

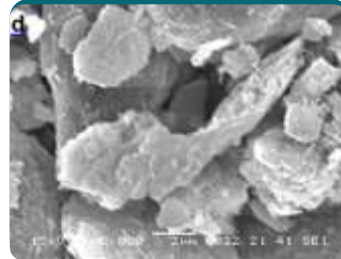
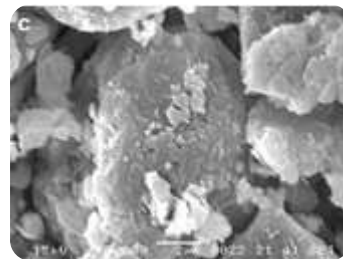
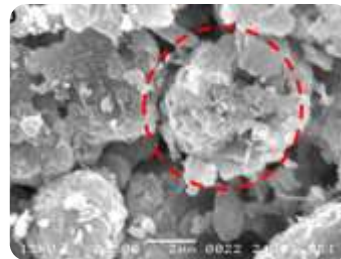
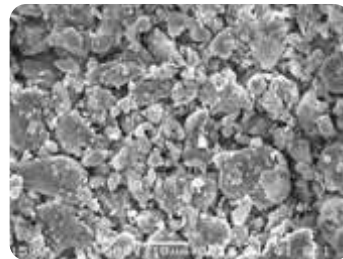
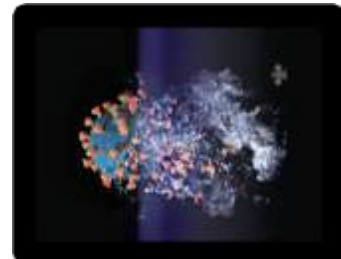
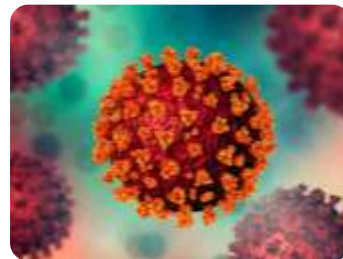
# IAQ & ENERGY

MAINE'S PREMIER  
INDOOR AIR QUALITY  
CONFERENCE

## 2025

## Indoor Air Quality Safeguarding Indoor Health

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## Pathogen Disinfection & Particulate Control

# AGENDA

01

ASHRAE Standards  
Direction

02

What is the  
problem to solve?

03

ASHRAE Standard  
241: Filtration vs  
ventilation

04

Applicable  
Technologies

05

Ancillary Benefits

06

Benefits, Power  
Savings & Payback

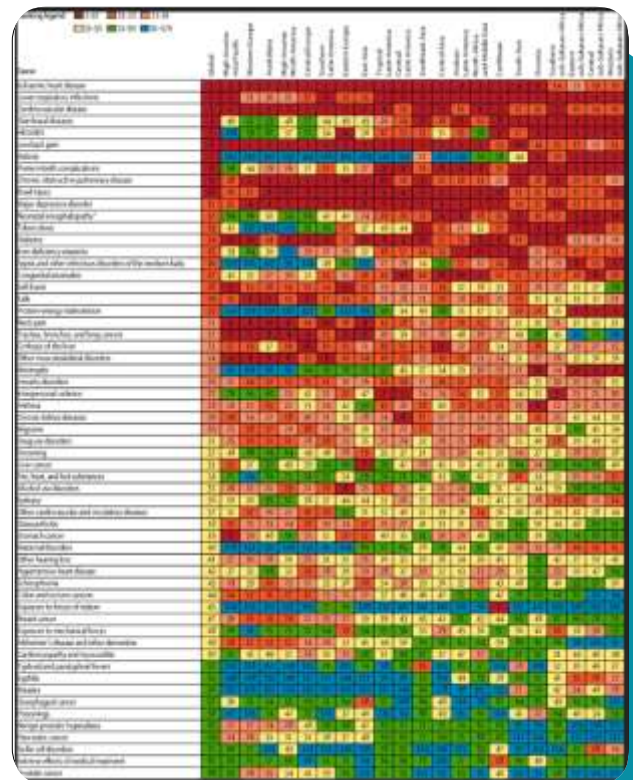
07

Applications

08

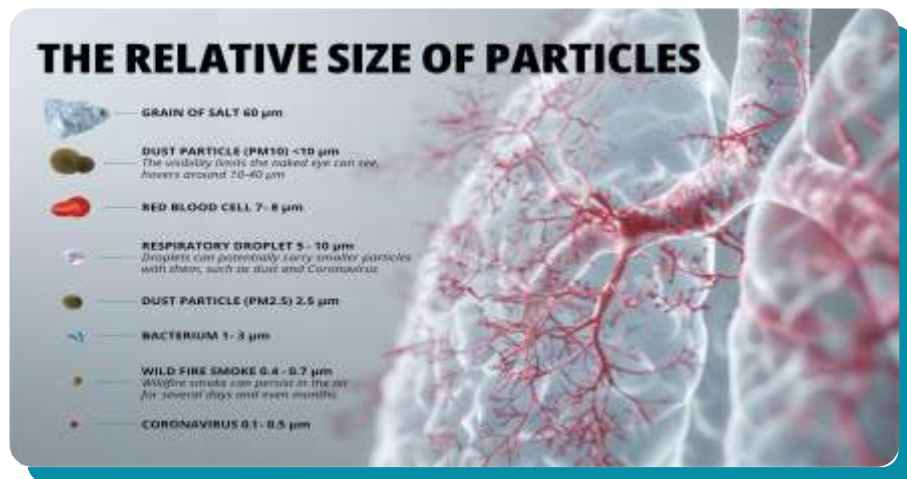
Closing Remarks  
and Questions

# DALY – Disability Adjusted Life Year



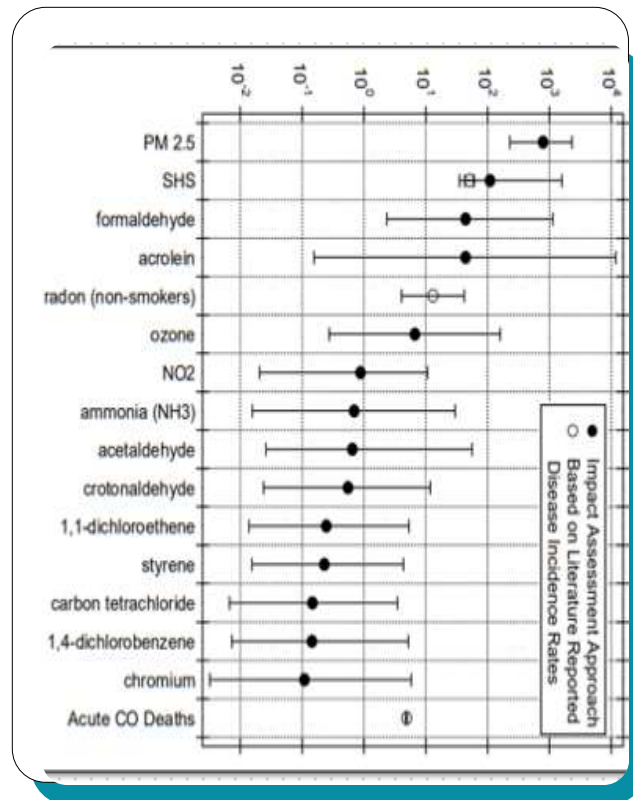
Respiratory system has no immune system leaving it highly susceptible to contagions such as Covid, Influenza, Staph, and PM 2.5. PM 2.5 size is the most dangerous to the respiratory system.

# Size Matters when Breathing & DALY



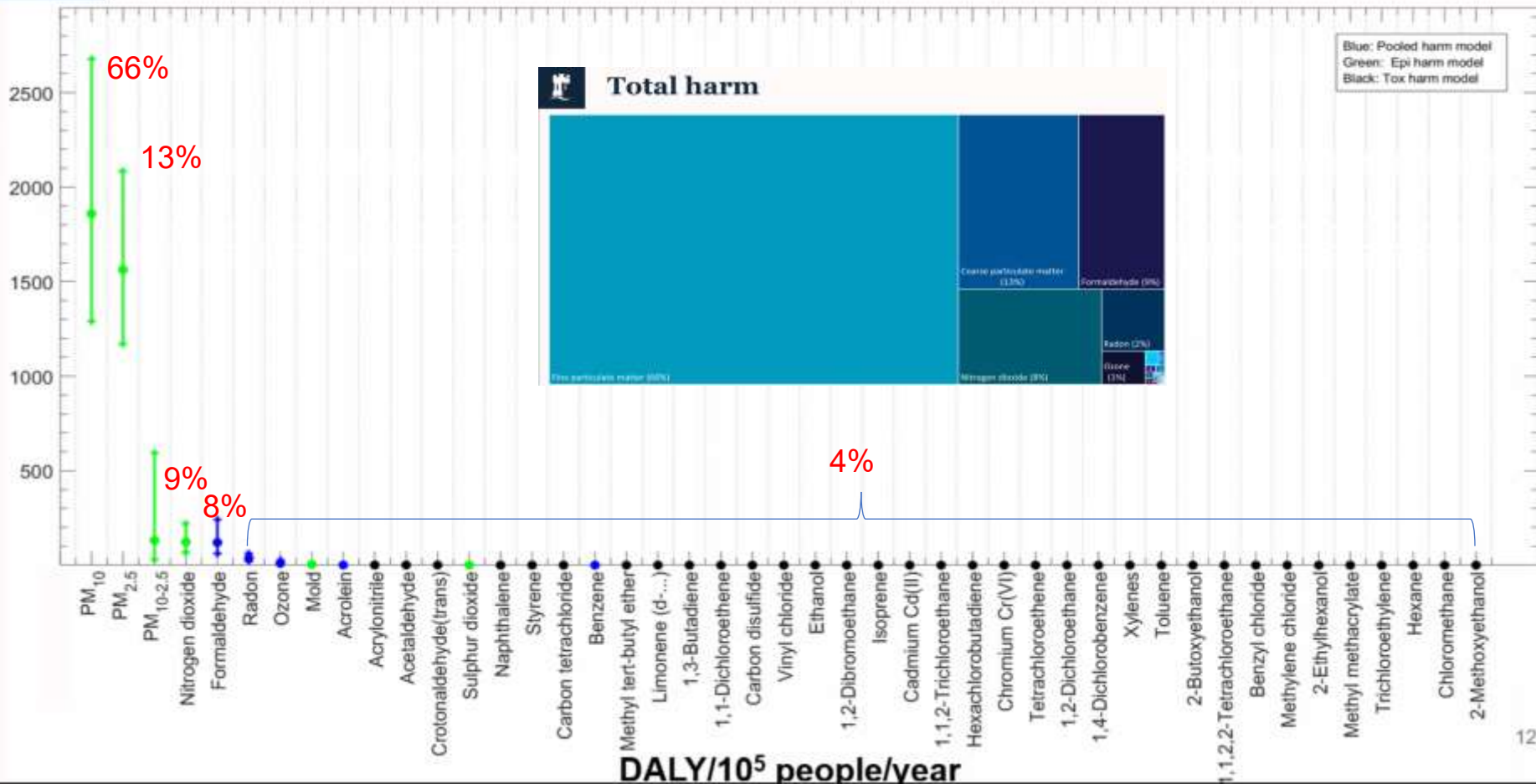
15 pollutants with the highest mean damage estimates.

