Mitigating the Transmission of Airborne Pathogens in Indoor Environments

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Air Cleaners Inc

"Cleaning The Air That We Share"

Speakers Background

Education:

BSME UNH

MSEE Northeastern

MBA Northeastern

Experience:

- Apollo Computer
- Hewlett Packard
- ANSYS Inc
- Fluent Inc
- Applied Math Modeling Inc
- Air Cleaners Inc

Job Responsibilities:

- Mechanical Design
- Electrical Design
- Product Line Management
- Vice President Marketing
- President/CEO
- President/CEO

President Granite State ASHRAE

Preface

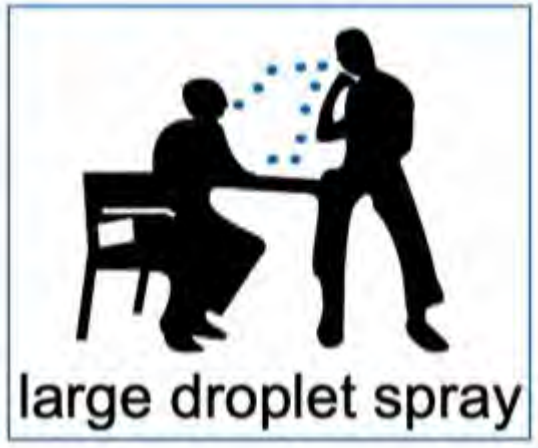
- Although this presentation is about the airborne transmission of SARs-CoV-2 virus, it is becoming clear that airborne transmission of other pathogens is significant
- The science of airborne pathogen transmission is evolving rapidly and there is significant evidence that other pathogens are transmitted by airborne methods including:
  - SARS, MERS, Influenzas, Tuberculosis, Measles, Common Cold, Annual Flu
- The methods described in this presentation for mitigating SAR-CoV-2 are the same as any of these others:
  - Including their variants
  - And mold spores, allergens, and dust.

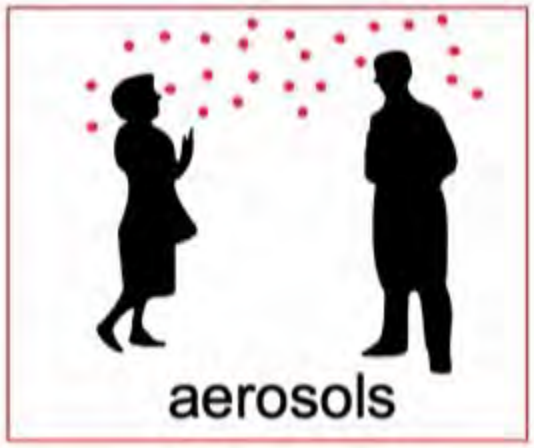
Aerosol Transmission history and background

- Current model of disease transmission is based on science of 1930's
  - William F. Wells work on Tuberculosis transmission
    - Large and small droplets with cut-off level from 5 to 10 uM
- Recent work reveals coughs and sneezes are multiphase turbulent gases
  - Moist and warm air allow for longer duration of droplets
    - Extends lifetime of a droplet from a fraction of a second to minutes.
    - Distance can extend to 23-27 feet base on turbulence and speed of gas cloud
      - Exit velocities of 33 – 100 Feet/sec
      - Influenced by Temperature, humidity, and airflow.
    - Once evaporated, nuclei may stay suspended for hours.

Virus Transmission Routes

Traditionally defined as > 5 μm and happening at close-range (< 6 ft)





Traditionally defined as < 5 μm and happening at long-distance (> 6 ft)

Why focus on Airborne Transmission

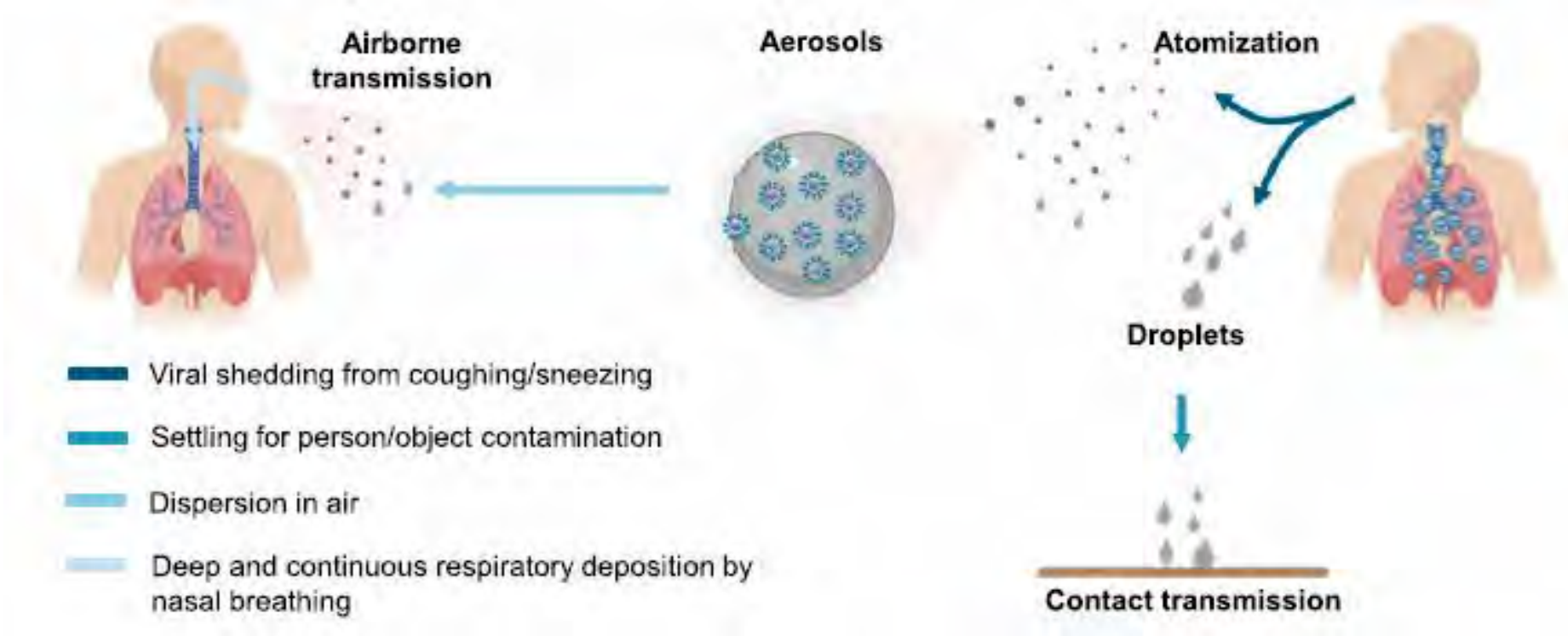
Evidence is significant:

- Skagit Valley Choir
  - 53 of 61 member tested positive after 2.5 hour practice
- Diamond Princess Cruise Ship
  - 621 of 3711 infected
- Zhejiang Province Bus Trip
  - 24 of 68 passengers infected during 100 minute bus ride
- Guangzhou Restaurant
  - 10 of 68 people infected in same area of restaurant
- Seoul South Korea
  - 97 of 1143 call center employees, 94 on the same floor

Transmission Mechanics

Definition of “Viral Load”

How exposure to viral load can start the reaction in respiratory system



Asymptomatic Transmission of Covid-19

https://tinyurl.com/FAQ-aerosols

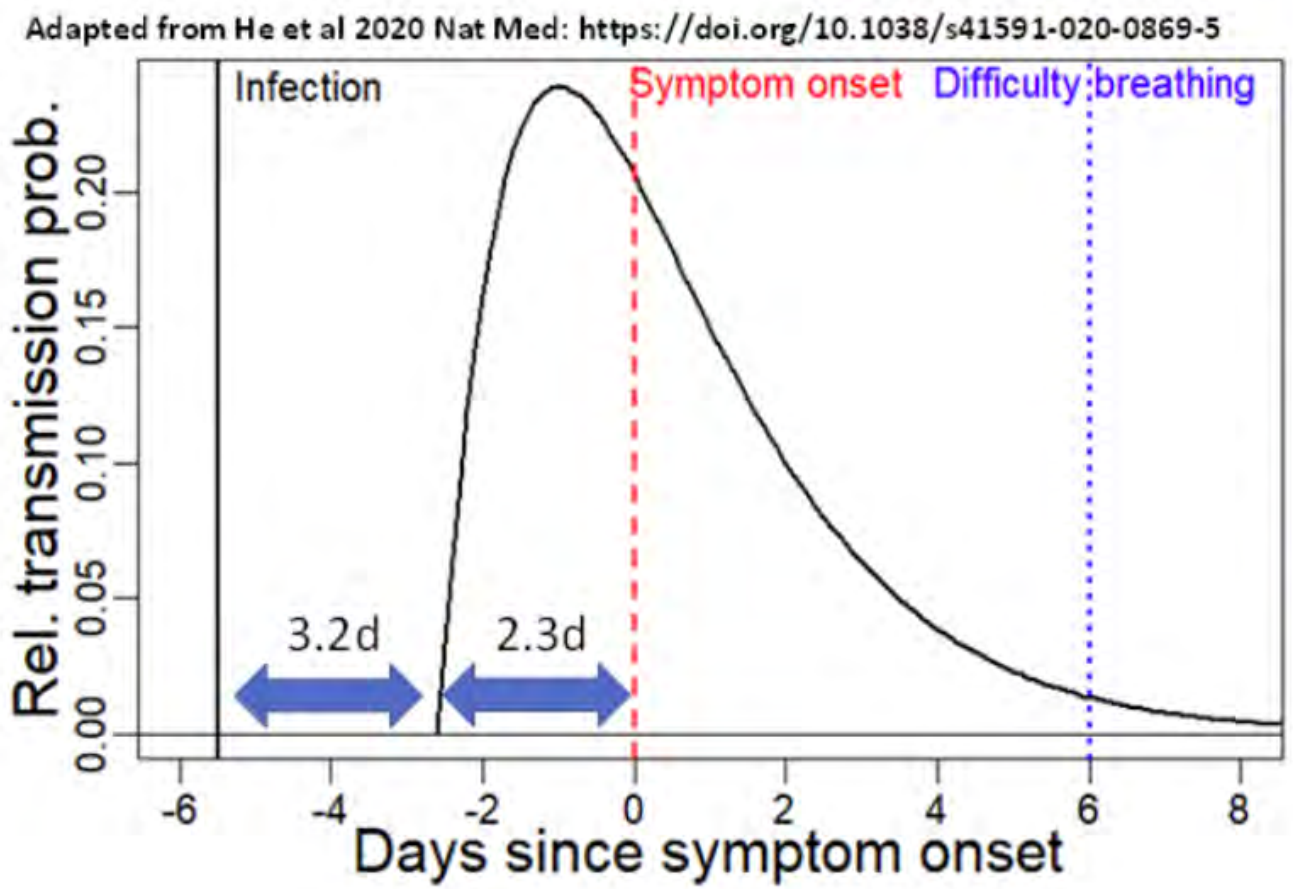


Figure: relative probability of transmission of SARS-CoV-2 from an infected individual as a function of time in the disease. The peak of infectiveness is just before the onset of symptoms. Reference: Prof. A Marm Kilpatrick, University of California-Santa Cruz.

