Regulatory Update/ COVID-19 Ventilation and IAQ Strategies

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March 28, 2020

Agenda

- The challenge
- What is new and proposed in 62.1 – 2019?
  - VRP
  - IAQP
- COVID-19 Strategies and Update

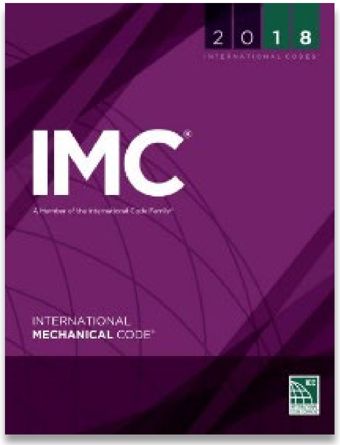

Poor IAQ
IAQ
Emission
CO_2
90%
OF OUR TIME
INDOORS
Ventilation
Energy

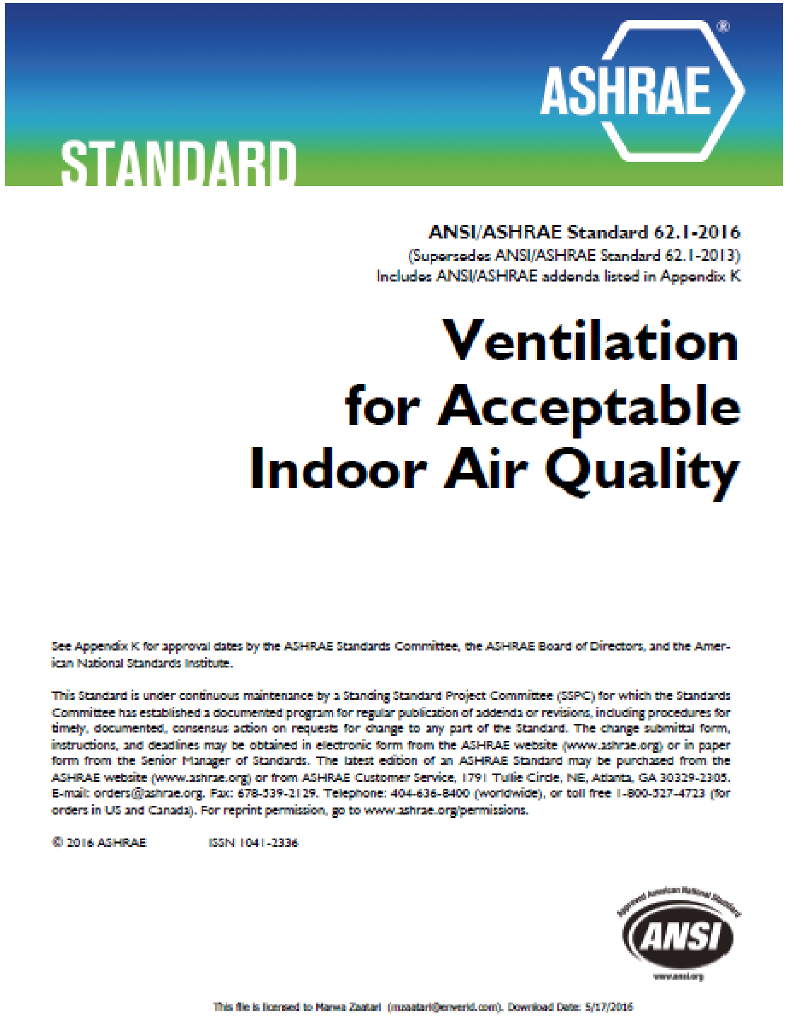
ASHRAE Standard 62.1

ASHRAE Standard 62.1 Overview

- ASHRAE Std. 62.1: Ventilation Rate Procedure (VRP)
  - *PRESCRIPTIVE*

- ASHRAE Std. 62.1: Indoor Air Quality Procedure (IAQP) – since 1979*
  - *PERFORMANCE-BASED*
  - Energy conservation
  - Less outdoor air pollution





STANDARD

ANSI/ASHRAE Standard 62.1-2016
(Supersedes ANSI/ASHRAE Standard 62.1-2013)
Includes ANSI/ASHRAE addenda listed in Appendix K

Ventilation for Acceptable Indoor Air Quality

See Appendix K for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, 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. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE website (www.ashrae.org) or in paper form from the Senior Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from the ASHRAE website (www.ashrae.org) or from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 678-539-2129. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

 ISSN 1041-2336

What is new in 62.1 – VRP?

VRP – 2019 Unusual sources

- **Published in 2019: when the engineer is in doubt of the indoor/outdoor pollutants sources**

→ the engineer <u>must use IAQP + air cleaning.</u>

→ Acknowledging that the ventilation rate procedure is inferior to the Indoor Air Quality procedure in terms of risk on the engineer/IAQP

6.2.2.1.2 Source Strengths. The Ventilation Rate Procedure minimum rates are based on contaminant sources and source strengths that are typical for the listed occupancy categories. Where unusual sources are expected, the additional ventilation or air cleaning required shall be calculated using Section 6.3.6 of the IAQ procedure or criteria established by the Environmental Health and Safety (EHS) professional responsible to the owner.

VRP – 2019 Ventilation Efficiency

- Elimination of **Table 6.2.5.2** System Ventilation Efficiency
- Replacing with two new equations based on diversity

E_v = 0.88*D + 0.22 for D<0.60 (6.2.5.3.1A)

E_v = 0.75 for D≥0.60 (6.2.5.3.1B)

TABLE 6.2.5.2 System Ventilation Efficiency

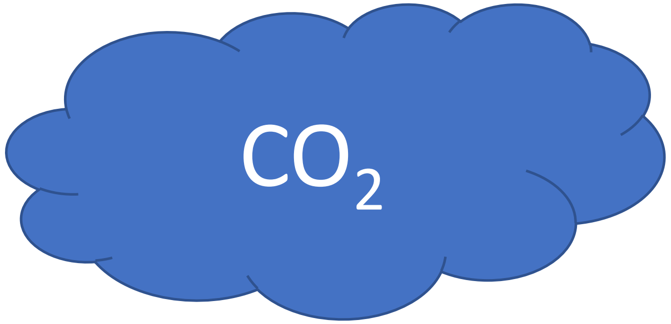
Max (Z_{PZ})	E_v
≤0.15	1.0
≤0.25	0.9
≤0.35	[illegible]
≤0.45	0.7
≤0.55	[illegible]
>0.55	Use [illegible]mative Appendix A

1. "Max (Z_{pz})" refers to the largest value of Z_{pz}, calculated using Equation 6.2.5.1, among all the ventilation zones served by the system.
2. For values of Max (Z_{pz}) between 0.15 and 0.55, the corresponding value of E_v may be determined by interpolating the values in the table.
3. The values of E_v in this table are based on a 0.15 average outdoor air fraction for the system. For systems with higher values of the average outdoor air fraction, this table may result in unrealistically low values of E_v and the use of Normative Appendix A may yield more practical results.

No changes to Appendix A method

VRP – 2019 Demand Control Ventilation

- Accuracy = ±75 ppm at 600 and 1000 ppm
- Sensors shall be factory calibrated
- Sensors shall be certified that they don't require calibration not more frequently than 5 years
- Sensor failure controls



Addendum al to 62.1-2016

Add new Section 6.2.7.1.3 as shown. Renumber the existing sections as appropriate.

6.2.7.1.3. Where CO_2 sensors are used for DCV, the CO_2 sensors shall be certified by the manufacturer to be accurate within plus or minus 75 ppm at a 600 ppm and 1000 ppm concentration when measured at sea level at 25°C. Sensors shall be factory calibrated and certified by the manufacturer to require calibration not more frequently than once every 5 years. Upon detection of sensor failure, the system shall provide a signal that resets the ventilation system to supply the required minimum quantity of outdoor air (V_{bz}) to the breathing zone for the design zone population (P_z).

VRP – 2019 Simplified Ventilation Rate for existing buildings

- Simplified Ventilation Rate Table for Existing Buildings

$$V_{target} = \Sigma_{all\ zones} A_z \times R_s \qquad \text{(D2)}$$

where

A_z = zone floor area, the net occupiable floor area of the ventilation zone, ft² (m²)

R_s = outdoor airflow rate required per unit area as determined from Table D2

	Outdoor Air Rate R_s	
Educational Facilities	cfm/ft²	L/s·m²
Classrooms (ages 5-8)	0.65	0.33
Classrooms (age 9 plus)	0.82	0.41
Computer lab	0.65	0.33
Media center	0.65	0.33
Music/theater/dance	0.72	0.36
Multi-use assembly	1.42	0.71
General		
Conference/meeting	0.44	0.22
Corridors	0.11	0.06
Office Buildings		
Breakrooms	0.65	0.33
Main entry lobbies	0.19	0.10
Occupiable storage rooms for dry materials	0.12	0.06
Office space	0.15	0.08
Reception areas	0.37	0.19
Telephone/data entry	0.63	0.32
Public Assembly Spaces		
Libraries	0.30	0.15

Outpatient Facilities

Outpatient health care facilities[a,b]
General examination room
Psychiatric examination room
Psychiatric consultation room
Psychiatric group room
Psychiatric seclusion room
Birthing room
Urgent care examination room
Urgent care treatment room
Urgent care triage room
Urgent care observation room
Physical therapy individual room
Physical therapy exercise area
Physical therapeutic pool area
Speech therapy room
Prosthetics and orthotics room
Dental operatory
Other dental treatment areas
Class 1 imaging rooms

Animal Facilities

- Small-animal-cage room (static cages)
- Small-animal-cage room (ventilated cages)
- Large-animal holding roor
- Animal imaging (MRI/CT/PET)
- Animal operating rooms
- Animal postoperative recovery room
- Animal preparation rooms
- Animal surgery scrub
- Necropsy
- Animal procedure room
- Animal exam room (veterinary office)

VRP – 2019
Addition of outpatient and animal facilities

What is proposed in 62.1 - IAQP?

What is proposed in ASHRAE IAQP 2019/2020?

Performance-based Approach → IAQP = Indoor Air Quality Procedure +air cleaning

Minimize the risk on the engineer behalf	• Define the requirements for design
Make requirement **more stringent** towards air cleaning	• Specify lab tests to get efficiency • Specify that the use of EAC is not allowed if they produce detectable by-products
Make key requirement **more prescriptive**	• Concentration limit, no by-product generation value, etc.