Logue JM, et al. - LBNL, 2011

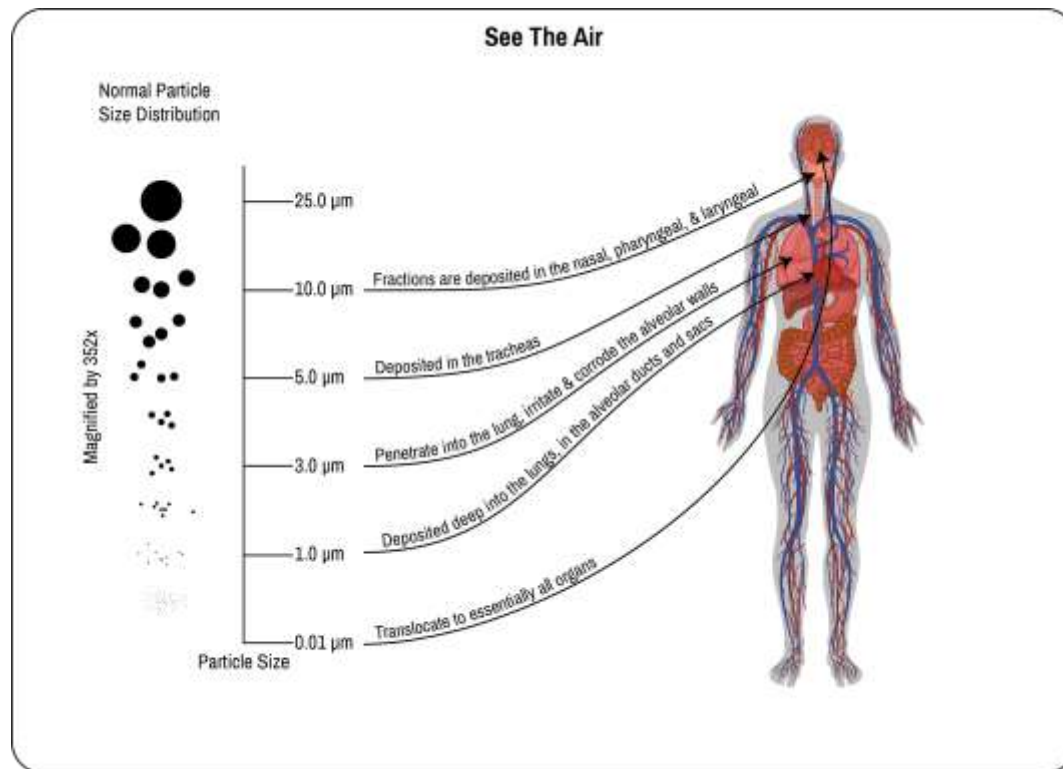




# Total harm



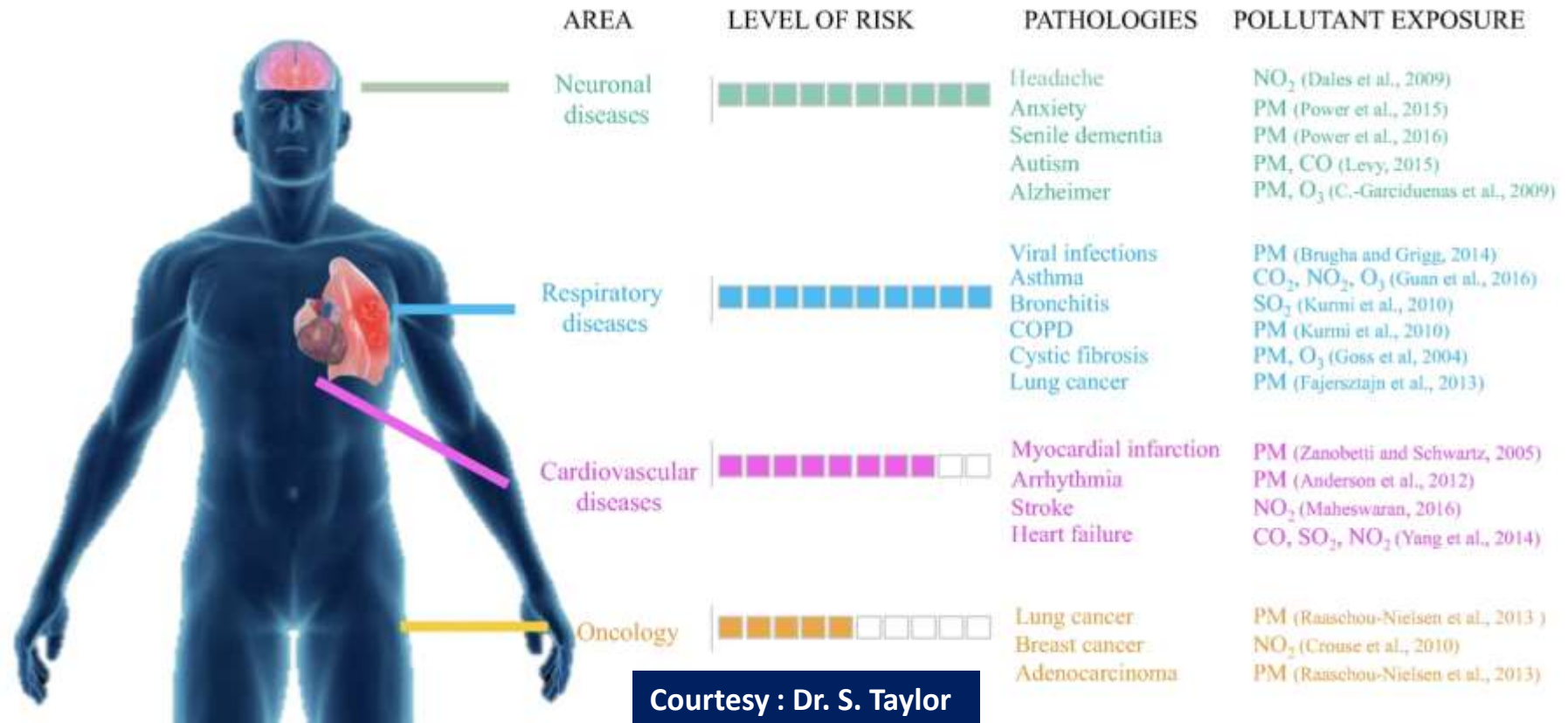
# Size Matters when Breathing & DALY



Courtesy "See The Air"

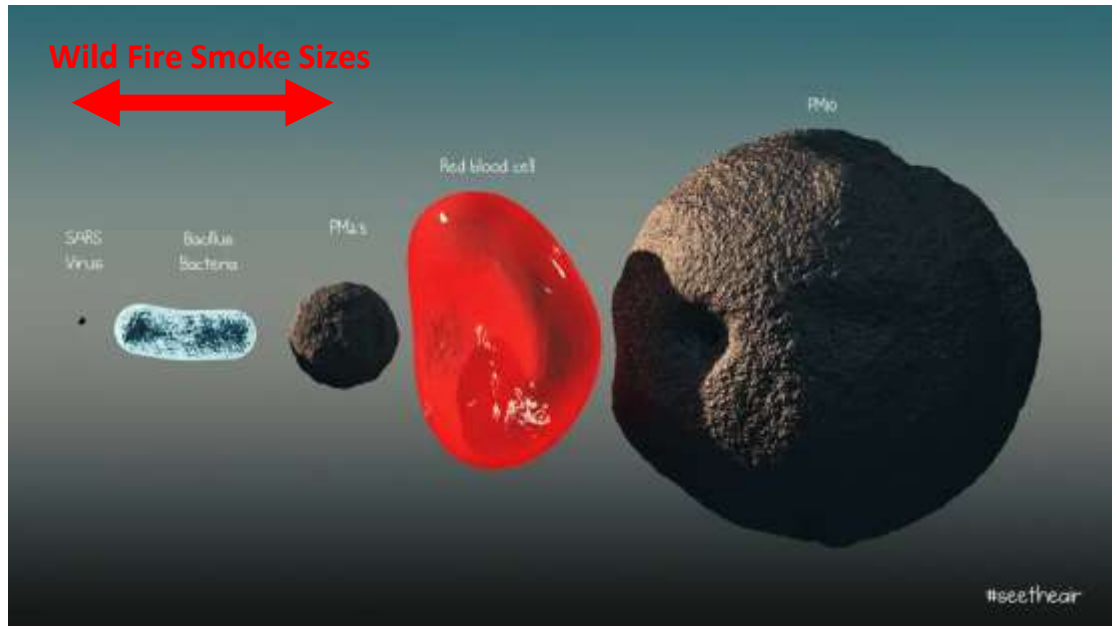
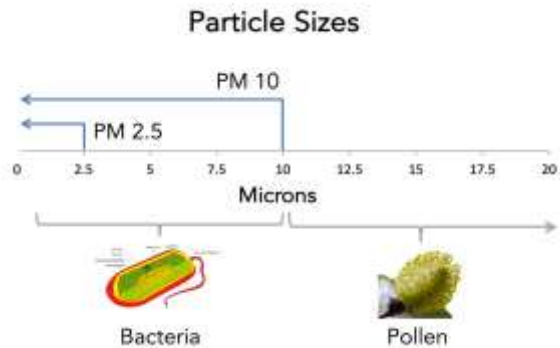
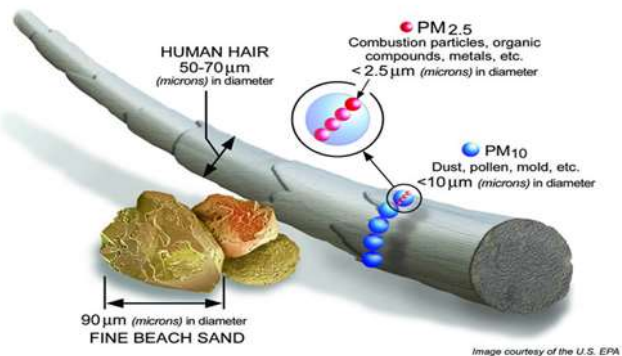


# Numerous research on indoor contaminants that influence health



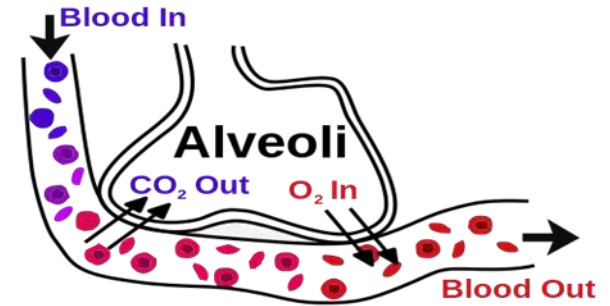
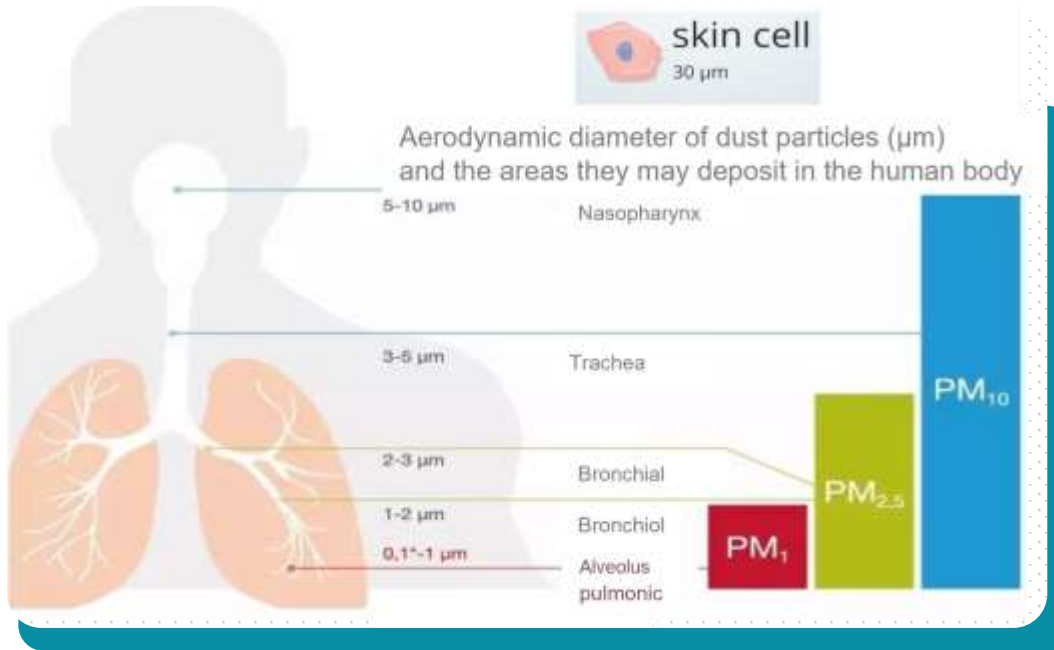
Courtesy : Dr. S. Taylor

# Size Matters when Breathing & DALY





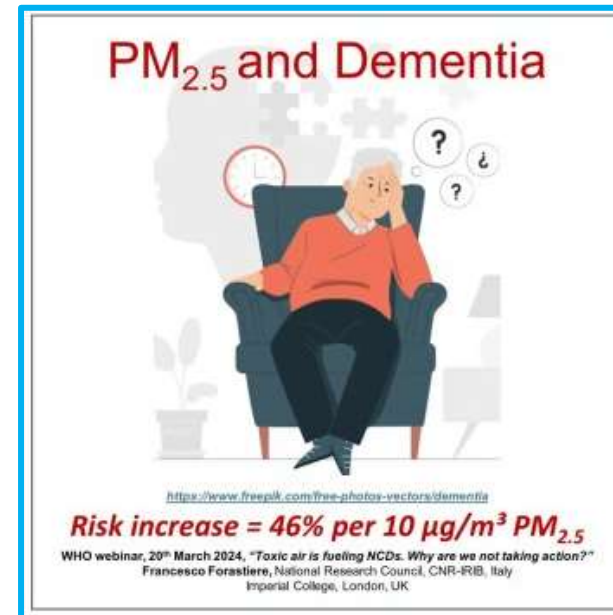
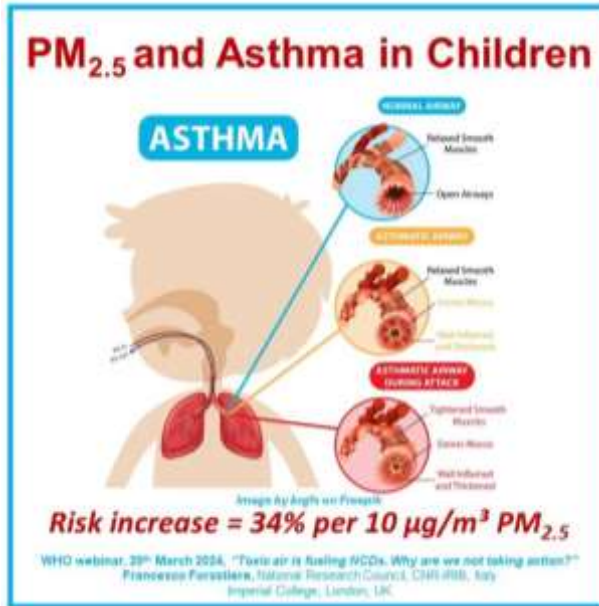
# Size Matters when Breathing & DALY



Blood-air barrier is fragile

**Respiratory system is highly susceptible to contagions such as Covid, Influenza, Staph, and most dangerous is PM 2.5 & smaller.**

# Developing Bodies (Children – Young Adults) & Elderly



This fact was presented by Francesco Forastiere, National Research Council, CNR-IRIB, Italy, Imperial College, London, UK, during the WHO webinar, 20th March 2024, "Toxic air is fueling Noncommunicable diseases - NCDs. Why are we not taking action?"

# A slight increase in $\text{PM}_{2.5}$ by only $10\mu\text{g}/\text{m}^3$ harms our thinking



Chess players made  
26% more mistakes



Incorrect calls by umpires  
increased by 2.6%



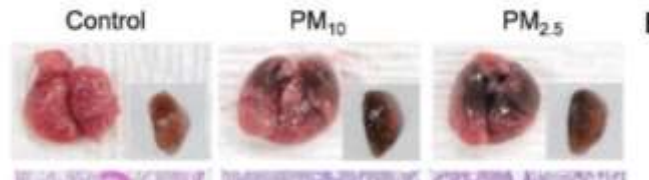
The probability of failing  
an exam increased by 8%

[Steffen Künn, Juan Palacios, Nico Pestel](https://doi.org/10.1287/mnsc.2022.4643) (2023) Indoor Air Quality and Strategic Decision Making. Management Science 69(9):5354-5377.  
<https://doi.org/10.1287/mnsc.2022.4643>.  
<https://doi.org/10.1086/698728>

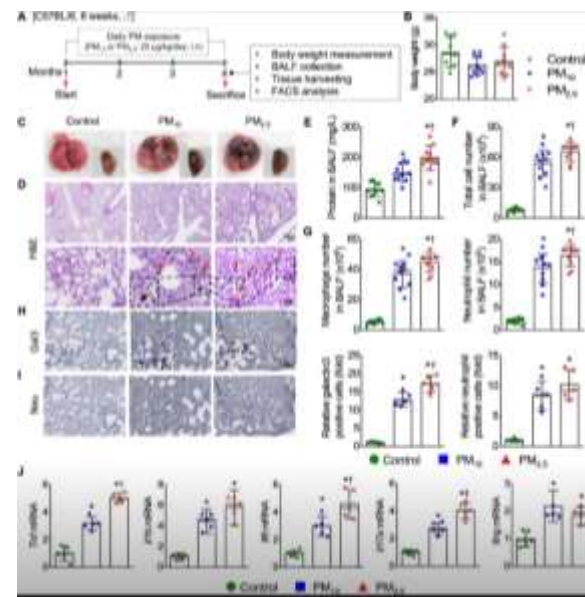
Air Pollution and Student Performance in the U.S. Michael Gilraine and Angela Zheng NBER Working Paper No. 30061 May 2022 JEL No. I14,I24,Q53

Courtesy: Dr. Stephanie Taylor

# Study reveals that exposure to airborne PM2.5 and PM10



- A study on mice reveals that exposure to airborne particulate matter (PM2.5 and PM10) can lead to significant lung injury.
- Key findings suggest that higher concentrations of PM2.5 cause more severe lung injury.
- This research provides crucial insights into the cytotoxicity of PM2.5, potentially guiding new strategies to combat air pollution-related respiratory diseases.