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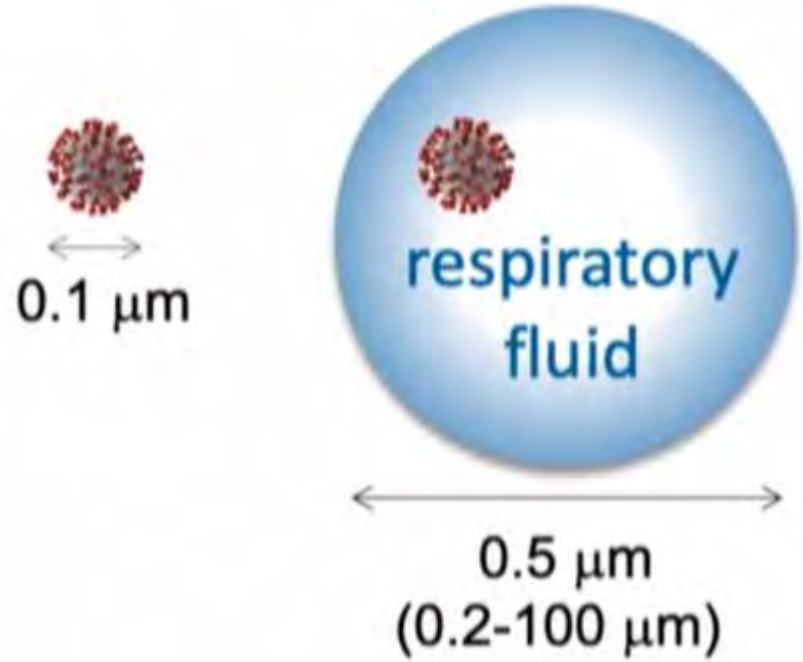
The Size of the Droplet/Aerosol is Important

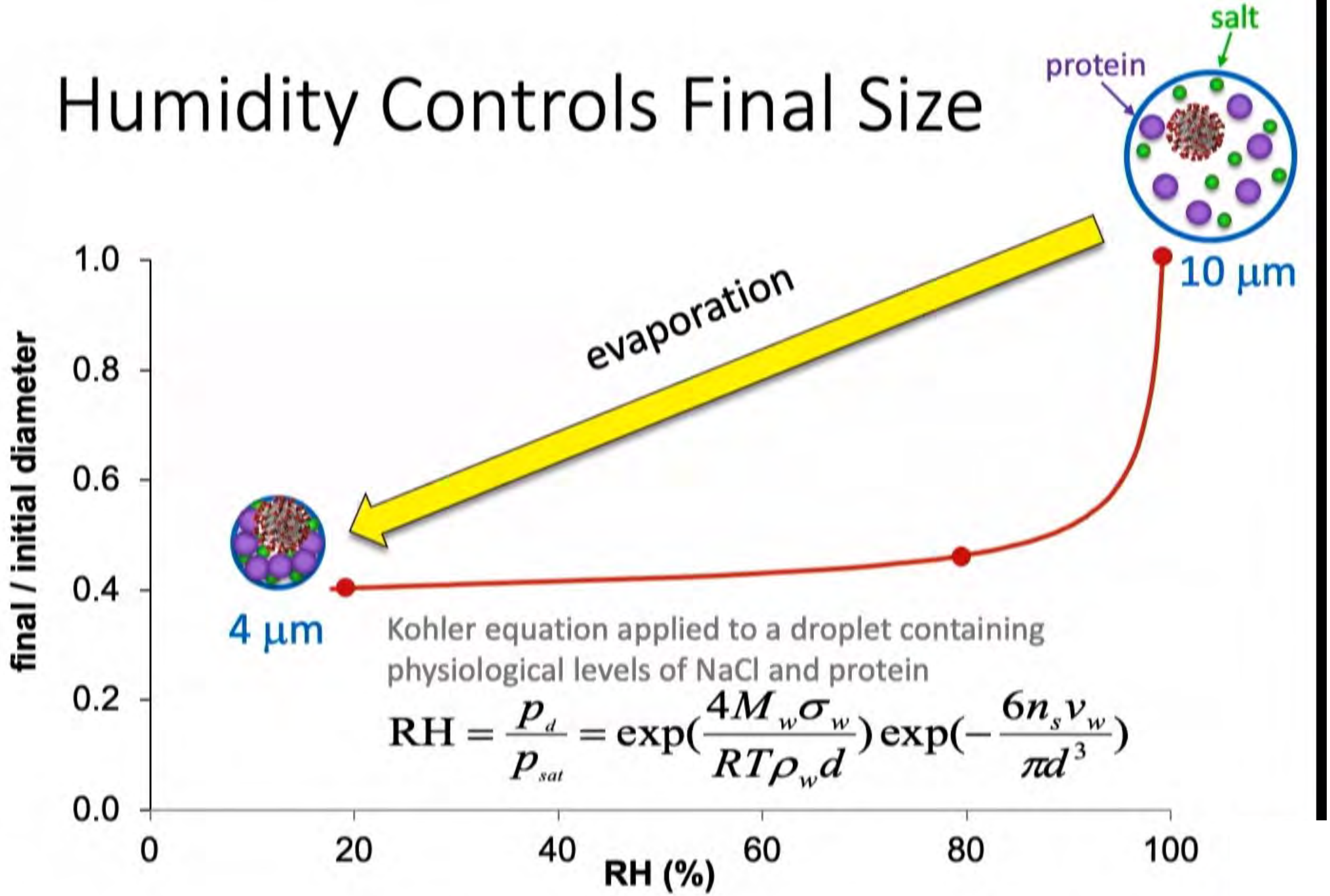
Airborne virus is not naked

Size of carrier droplet/aerosol defines transport

- How long it stays in the air
- How far it can travel
- How quick it falls to the surface
- Where it deposits in the respiratory system
- How efficiently it is removed by masks and filters
- The physics is the same for all viruses



Humidity Controls Final Size



Kohler equation applied to a droplet containing physiological levels of NaCl and protein

$$\mathrm{RH} = \frac{p_d}{p_{sat}} = \exp\left(\frac{4M_w\sigma_w}{RT\rho_w d}\right)\exp\left(-\frac{6n_s\nu_w}{\pi d^3}\right)$$

(1) Mikhailov, E., Vlasenko, S., Niessner, R., et al., 2004, Interaction of aerosol particles composed of protein and salts with water vapor:

Background on PM 2.5

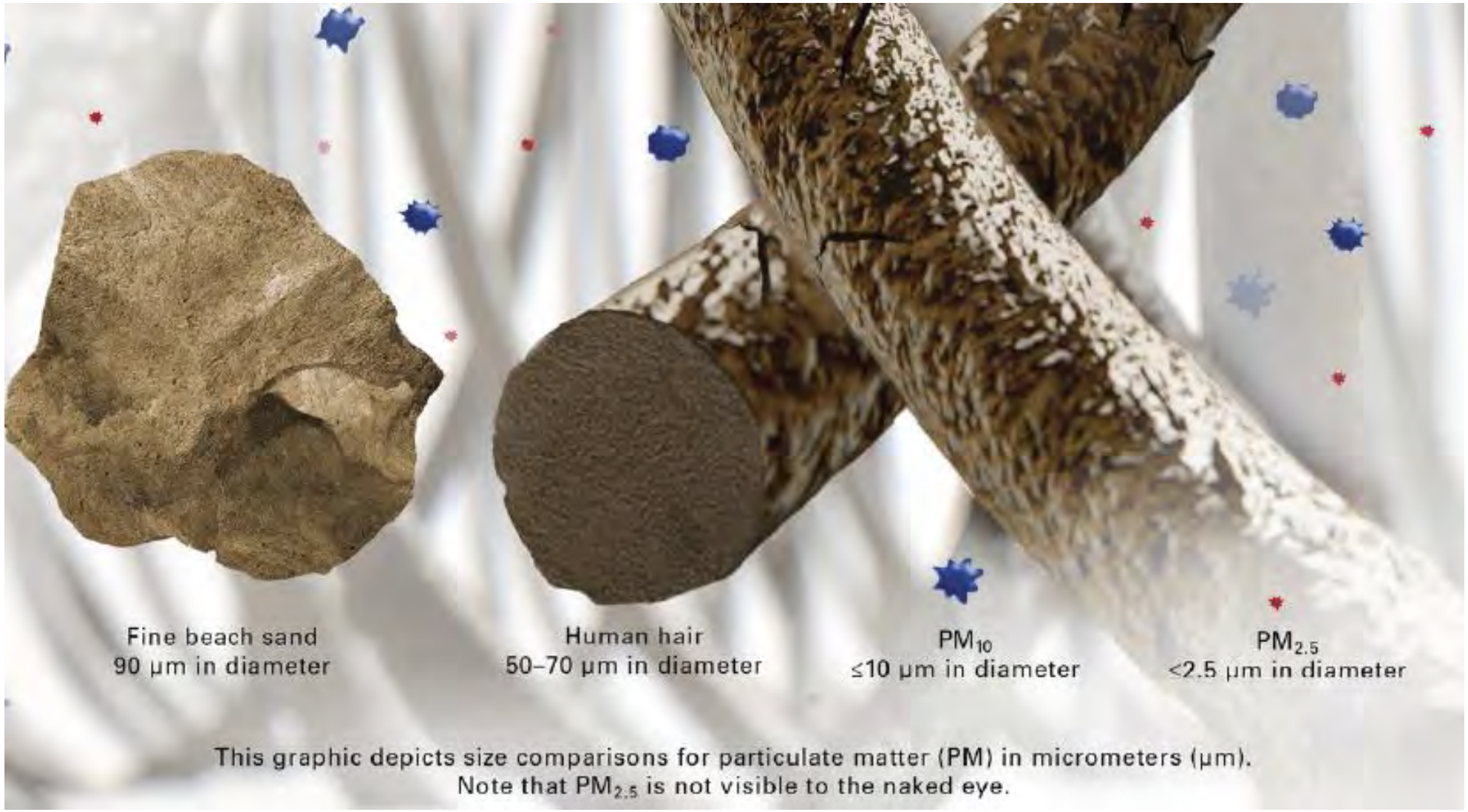
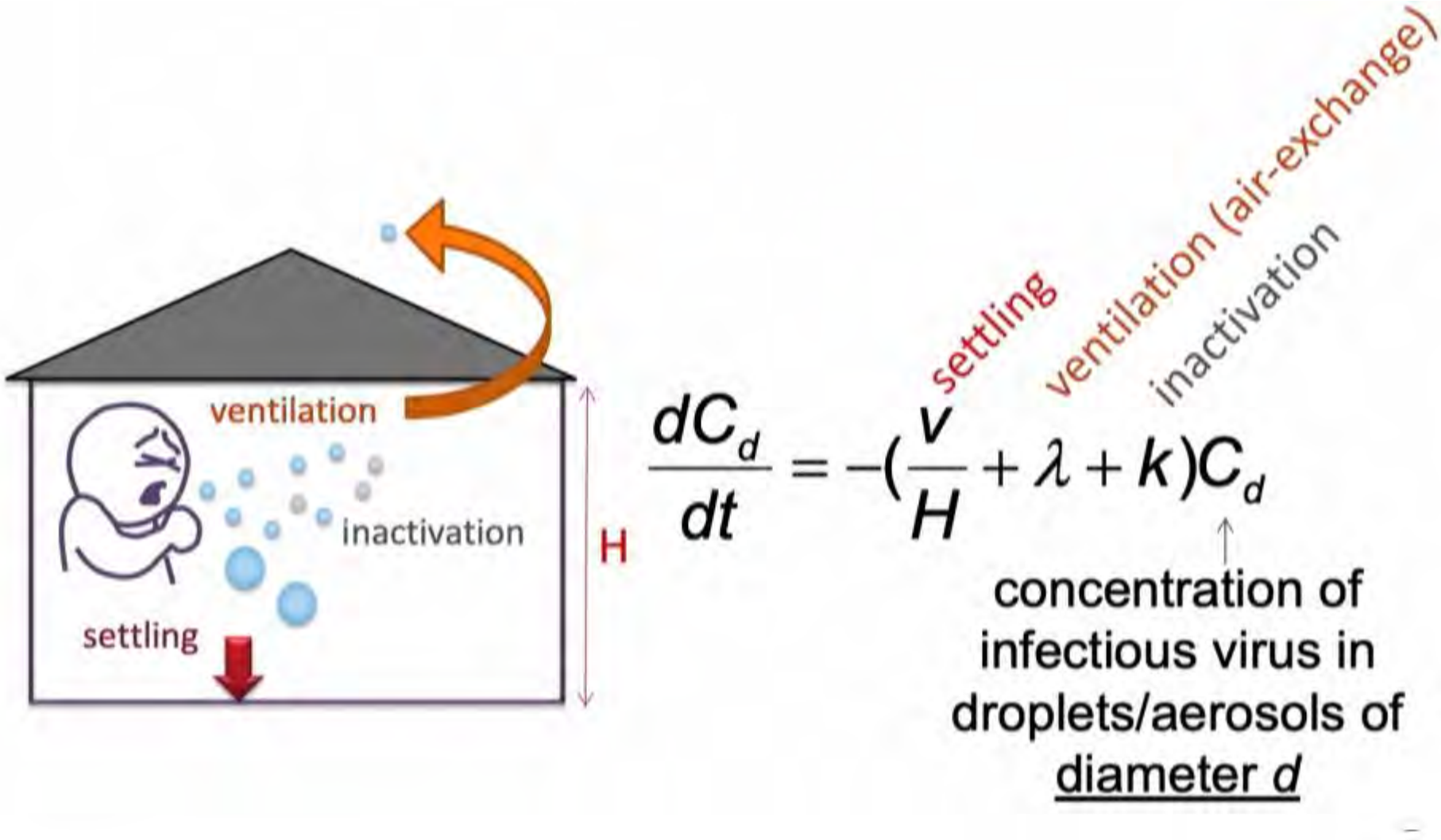