IAQP Methodology - 2016

The IAQP allows compliance based on:

1. Objective Evaluation (contaminants concentrations)
2. Subjective Evaluation (survey)

ASHRAE + LEED

Design

Contaminants and/or mixtures, sources, and emissions → Concentration limits → Identify air cleaning solution and efficiency → Use mass balance equation

LEED

Verification

IAQ Testing + Survey

- Locations at breathing level
- EPA methods

IAQP Methodology - 2016

The IAQP allows compliance based on:

1. Objective Evaluation (contaminants concentrations)
2. Subjective Evaluation (survey)

ASHRAE + LEED

Design

Not Defined — Contaminants and/or mixtures, sources, and emissions →
Not Defined — Concentration limits →
Not Defined — Identify air cleaning solution and efficiency →
Defined Appendix E — Use mass balance equation

Verification

LEED — IAQ Testing

- Locations at breathing level
- EPA methods

\+

Not Defined — Survey

IAQP Methodology - Proposed

Design

Contaminants and/or mixtures, sources, and emissions → Concentration limits → Identify air cleaning solution and efficiency → Use mass balance equation

Verification

IAQ Testing + Survey

IAQP Methodology - Proposed

2016

Contaminants and mixtures, sources, and emissions

Not defined

Proposed

New terminology:

Design Compounds, $PM_{2.5}$

design compounds (DCs): commonly encountered chemical compounds found in the indoor environment that have the potential to reduce acceptability of the air.

Particulate Matter 2.5 (PM2.5): particles with an aerodynamic diameter less than or equal to a nominal 2.5 micrometers.

Defined:

Design Compounds, $PM_{2.5}$

Defined:

Mixtures of concern

IAQP Methodology - Proposed

2016

Contaminants and mixtures, sources, and emissions

Not defined

Proposed

New terminology:

Design Compounds, $PM_{2.5}$

Defined:

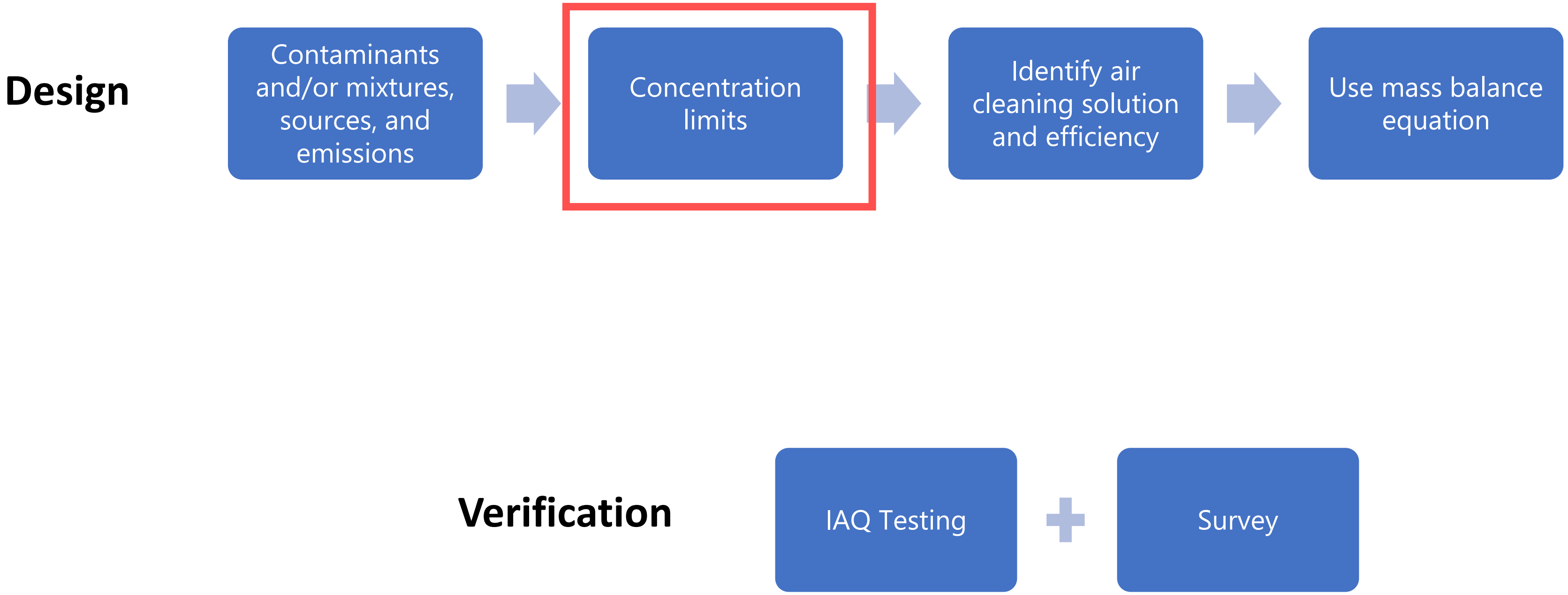
Design Compounds, $PM_{2.5}$

Defined:

Mixtures of concern

Compound or $PM_{2.5}$
Acetaldehyde
Acetone
Benzene
Dichloromethane
Formaldehyde
Naphthalene
Phenol
Tetrachloroethylene
Toluene
1,1,1-trichloroethane
Xylene, total
Carbon monoxide
$PM_{2.5}$
Ozone
Ammonia *(presence of animals)*

IAQP Methodology - Proposed



IAQP Methodology - Proposed

2016 — Concentration limits — Not defined

Proposed — *Defined:*

Concentration limits and cognizant authority

Compound or $PM_{2.5}$	Cognizant Authority	Design Target
Acetaldehyde	Cal EPA CREL (June 2016)	140 ug/m^3
Acetone	AgBB LCI	1,200 ug/m^3
Benzene	Cal EPA CREL (June 2016)	3 ug/m^3
Dichloromethane	Cal EPA CREL (June 2016)	400 ug/m^3
Formaldehyde	Cal EPA CREL (2004)	33 ug/m^3
Naphthalene	Cal EPA CREL (June 2016)	9 ug/m^3
Phenol	AgBB LCI	10 ug/m^3
Tetrachloroethylene	Cal EPA CREL (June 2016)	35 ug/m^3
Toluene	Cal EPA CREL (June 2016)	300 ug/m^3
1,1,1-trichloroethane	Cal EPA CREL (June 2016)	1000 ug/m^3
Xylene, total	AgBB LCI	500 ug/m^3
Carbon monoxide	USEPA NAAQS	9 ppm
$PM_{2.5}$	USEPA NAAQS (annual mean)	12 ug/m^3
Ozone	USEPA NAAQS	70 ppb
Ammonia	Cal EPA CREL (June 2016)	200 ug/m^3

IAQP Methodology - Proposed

Design

Contaminants and/or mixtures, sources, and emissions → Concentration limits → Identify air cleaning solution and efficiency → Use mass balance equation

Verification

IAQ Testing + Survey

IAQP Methodology - Proposed

2016

Identify air cleaning solution and efficiency

Not defined

Proposed

Defined:

Air Cleaning

$$V_{oz} = \frac{N - E_z R V_r E_f C_{bz}}{E_z (C_{bz} - C_o)}$$

1) Particle filters
   - MERV
   - ASHRAE Standard 52.2, ISO

Defined:

Gaseous scrubbers Documentation

2) Gaseous scrubbers
   - Efficiency
   - ASHRAE Standard 145.2, ISO, or third party test

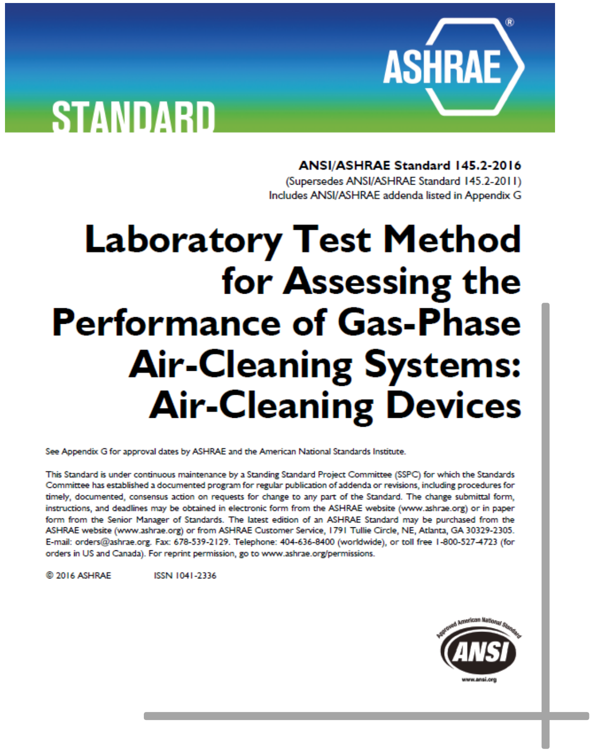
Defined:

Gaseous scrubbers Requirements

   - No by products: ozone and formaldehyde

Summary of ASHRAE Testing Standards

Standard 145.2


STANDARD

ASHRAE

ANSI/ASHRAE Standard 145.2-2016
(Supersedes ANSI/ASHRAE Standard 145.2-2011)
Includes ANSI/ASHRAE addenda listed in Appendix G

Laboratory Test Method for Assessing the Performance of Gas-Phase Air-Cleaning Systems: Air-Cleaning Devices

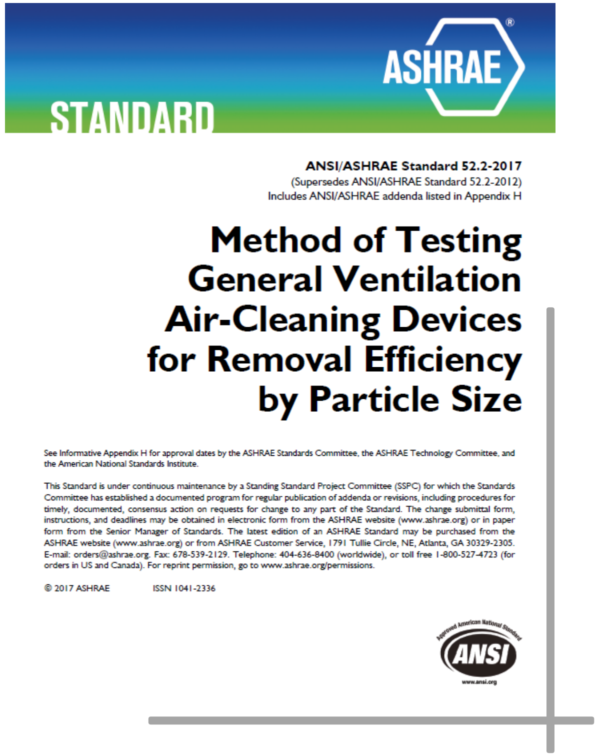
See Appendix G for approval dates by ASHRAE and the American National Standards Institute.

