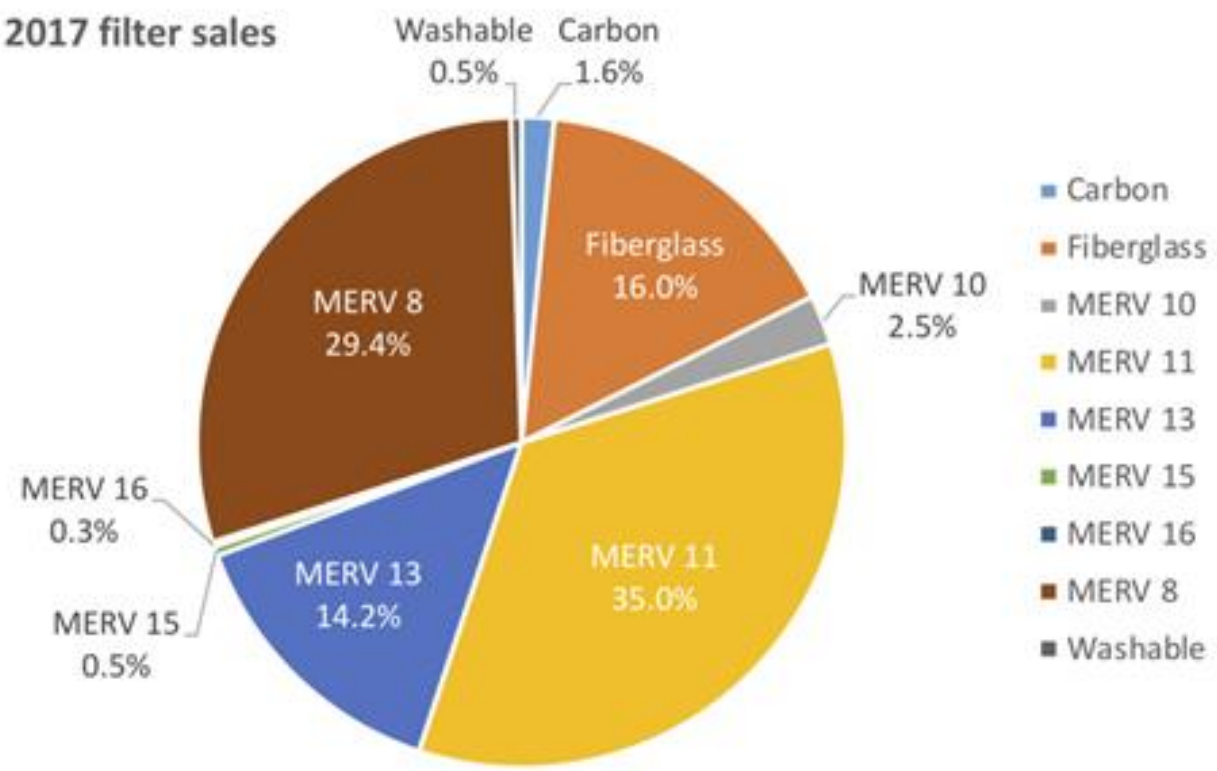
McILVAINE

Historical Filter Sales Based on Efficiency

As of 2017 in the U.S. the MERV 8 filters were outselling less efficient fiberglass filters by nearly 2-1. MERV 11 held the biggest market share.