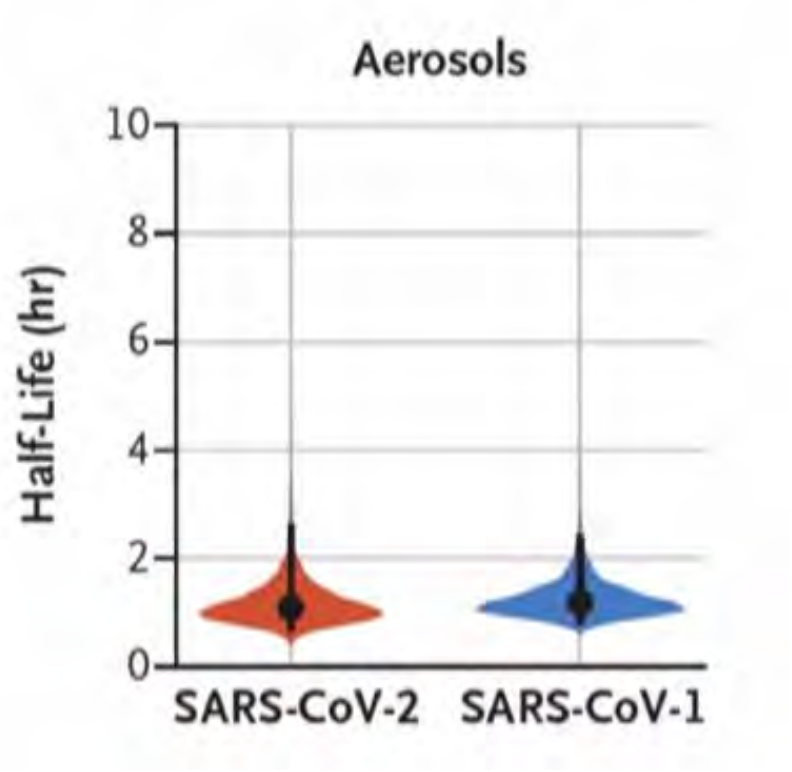
Image depicts the relative size of PM 2.5 particles compared to a grain of sand and human hair

Removing the Virus in Indoor Air

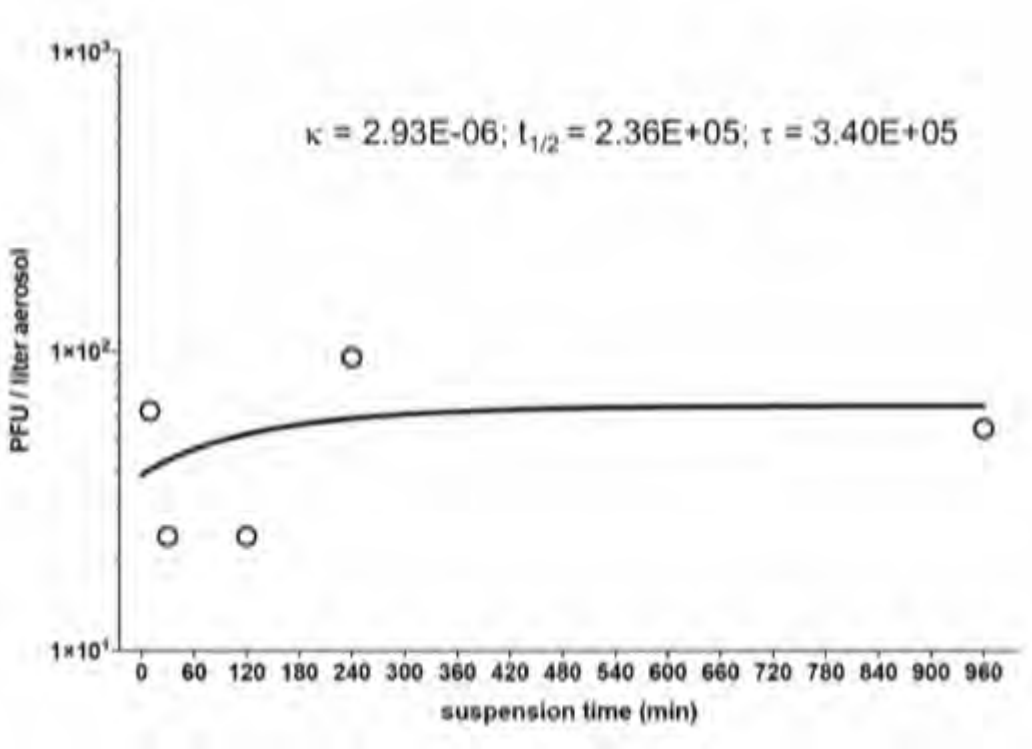


The focus should be on Ventilation and Inactivation

SARS-CoV-2 Survival in Aerosols



Half-life is 1.1 hours at 65% RH



Virus survives 16 hours at 53% RH

Covid focuses attention on pathogens and infection risk…but raises more general questions about what is acceptable

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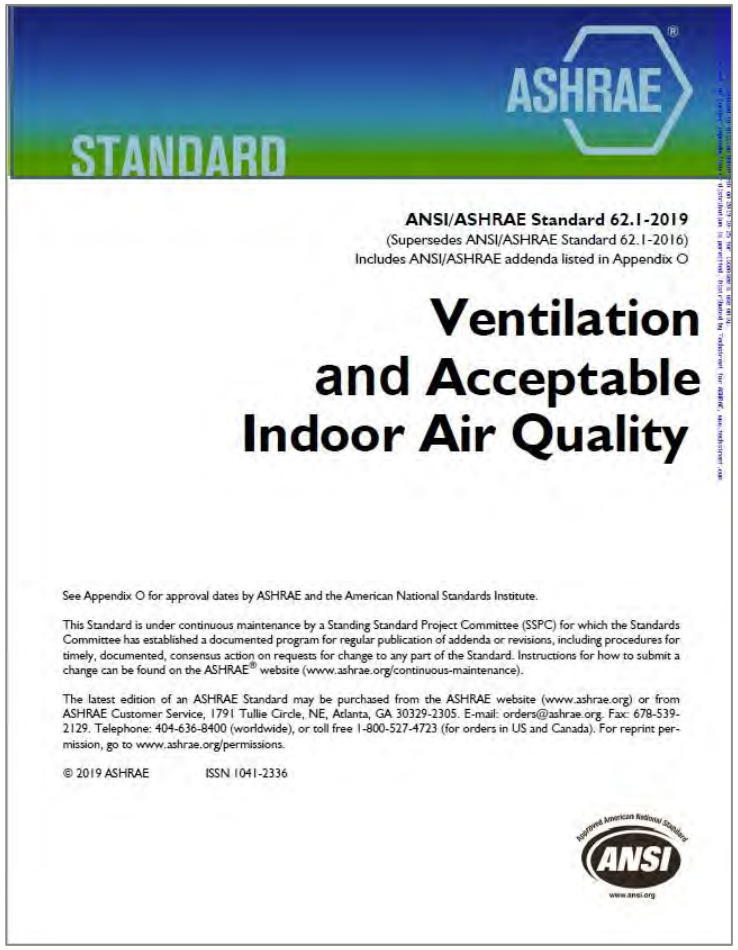
Acceptable IAQ today

Safe and Satisfactory

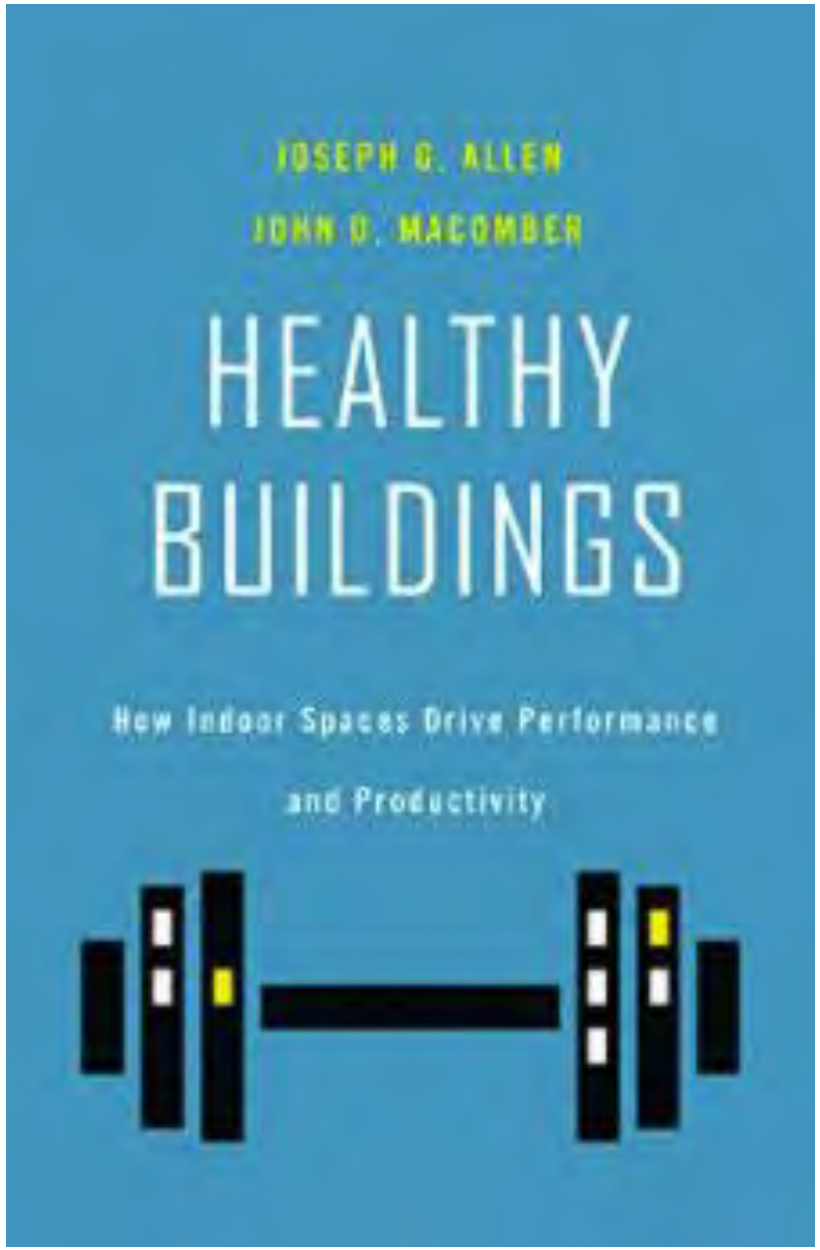
- American Society of Heating, Refrigeration, Air-conditioning, Engineers
- Acceptable indoor air quality (IAQ): air in which there are no known contaminants at harmful concentrations.



Source of Productivity Gain	Potential Annual Health Benefits	Potential U.S. Annual Savings or Productivity Gain (1996 U.S. $)
Reduced Respiratory Illness	16 Million to 37 Million Avoided Cases of Common Cold or Influenza	$6 Billion to $14 Billion
Reduced Allergies And Asthma	8% to 25% Decrease in Symptoms within 53 Million Allergy Sufferers and 16 Million Asthmatics	$1 Billion to $4 Billion
Reduced Sick Building Syndrome Symptoms	20% to 50% Reduction in SBS Health Symptoms Experienced Frequently at Work by ~15 Million Workers	$10 Billion to $30 Billion
Improved Worker Performance from Changes in Thermal Environment and Lighting	Not Applicable	$20 Billion to $160 Billion

Table 1: Estimated potential productivity gains.