Citation Link  :

Jo, Y., Kim, B., Lee, S. M., Park, J., Kim, W., Shim, J. A., Park, J. H., Park, J., Shin, Y., Ryu, J. H., & Hong, C. (2025). Particulate matter exposure induces pulmonary TH2 responses and oxidative stress-mediated NRF2 activation in mice. Redox Biology, 103632. <https://lnkd.in/dG9RtyDb>

# WILDFIRE SMOKE: Standard 62.1 & Guideline 44 Coordination



**ANSI/ASHRAE Standard 62.1-2022**  
(Supersedes ANSI/ASHRAE Standard 62.1-2019)  
Includes ANSI/ASHRAE addenda listed in Appendix Q

## Ventilation and Acceptable Indoor Air Quality

See Appendix Q for approval data by ASHRAE and the American National Standards Institute.

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely documented consensus action on requests for change to any part of the Standard. Instructions for how to submit a change are featured on the ASHRAE® website ([www.ashrae.org/standards](http://www.ashrae.org/standards)).

The latest edition of an ASHRAE Standard may be purchased from the ASHRAE website ([www.ashrae.org](http://www.ashrae.org)) or from ASHRAE Customer Service, 180 Technology Parkway, Peachtree Corners, GA 30091. E-mail: [orders@ashrae.org](mailto:orders@ashrae.org) Fax: 478-221-2129 Telephone: 404-639-9000 (toll-free 1-800-521-4772 for orders in US and Canada). For reprint permission, go to [www.ashrae.org/permissions](http://www.ashrae.org/permissions).

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ASH includes hyperlinks for convenient navigation. Click on a reference to a section, table, figure, or equation to jump to its location. Return to the previous page via the backarrow icon.



**ASHRAE Guideline 44-2024**

## Protecting Building Occupants from Smoke During Wildfire and Prescribed Burn Events

Approved by ASHRAE on November 11, 2024

ASHRAE® Guidelines are acknowledged to be approved not as the same as the ASHRAE Standard number in the past of ASHRAE approval. The same edition of an ASHRAE Guideline may be purchased on the ASHRAE website ([www.ashrae.org](http://www.ashrae.org)) or from ASHRAE Customer Service, 180 Technology Parkway, Peachtree Corners, GA 30091. E-mail: [orders@ashrae.org](mailto:orders@ashrae.org) Fax: 478-221-2129 Telephone: 404-639-9000 (toll-free 1-800-521-4772 for orders in US and Canada). For reprint permission, go to [www.ashrae.org/permissions](http://www.ashrae.org/permissions).

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Courtesy By **Abdel K Darwich** PE, LEED AP, HFDP

# WILDFIRE SMOKE: Standard 62.1 & Guideline 44 Coordination



Sacramento, CA

October 2018



Sacramento, CA

November 2018

Courtesy By **Abdel K Darwich** PE, LEED AP, HFD



# WILDFIRE SMOKE: Standard 62.1 & Guideline 44 Coordination



San Francisco September 2020



New York City 2023



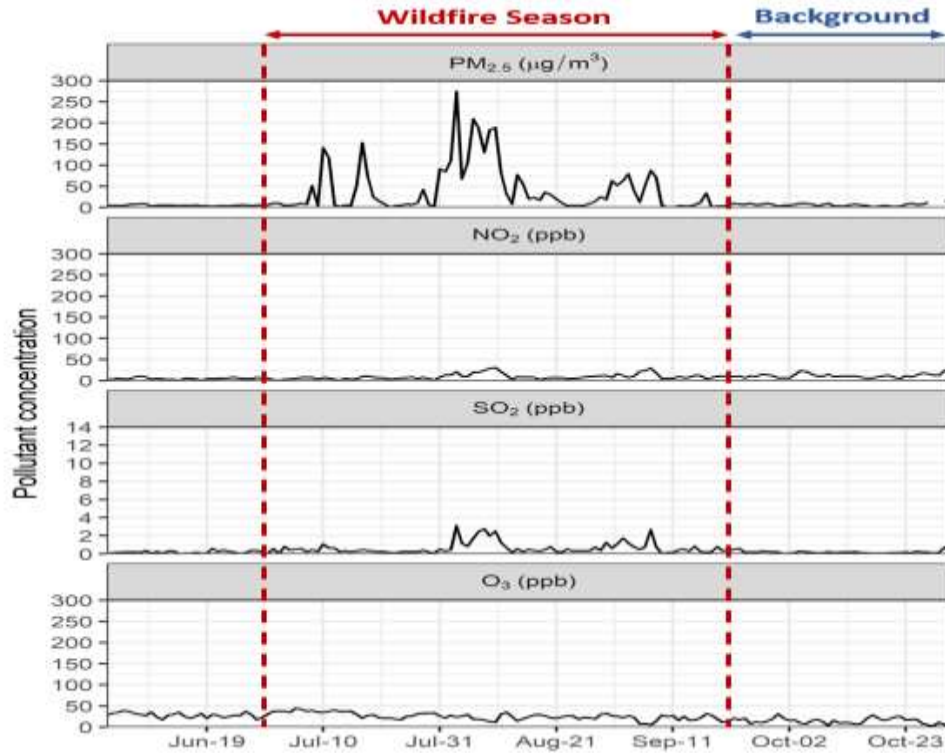
Maui, HI August 2023



Los Angeles 2025

Courtesy By **Abdel K Darwich** PE, LEED AP, HFDP

# Wildfire Smoke: Focus on PM 2.5 Because

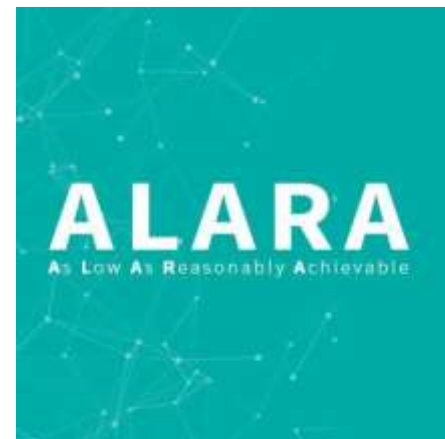


- Most noticeable increase in wildfires
- It has the clearest outdoor and indoor air quality impacts.
- There is specific evidence of acute and chronic health impacts.

# Wildfire Smoke: Indoor PM 2.5 Concentrations

- Indoor PM2.5 is still not regulated
- Use the outdoor? 12  $\mu\text{g}/\text{m}^3$  ? 9  $\mu\text{g}/\text{m}^3$ ?
- Guideline 44 recommends ALARA limit - As Low As Reasonably Achievable – 20% of outdoor

Range of 1-Hour PM2.5 Concentrations	Risk Category	Health Message for People at Higher Risk	Health Message for the General Population
0 to 30 $\mu\text{g}/\text{m}^3$	Low	Enjoy your usual activities	Enjoy your usual activities
31 to 60 $\mu\text{g}/\text{m}^3$	Moderate	Consider reducing activities if you experience symptoms	Enjoy your usual activities unless you experience symptoms
61 to 100 $\mu\text{g}/\text{m}^3$	High	Reduce or reschedule strenuous activity	Consider reducing activities if you experience symptoms
>100 $\mu\text{g}/\text{m}^3$	Very high	Avoid strenuous activity	Reduce or reschedule strenuous activity, especially if you experience symptoms



# ASHRAE C Filter Mini



## AQ13

Air Quality MERV 13/10A Panel Filter  
with Long Service Life



The Camfil AQ13 high-capacity pleated panel filter delivers high indoor air quality and extended service life with pressure drops suitable for most applications.

The AQ13 is the first choice for those facilities whose air handling equipment is limited to air filters 4" or less. Unlike other MERV 13 pleated panel filters which must be replaced every two or three months, the AQ13 can remain in service up to six months in environments typically found in schools, public buildings, and retail shops.

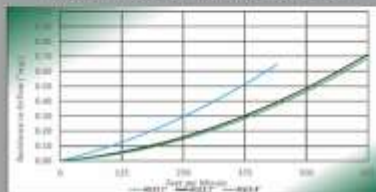
The AQ stands for air quality and carries a MERV value of MERV 13/10A. This is the highest published MERV value for a standard pleated panel filter with an initial pressure drop similar to commonly used MERV 8 panel filters which often test two MERV levels below, MERV 13/8A.

Engineered to comply with MERV 13 requirements or guidelines and remain in service twice as long as any comparable pleated panel filter, the AQ 13:

- Has 15 pleats per linear foot on the widely used 2" model.
- Includes a synthetic fiber blend with a unique media loft that delivers a MERV 13/10A capture efficiency.
- Has a welded wire media grid backing, treated for corrosion resistance, preventing media oscillation or filter pack failure as filter pressure drop increases.
- The welded wire backing holds the pleats in a "U" shape which maximizes surface area for long life and lowers resistance to airflow.
- Has a high wet-strength beverage board frame that creates a rigid and durable filter pack. The AQ13 will not bow or deflect throughout its anticipated six-month service life.

These engineered features allow the AQ13 to deliver the highest quality indoor air for twice as long as any other comparable pleated panel filter and with a low-pressure drop that allows it to be used in virtually all pleated panel filter applications.

Low average pressure drop and highest rated average efficiency in its class makes the AQ13 an ideal choice for MERV 13 upgrades.



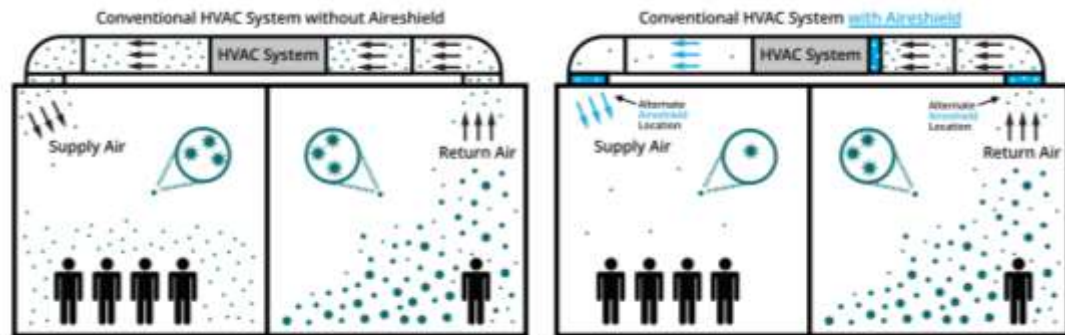
- Minimum M
- MERV-13 w
- through, bu
- Assumptio
- recommen

Minimum % of particles trapped		
"PM 2.5 Zone"		
0.3 - 1.0 Microns	1.0 - 3.0 Microns	3.0 - 10.0 Microns
>95%	>95%	>95%
>85%	>90%	>95%
>75%	>90%	>95%
>50%	>85%	>90%
>35%	>80%	>90%
>20%	>65%	>85%
-	>50%	>80%
-	>35%	>75%
-	>20%	>70%
-	-	>50%
-	-	>35%
-	-	>20%
-	-	<20%
-	-	<20%
-	-	<20%
-	-	<20%

WHAT IS THE PROBLEM TO SOLVE?

# Market Need – Problem to Solve

HVAC systems will increase the spread of aerosols within buildings without a pathogen mitigation strategy.

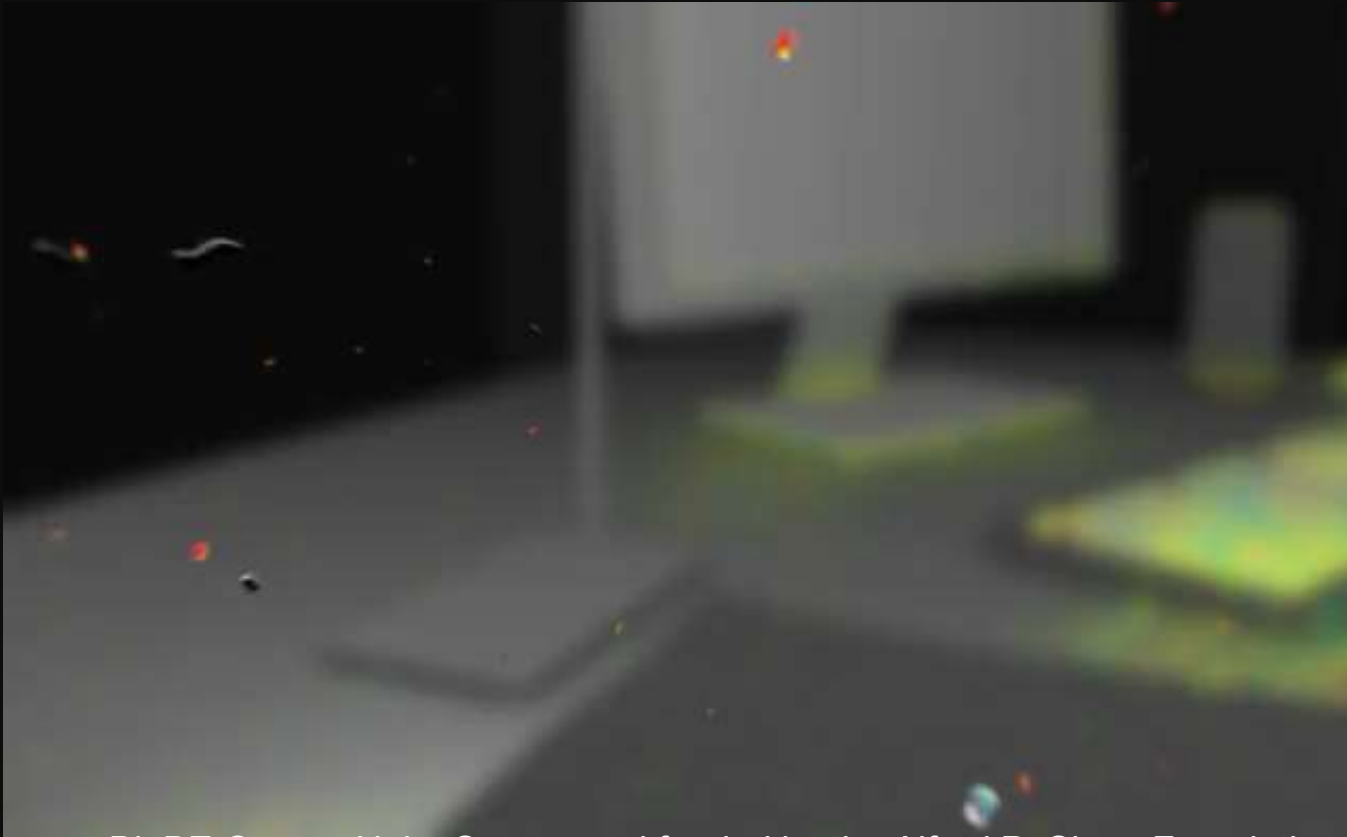


HVAC systems will increase the spread of aerosols within buildings without a pathogen mitigation strategy.