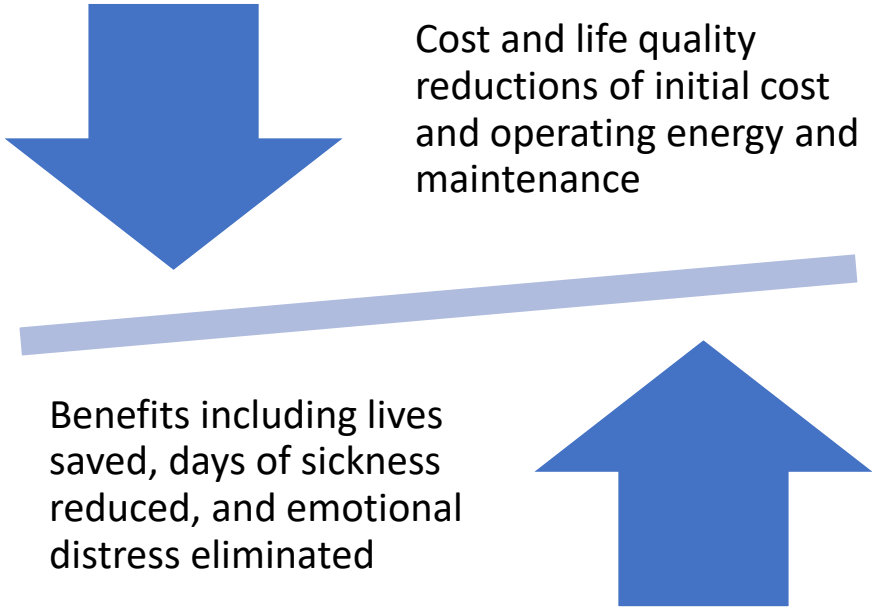
As of Mid 2020 there is a huge demand for MERV 13 filters. With the proactive program the future growth will be in MERV 16 and higher.

The U.S. distribution is not representative for all countries. In China more efficient filters have been utilized due to air pollution concerns.



Shaping the Market through Analysis and Collaboration

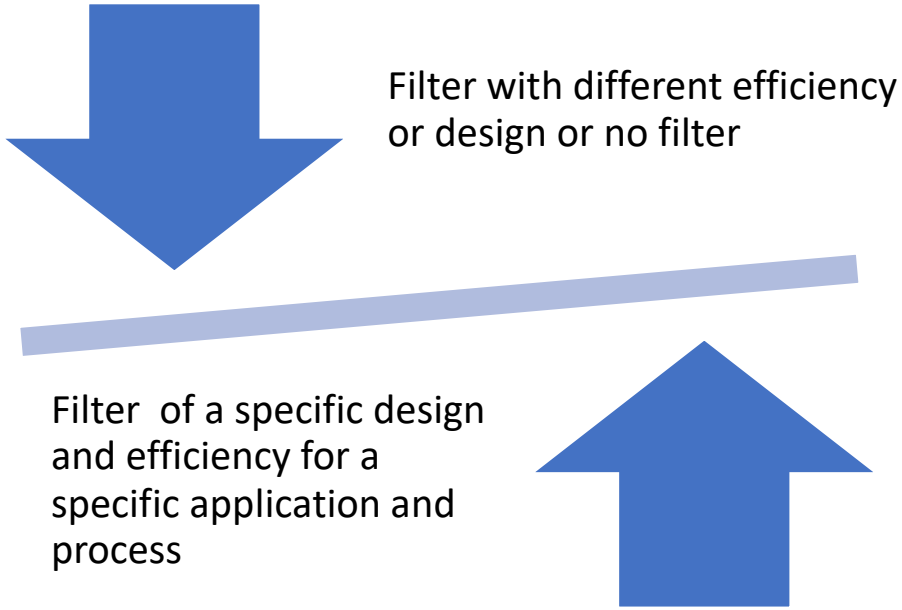
The investment in filters is a function of perceived life quality net impacts. A true cost analysis will be performed for each filter type in each application. A common metric to measure all harm and good was originally developed through a contract with a major surgical gown supplier but it is uniquely applicable to all COVID related choices. Since this metric incorporates the life quality risk choices as well as tribal and discounted future values, it is a true reflection of the will of the people rather than imposed morality.



Many of the factors such energy consumption and upgrade cost are those within the control of suppliers. Collaboration among suppliers can result in shaping the basis for true cost. For example, a major filter media company has volunteered to test the aerosol generation from cloth masks and filters. With this program and collaboration of the participants the market can be shaped to the benefit of everyone.