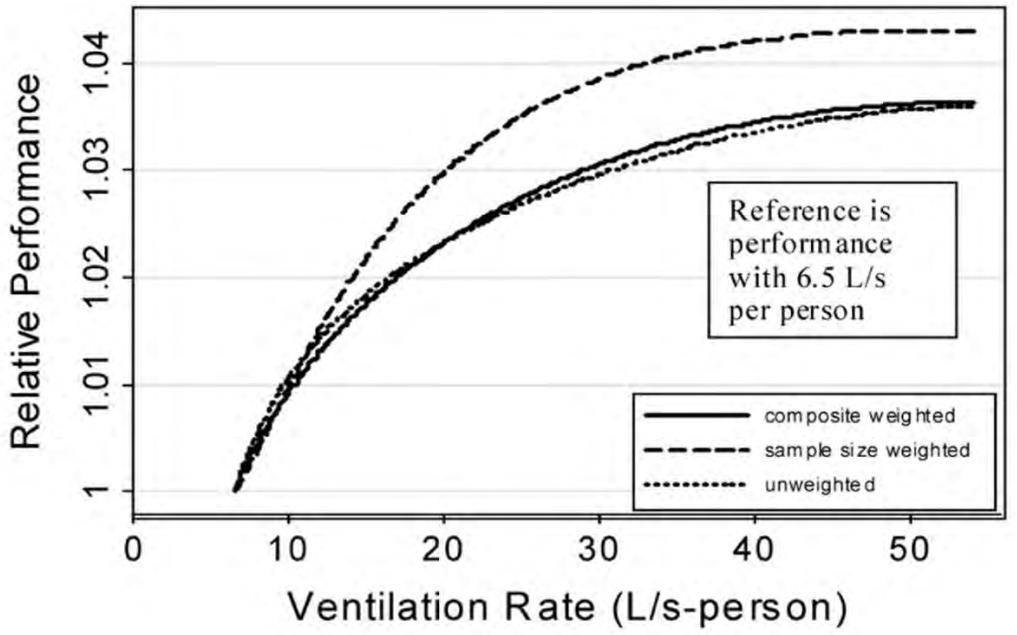
1996 data



2020 Data

Productivity and Ventilation rates

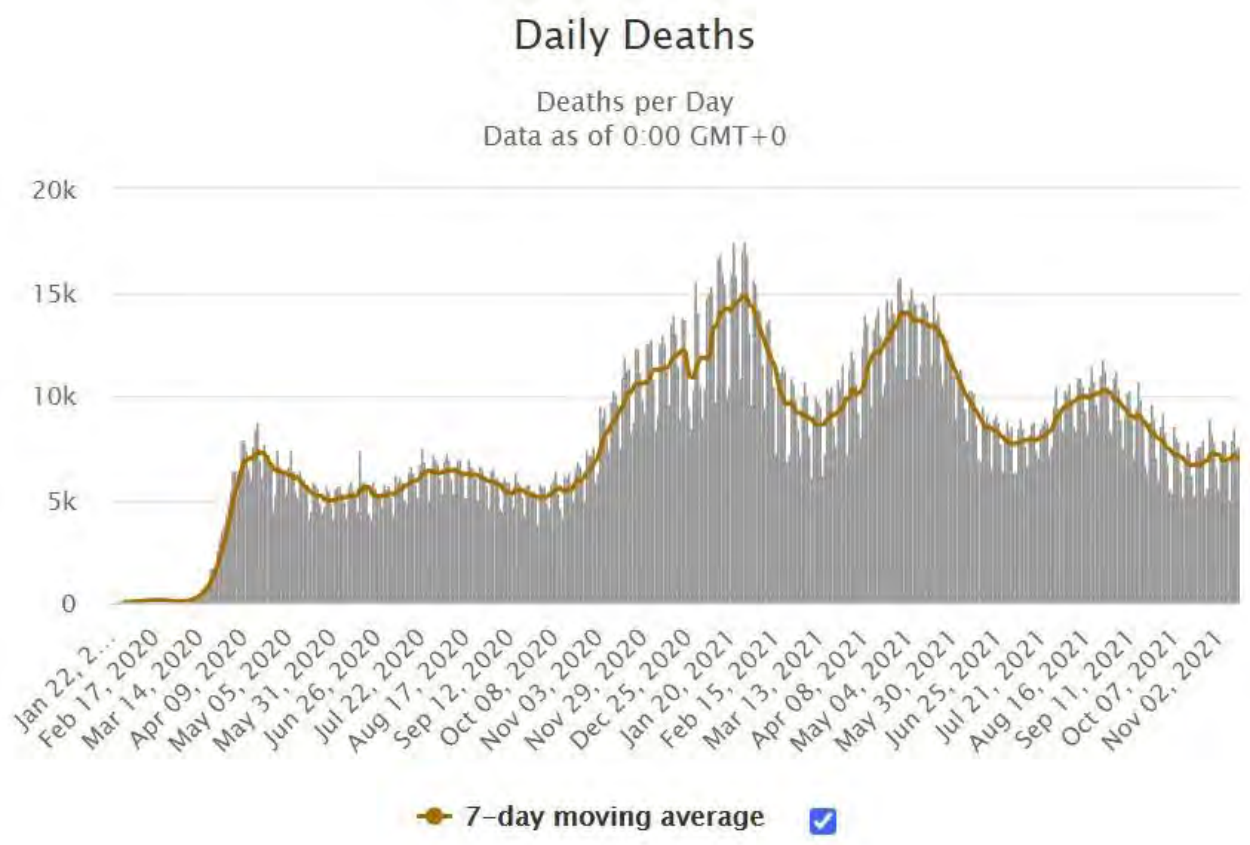
- As ventilation and/or air filtering rate increases, personal productivity increases dramatically



Seppänen, O. and W. Fisk. 2006. Some Quantitative Relations between Indoor Environmental Quality and Work Performance or Health. HVAC&R Research.

Covid focused all attention on infection control

- Index case – Dec. 1, 2019
- First reported death Jan. 9, 2020
- Reported totals as of Nov. 14, 2021
  - *254 million cases*
  - *5.1 million deaths*
- Actual mortality is probably underestimated by 2-3X based on excess mortality data



www.worldometers.info/coronavirus/

What we've learned from the pandemic

- Airborne transmission of respiratory infections occurs and is dominant
- Some long-held orthodoxies of infectious disease transmission are questionable at best
- All confirmed infections occur indoors
- HVAC systems (forced air) can play a role an important role in indoor airborne risk mitigation
- Existing buildings do not provide a lot of protection against airborne transmission

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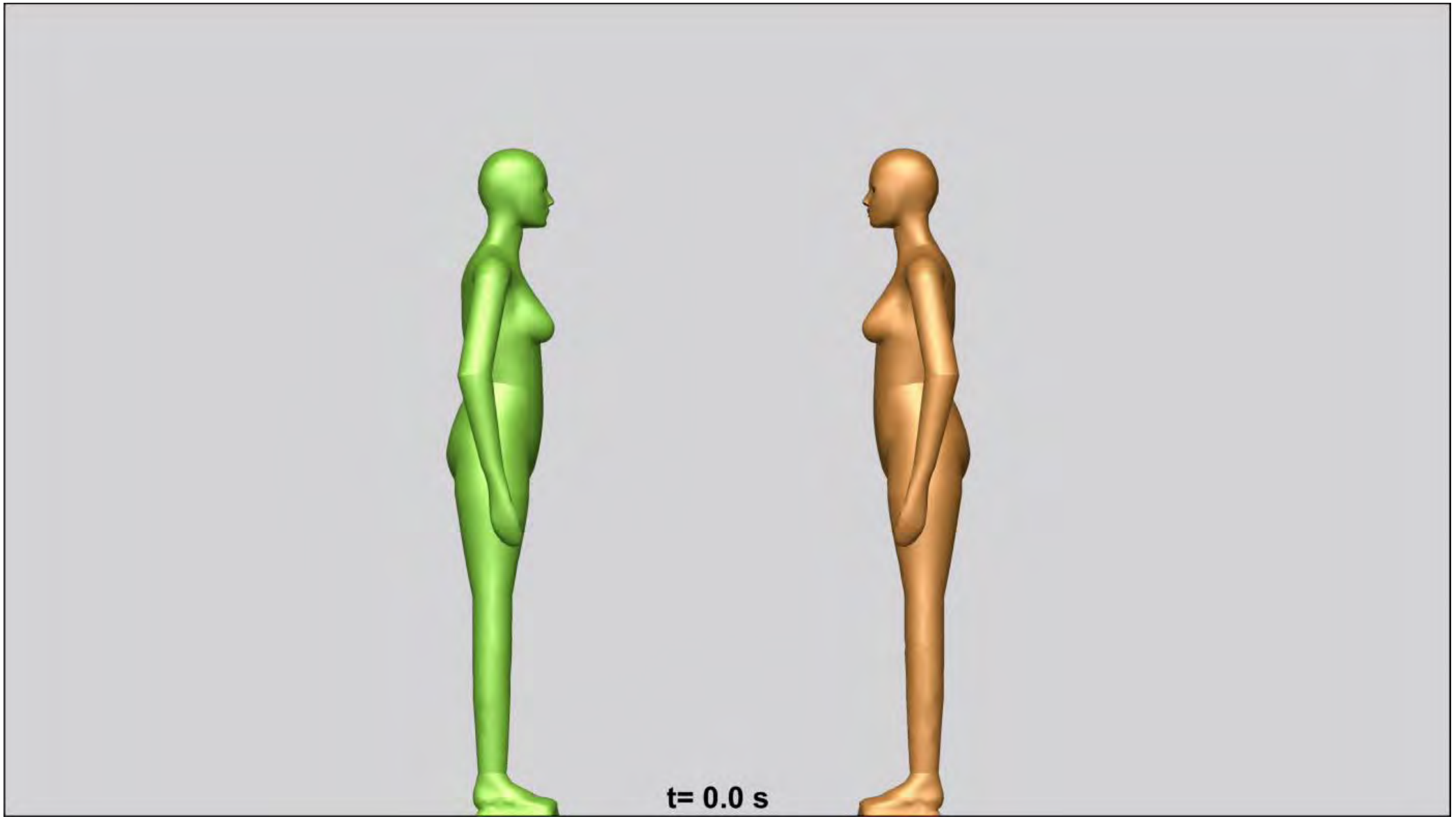
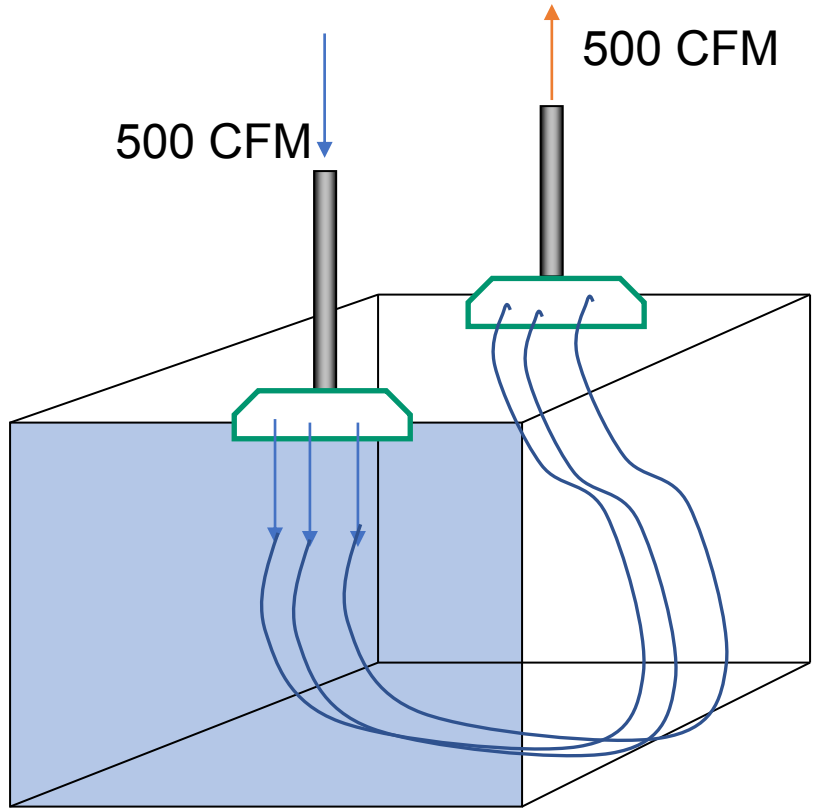
How is Covid-19 Spread?



Air Changes Per Hour

abbreviated as ACH

The measure of air volume added to or removed from a space in one hour divided by the volume of the space.



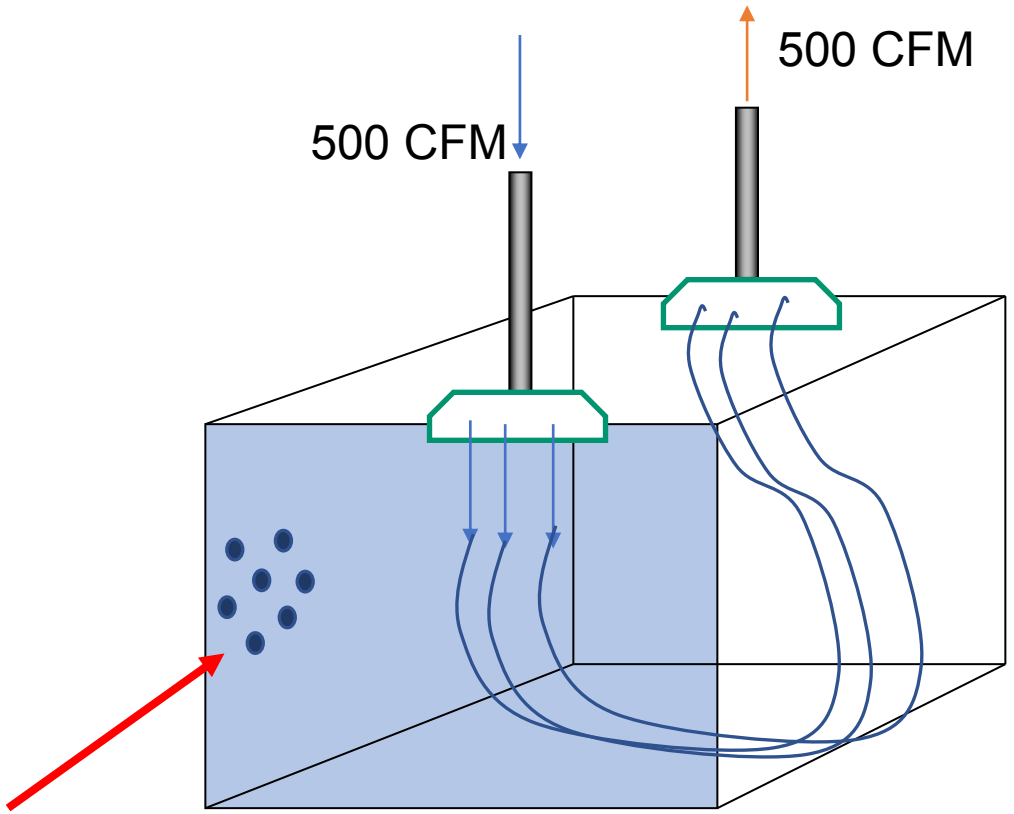
Or in other words…

ACH Is the number of times the air gets replaced in a room every hour.