“While HVAC systems and purified air cannot solve all aspects of infection control, they can be effective against the distribution and biological burden of infectious aerosols.”

Excerpt: ASHARE position document on infectious aerosol - April 14, 2020

# A closer look at humans and microbes indoors



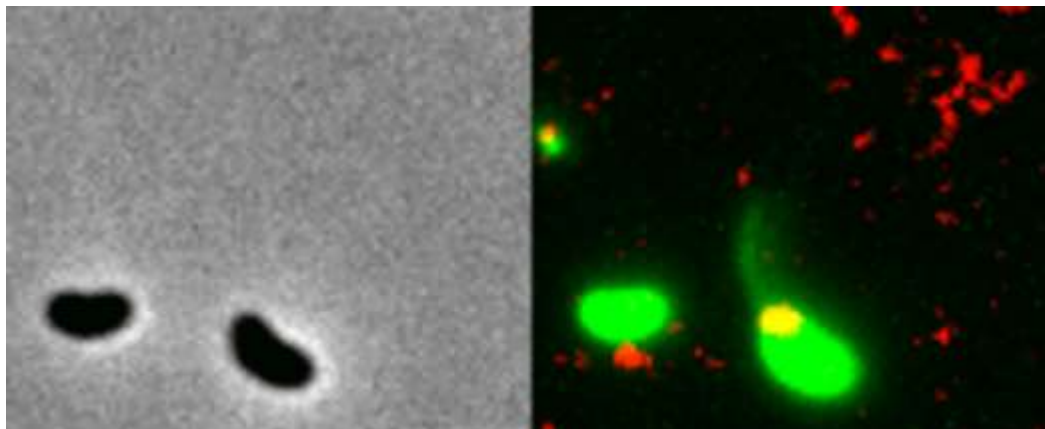
Courtesy : Dr. S. Taylor, and BioBE Center, Univ. Oregon and funded by the Alfred P. Sloan Foundation



This was a startling and very important finding

**"Antibiotic Resistance Can Spread Through The Air, Scientists Warn, And  
Yes - You Should Be Terrified"**

*July 26, 2018*



Poor air quality increases the airborne transfer of antibiotic resistance genes

## PREPAREDNESS

# Building Resiliency

### INFECTIOUS RISK MANAGEMENT MODE

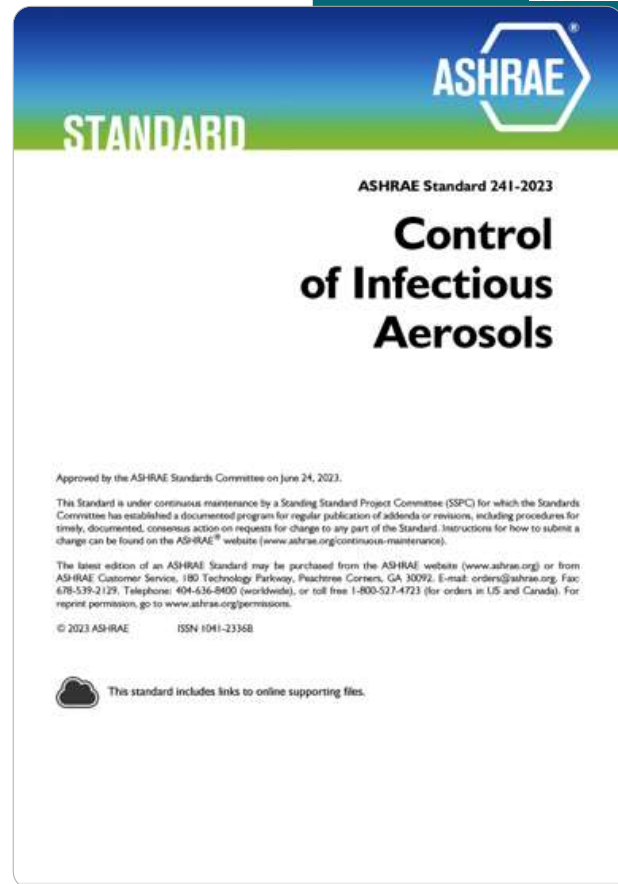
### TWO OPTIONS ▾



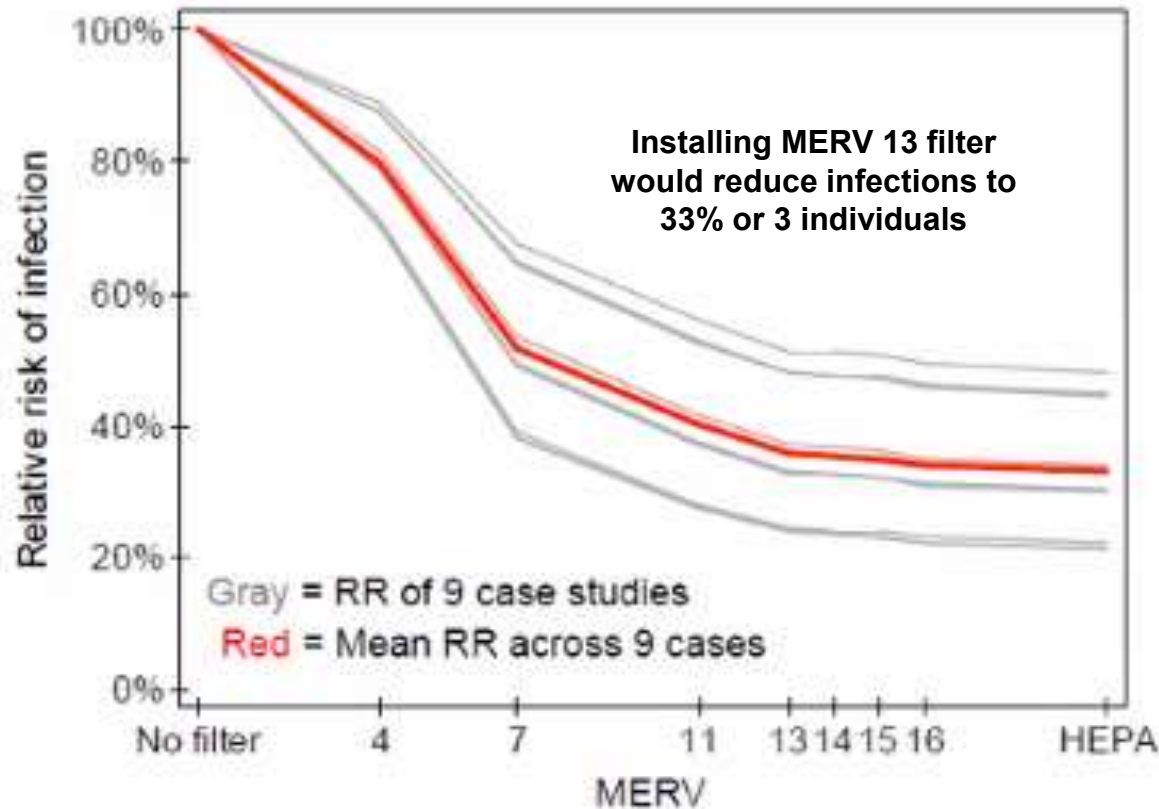
Ventilation Option



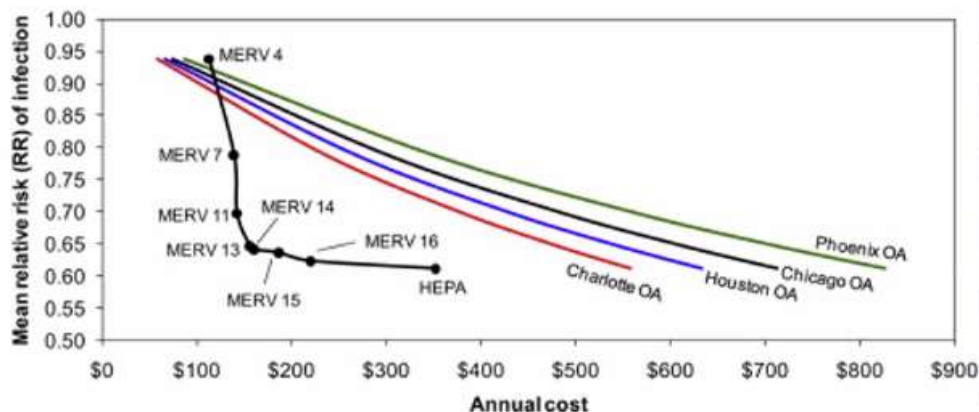
Equivalent Outdoor Air using Filtration: (PREFERRED METHOD)



# Wells-Riley Equation – Probability of Infection



## Cost of Filtration vs Ventilation



Parham Azimi, Brent Stephens,  
HVAC filtration for controlling infectious airborne disease transmission in indoor  
environments: Predicting risk reductions and operational costs, Building and  
Environment, Volume 70, 2013, Pages 150-160,

TABLE 2 Cost per cfm of outdoor air and particulate filtration (MERV 7 and MERV 13) for 15 climate zones.

CLIMATE ZONE	\$/cfm OF OUTDOOR AIR	\$/cfm FILTRATION STRATEGY		BLENDED UTILITY RATE \$/kWh
		MERV 7	MERV 13	
1A	1.66	0.03	0.11	0.15
2A	1.55	0.03	0.12	0.14
2B	0.81	0.03	0.12	0.15
3A	0.65	0.03	0.12	0.14
3B	0.79	0.03	0.12	0.14
3C	0.16	0.06	0.25	0.28
4A	1.82	0.06	0.22	0.24
4B	0.84	0.03	0.14	0.15
4C	0.63	0.03	0.11	0.12
5A	3.25	0.06	0.26	0.28
5B	0.74	0.03	0.12	0.14
6A	2.63	0.03	0.16	0.16
6B	1.21	0.03	0.09	0.10
7A	2.98	0.03	0.16	0.16
8A	4.16	0.03	0.16	0.16

Zaatari, M, A. Goel, and J. Maser. 2023. ASHRAE J. 65(9):18-24.

## PREPAREDNESS

# Building Resiliency

### INFECTIOUS RISK MANAGEMENT MODE

#### Four Critical Considerations for Compliance

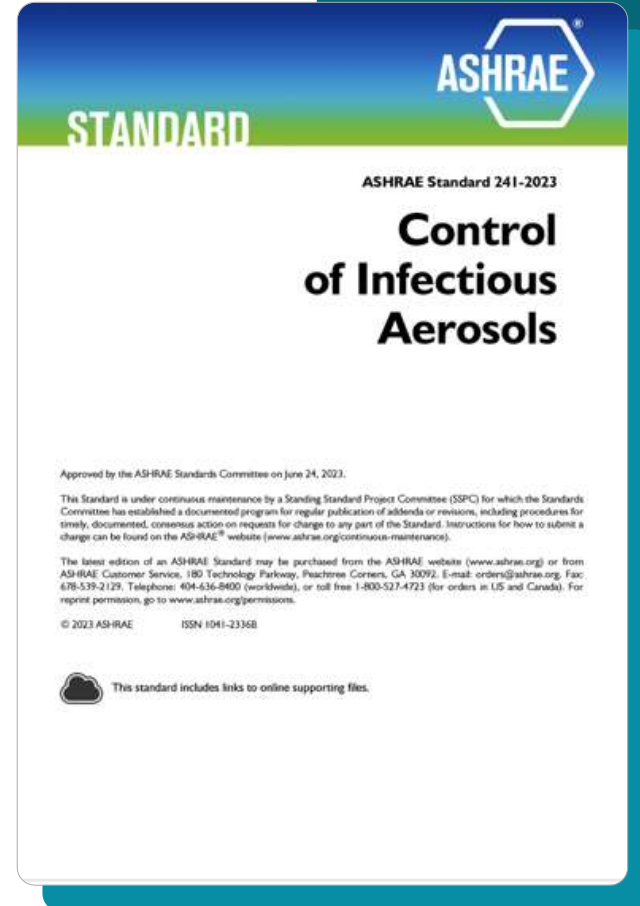
- 1 AHAM Chamber Testing Ventilation Option  
Recommendation: No test duct, Shoe box, or ovens.

Minimum 800 cu.ft. chamber

- 2 Test against MS2 (Bacteriophage)  
Can not use SARS, we now know to be too weak of a Virus

- 3 By Product Testing  
Can not be generating by-products such as Formaldehyde

- 3 Ozone Testing  
Can not be generating Ozone.  
  