McILVAINE

True costs need to be determined for each circumstance. Everyone agrees that there are high virus load situations where HEPA filters are unquestionably the choice. In a crowded subway FFFUS with HEPA filters may be the best choice. An M16 filter may be the best choice in some residential settings..



The filter comparison includes the common metric of Quality Enhanced Life Days (QELD). Every minute we drive in a zone with a 65-mph limit reduces life expectancy by 30 seconds . If we went back to the 55-mph limit, we would statistically lose 25 seconds of life for each minute spent traveling. The difference is a few days over a lifetime. But we make many decisions such as eating ice cream that shorten life but enhance life quality. We can probably justify a lower filter efficiency equal to the risk of a 65-mph speed limit, but few people will want to take the risk of raising the limits to 100 mph or being in a space with inefficient filtration which adds that much extra risk.

McILVAINE

Fan Filter Units are Better than Partitions

Fan Filter Units (FFUs) are widely used in the cleanroom industry. They clean and move 500 cfm economically.

Many establishments from restaurants to meat processors are using partitions which cause air turbulence when they would be much better off with FFUs.

HEPA filtered air moves downward sweeping any virus away from the breathing zone toward the floor. It then rises and is re-filtered.

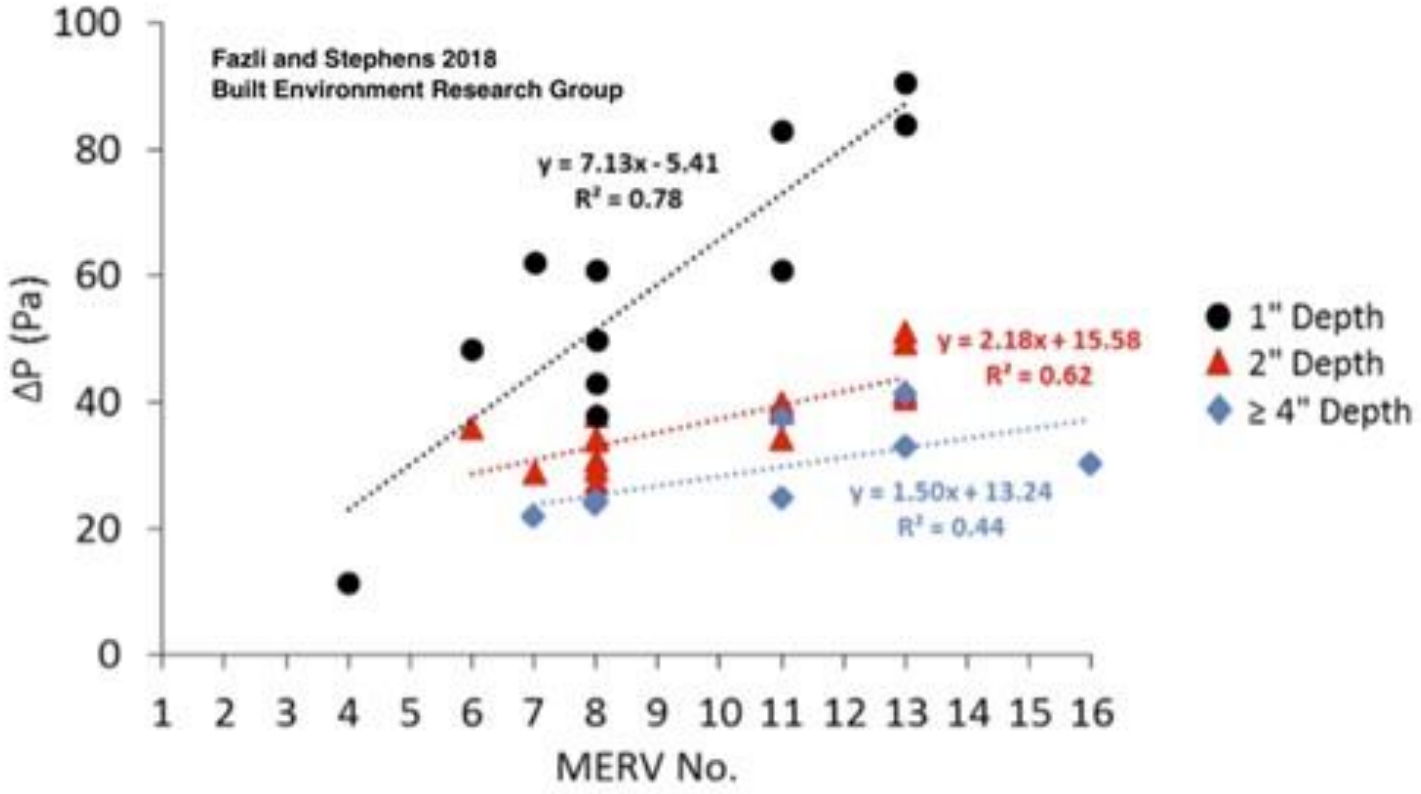
McILVAINE

Big Box Store with laminar flow from ceiling to floor.

HEPA filtered air flows from ceiling units such as FFUs in a downward path thereby removing viruses from the breathing zone. If you think of the virus as traveling like second-hand smoke, you quickly realize the advantages of this approach rather than social distancing.