But these calculations assume “perfect mixing”

Depending on the positioning of the supply/return grills, there can be a significant amount of “short cycling.”

- ***Just because the test shows air, it does not tell us where the air came from.***



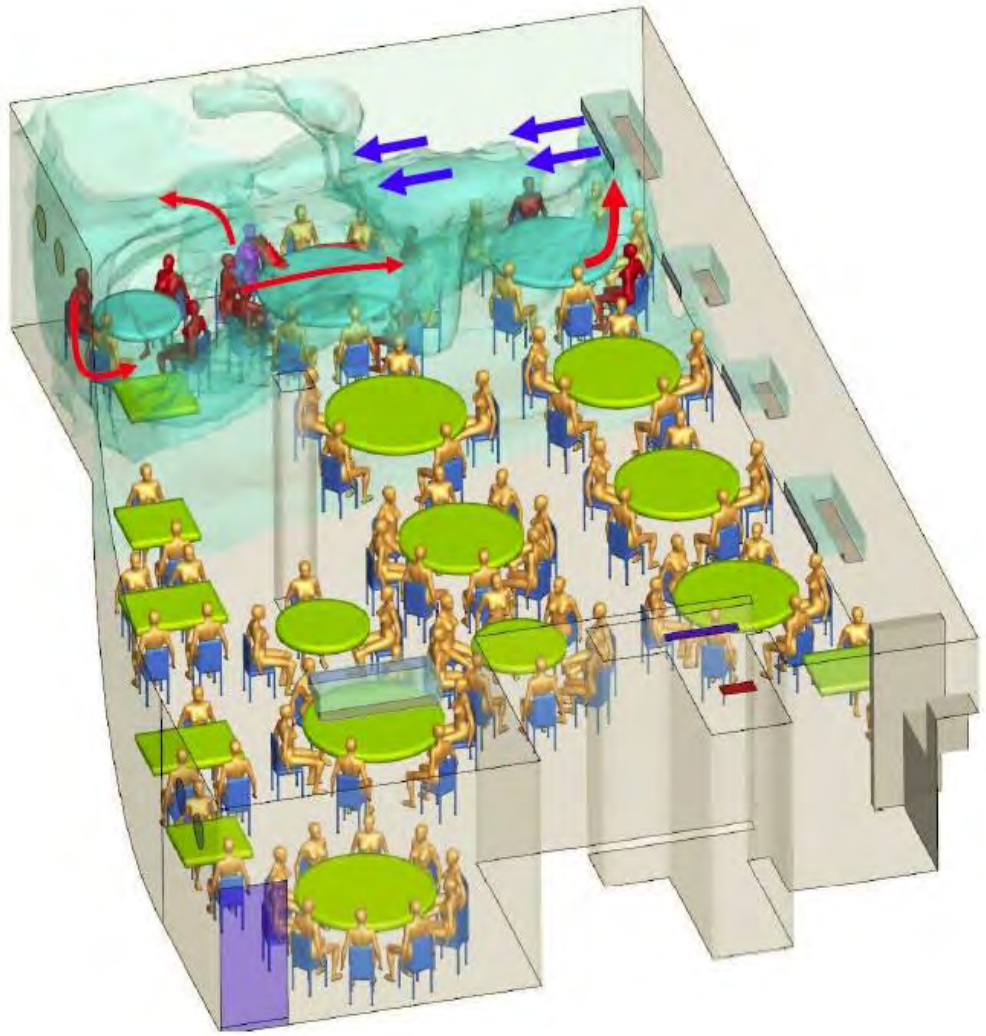
Stagnant pockets of air do not get filtered or diluted with fresh air even when the ACH and OACH are set to design recommendations.

Location of diffusers make a difference.

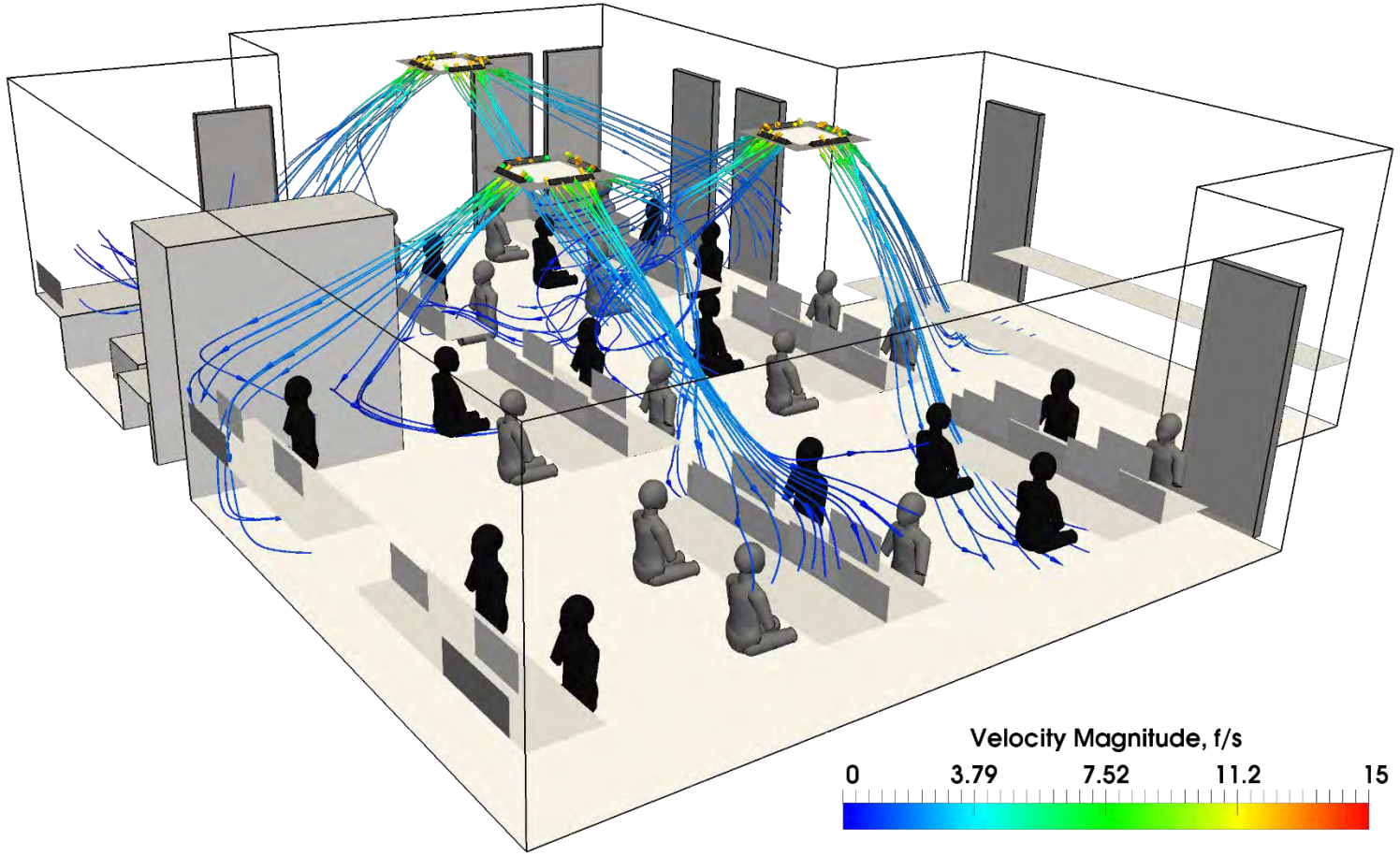
Relocating these Supply and Return diffusers can redirect airflow patterns to help eliminate these stagnant air pockets significantly.