ISSN 1041-2336

Approved American National Standard ANSI www.ansi.org

- Tests for: VOCs, aldehydes, ozone, basic and acidic gases

Standard 52.2


STANDARD

ASHRAE

ANSI/ASHRAE Standard 52.2-2017
(Supersedes ANSI/ASHRAE Standard 52.2-2012)
Includes ANSI/ASHRAE addenda listed in Appendix H

Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size

See Informative Appendix H for approval dates by the ASHRAE Standards Committee, the ASHRAE Technology Committee, and the American National Standards Institute.

ISSN 1041-2336

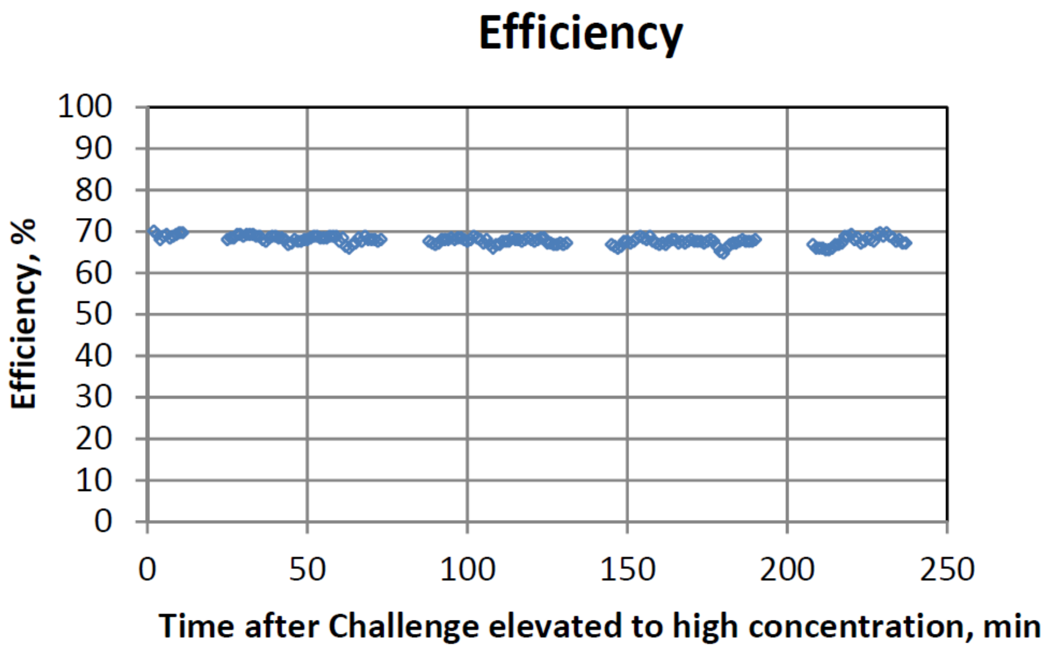
Approved American National Standard ANSI www.ansi.org

- Applies to filters
- Tests for: particle filtration

Sorbent-based Air Cleaning Performance

Example: Ozone test data from RTI:

- Efficiency = 70%
- By-product VOCs and ozone concentrations = 0 ppb



IAQP Methodology - Proposed

Design

Contaminants and/or mixtures, sources, and emissions → Concentration limits → Identify air cleaning solution and efficiency → Use mass balance equation

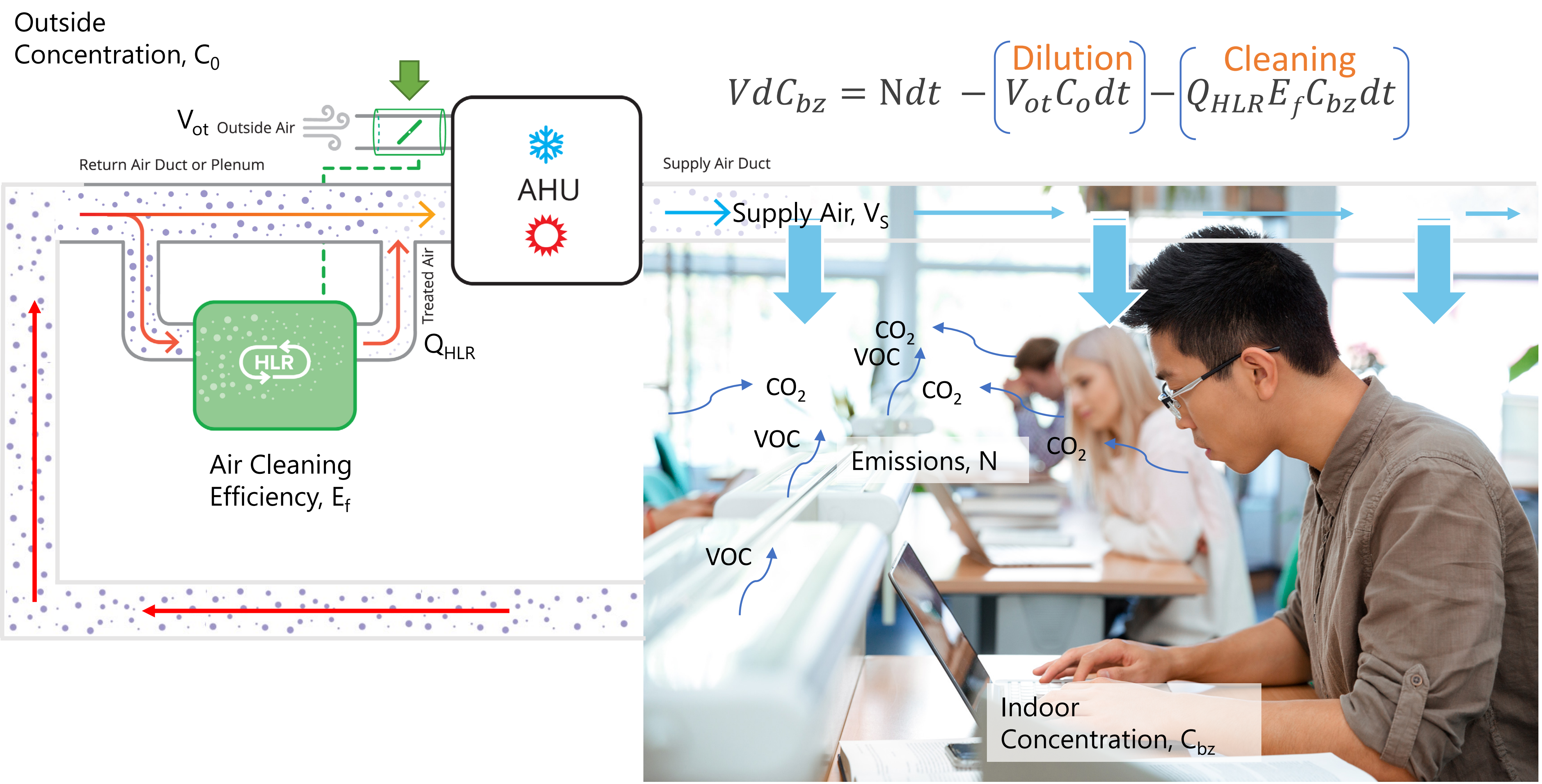
Verification

IAQ Testing + Survey

IAQP: Objective Evaluation Steps

Mass Balance Analysis

$$V dC_{bz} = N dt - \underbrace{\left(V_{ot} C_o dt\right)}_{\text{Dilution}} - \underbrace{\left(Q_{HLR} E_f C_{bz} dt\right)}_{\text{Cleaning}}$$



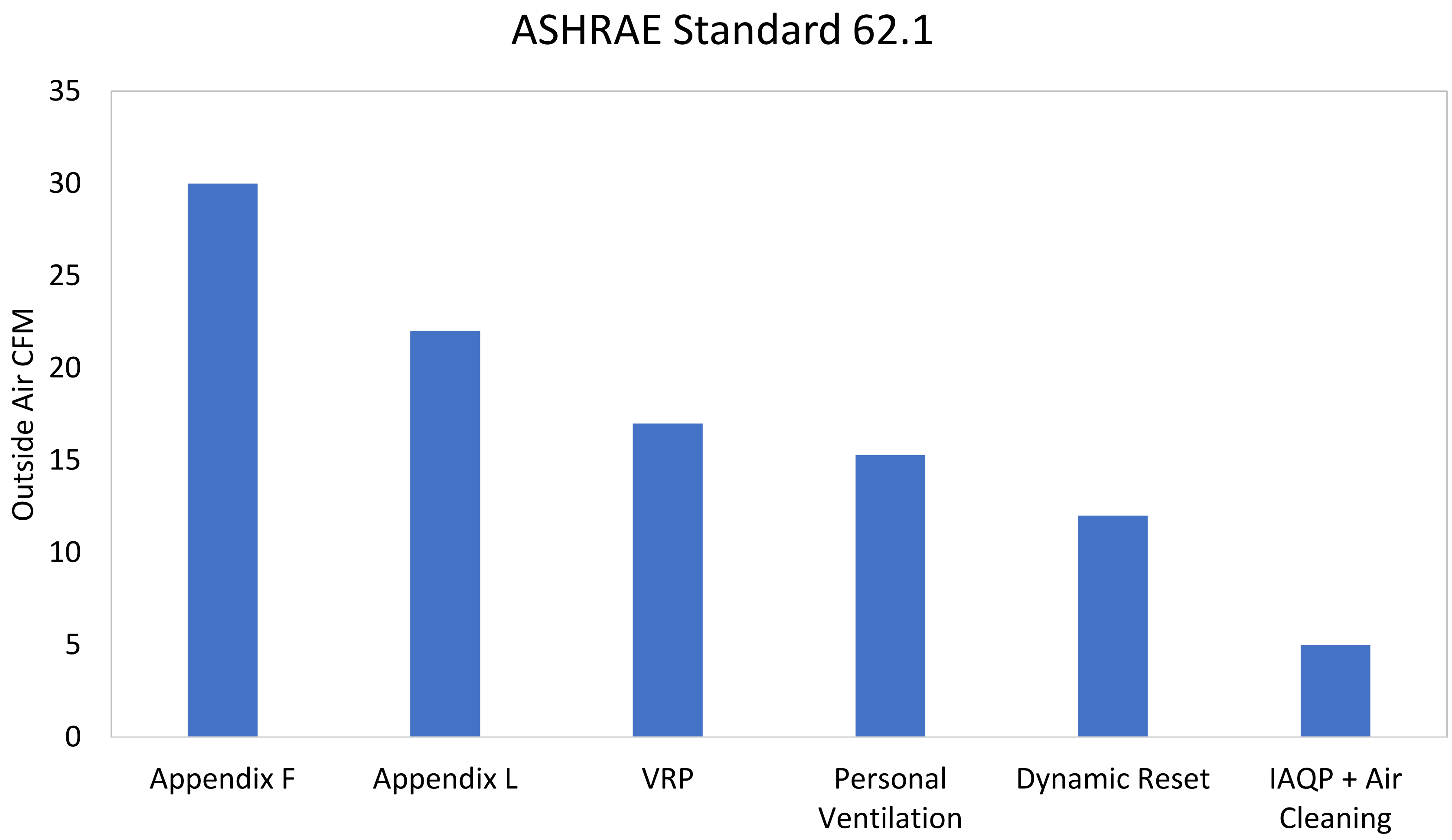
IAQP Use Cases

- Outdoor air is non-attainment for NAAQS or polluted
- Buildings with existing capacity limitations / Densification (aging of HVAC equipment, re-purpose of the space, adding more people
- New buildings with limited HVAC capacity (e.g., geothermal projects)
- Identified COC concentrations are high, requiring additional ventilation
- Building is located in cold or hot/humid climates
- LEED buildings