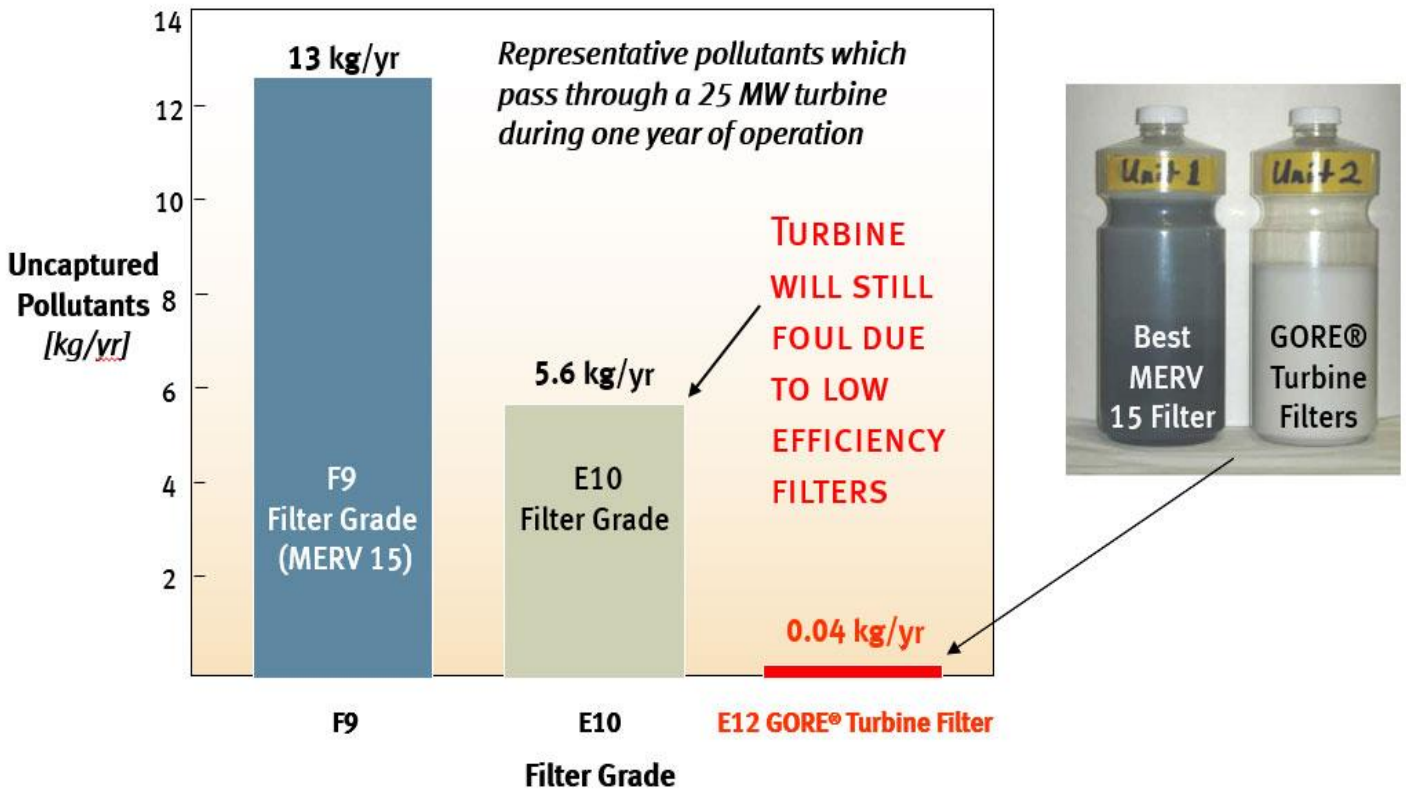
McILVAINE

Pressure drop is a function of both efficiency and depth. So filter replacement can take place by increasing depth and not having to change the fan.



McILVAINE

The difference between an E 10 (MERV 16) and E 12 filter is substantial in terms of removing small particles the size of virus or ambient air particles in gas turbine intakes. In this case the E 10 emits 140 x as much as the E 12.