Must conform to UL-2998 Zero Ozone Emissions (Max. 5 PPB)



# New & Existing Technologies





# New & Existing Technologies



**Non-Thermal Plasma Technology**

# LESSONS LEARNED FOR

# Existing Technologies Ionization Systems

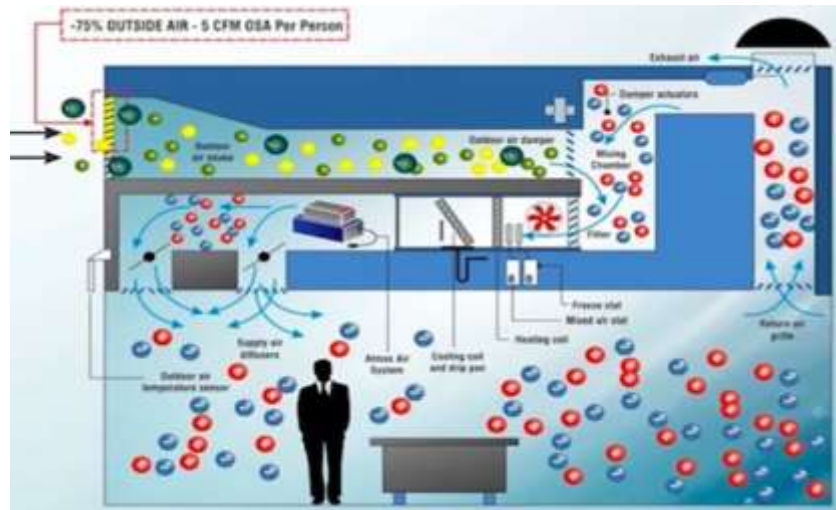
## DESCRIPTION

Bipolar ionization (also called needlepoint bipolar ionization) is a technology that can be used in HVAC systems or portable air cleaners to generate positively and negatively charged particles (Source: EPA)

✓ Removal Strategy  
Emitter

✓ UL2998 Compliance:  
No and some Yes complaint

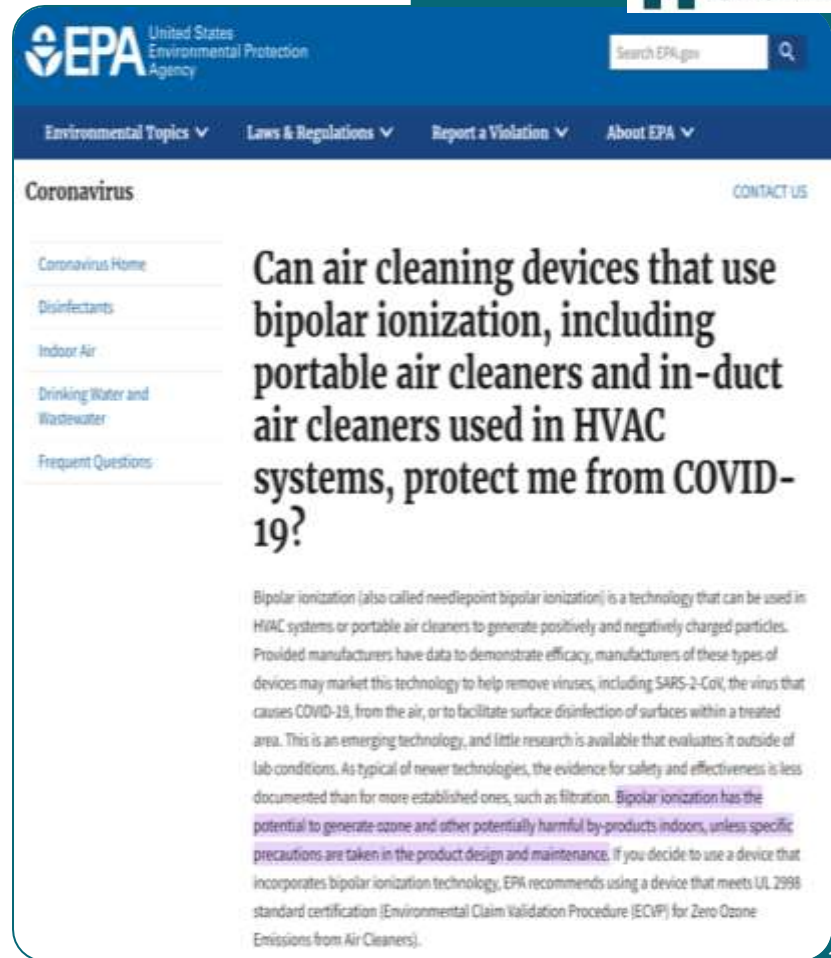
✓ Bi-Product Generation:  
Some Yes (EPA)



LESSONS LEARNED FOR

# Existing Technologies Ionization Systems

Bipolar ionization has the potential to generate ozone and other potentially harmful by-products indoors, unless specific precautions are taken in the product design and maintenance.



The screenshot shows the EPA website with the following elements:

- Header:** EPA United States Environmental Protection Agency logo and a search bar.
- Navigation:** Environmental Topics, Laws & Regulations, Report a Violation, About EPA.
- Section:** Coronavirus (with a CONTACT US link).
- Left Sidebar:**
  - Coronavirus Home
  - Disinfectants
  - Indoor Air
  - Drinking Water and Wastewater
  - Frequent Questions
- Main Content:**

## Can air cleaning devices that use bipolar ionization, including portable air cleaners and in-duct air cleaners used in HVAC systems, protect me from COVID-19?

Bipolar ionization (also called needlepoint bipolar ionization) is a technology that can be used in HVAC systems or portable air cleaners to generate positively and negatively charged particles. Provided manufacturers have data to demonstrate efficacy, manufacturers of these types of devices may market this technology to help remove viruses, including SARS-2-CoV, the virus that causes COVID-19, from the air, or to facilitate surface disinfection of surfaces within a treated area. This is an emerging technology, and little research is available that evaluates it outside of lab conditions. As typical of newer technologies, the evidence for safety and effectiveness is less documented than for more established ones, such as filtration. **Bipolar ionization has the potential to generate ozone and other potentially harmful by-products indoors, unless specific precautions are taken in the product design and maintenance.** If you decide to use a device that incorporates bipolar ionization technology, EPA recommends using a device that meets UL 2998 standard certification (Environmental Claim Validation Procedure (ECVP) for Zero Ozone Emissions from Air Cleaners).

## LESSONS LEARNED FOR

# Existing Technologies Photo-Catalytic Oxidation

### DESCRIPTION

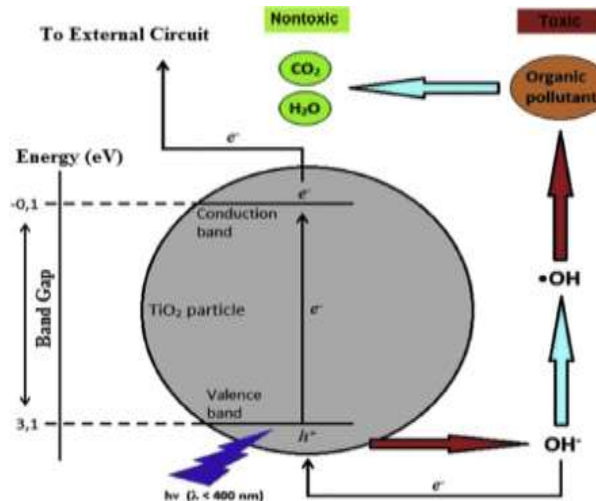
Ultraviolet light shines onto a catalyst, which converts water in the air into a form that turns molecules of pollution into more harmless substances. (Source: Explain the Stuff)

✓ Removal Strategy  
Emitter

✓ UL2998 Compliance:  
Yes & No

✓ Bi-Product Generation:  
Yes

Photocatalytic oxidation (PCO) is based on the generation of many reactive oxygen radicals (e.g., radical forms of OH and O). Source: Interface Science and Technology, 2021



*"Imagine if, in an effort to clean the air more efficiently, you were involuntarily introducing chemicals more dangerous than the ones you were trying to scrub."*

Concordia University,  
2015

## LESSONS LEARNED FOR

# Existing Technologies Hydrogen Peroxide (H2O2)

**DESCRIPTION**

Like with many atmospheric hazards, symptoms and health effects related to VHP exposure become more severe with higher concentrations of hydrogen peroxide. At high concentrations, hydrogen peroxide is corrosive to skin, eyes, and mucus membranes.

✓ Removal Strategy  
Emitter

✓ UL2998 Compliance:  
Not Applicable

✓ Bi-Product Generation:  
Unknown



## LESSONS LEARNED FOR

# Existing Technologies Ultraviolet Light

### DESCRIPTION

UV light produces electromagnetic energy that destroys the ability of microorganisms to reproduce and cause inactivation of microbes by causing mutations and/or cell death. UV light produces electromagnetic energy that can destroy the ability of microorganisms to reproduce and by causing photo-chemical reactions in nucleic acids (DNA & RNA).

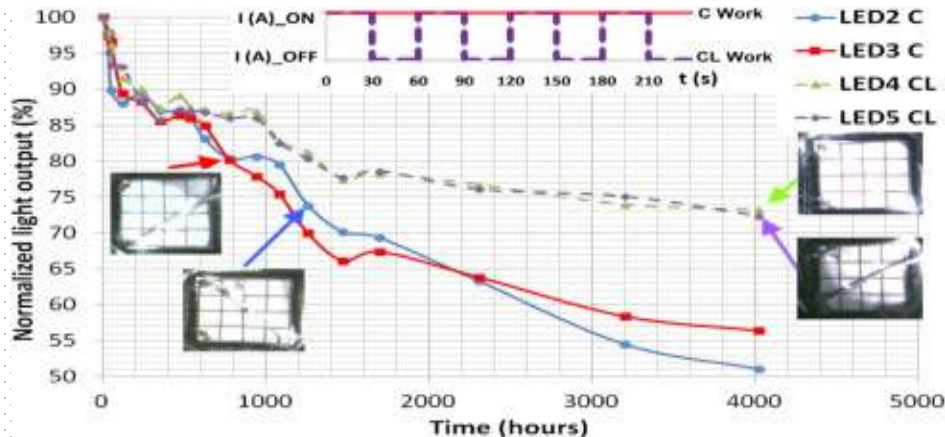
✓ Removal Strategy  
Emitter

✓ UL2998 Compliance:  
Yes & No

✓ Bi-Product Generation:  
Possible



Information source  
[www.sciencedirecthvacschool](http://www.sciencedirecthvacschool)



Named ultraviolet (beyond violet) because it is located just beyond violet on the electromagnetic spectrum.



## LESSONS LEARNED FOR

# Existing Technologies Ultraviolet Light

The question is, are the UV lights in UV light air purifiers and far-uv-c technology powerful enough to kill the coronavirus? Scientists have shown a dose of  $75\text{mJ}/\text{cm}^2$  is needed to kill >99.9% of the COVID-19 virus.

After analyzing China's biggest e-commerce platform – Taobao, we found data on the UV light strength for 3 UV light air purifiers. This includes one purifier from Samsung:

UV Purifier Name	UV Light Power	Time Air Spends in Air Purifier
SOLEUS AIR	6W	0.15s
SAMSUNG	4W	0.65s
NOBICO	8W	0.26s
Average:	6W	0.35s

The average UV bulb power for these three purifiers is 6 W. Using a simple rule of thumb, for the average distance of 10 cm from the UV light, these purifies give out on average  $6\text{ mW}/\text{cm}^2$  of UV light.

**$1\text{ mJ}/\text{cm}^2 = 1\text{ mW}/\text{cm}^2$  for  
1 second of exposure**

LESSONS LEARNED FOR

# Existing Technologies Ultraviolet Light

## Residence Time Example:

HVAC Unit Cross-sectional area: 500 FPM

Sample Area =  $16" \times 16" = 256$  square inches  $\div 144 \approx 1.778$  square feet (506 FPM)

Q (Airflow) = 900 cfm

Required Plenum length  $L = (Q \times t) / \text{Area}$

Residence time (t) is 0.35 seconds:  $t$  (minutes) =  $0.35 \text{ seconds} \div 60 \approx 0.00583$  minutes

Substituting the values into the formula:

$L = (900 \text{ cfm} \times 0.00583 \text{ minutes}) / 1.778 \text{ square feet} = \approx \mathbf{2.95 \text{ feet}}$

**A duct at 1000 FPM, you would need approx. 6 feet of UV Light!**

LESSONS LEARNED FOR

# Existing Technologies Ultraviolet Light

ACS Publications  
Most Trusted. Most Cited. Most Read.

Search: test, 2021 authors, etc.

## Influence of Germicidal UV (222 nm) Lamps on Ozone, Ultrafine Particles, and Volatile Organic Compounds in Indoor Office Spaces

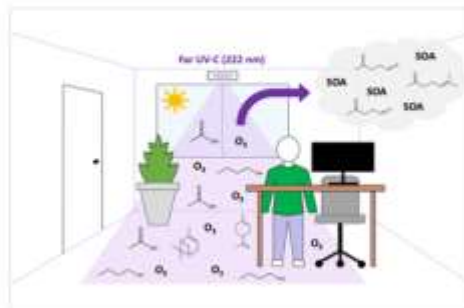
Sara Bjerre Samuelsen, Frederik Rask Dalby, Seren Kristian Ögren, and Kasper Kristensen\*

Open PDF

Supporting Information (1)

### Abstract

Germicidal ultraviolet lamps with a peak emission at 222 nm (GUV222) are gaining prominence as a safe and effective solution to reduce disease transmission in occupied indoor environments. While previous studies have reported  $O_3$  production from GUV222, less is known about their impact on other indoor constituents affecting indoor air quality, especially in real occupied environments. In this study, the effects of GUV222 on the levels of ozone ( $O_3$ ), ultrafine particles (UFPs), and volatile organic compounds (VOCs) were investigated across multiple offices with varying occupancies.  $O_3$  from the GUV222 operation was observed to increase linearly ( $\sim 300 \mu g h^{-1} m^{-1}$ ) with a UV light path length from 0 to 3 m beyond which it stabilized. When applied in offices, the  $O_3$  production models based on continuous measurements revealed  $O_3$  production rates of  $1040 \pm 87 \mu g h^{-1}$ . The resulting increases in steady-state concentrations of  $5\text{--}21 \mu g m^{-3}$  were highly dependent on the number of office occupants. UFP production occurred during both unoccupied and occupied conditions but predominantly in newly renovated offices. Time-resolved measurements with a proton-transfer-reaction time-of-flight mass spectrometer (PTR-TOF-MS) revealed clear alterations in office VOC concentrations. Unsurprisingly,  $O_3$  oxidation chemistry was observed, including monoterpene deprivation and 4-oxopentanal (4-OPA) production. But additionally, significant alterations from unidentified mechanisms occurred, causing increased levels of various PTR-TOF-MS signals including  $C_2H_5O_2^+$  and  $C_4H_9^+$  hypothesized to arise from photoinduced formation or off-gassing during the GUV222 lamp operation.

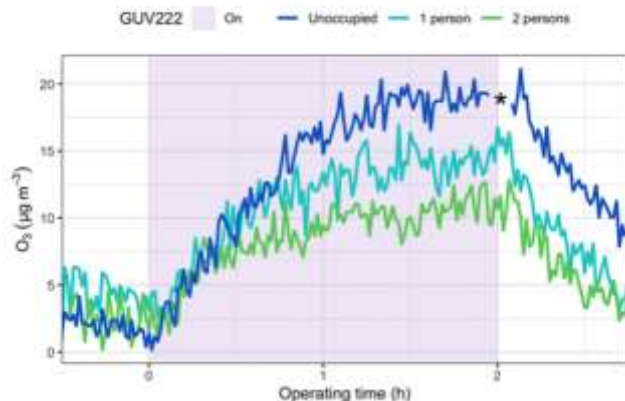


<https://pubs.acs.org/doi/10.1021/acs.est.4c03903>

# LESSONS LEARNED FOR

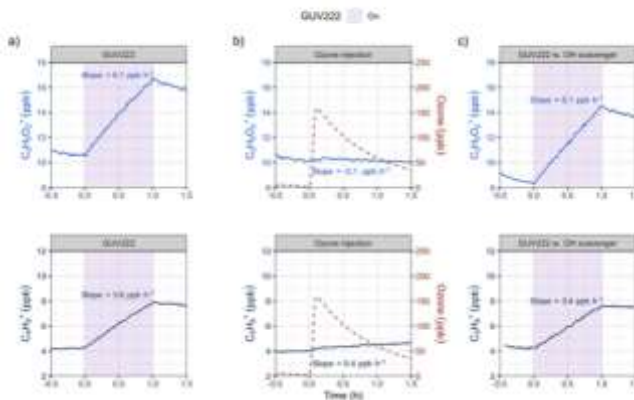
# Existing Technologies Ultraviolet Light

Figure 2



- Ozone (Dangerous to health): Irritates airways.
- Low levels of O<sub>3</sub> can cause health effects.
- Long-term exposure to ozone can result in serious health problems.
- People with asthma are at greater risk of harm from breathing air containing ozone.