Summary

- James has a 200 sf office
- What ventilation is required?
- Appendix F 200 * 0.15 = 30 cfm
- Appendix L 200 * 0.11 = 22 cfm
- V_{bz} Equation 6.2.2.1 1 * 5 + 0.06 * 200 = 17 cfm
- V_{ot} = 17 cfm (Assume E_z = 1)
- Personal Ventilation V_{ot} = (1 * 5)/1.5 + 0.06 * 200 = 15.3 cfm
- Dynamic Reset?
  When James is not present during working hours V_{ot} = 12 cfm
- Natural Ventilation? One window or two must be open depending
- IAQP? V_{ot} = 5 cfm Assuming building sources are managed to below limits

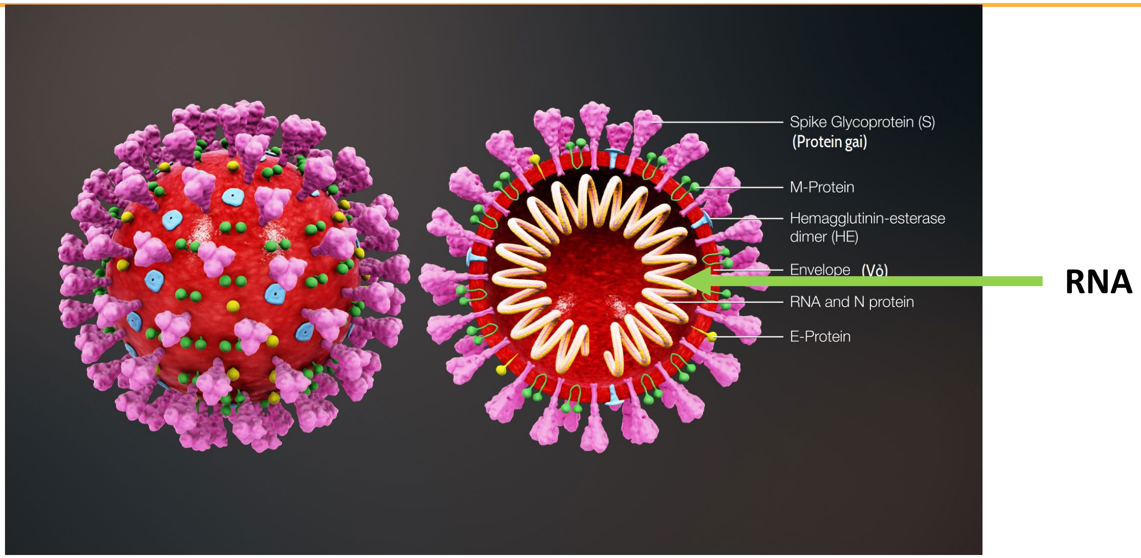
Graph of Mechanical Ventilation, Vot

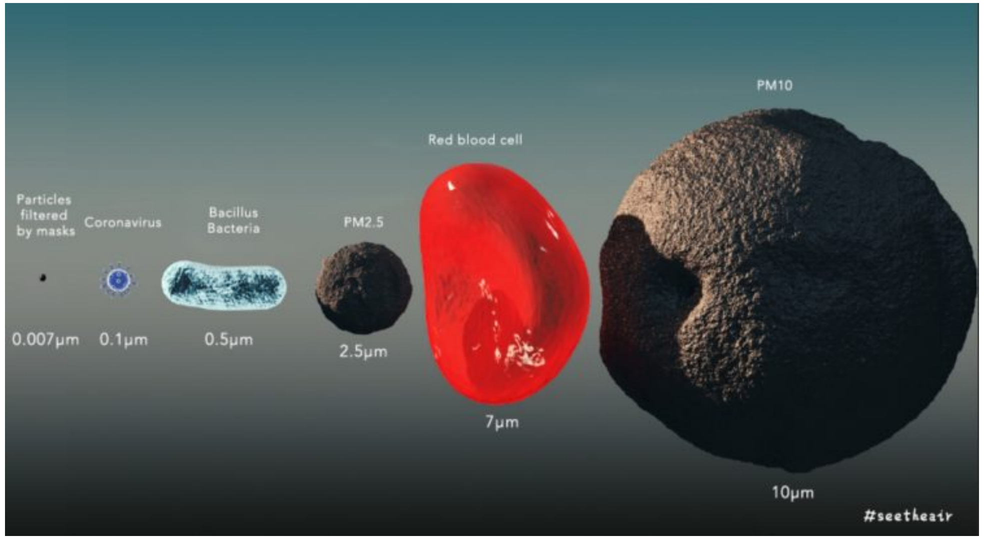


COVID-19

Background on COVID-19

- COVID-19 Size ~120nm in diameter
- Enveloped RNA viruses
- RNA is the target of most of the current COVID-19 tests (RT-PCR protocol)
  - ➢ RNA is a stable molecule that can be detected after a long time (weeks) even if the virus is inactive
- COVID-19 survives outside the body **only** within droplets or aerosols (the virus membrane will dry and break outside of those particles)





Current Research on COVID-19 Airborne Transmission

Consensus from WHO and CDC is airborne transmission is not driving the pandemic.

  - Anne Schuchat, principal deputy director at the U.S. CDC, “there is no current evidence to suggest that the coronavirus spreads through air-handling systems”.

- There is emerging evidence that COVID-19 can exist as an aerosol.
- As long as this route of transmission is not fully known, we have to take seriously the fact that COVID-19 can be transported via air.

Current Research on COVID-19 Airborne Transmission

1) Singapore. Field measurements in hospital rooms with patients with COVID-19. *12 air exchange rate.*
   - No virus in the air
   - Virus on ventilation fans

2) China, Wuhan University. Field measurements in hospital rooms with patients with COVID-19.
   - Low concentration of virus in the air
   - Highest concentration of virus near patient toilets. "Receptors for coronavirus exist not only in the airways but also in the gastrointestinal tract, so cells there can become infected, shedding virus into fecal material. " Author suggest sanitization of surfaces.

3) Nebraska. Field measurements in hospital rooms with patients with COVID-19.
   - Virus in the air (in most samples)

4) Lab study. Used a high-powered nebulizer to produce aerosols.
   - Detected viable virus in aerosols for up to three hours.
   - "The high-powered nebulizer used to produce the aerosol may mimic what occurs during procedures such as intubation and not what is generated from coughing and sneezing. " Same recommendation from WHO.

Can HVAC System Design and Operation Prevent COVID-19 Airborne Transmission?

Filtration? **YES**

- HVAC filters are designed to efferently remove airborne particles from the air.
- The higher the MERV (Minimum efficiency Rated Value) the higher the filtration.
- HEPA filters can probably eliminate all airborne viruses.

UV? **YES**

- UV is a proven technology that can effectively disinfect the air.
- Need to be properly design, installed and maintain.

Electronic air Cleaners? **NO**

- "None of these technologies have been proven to reduce infection in real buildings, even if they have promise based on tests in a laboratory or other idealized settings. Some of them have substantial concerns about secondary issues (such as production of ozone, a respiratory irritant)."

https://www.nafahq.org/covid-19-corona-virus-and-air-filtration-frequently-asked-questions-faqs/

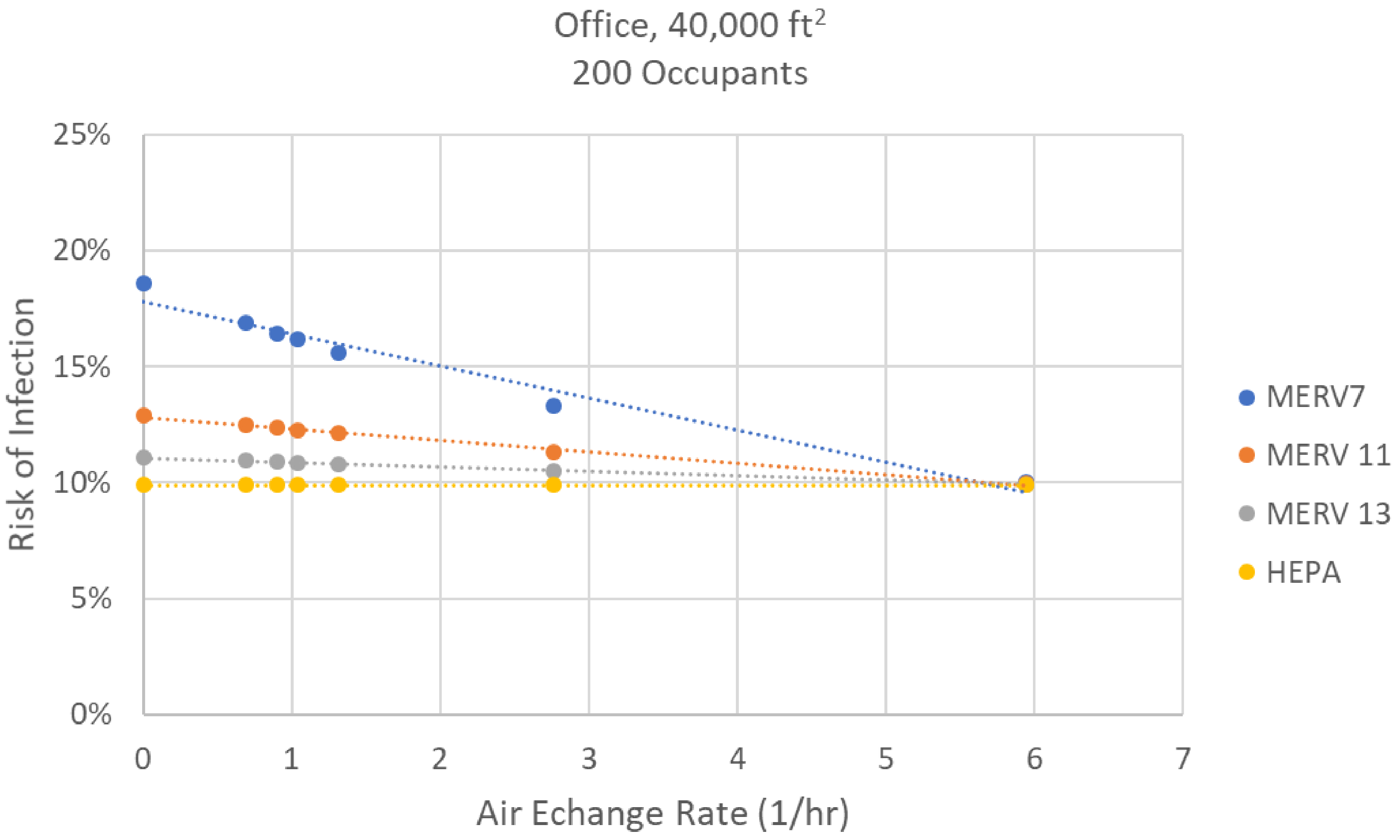
https://www.esmagazine.com/articles/100270-can-building-air-filtration-protect-me-from-getting-covid-19