Factors in indoor airborne transmission

Poor ventilation and Distribution

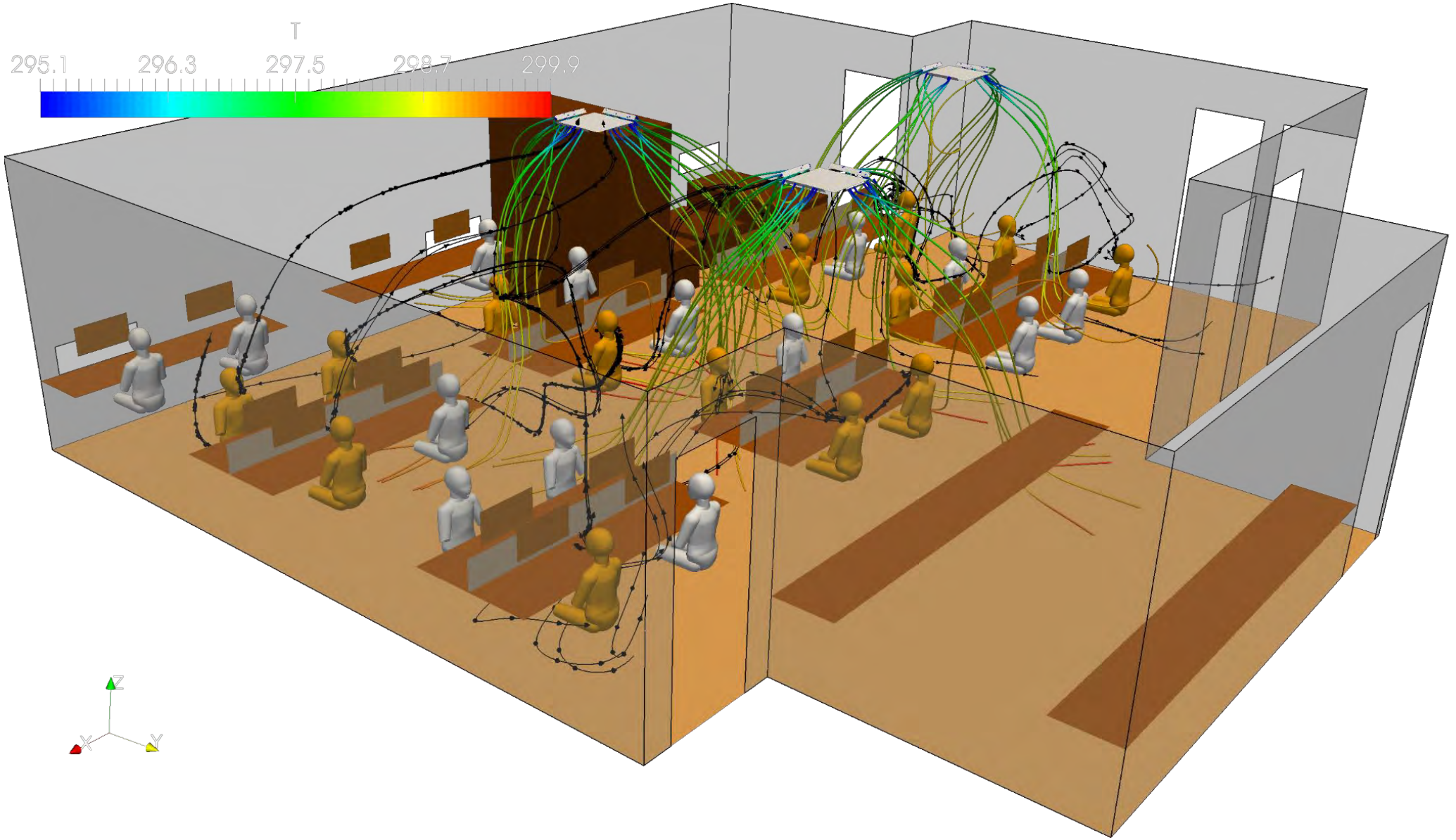


Example: Typical Office Environment

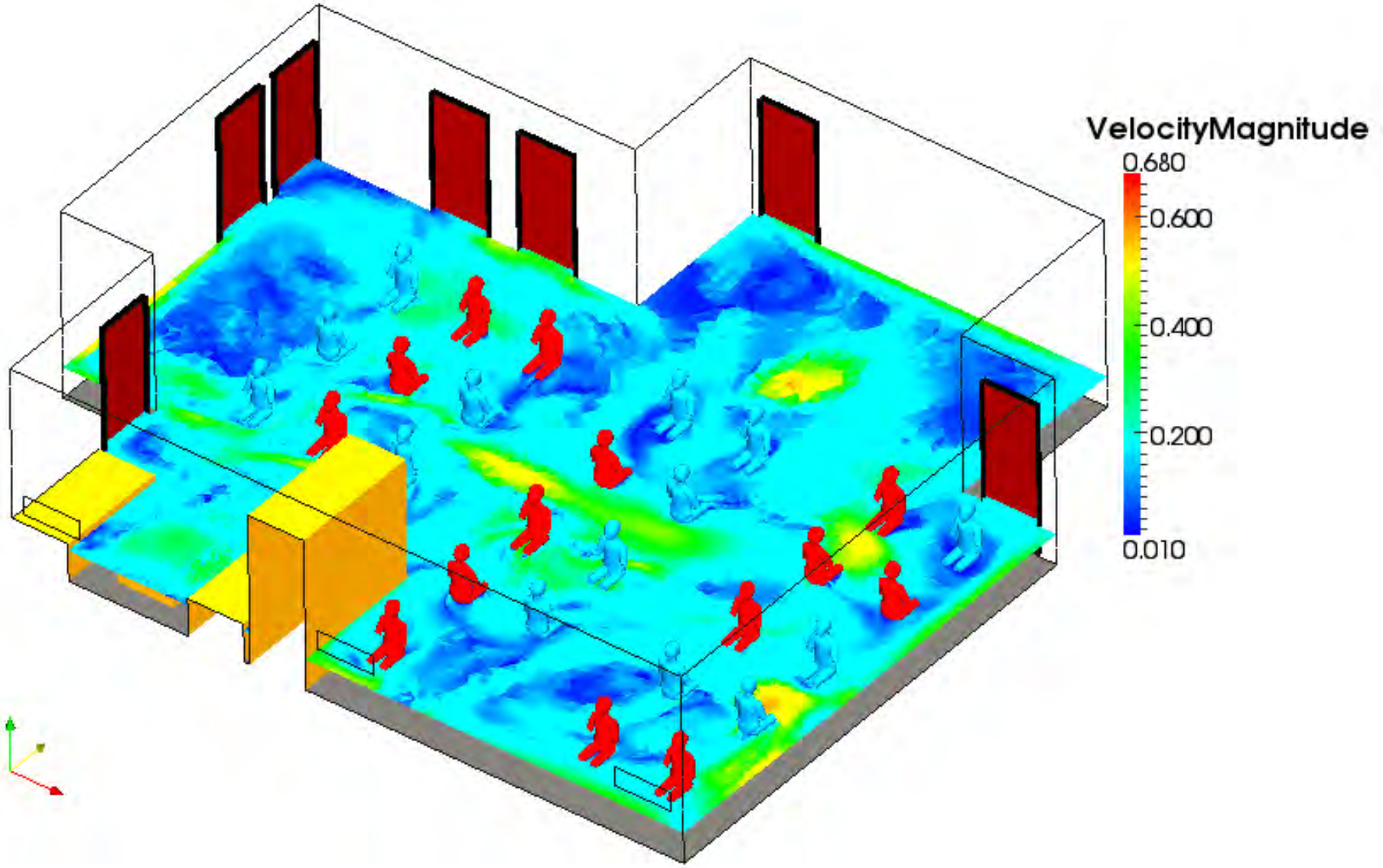


Air from HVAC system delivered to office environment

Typical Office Environment



Air Distribution In Room is Not Even



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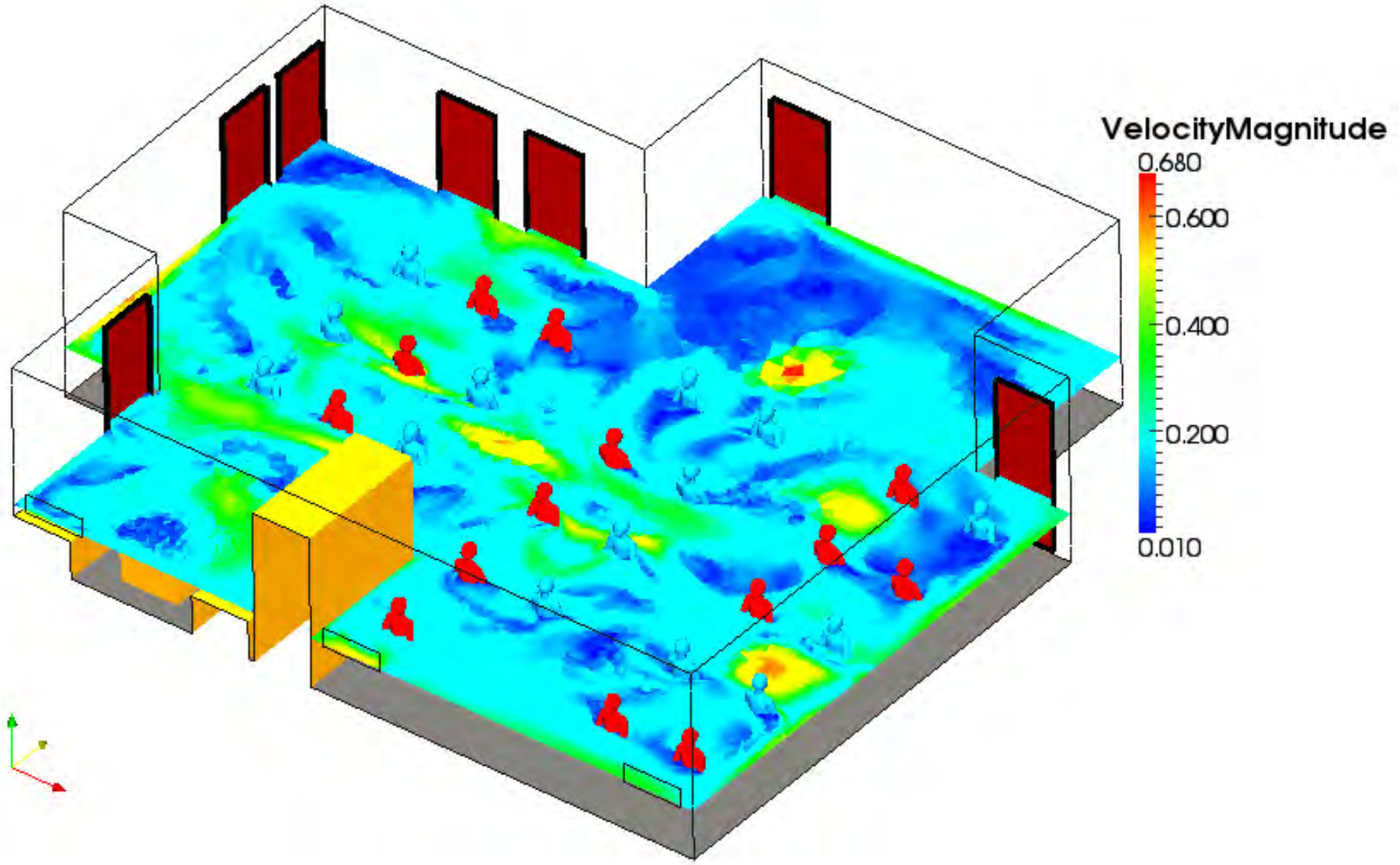

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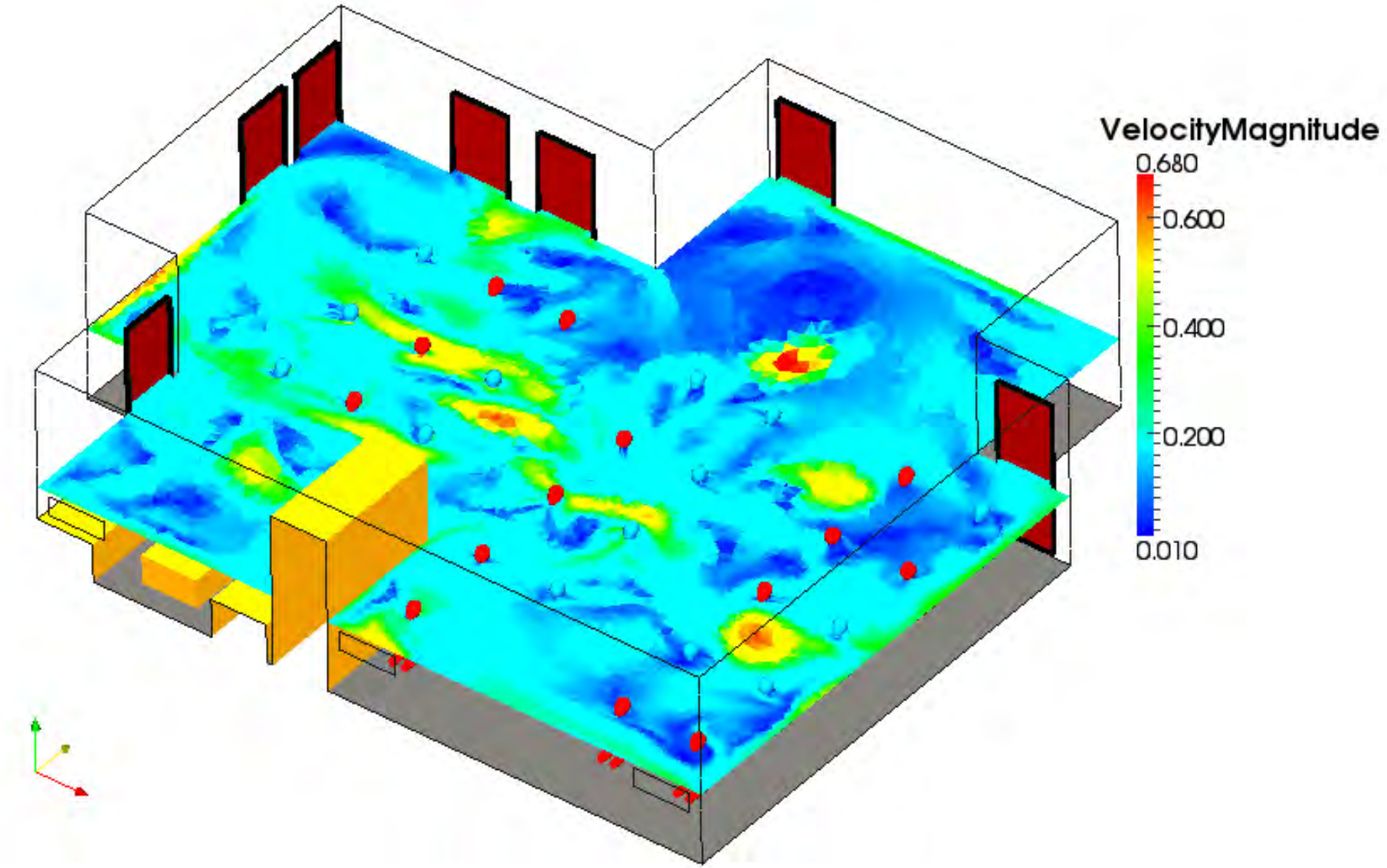
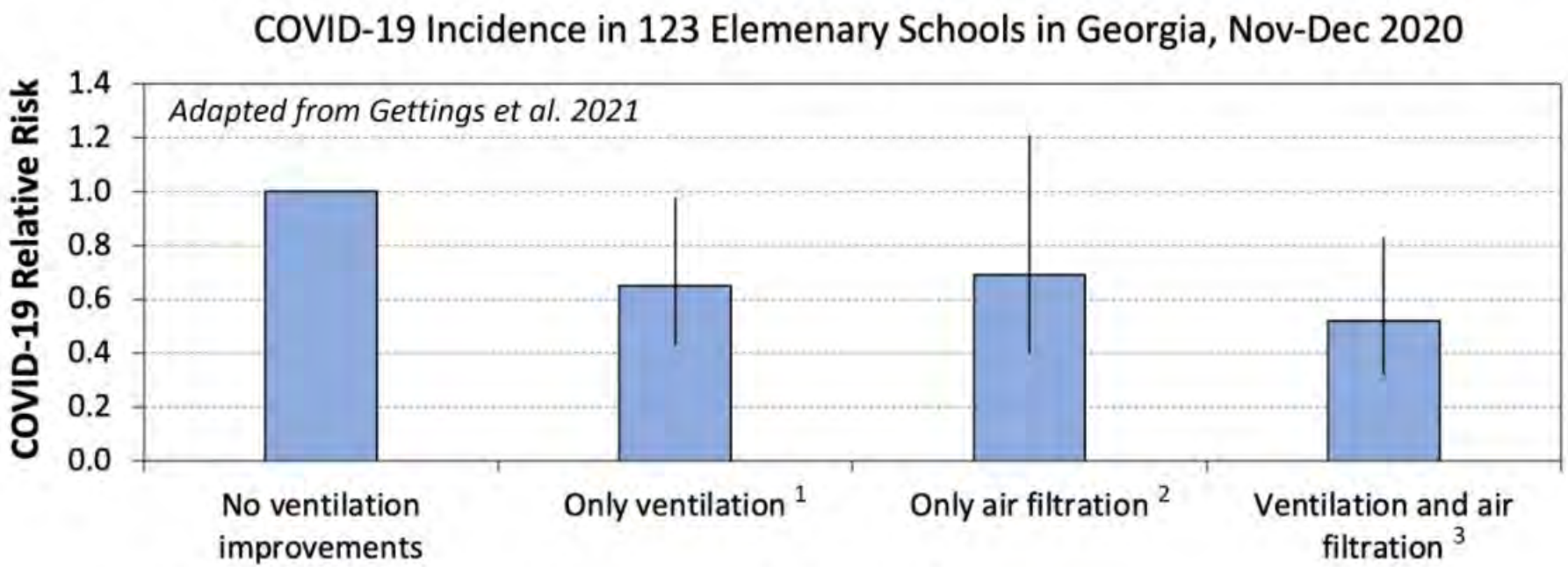