Figure 5

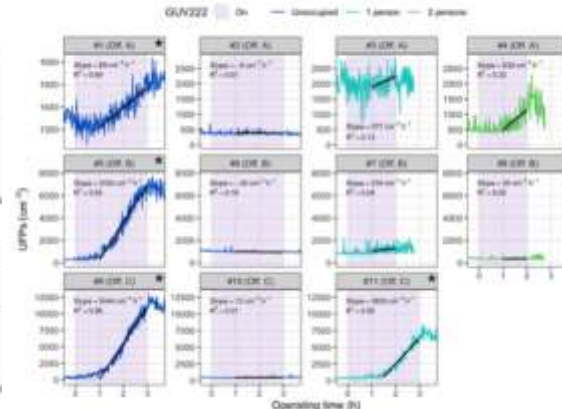


Poly(Methyl Methacrylate)  
Respiratory Irritations

Acetic acid

It is corrosive to the skin and eyes, and can cause damage to internal organs if ingested or inhaled

Figure 3



- Ultra fines are smaller than 1.0 micron
- Recent study led by researchers at McGill University Study: Contribute to more than 1,000 premature deaths a year in that city and Toronto.

<https://www.cbc.ca/newsinteractives/features/ultrafine-particles>

EMERGING TECHNOLOGIES?

# Plasmic Fields Technology

The three states of matter are:



Solid



Liquid



Gas

When energy is supplied to any matter, it changes its state.

Example:

- Solid become Liquid
- Liquid becomes Gaseous

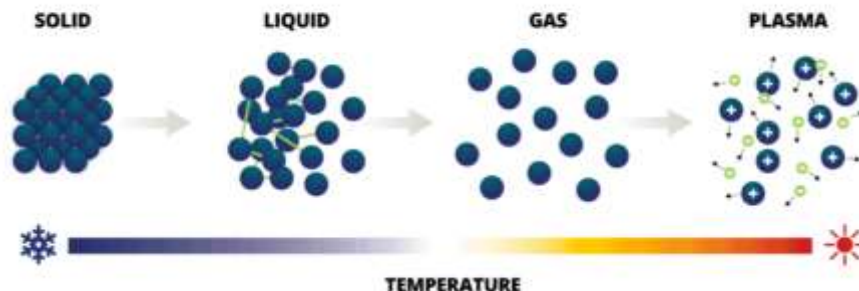
If we give more energy to a gas, it goes into an Energy – Rich state called Plasma State



Plasma was first discovered by **Irving Langmuir in 1928**. More than **99%** of the visible matter in the universe is in the **plasma state**.

For example: the natural lightning or polar light in the Arctic and Antarctic, or the bright circle of light around a sun during solar eclipse are examples of natural forms of plasma observed.

## STATES OF MATTER



WHAT IS PLASMA?

# Plasmic Fields Technology

Plasma is classified based on the relative temperature of the ions and electrons. Plasma Types:

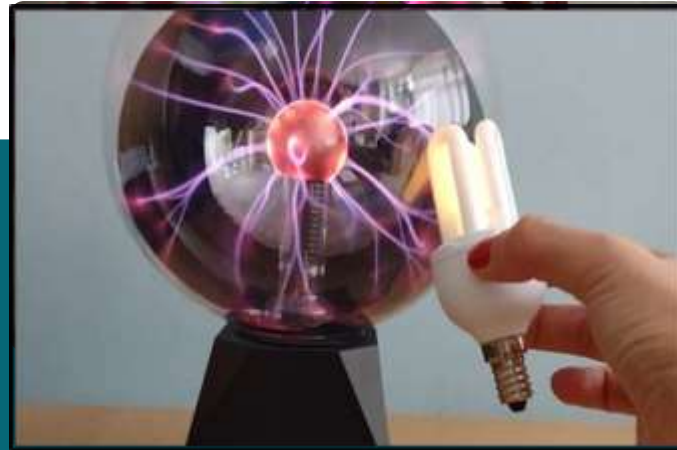
## HOT PLASMA

- Hot plasma is also called thermal plasma, they have electrons and heavy particles at thermodynamic equilibrium in nature



## COLD PLASMA

- Cold plasma called Non-Thermal Plasma (Reviveaire) is less ionized. Non-thermal plasma is near ambient temperature requiring low energy.
- Cold plasma unlike hot plasma is thermodynamically in a non – equilibrium nature.







# CERTIFICATIONS

# SARS-CoV-2 Live Pathogen Test Report

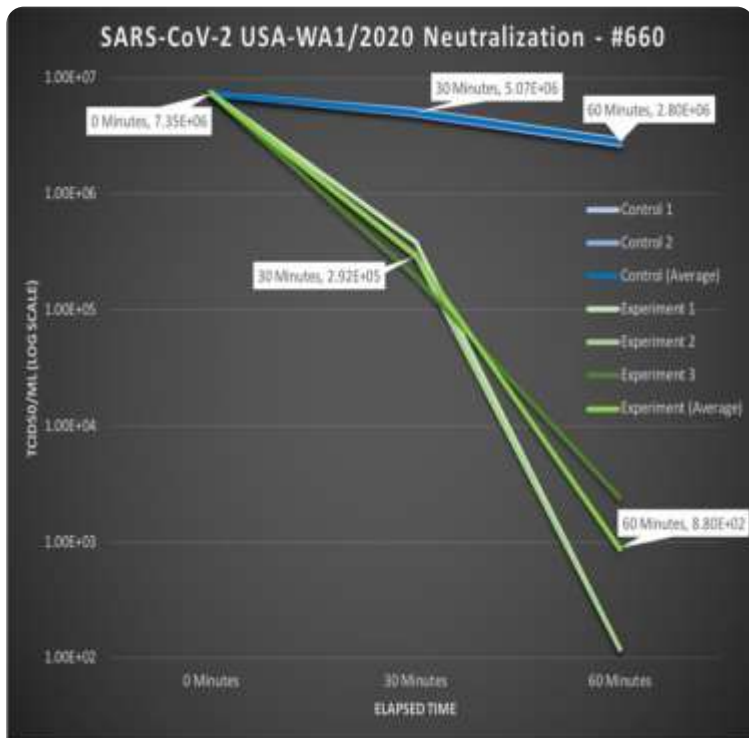


Figure 5: Log-scaled graph of aerosolized SARS-CoV-2 neutralization using the EcoTexas 560 air purifier over 60 minutes.

\*\*As it pertains to data represented herein; the percentage error equates to an average of  $\pm 5\%$  of the final concentration.

Table 2: Results Data and Calculated Percentage Reductions for SARS-CoV-2

Time (min)	0	30	60
Control 1 (TCID50/mL)	7.35E+06	5.25E+06	2.96E+06
Control 2 (TCID50/mL)	7.35E+06	4.90E+06	2.65E+06
Average Control (TCID50/mL)	7.35E+06	5.07E+06	2.80E+06
Average % Gross Reduction - Control		-31.010	-61.903
Experiment 1 (TCID50/mL)	7.35E+06	3.86E+05	1.20E+02*
Experiment 2 (TCID50/mL)	7.35E+06	2.95E+05	1.20E+02*
Experiment 3 (TCID50/mL)	7.35E+06	1.95E+05	2.40E+03
Average Experiment (TCID50/mL)	7.35E+06	2.92E+05	8.80E+02
Average % Gross Reduction - Experiment		-96.026	-99.988
% Net Reduction		-94.240	-99.969

**99.969%  
Reduction**

## PRIVATE RESIDENCE AIR TESTING BEFORE & AFTER.



Third party tested by ACM engineering & environmental services.

# CERTIFICATIONS

## ASHRAE STD 241 MS2 Live Pathogen Test Report

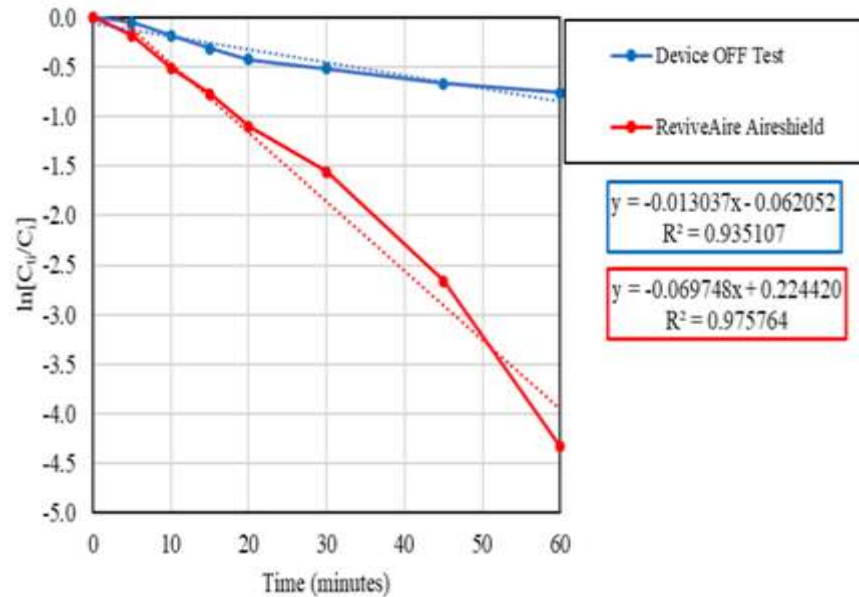


Figure 2.  $\ln[C_t/C_0]$  of MS-2 PFU data for ReviveAire Airesshield and Device OFF tests

### Test Results – Ozone Generation

The ReviveAire Airesshield was powered on in the test duct connected to the 1007  $\text{ft}^3$  test chamber with the recirculating airflow set at 200 CFM for a 24-hour period. The monitored ozone data is shown in Figure 3. There was no ozone generation observed during this test period. The average ozone concentration over this 24-hour period was 2.33 ppb.

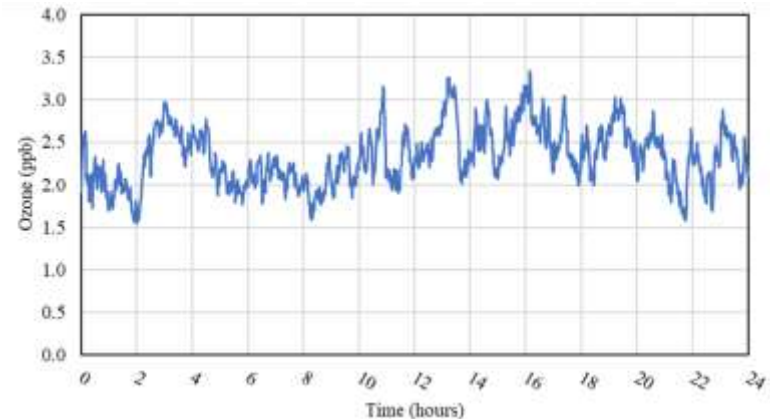


Figure 3. Ozone monitoring of ReviveAire Airesshield air cleaner for 24-hours

## CERTIFICATIONS

# ASHRAE STD 241 MS2 By-Product Test Report

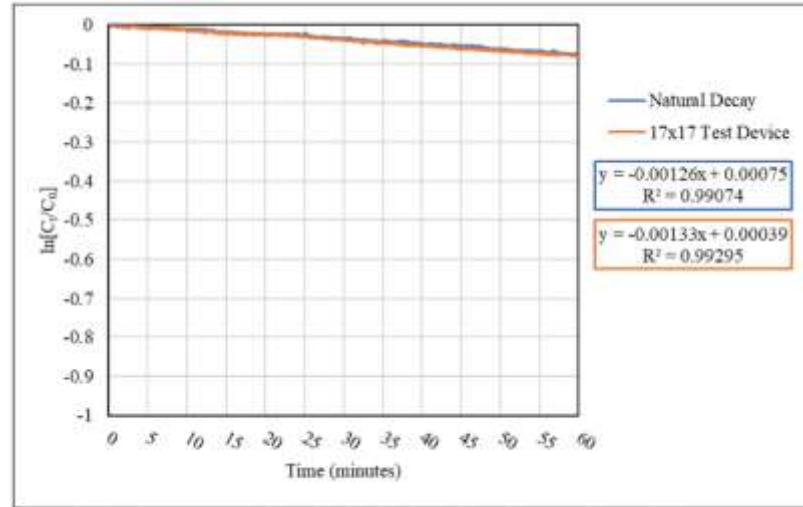
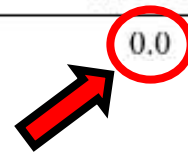


Figure 6.  $\ln[C_t/C_0]$  of toluene data for the 17"x17" test device and natural decay tests

**Table 5. Formaldehyde CADR results for all test**

	Natural Decay	Device (Initial Settings)
k-value	0.001326	0.001330
CADR (cfm)		0.0



## CERTIFICATIONS

# UL-2998 & CARB



VERIFIED  
ZERO OZONE

Intertek does hereby certify that an independent assessment has been conducted on behalf of



Certificate Number: 202-90668-2025a  
Certification issued: 4 March 2025

certificate valid until: 4 March 2026

Applicant Address: 217 Market Street  
Kensington, NJ 07033, USA

Industry Category: Appliances & Electronics

Product Details: See Appendix

Conformance Criteria: Conforms to UL 2998 [3rd Edition, July 10, 2020] clause 6.2, emissions of ozone not exceeding a concentration of 0.005 ppm.

Issuing Office Name & Address: Intertek Testing Services NA, Inc.  
4700 Broadmoor Ave SE, Suite 200  
Kennesaw, GA 30142 USA  
Ph: +1-416-456-7801

*Paul Kiser*  
Paul Kiser  
Certification Officer  
Intertek

This certificate is for the exclusive use of the client's product and is provided pursuant to the agreement between the client and the client. Intertek's responsibility and liability are limited to the terms and conditions of the agreement. Intertek assumes no liability to any party, other than the client, in connection with the agreement, its use, misuse or damage caused by the use of this certificate. Intertek's liability is limited to the amount of the fee paid for the certificate. Intertek's liability is limited to the amount of the fee paid for the certificate. Intertek's liability is limited to the amount of the fee paid for the certificate. Intertek's liability is limited to the amount of the fee paid for the certificate.

Intertek Testing Services NA, Inc.

10 September 2020

5471

State of California  
AIR RESOURCES BOARD

EXECUTIVE ORDER G-25-136

Relating to Certification of Indoor Air Cleaning Devices



Models: AS-1625-1, AS-2020-1, AS-2025-1, AS-2424-1, AS-1224-1

Meets California ozone emissions  
limit: CARB certified.