Can HVAC System Design and Operation Prevent COVID-19 Airborne Transmission?

Outside air ventilation? **YES, BUT**

- Outside air ventilation has a smaller contribution to virus removal compared to filtration
- Increasing ventilation will make it hard to keep the building at 50% RH. RH at 50% is strongly related to virus inactivation.
- Particulate matter (PM) can serve as a carrier for virus aerosols, therefore increasing ventilation may increase PM and lead to an increase in the number of virus aerosols indoor.

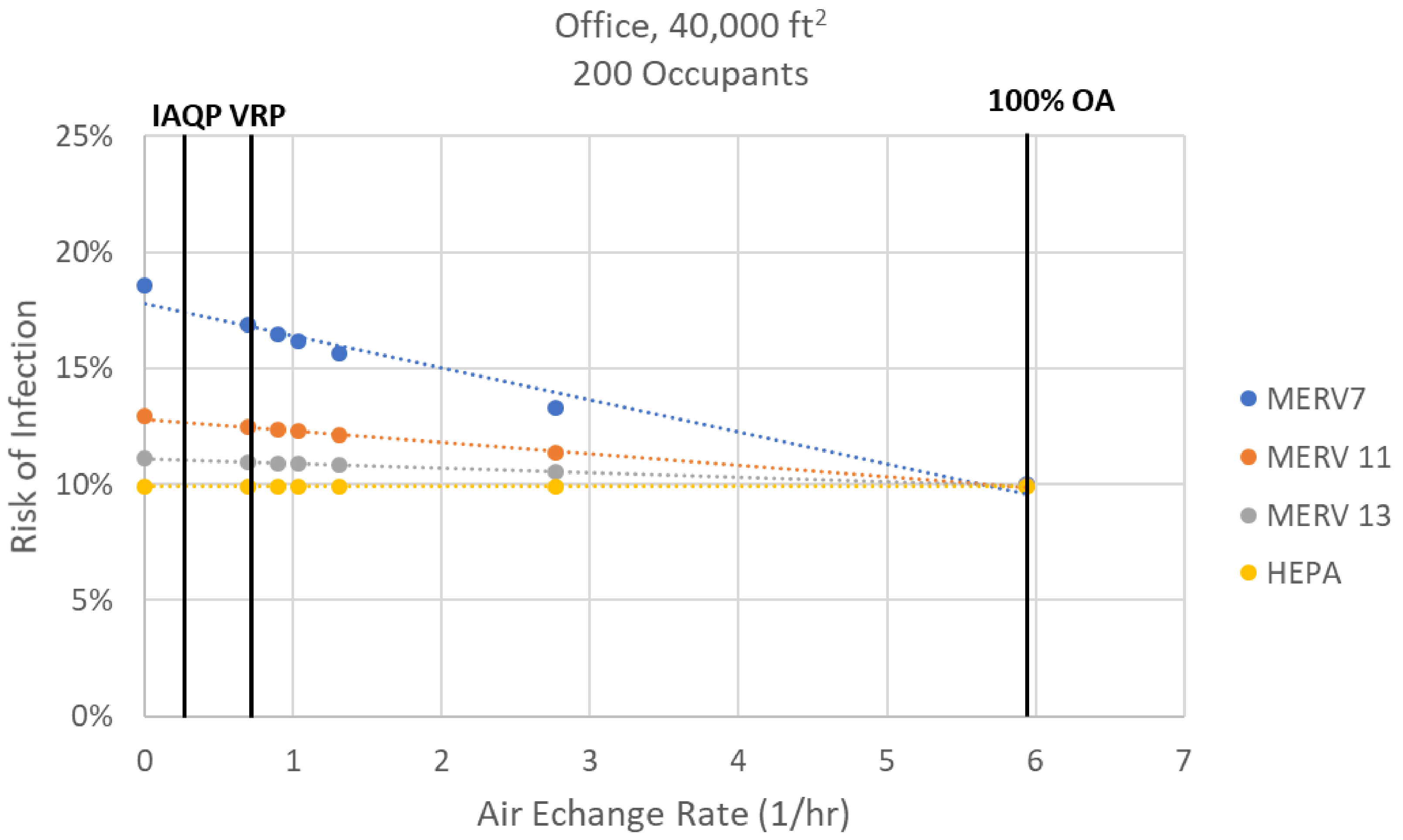
Filtration is the Dominate Mechanism for Virus Removal



Filtration:

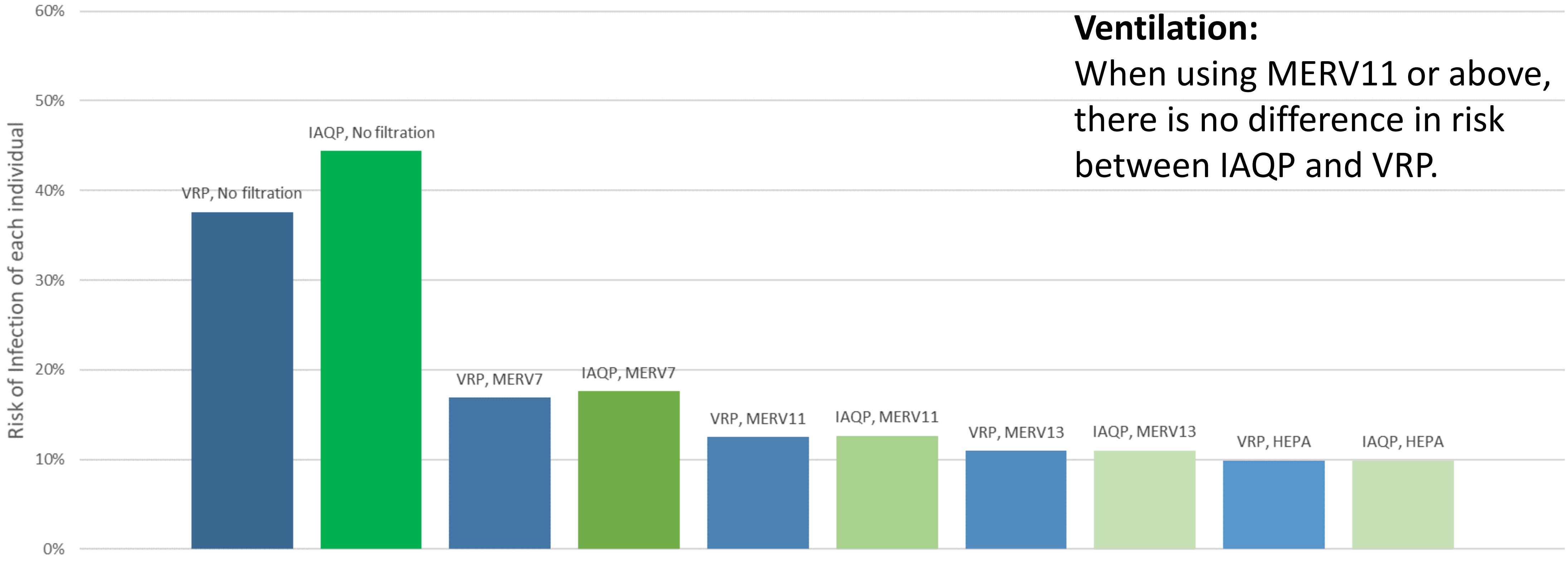
- Using higher MERV have a positive impact on decreasing infection risk.
- The higher the MERV, the smaller the effect of OA. OA has 0 effect when HEPA is used.
- HEPA offers similar infection risk reduction than MERV11 at high air exchange rate(>2.5 ACH) and less than 4% better risk than MERV11 at lower air exchange rate (<2.5 ACH)

Filtration is the Dominate Mechanism for Virus Removal



Ventilation:
When using MERV11 or above, there is no difference in risk between IAQP and VRP.