Air Cleaning and Ventilation Are Additive

Improved ventilation and mask rules for staff in elementary schools resulted in fewer COVID-19 cases, CDC study finds ©CBS NEWS

www.cbsnews.com/news/covid-school-masks-ventilation/



[1]Ventilation only = open doors, open windows or fans

[2]Air filtration only = using HEPA filters with or without UVGI and no ventilation

[3]Ventilation and air filtration = both [1] and [2]

Source: Gettings et al. 2021, *CDC MMWR* Vol. 70, May 21, 2021

Ventilation, Filtration, Air Cleaning

Air Cleaners

- *Only use air cleaners for which evidence of effectiveness and safety is clear.*
- Importance
  - *Many air cleaners, purifiers, etc. make poorly supported claims*
  - *ASHRAE recommends HEPA based air filtration as primary solution*
  - *Ultraviolet radiation is also well accepted and can be effective if implemented correctly*

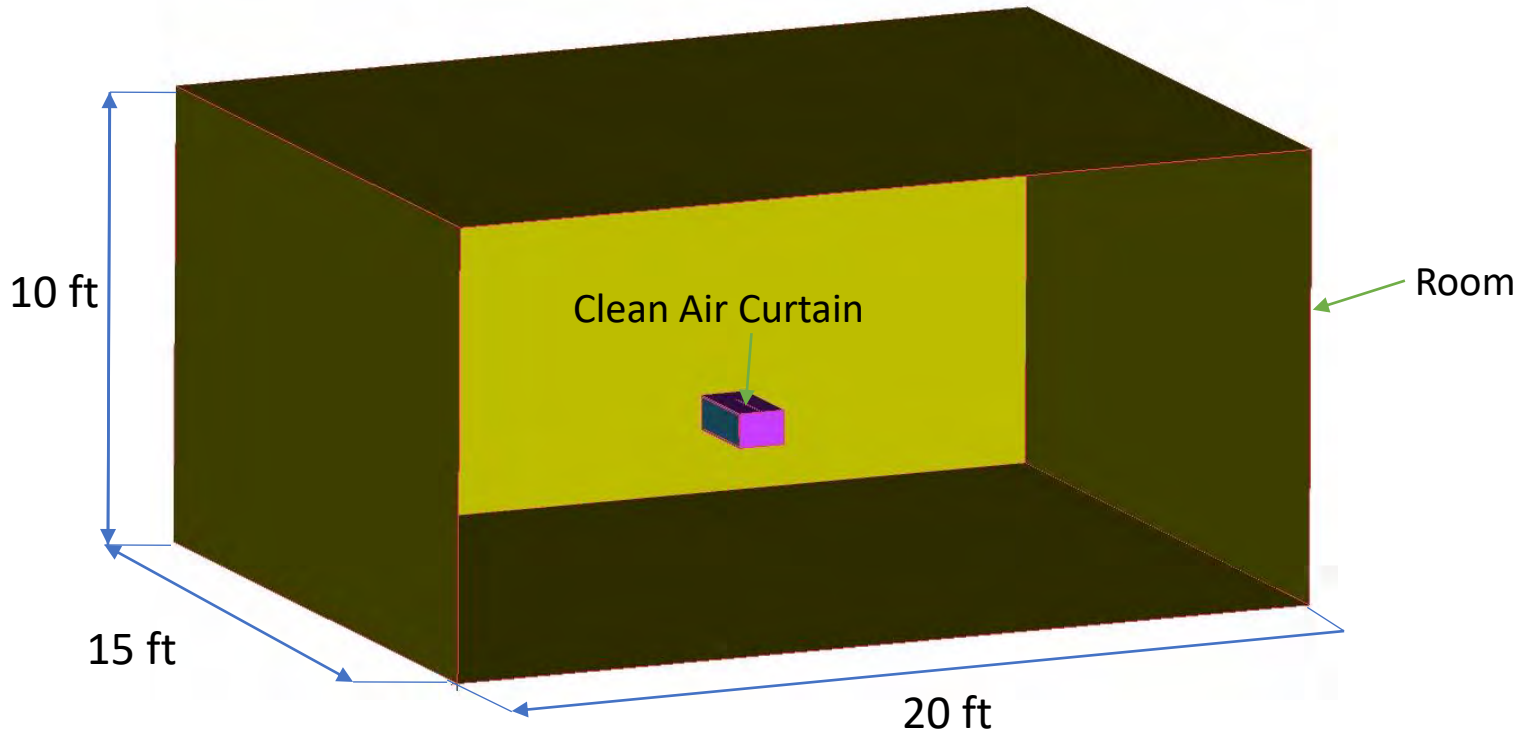
EPA Position on Air Cleaners and PM 2.5

- Intervention studies of air cleaners operating in homes have consistently found statistically significant reductions in indoor exposures to indoor PM2.5, PM10, and/or particle number counts with the use of portable air cleaners.
- Most air cleaner intervention studies have found statistically significant associations between the introduction and use of portable air cleaners in homes and [the improvement of] at least one measure or marker of improved health outcome.
- Several recent studies have shown that the use of portable air cleaners with Clean Air Delivery Rate (CADR) of 100 to 300 cubic feet per minute (CFM) in living rooms and/or bedrooms can substantially reduce indoor concentrations of PM of both indoor and outdoor origin, often reducing indoor PM2.5 concentrations by around 50 percent.
- Air cleaners have also been linked to reductions in some allergy and asthma symptoms, and lowering indoor PM concentrations with air cleaners has been shown to beneficially impact some markers of cardiovascular effects associated with exposure to indoor PM of both indoor and outdoor origin.

Source: EPA Residential Air Cleaners A Technical Summary

Air Cleaner Performance in a Room

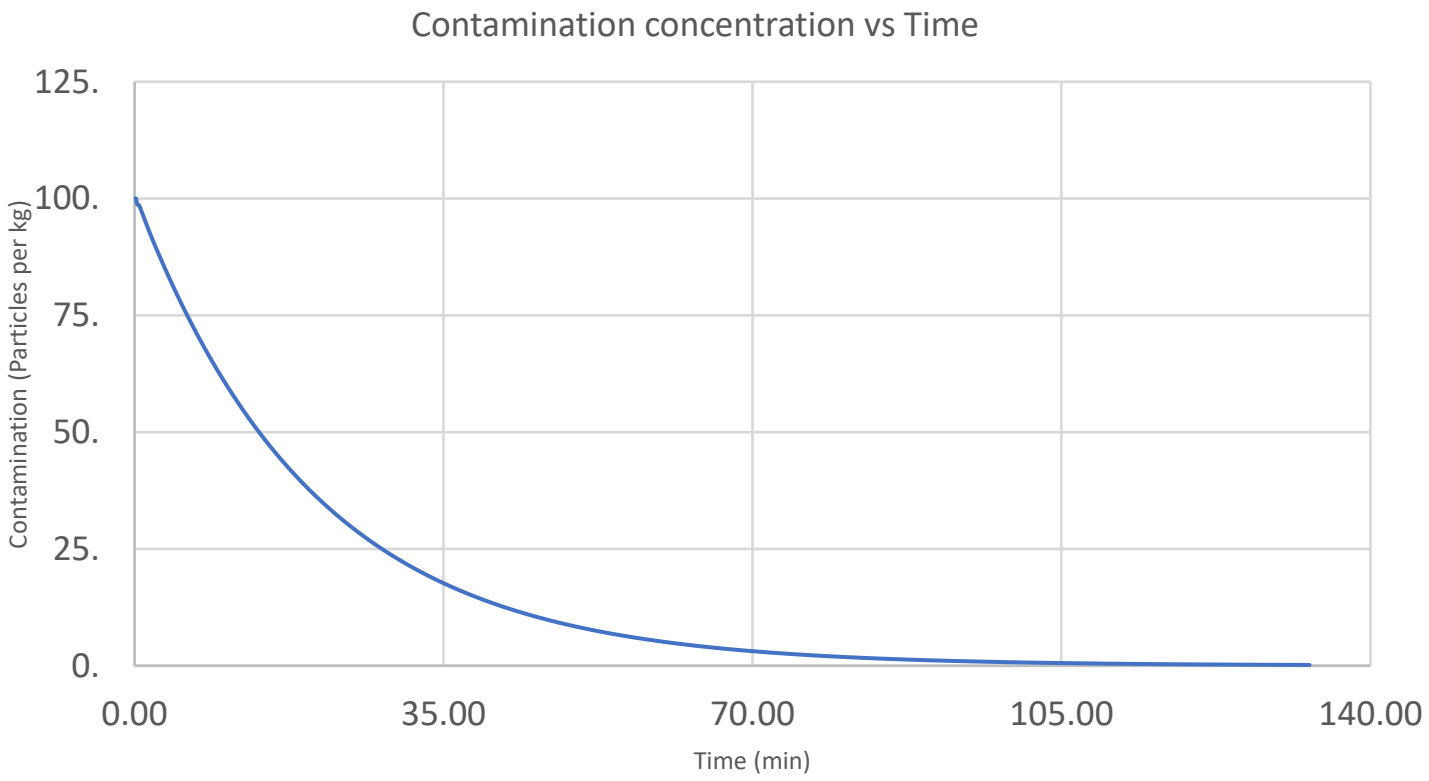
- The CFD study provides the analysis of a uniformly infected room
  - Color represents the contamination level across the room
- The overall dimension of the room is 20 ft. X 15 ft. X 10 ft. (L X W X H)



Placed one Clean Air Cleaner in center of room

Air Cleaner Simulation results

- Plot shows the decay in the contamination level inside the room as time passes, after 120 minutes the steady state condition for the contaminants is reached
- Y axis shows the contamination particles per kg and X axis shows time in seconds



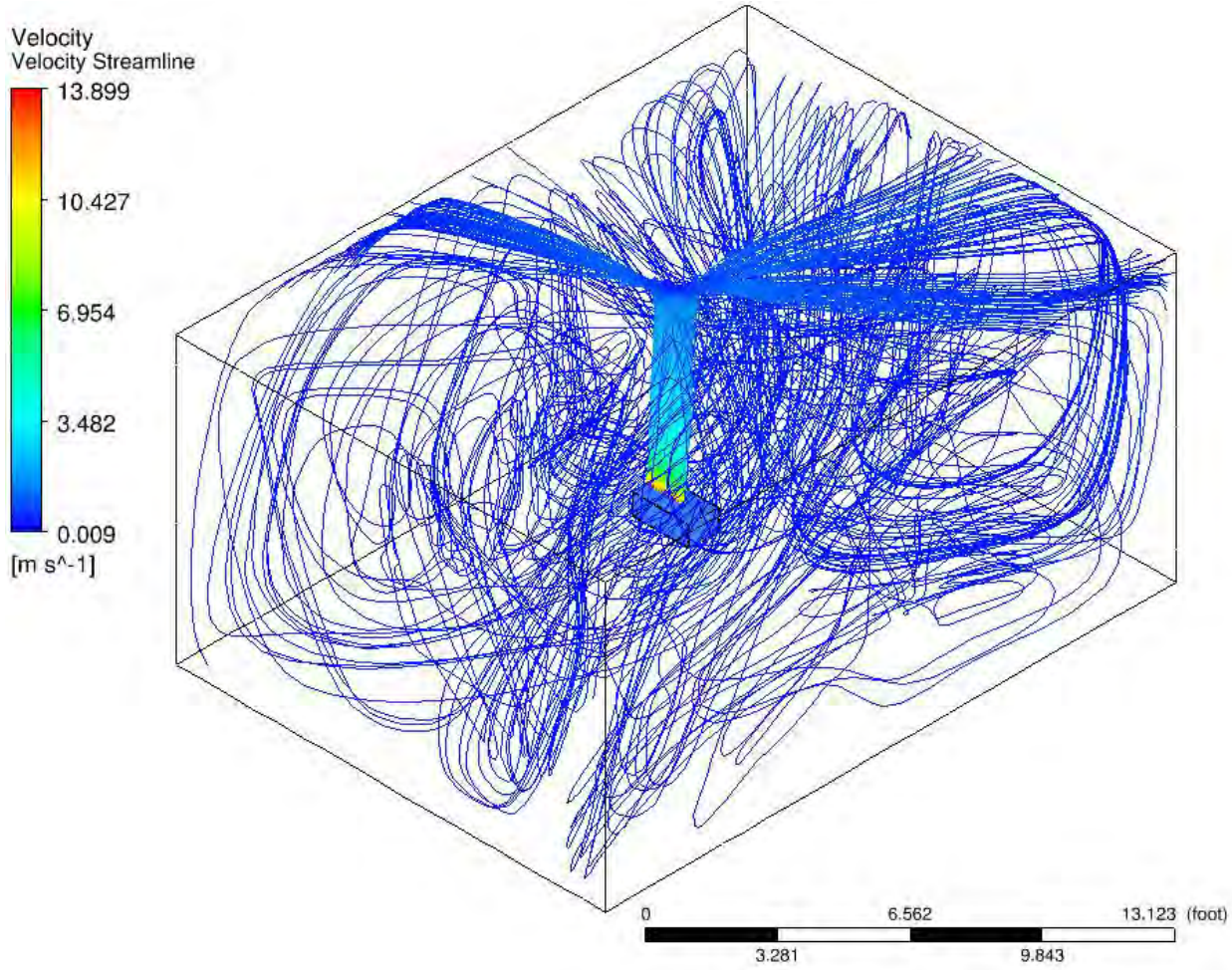
60% Reduction of Pathogen Concentration in 20 Minutes