# ASHRAE Journal (December 2023) Research

TECHNICAL FEATURE

## Airborne Particulate Matter Filtration Using Non-Thermal Plasma Air Purification

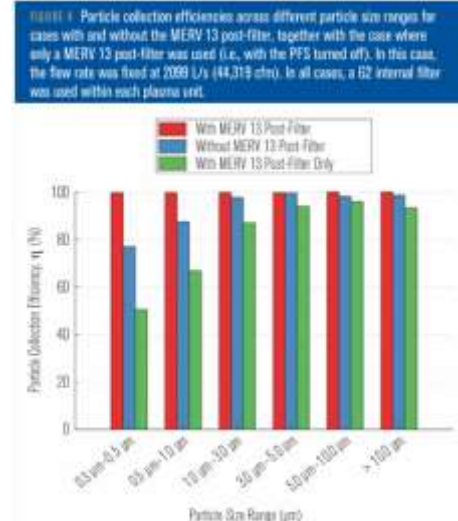
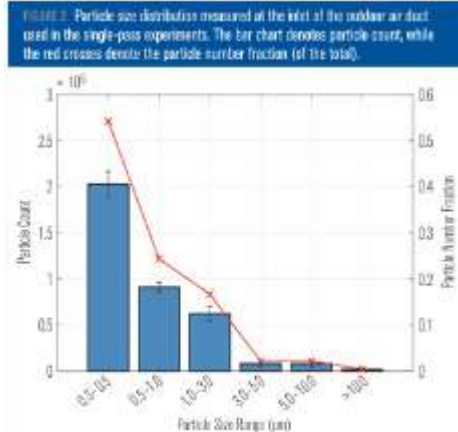
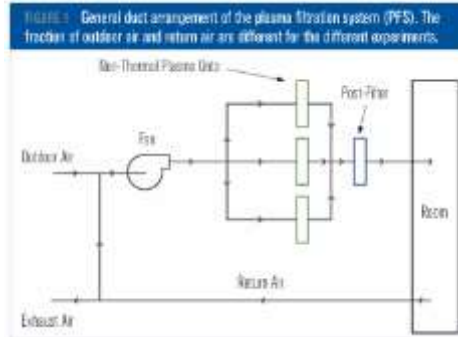
BY THOMAS LEE PHD, MAURICE CHENGE PHD

Particulate matter typically consists of small solid or liquid particles that can remain suspended in the air for long durations. It is typically less than tens of  $\mu\text{m}$  in size and can be carried over large distances by the airflow, both in natural environments (e.g., wind) or in mechanically assisted systems. In addition, it is almost impossible to avoid due to the sheer number of sources, which may include common household dust, pollen, powders, construction dust, bushfire smoke, etc. A new generation of air filtration systems to reduce airborne particulate matter is emerging that relies on air purification, rather than purely on capture and storage. One such option is via the use of non-thermal plasma air purification devices. In this article, the authors aim to provide experimental measurements demonstrating the efficacy of a plasma filtration system (PFS) under various conditions relevant to HVAC systems.

It is well established that inhalation of small solid or liquid particles, particularly those around the 0.1  $\mu\text{m}$  to 5  $\mu\text{m}$  range, can have significant adverse impacts on human health, both short and long term.<sup>1</sup> For example, estimates are that more than 4 million people die prematurely each year due to the effects of atmospheric particles smaller than 2.5  $\mu\text{m}$  ( $\text{PM}_{2.5}$ ).<sup>2</sup> Additionally, the inhalation of airborne droplets is also a likely mode of airborne pathogen transmission. In particular, respiratory pathogens such as the coronaviruses responsible for the SARS-CoV-2 and recent COVID-19 outbreaks are likely to spread via transmission of liquid particles.<sup>3</sup> Therefore, an urgent and important need exists for effective methods to remove small filter particles from environments, particularly within confined environments.

Shuang Lin, Ph.D., is a senior research engineer at The University of South Australia, Australia. He is also a senior research fellow at the University of South Australia, Australia. He is also a senior research fellow at the University of South Australia, Australia.

MAURICE CHENGE, Ph.D., is a senior research fellow at the University of South Australia, Australia.



## Conclusions

Experiments of PM count have revealed a non-thermal plasma air purification system can achieve single-pass particle collection efficiencies in excess of 99.95% (similar to a H13 HEPA filter) across all measured particle sizes between 0.3  $\mu\text{m}$  and 10  $\mu\text{m}$  where filter face velocities are  $<1$  m/s ( $<197$  fpm) and a MERV 13 post-filter is used. At greater face velocities

# Journal of Engineering: For Sustainable Buildings & Cities

## Effect of Nonthermal Plasma Technology on Reducing Airborne Contaminants in an Indoor Setting

Authors: Deify Law, Elbert Ho

Nonthermal plasma ionization includes dielectric barrier discharge & needlepoint bipolar ionization

PM 2.5 Removal Efficiency (%)

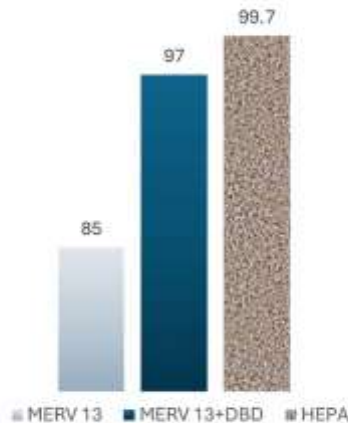


Fig. 2 Comparison of the PM<sub>2.5</sub> removal efficiency of MERV 13 filter assisted with and without DBD bipolar ionization and a stand-alone HEPA filter

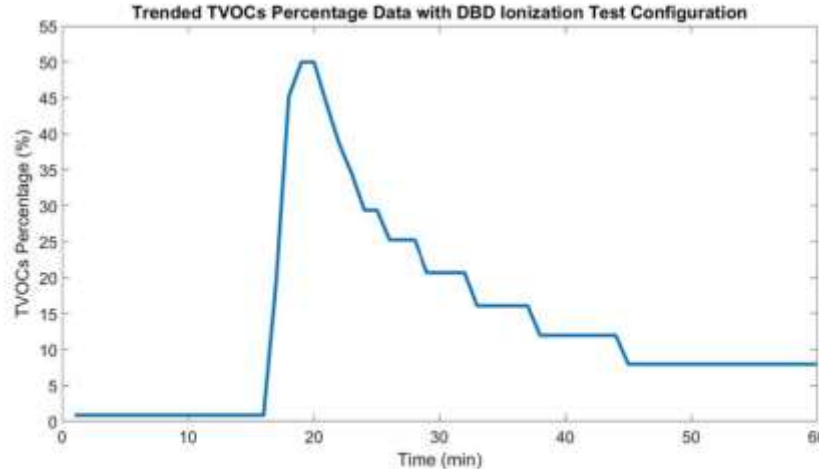


Fig. 6 Trended TVOCs percentage data with DBD ionization test configuration





## ANCILLARY BENEFITS

# Agglomeration Of Particulate Matter (PM) Particles

The conglomeration of particulate matter (PM) particles, when they pass through a plasma field, is a phenomenon that leverages the unique properties of plasma to affect the behavior and characteristics of particles suspended in air.

**Plasma can influence the behavior of particulate matter in several ways, see below:**

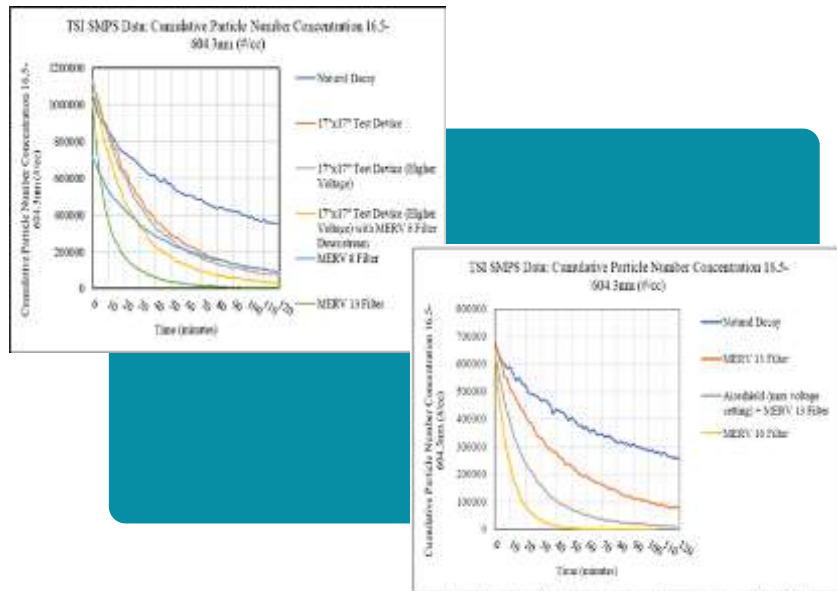
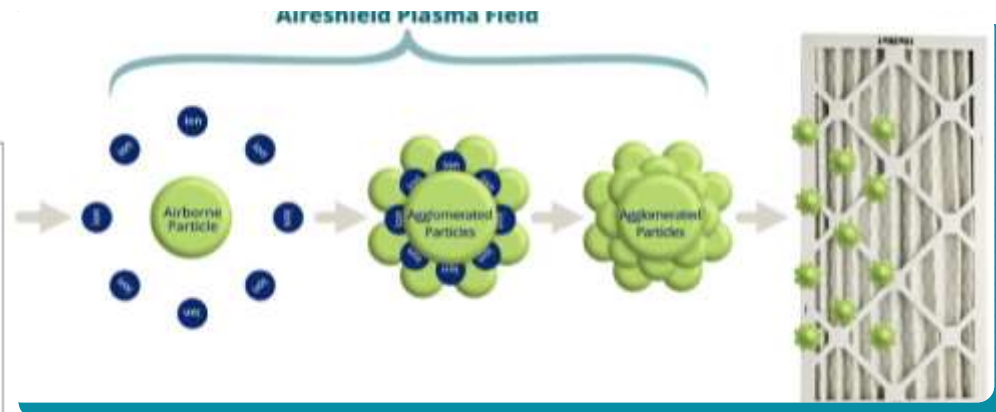


Figure 2. Cumulative 16.5-504.3nm particle number concentration graphs for all trials





## ANCILLARY BENEFITS

# BioFilm Formation – Energy Savings and cleaning costs

FIG 1: The presence of biofilms on the cooling coils of air conditioning (AC) units: and can significantly reduce the heat transfer efficiency of the coils and may lead to the aerosolization of microbes into occupied spaces of a building.

© 2019 John Wiley & Sons A/S. Published by John Wiley & Sons Ltd.

SOURCE: HVAC Insider Jan 2020.

<https://hvacinsider.com/new-cooling-coil-restoration-process-delivers-measurable-savings/>

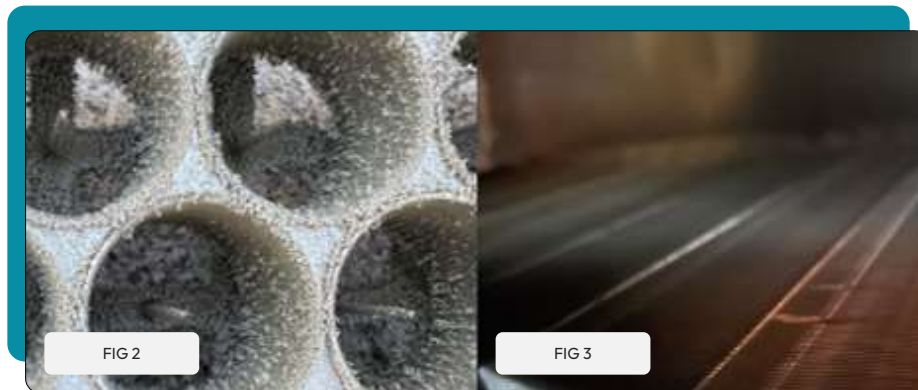
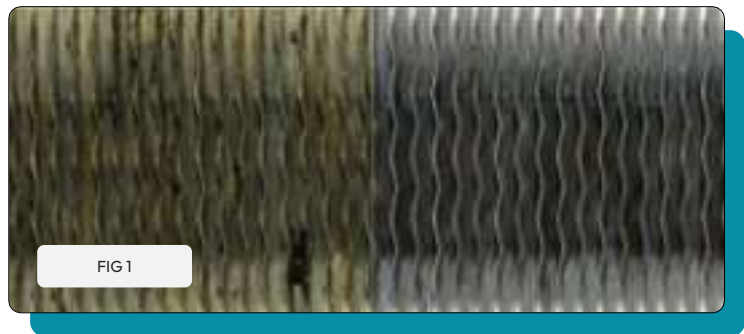


FIG 2 & 3: above and to the right is a test install. The Airesshield filter was left (neglected) for two years without filter service. Notice the extreme amount of buildup on the center photo

[FIG 2]. What was observed was, the coils preceding this filter where extremely clean, without a post filter [FIG 3]. PHOTO SOURCE: Ellison Rd., Watchung NJ test install.