Risk of Infection in Different Filtration/Ventilation Scenarios

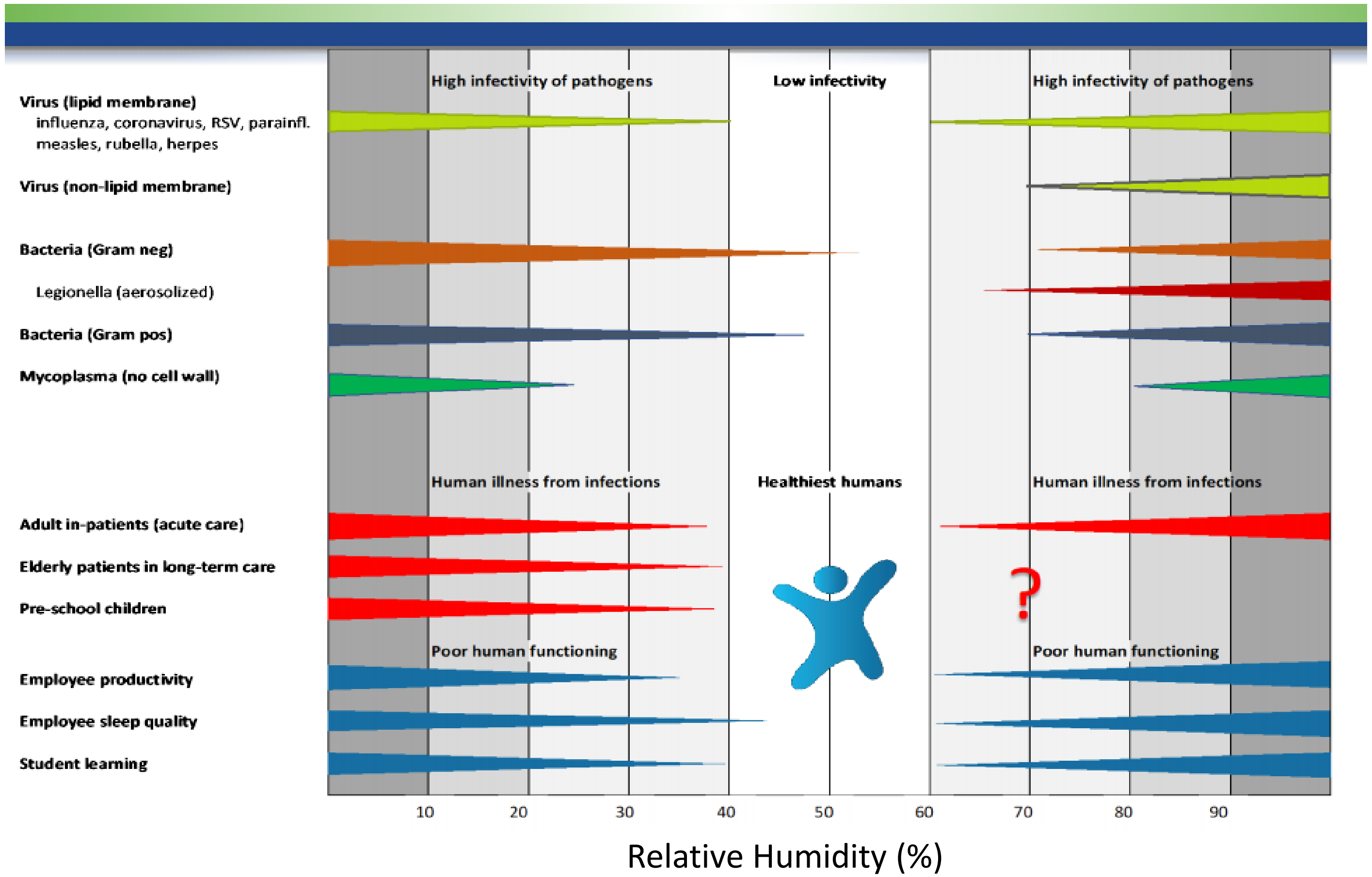


Ventilation:
When using MERV11 or above, there is no difference in risk between IAQP and VRP.

Why Increased Ventilation might not be a good approach (1)

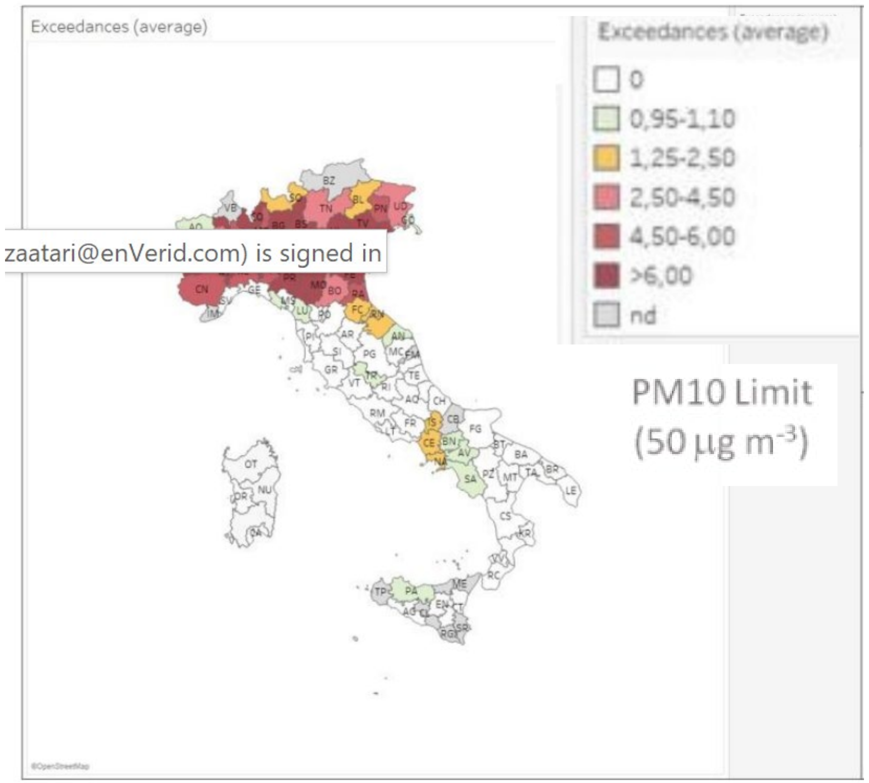
HVAC systems need to maintain RH near 50% to enable COVID-19 fast inactivation

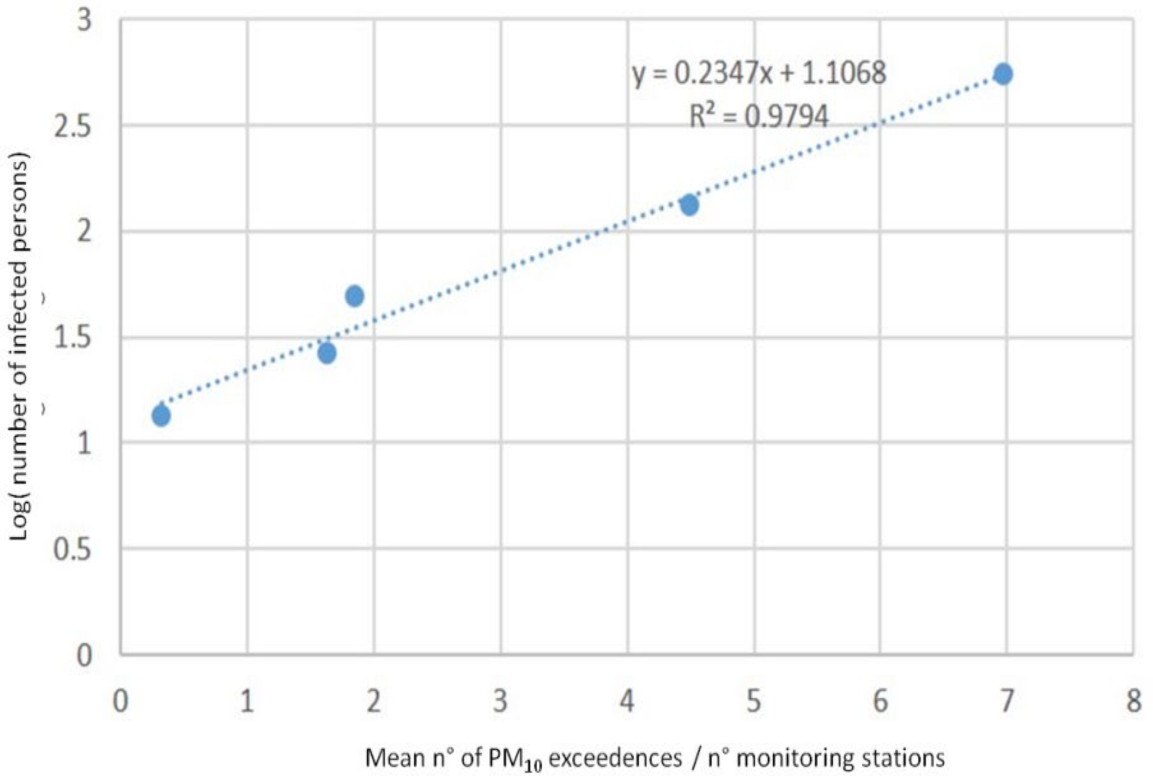
- Airborne COVID 19 survives much longer at RH <40% and RH >65%
- **Increasing OA ventilation will undermine the ability to maintain RH near 50%,** resulting in:
  - Higher humidity (>65%) when it is hot or rainy
  - Lower humidity (<40%) when it is cold and dry
- This can lead to a longer time in which COVID-19 is viable and increase probability of airborne transmission.



Why Increased Ventilation might not a good approach (2)

PM can serve as virus carriers - Increased OA ventilation will increase PM indoors and therefore the probability of airborne virus transmission





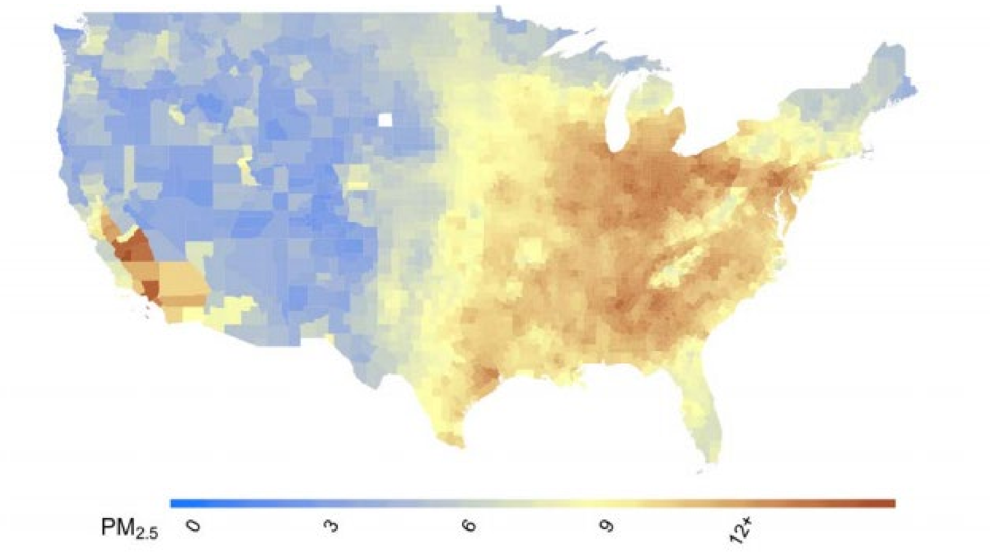
Correlation infected persons - PM10 exceedances in Italy 2020