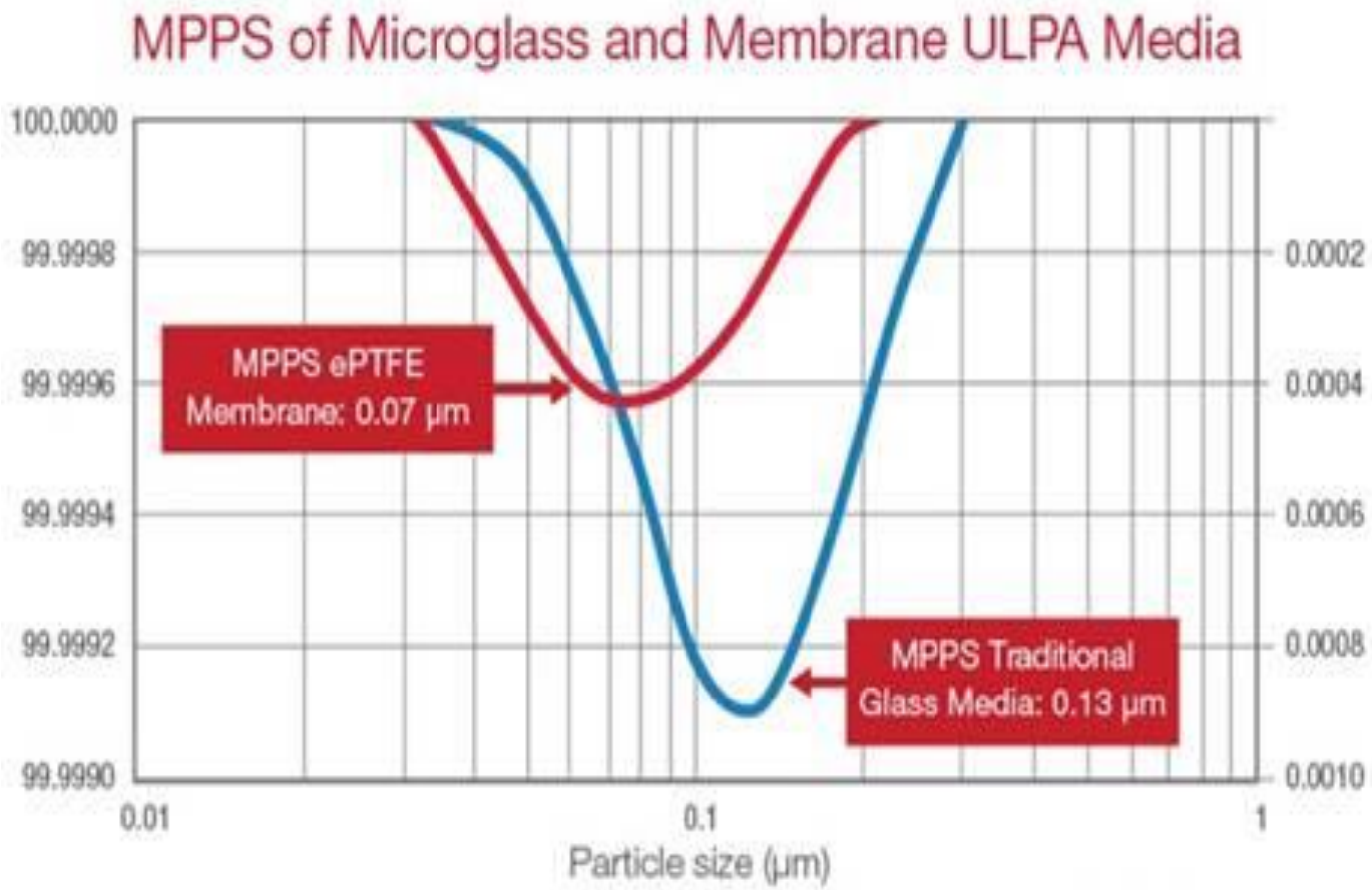


AAF shows that an M16 filter will emit 9 x less particles than an M 14 in the 0.3-micron range where much of the virus may reside.

Particle Size Range	Particle Capture Rate		Approximate Particle Penetration Count per 100,000 Particles		Reduction in Particle Penetration by upgrading from MERV 14 to MERV 16
	MERV 14	MERV 16	MERV 14	MERV 16	
0.30-0.40µ	57.2%	95.4%	42,800	4,600	9.3X
0.40-0.55µ	73.1%	98.4%	26,900	1,600	16.8X
0.55-0.70µ	83.9%	99.3%	16,100	700	23X
0.70-1.00µ	88.8%	99.7%	11,200	300	37.3X
1.00-1.30µ	93.5%	99.8%	6500	200	32.5X
1.30-1.60µ	95.5%	99.9%	4500	100	45X
1.60-2.20µ	96.9%	99.9%	3100	<100	31X
2.20-3.00µ	98.5%	99.9%	1500	<100	15X

McILVAINE

As depicted in this line graph from AAF, filters that achieve the same efficiency rating, in this case ULPA filters rated at 99.999%, are not necessarily equal in their MPPS performance.



Market by Application

- Efficient filters will be a primary weapon to vanquish COVID. The individual will wake to clean air in his residence, ride a subway with clean HEPA filtered air emanating from the roof and then enter a building with clean filtered air in the elevator and in the working space. He will enjoy lunch in a restaurant with HEPA filters and laminar downward air flow.

- The new evidence that much of the transmission is by small aerosols which can travel long distances means that filters become the first line of defense.

- Selection of filter efficiency will be influenced by the viral load.
- The most accurate way to forecast filter use in any country is to analyze each of the applications rather than just use total population figures. Each application will also be impacted by pollutants generated internally and pollutants in the ambient air.
- The next display segments these applications.

Filter Market by Application - $ Millions

Subject	2018	2019	2020	2021	2022	2023	2024	2025
Commercial	x	x	x	x	x	x	x	x
Education	x	x	x	x	x	x	x	x
Government	x	x	x	x	x	x	x	x
Hospitals	x	x	x	x	x	x	x	x
Nursing homes	x	x	x	x	x	x	x	x
Food processing	x	x	x	x	x	x	x	x
Pharmaceutical	x	x	x	x	x	x	x	x
Semiconductor	x	x	x	x	x	x	x	x
Other healthcare	x	x	x	x	x	x	x	x
Other industrial	x	x	x	x	x	x	x	x
Residential	x	x	x	x	x	x	x	x
Transportation	x	x	x	x	x	x	x	x
Entertainment, dining	x	x	x	x	x	x	x	x

McILVAINE