CERTIFICATIONS

# Lincoln Center Study: Energy Savings & Payback



## B E N E F I T S   &amp;   P O W E R   S A V I N G S

# Low SP (in) Filter Design = Less Energy Consumption

Calculation Based On the Operation of **30000 CMH (17,000 CFM)** air volume units for **10 years**

Items	Code	Coarse effect MERV8	High Medium effect MERV13	HEPA/MERV16	ReviveAir®
Air Unit Volume (m3/h)(Approx. 17,000)	Q	30,000	30,000	30,000	<b>30,000</b>
Initial filter pressure drop (Pa)	P	40	100	400	<b>45</b>
Final Filter Pressure Drop (Pa)	P	200	350	600	<b>45</b>
Average filter pressure drop (Pa)	P	120	250	500	<b>45</b>
Electric Consumed per unit air volume	W	1.18	2.45	4.90	<b>0.44</b>
Power rate (\$) NYC, NY cost 23 C /(kWh)		0.23	0.23	0.23	<b>0.23</b>
Years		10	10	10	<b>10</b>
Hours per day		24	24	24	<b>24</b>
Cost Comparison of Different Technologies		\$23,704	\$49,382	\$98,765	<b>\$8,889</b>

## BENEFITS & POWER SAVINGS

# MERV16 Cost Benefit Comparison

Disposable MERV 16 (24 x24 x1)

- Based on 23 cents/kWh
- Based on average filter replacement costs every other month
- High maintenance
- Landfill

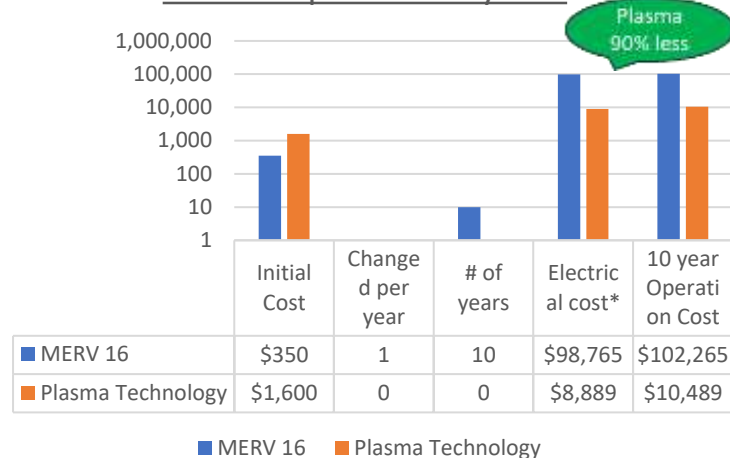
**AIRESHIELD (24 X24 X1)**

**\$8,889.00**

/ Operating Cost\*

- Breakthrough air disinfection technology
- Low power consumption < 12 watts
- Easy Maintenance: No Chemicals/Consumables
- Earth Friendly
- Priceless health benefits

### Ownership Cost & Payback



1-year filter cost:  $\$350 \times 1 \times 1 \text{ years} = \$350 = 1 \text{ year}$   
 electrical:  $\$9,876 \times 1 = \$9,876$  (\$10,226.00 Total)

**Airesield is cost-neutral in  
1-year payback!**

## BENEFITS & POWER SAVINGS

# MERV 13 Cost Benefit Comparison

Disposable MERV 13 (24 x24 x1)

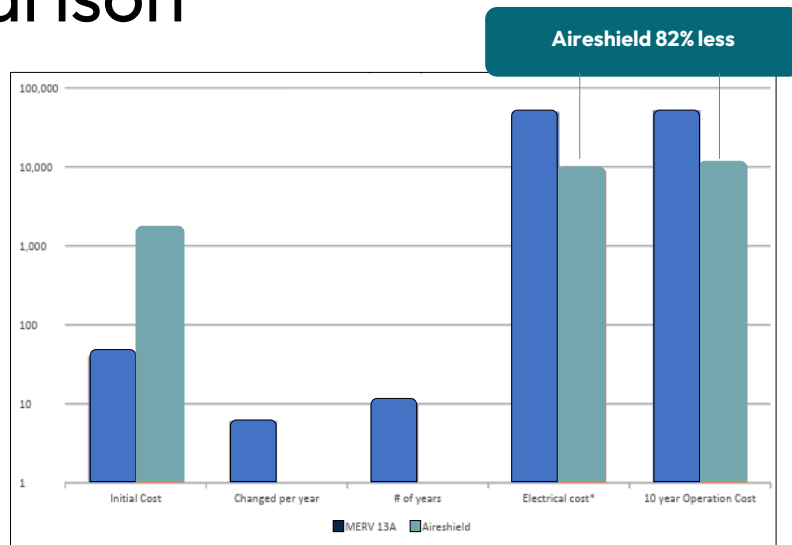
- Based on 23 cents/kWh
- Based on average filter replacement costs every other month
- High maintenance
- Landfill

**AIRESHIELD (24 X24 X1)**

**\$8,889.00**

/ Operating Cost\*

- Breakthrough air disinfection technology
- Low power consumption < 12 watts
- Easy Maintenance: No Chemicals/Consumables
- Earth Friendly
- Priceless health benefits



2-year filter cost:  $\$40 \times 6 \times 2 \text{ years} = \$480$  = 2 year  
 electrical:  $\$4938 \times 2 = \$9,876$  (\$10,356.00 Total)

**Airoshield is cost-neutral in 2-year payback!**

**(3.7 yrs w/o MERV8)**

B E N E F I T S   &   P O W E R   S A V I N G S

# On-Site test Protocol

## Test Protocol

Performance Metrics:

- **Indoor Air Particle Count Reduction**
- **Electrical Consumption Impact (Amps and Watts)**



## Test Dates

- **Pre-installation (MERV 13 & MERV 16) – June 9**
- **Post-installation (Airesield & MERV 13) – June 27**

## Test Location

Lincoln Center, New York City AHU #7 maintenance and engineering offices.

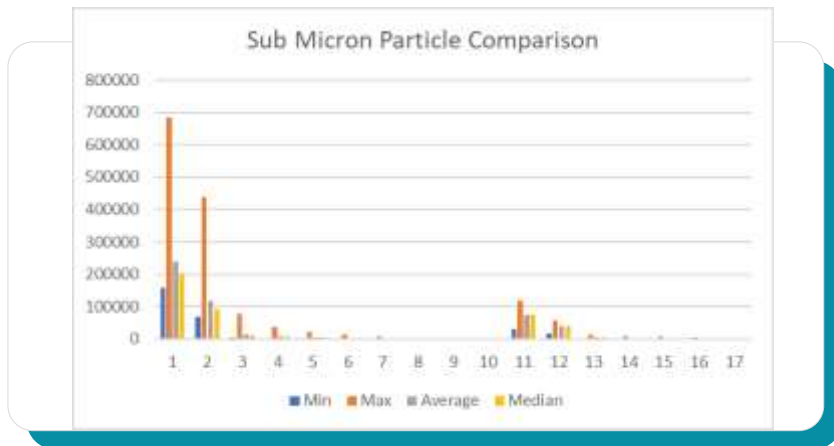


## BENEFITS & POWER SAVINGS

# On-Site test Results

## Electric Performance

Metric	June 9–27	June 12–28	Average
AMP Reduction	-41.7%	-29.6%	-35.6%
Watt Reduction	-36.2%	-24.6%	-30.4%



## HEPA Level performance

## Particle Performance

Average particle counts across all sizes were reduced by **74%**, with particularly strong performance on the **sub-PM2.5 spectrum**.

DATE	TIME	0.3um	0.5um	0.7um	1.0um	2.5um	5.0um	10.0um
6/12/25	Min	159640	68203	3905	1669	735	141	0
	Max	683926	438253	77004	35742	21451	14433	8801
	Average	238390.1	117305.9	15050.61	8630.681	5714.251	3589.689	2090.606
	Median	201877.5	92017	11489	7244	4909.5	3028	1726

DATE	TIME	0.3um	0.5um	0.7um	1.0um	2.5um	5.0um	10.0um
6/28/25	Min	30054	16102	1584	650	141	0	0
	Max	117105	57703	12706	9140	6792	4471	2433
	Average	75894.09	38572.13	4394.083	2245.003	1324.578	722.956	368.8316
	Median	75787	38855.5	4202	1981	1103	594	311

		Reduction						
		0.3um	0.5um	0.7um	1.0um	2.5um	5.0um	10.0um
	Min	-81%	-76%	-59%	-61%	-81%	-100%	-
	Max	-83%	-87%	-83%	-74%	-68%	-69%	-72%
	Average	-68%	-67%	-71%	-74%	-77%	-80%	-82%
	Median	-62%	-58%	-63%	-73%	-78%	-80%	-82%



# LEED Points

## Innovation

1 LEED Point



LEED Innovation  
(ID-EP-IO)

## Pollution Reduction

1 LEED Point



Indoor  
Environmental  
Quality

## Energy Reduction

1 LEED Point



Energy &  
Atmosphere

# Applications

## Healthcare

### Challenge



- COVID-19 Public Health Clinical
- Hospitals are more at risk from COVID-19 than other buildings

## School Applications

### Challenge



- Cassettes for Unitary Devices
- School classrooms have historically been places with high incidence of infectious diseases

## Commercial Buildings

### Challenge



- University application: High density application using fan coil units
- Terminal VRF with low static pressure capacity.

# New York City Code Position

## ASHRAE

ASHRAE  
1791 Tullie Circle, NE  
Atlanta, GA 30329

Standard reference number	Title	Referenced in code section number
ASHRAE—2005	ASHRAE Fundamentals Handbook—2005	603.2
+++15—2022	Safety Standard for Refrigeration Systems	1101.6, 1101.11, 1104.2, 1105.3, 1105.7, 1105.8, 1105.11, 1108.1
+++34—2022	Designation and Safety Classification of Refrigerants	202 (FLAMMABILITY CLASSIFICATION; REFRIGERANT SAFETY CLASSIFICATIONS; TOXICITY CLASSIFICATION), 1102.2.1, 1103.1, Table 1103.1, 1104.1
52.2—2012	Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size	605.2.1
62.1—2016	Ventilation for Acceptable Indoor Air Quality	403.2, 403.3.1.1, 403.3.1.1.2.3.2, 501.3.1, 514.4, 601.4, 605.2.1
62.2—2016	Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings	605.2.1
ANSI/ASHRAE/ASH170—2008	Ventilation of Health Care Facilities	401.4

**ASHRAE standard 241** is designed to be adopted without a change in your present ventilation standard year.

However, recent changes to standard 62 should be considered for adoption.

## New York City subway riders are breathing in hazardous air, study finds

Study shows average platform has four times the level of pollution exposure deemed safe by EPA



✎ A subway station in Brooklyn in 2021. Photograph: Michael M. Santiago/Getty Images

New York City subway riders are breathing in hazardous air, with Black and Hispanic commuters exposed to higher levels of pollution, a new study shows.

New York University researchers found that the average subway platform had **four times** the particulate pollution (PM2.5) exposure standard deemed safe over a 24-hour period by the Environmental Protection Agency, and **nine times** the exposure guideline set by the World Health Organization.

## B E N E F I T S   &amp;   P O W E R   S A V I N G S

# Environmental Benefits

**COST-EFFECTIVENESS****Changed every 1 -3 months****No waste, No Landfill,  
No handling of contaminated filters**

Unlike standard air filters, **Emerging Technologies** do not produce any waste or end up in landfills. This makes it an environmentally friendly choice for those looking to reduce their carbon footprint.



# Thank You

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Contact Information:

**Nick Agopian**

608-807-8677

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[nick@reviveaire.com](mailto:nick@reviveaire.com)

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[www.reviveaire.com](http://www.reviveaire.com)



# In-Situ Field Test of Residential Home in Florida

Optical Microscopic Analysis at 1,000 Times Magnification				
Sample ID / Location	Air Volume (L)	Raw Counts of Fungal Struct.	Fungal Structures/m <sup>3</sup>	Presumptive Fungal ID
FL21-002-A01 Outside Ambient Air	158	38	108	Basidiomycetes, Non-Specified
		36	968	Aspergillus/Penicillium-like
		6	200	Ascomycetes, Non-Specified
		2	50	Bipolaris/Drechslera/Helminthosporium/Exserohilum
		2	50	Cladosporium
		2	50	Monocorypha-like
	Total:	86	1300	
				Reporting Limit: 30 fungal structures per cubic meter
FL21-002-A02 Office	150	32	850	Basidiomycetes, Non-Specified
		15	480	Aspergillus/Penicillium-like
		7	280	Ascomycetes, Non-Specified
	Total:	54	1480	
				Reporting Limit: 30 fungal structures per cubic meter
FL21-002-A03 Kitchen/Dining Area	159	25	610	Basidiomycetes, Non-Specified
		14	370	Aspergillus/Penicillium-like
		4	100	Ascomycetes, Non-Specified
	Total:	41	1100	
				Reporting Limit: 30 fungal structures per cubic meter
FL21-002-A04 Master Bedroom	150	54	1400	Basidiomycetes, Non-Specified
		32	1000	Drechslera-like
		18	480	Ascomycetes, Non-Specified
		13	350	Cladosporium
		12	320	Aspergillus/Penicillium-like
		3	80	Ascomycetes/Penicillium-like/Sord
		2	50	Aspergillus/Penicillium-like
	Total:	154	4300	
				Reporting Limit: 30 fungal structures per cubic meter
NOTE: The results listed above in this report relate only to the samples tested as received. Sample volume is provided by the customer. Information provided by the customer, or lack thereof, can affect the validity of results. Due to rounding for significant figures, the raw fungal count(s) may vary slightly from the value obtained by summing each fungal structure category obtained within a sample.				
SIGNATURE: <i>[Signature]</i>		NAME & TITLE: Julie Smith-Laboratory Quality Manager		DATE: 1/15/2021
REVIEWED BY: <i>[Signature]</i>		NAME & TITLE: Evelyn Hernandez-Laboratory Assistant		DATE: 1/15/2021
ACM ENGINEERING & ENVIRONMENTAL SERVICES 3404 HOOVER BLVD, SUITE 5, TAMPA, FL 33634 PHONE (813) 885-7868 FAX (813) 885-7967 www.acmenv.com				

Before installation of Reviveaire devices

Sample ID/ Location	Air Volume (L)	Raw Counts of Fungal Struct.	Fungal Structures/m <sup>3</sup>	Presumptive Fungal ID
FL21-002A-A01 Outside Ambient Air	158	97	2400	Ascomycetes, Non-Specified
		87	2200	Basidiomycetes, Non-Specified
		29	750	Cladosporium
		18	480	Bipolaris/Drechslera/Helminthosporium/Exserohilum
		3	80	Aspergillus/Penicillium-like
	Total	234	6280	Reporting Limit: 30 fungal structures per cubic meter
FL21-002A-A02 Office	150	3	80	Basidiomycetes, Non-Specified
		1	30	Ascomycetes, Non-Specified
		1	30	Asium-like
	Total	3	100	Reporting Limit: 30 fungal structures per cubic meter
FL21-002A-A03 Kitchen/Dining Area	158	3	80	Basidiomycetes, Non-Specified
		2	50	Ascomycetes, Non-Specified
		1	30	Cladosporium
	Total	6	200	Reporting Limit: 30 fungal structures per cubic meter
FL21-002A-A04 Master Bedroom	150	2	50	Ascomycetes, Non-Specified
		2	50	Basidiomycetes, Non-Specified
		Total	4	100

NOTE: The results listed above in this report relate only to the samples tested as received. Sample volume is provided by the customer. Information provided by the customer, or lack thereof, can affect the validity of results. Due to rounding for significant figures, the raw fungal count(s) may vary slightly from the value obtained by summing each fungal structure category observed within a sample.

SIGNATURE: 	NAME & TITLE: Julie Smith-Laboratory Quality Manager	DATE: 1/15/2021
REVIEWED BY: 	NAME & TITLE: Evelyn Hernandez-Laboratory Assistant	DATE: 1/15/2021

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After the installation of Reviveaire devices  
(only return air inlet)  
(ACM Engineering & Environmental Service)

There are 16 kinds of bacteria, fungi and mold, in all household environments

After installation, the outdoor air quality on the test day is deteriorated (theoretically indoor air quality will also deteriorate)

After installation, the bacteria in the closed study room decreased (92.86%)

Bacteria in the kitchen decreased (81.82%) after installation

After installation, the bacteria in the bedroom decreased significantly (97.56%)

Asthma patients used Reviveaire devices at home and reported no asthma attacks for a full quarter.