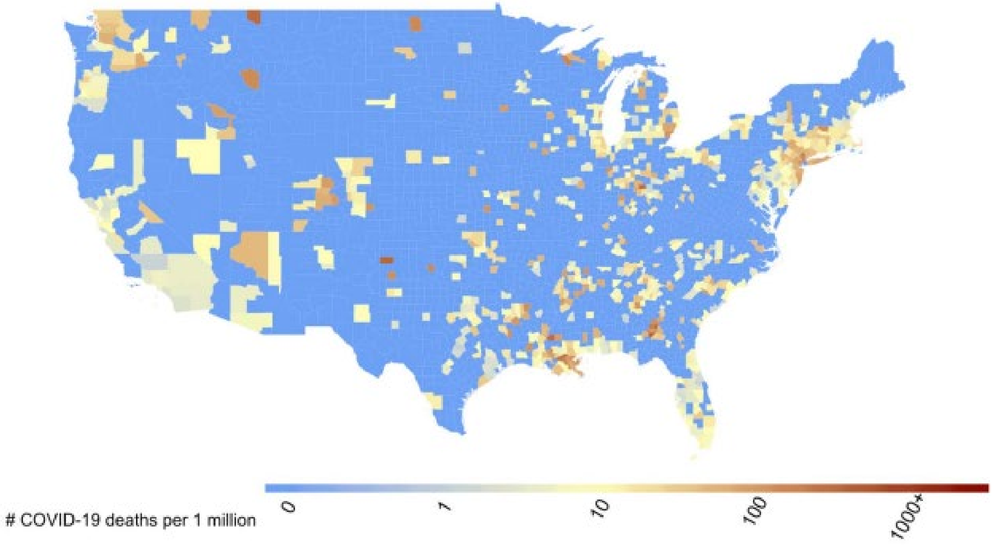
http://www.simaonlus.it/wpsima/wp-content/uploads/2020/03/COVID_19_position-paper_ENG.pdf

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7156797/#!po=3.84615

Why Increased Ventilation might not a good approach (2)

A new study from Harvard Public School of health found statistically significant evidence that increase of 1 $\mu g/m^3$ in long-term $PM_{2.5}$ exposure is associated with a 15% increase in the COVID-19 mortality rate.





https://projects.iq.harvard.edu/files/covid-pm/files/pm_and_covid_mortality.pdf

Thank you!

Marwa Zaatari

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Bonus Slides: Electronic Air Cleaners

Electronic Air Cleaners

- Lots of names:
  - Photocatalytic Oxidation (PCO)
  - Photocatalytic Activation
  - Ionization
  - Bi-polar ionization (BPI)
  - Needlepoint ionization
  - Plasma
  - Ozone generator
  - Activated Oxygen
  - Surface irradition
  - High voltage coronas
  - Hydroxlation
  - Precipitators

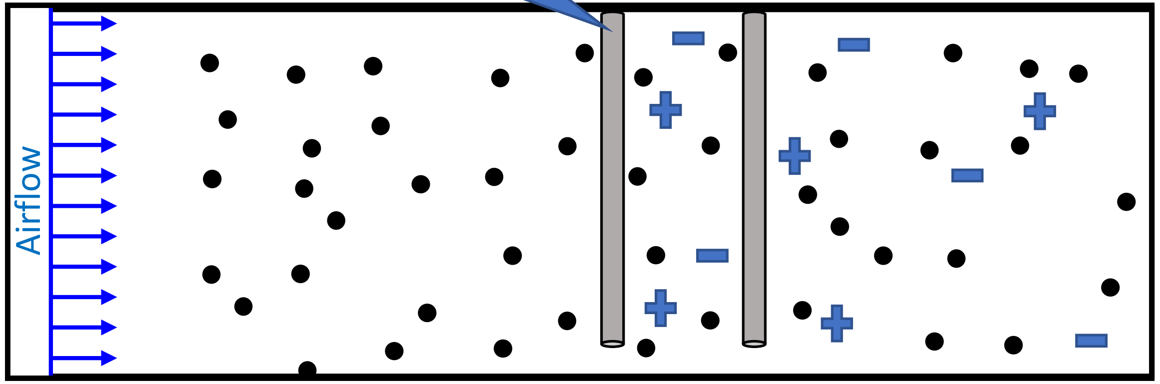
- But the mechanism is always the same:
  1. Apply high energy to air
  2. Creates new, highly reactive chemical species
  3. Species react with contaminants & particles

- Why so many names?
  - No industry rules for product names
  - Each vendor wants to appear different

Electronic Air Cleaners

"Ionization" tubes in supply air duct

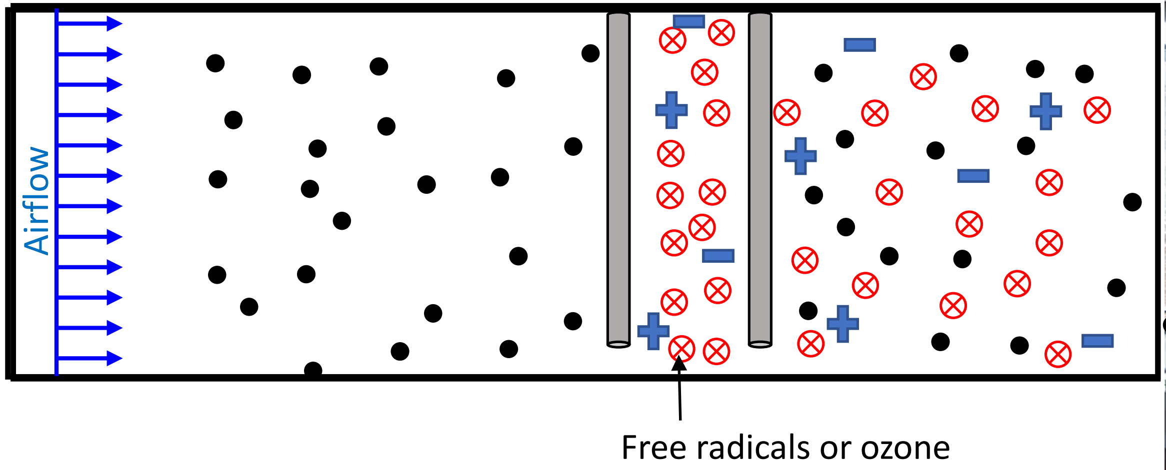
Energy applied to air breaks down molecules and creates ions

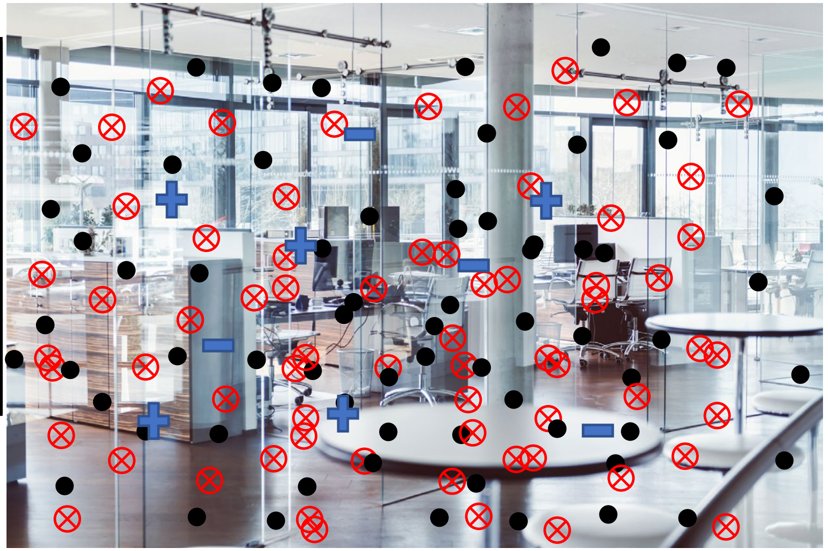


Ions are blown into space to chemically react with molecular contaminants and/or react with particles to increase their weight so they drop below breathing zone

Chemistry Fact #1: Free Radicals & Ozone Produced

Electronic Air Cleaners





Produce ions called Reactive Oxygen Species (ROS, or radicals) and ozone:

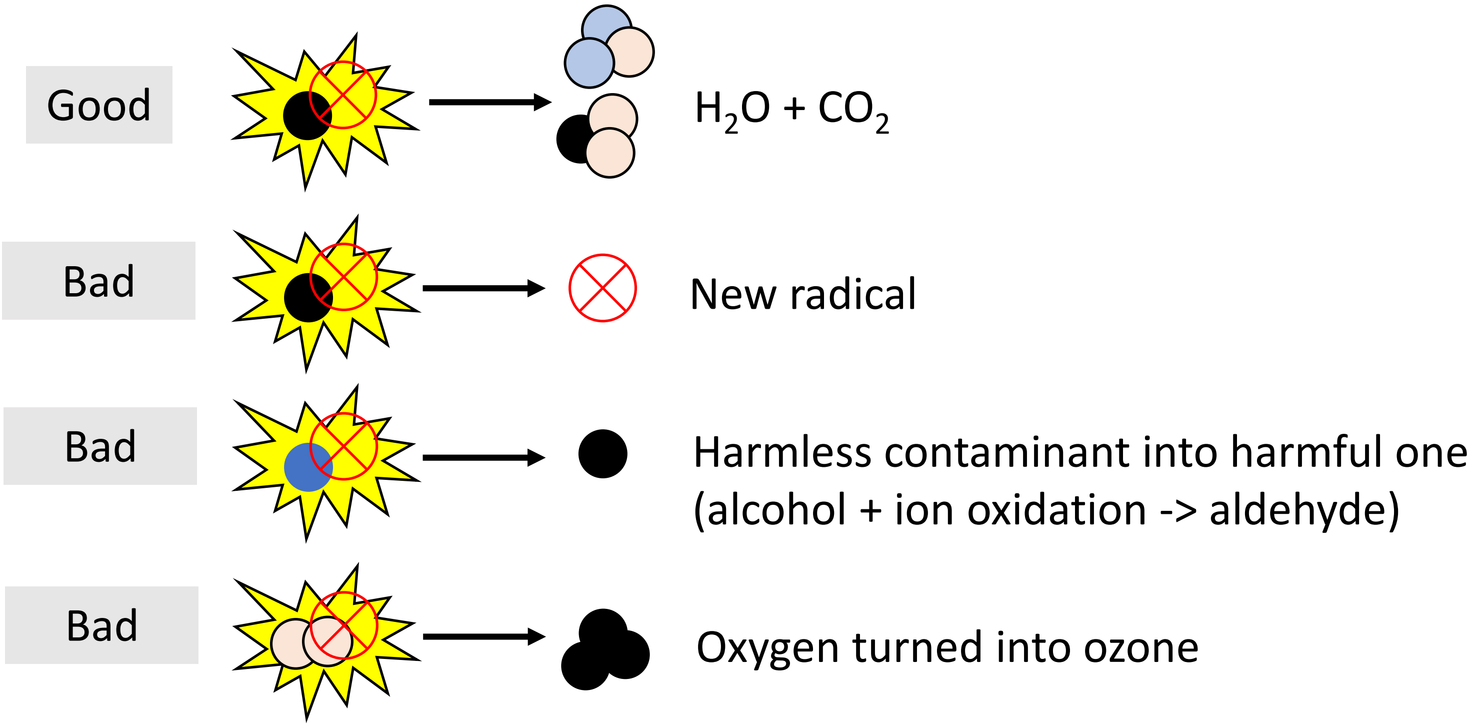
- Superoxide anion radical: $O_2 + e^- \rightarrow {}^{\bullet}O^-_2$
- Hydrogen peroxide: $2\ H^+ + {}^{\bullet}O^-_2 + {}^{\bullet}O^-_2 \rightarrow H_2O_2 + O_2$
- Hydroxyl radical: $H_2O_2 + e^- \rightarrow HO^- + {}^{\bullet}OH$
- Ozone: $O_2 + O \rightarrow O_3$

Ozone and ROS cause:

- Respiratory disease
- Cancer
- Auto-immune disease

Chemistry Fact #2: Indiscriminate & Unpredictable Reactions

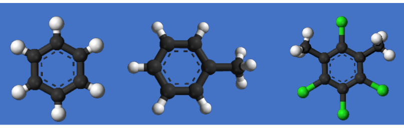
Electronic Air Cleaners



Chemistry Fact #3: Not all contaminants addressed

Electronic Air Cleaners

VOCs with low reactivity (“aromatics”)

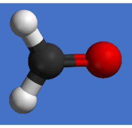


- Ions/radicals cannot chemically react with these VOCs
- Includes common indoor VOCs such as benzene, toluene, xylenes

Carbon dioxide

- Not addressed. CO_2 proven to impact productivity and cognitive performance

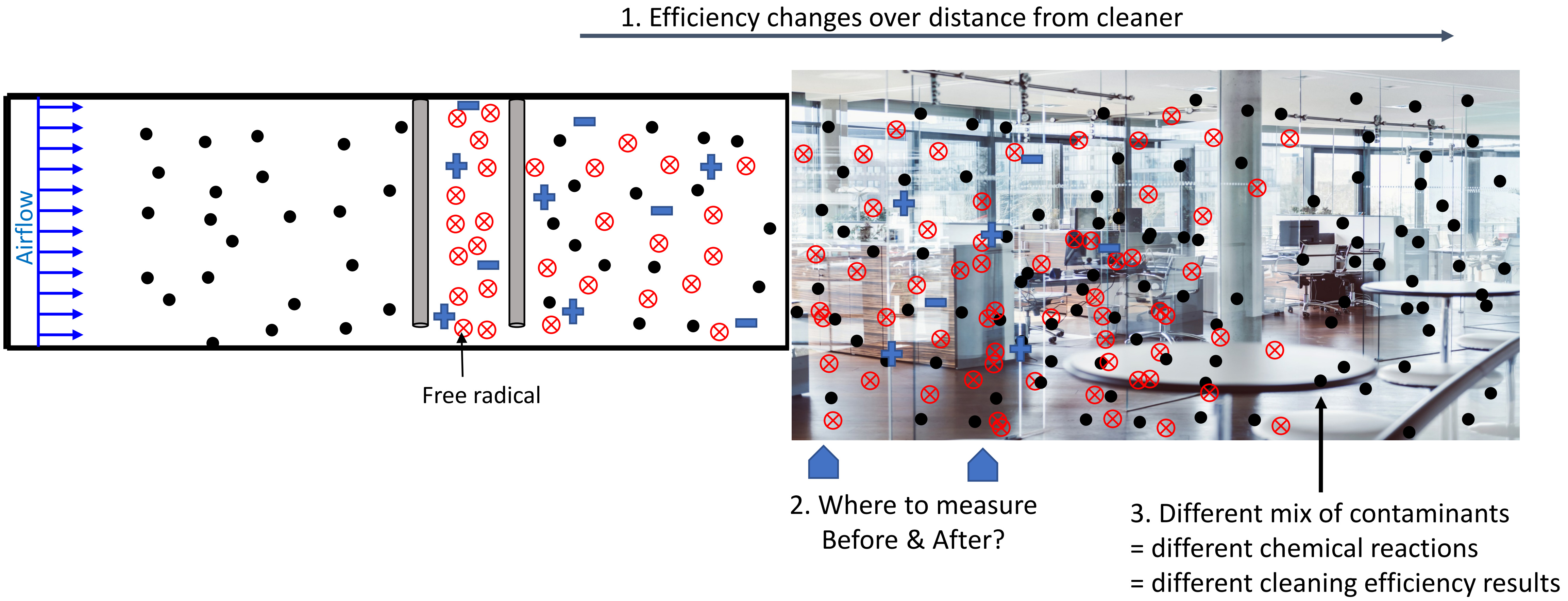
Formaldehyde



- Some products create formaldehyde, generally as a reaction byproduct

Chemistry Fact #4: Measuring Efficiency is Difficult

Electronic Air Cleaners



Numerous studies show electronic air cleaners do not work or are hazardous

- https://www.cleanairplus.com/blogs/blogs-and-news/ozone-caused-by-ionic-air-purifiers-poses-health-risks
- University of California - Irvine. "Indoor Air Purifiers That Produce Even Small Amounts Of Ozone May Be Risky For Health." ScienceDaily. ScienceDaily, 10 May 2006. <www.sciencedaily.com/releases/2006/05/060509235740.htm
- http://www.nbcnews.com/id/7391185/ns/health-health_care/t/consumer-reports-calls-air-purifier-unhealthy/#.WUGtZGj1DIE
- http://www.allergyclean.com/formaldehyde-increases-through-exposure-to-ozone-from-ionizers-and-ozone-generators/
- https://www.biotek.com/resources/white-papers/an-introduction-to-reactive-oxygen-species-measurement-of-ros-in-cells/
- https://en.wikipedia.org/wiki/Reactive_oxygen_species

Example Study: CDC found electronic ionizers produce ozone

Device	Company	Technology	Back-ground Concen-tration (ppb)	Unit Concen-tration (ppb)
Nanobreeze, Unit #2	NanoTwin Technologies	Photocatalytic Oxidation	6.9	10.3
Prototype	ActiveTek	ActivePure Technology (H_2O_2)	4	115.9
AF1000, Ser No. 008011	Air Fantastic	Quadruple Ion Technology	6.7	287.9
AF1000, Ser No. 002813	Air Fantastic	Quadruple Ion Technology	4.9	305.5
AFMini, Ser No. 008033	Air Fantastic	Quadruple Ion Technology	4.9	745.4
AFMini, Ser No. 008031	Air Fantastic	Quadruple Ion Technology	5.5	459.3
Prototype	AERISA	Cold Plasma	4.4	42.8
AtmosAir T-400 Ser No. 401107MTG1220	Clean Air Group	Bipolar Ionization	3.5	892.6
AtmosAir T-400 Ser No. 401107MTG1227	Clean Air Group	Bipolar Ionization	5.1	1297
AirOCare, Ser No 0033, with screen*	AirOcare	Reactive Oxygen Species	5.5	88.5
AirOCare, Ser No 0033, no screen*	AirOcare	Reactive Oxygen Species	5.5	61.6
AirOCare, Ser No 0034, with screen*	AirOcare	Reactive Oxygen Species	3.4	115.5
AirOCare, Ser No 0034, no screen*	AirOcare	Reactive Oxygen Species	3.4	82.5

Ozone Levels (> 50ppb is harmful)

EVALUATION OF MITIGATION STRATEGIES FOR REDUCING FORMALDEHYDE CONCENTRATIONS IN UNOCCUPIED FEDERAL EMERGENCY MANAGEMENT AGENCY-OWNED TRAVEL TRAILERS

Michael G. Gressel, PhD, CSP
Lynn Wilder, MSHyg, CIH

Division of Environmental Hazards and Health Effects
National Center for Environmental Health
Centers for Disease Control and Prevention

Example study: CARB found electronic air cleaners can increase VOCs, formaldehyde, and/or ozone

Evaluation of Pollutant Emissions from Portable Air Cleaners

Draft Final Report: Contract No. 10-320

Prepared for the California Air Resources Board and the California Environmental Protection Agency
Research Division
PO Box 2815
Sacramento CA 95812

Table 5.4.4: Pollutant concentration change *ΔC$_i$* (μg m^{-3}) in Scenario 2 based on results from Phase 2. Negative changes (concentration reductions) are shown in black, and positive changes (increases in concentration) are shown in red

	Photocatalysts			Plasma	Ionizers		400 F heater
	PAC1	**PAC2**	**PAC3**	**PAC4**	**PAC5**		**PAC6**
					ionizer	**ion + heat**	
ozone	-	-	22 - 191	0.6 – 5.5	-	-	-
SOA	-		0.4 - 6.7		-	-	-
VOCs							
ethanol		11	-3.6	-359	143	4.9	7.3
hexane	-388		-77	-272	265	134	-64
butanal	-20		-15	-15		41	-20
benzene	-23	8.7	-25	-66	27	28	-16
TCE	-31	43	-49	-81	33	24	-19
toluene	-53	98	-114	-178	64	115	-40
pyridine	-6.7		-44	-60	13	30	-90
o-xylene	-25	27	-61	-42	47	117	-108
styrene	-4.7	8.0	-89	-15	27	89	-34
d-limonene	-5.5		-182	-14	74	403	-26
formaldehyde	22	20	-24	17	-33	-152	-8.0
acetaldehyde							
acetone	*-6.0*	*-3.3*	*57*			*-59*	
benzaldehyde			*74*				
TOTAL VOCs	**-528**	**213**	**-553**	**-1086**	**661**	**895**	**-422**

The compounds listed in italics were not present in the challenge mixture.

Example study, NY department of health

Report of Bureau of Toxic Substance Assessment Testing the AtmosAir Bi-Polar Ionization Product at the Glens Falls High School, Glens Falls, NY on February

Results Published in 2018 in ASHRAE Journal:

1. The average indoor ozone concentrations more than doubled when the corona discharge was on.
2. The concentrations of the aldehydes and acetone increased when the corona discharge was operating
3. Ultrafine particles counts increased following the deployment of limonene in the classroom