80% Reduction of Pathogen Concentration in 30 Minutes

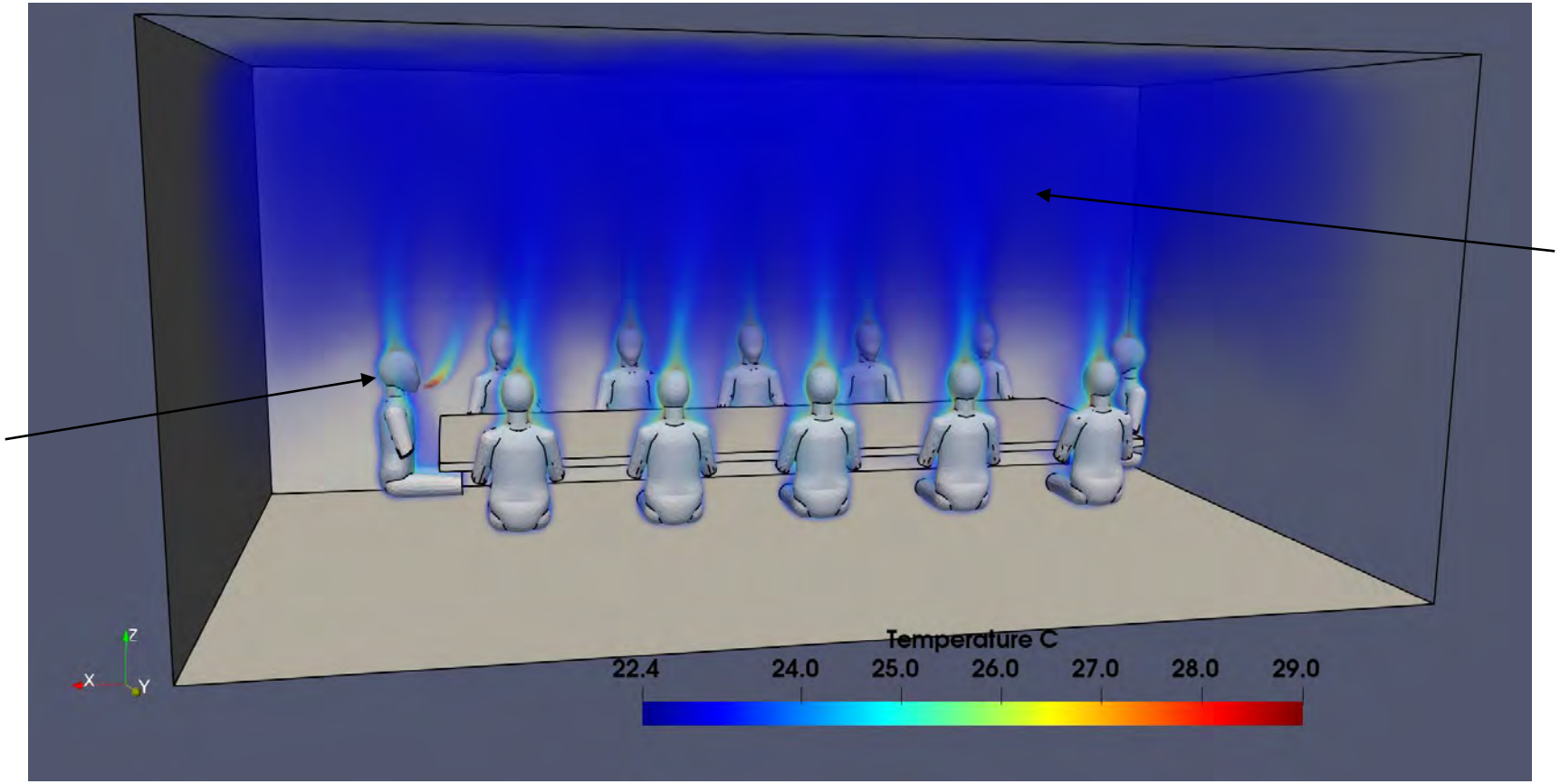
CONTINUOUS Reduction To LESS THAN 1% on a continuing basis—
All The Time

Airflow in Room with Air Cleaner in Place

- Streamlines shows air flow distribution inside the room, air is leaving from top of air cleaner
- Room receives air in all corners of room eliminate stagnant areas
- Clean air from device dilutes the pathogens in room and eliminates small “trigger” particles



Buoyancy In Undisturbed Room



- Since the flow of air inside the room is undisturbed, the effect of buoyancy is accounted in the simulation to predict accurate transmission of emitted particles
- The temperature of human body, head and exhaled air is assigned 85F, 92F and 100F respectively
- The temperature of walls, ceiling and table is assigned 70F

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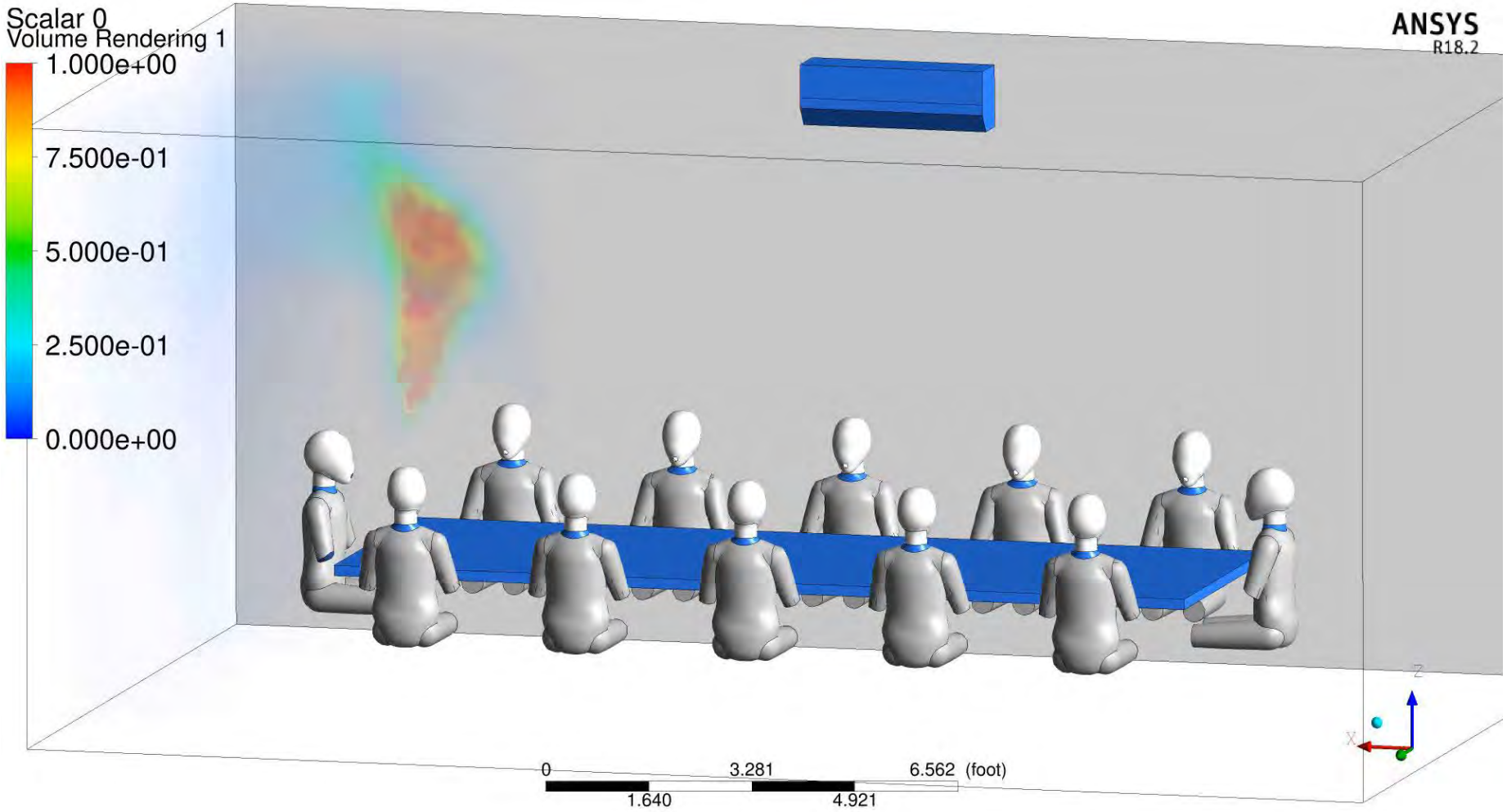
Build up of Pathogens Conference Room



Over the period of 1 hour, concentration of pathogens build and begin to contaminate the entire room

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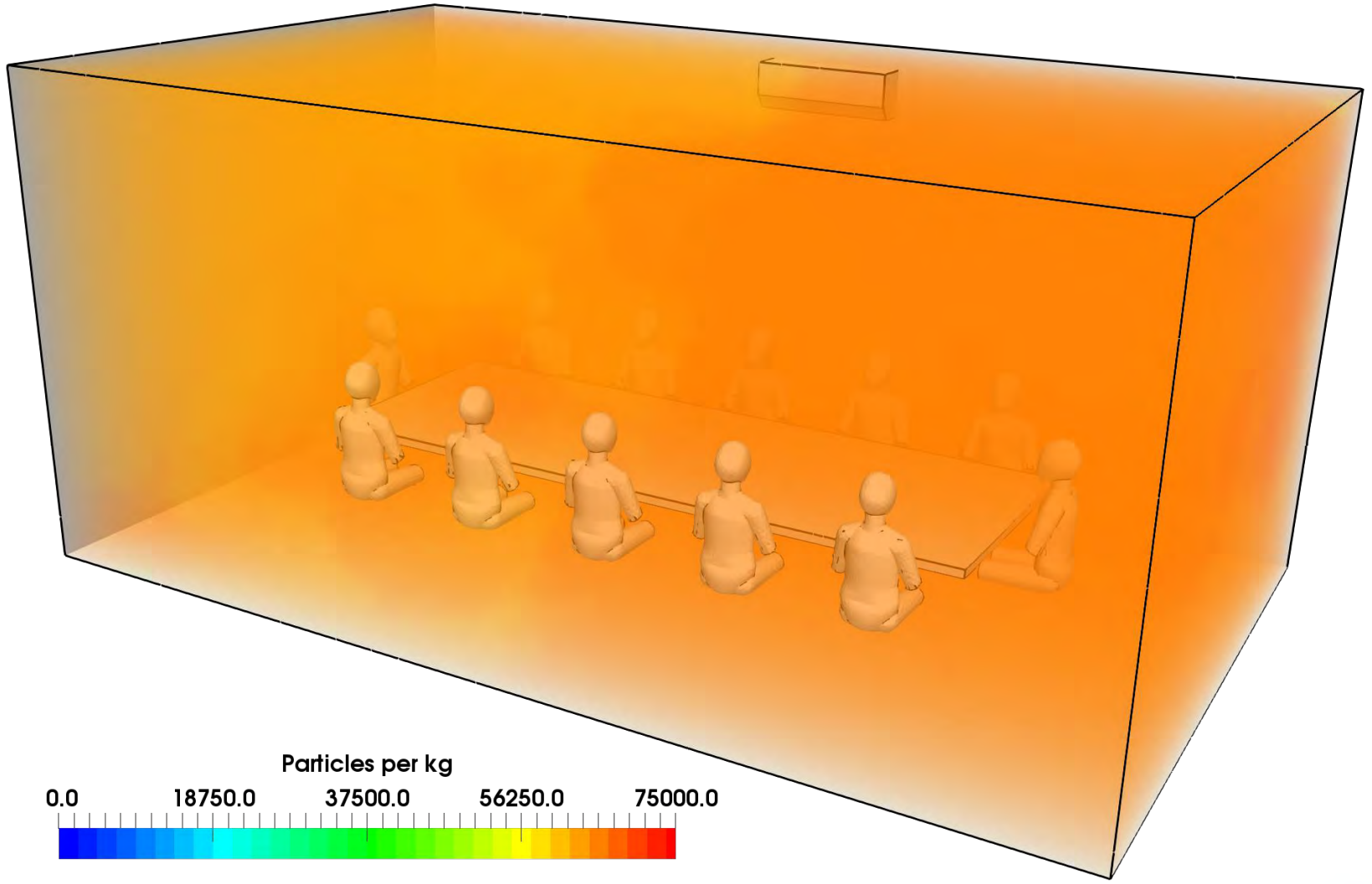
Overall Steady State Pathogen Concentration



Steady state concentration of pathogens in room shows high concentrations without air cleaner in place

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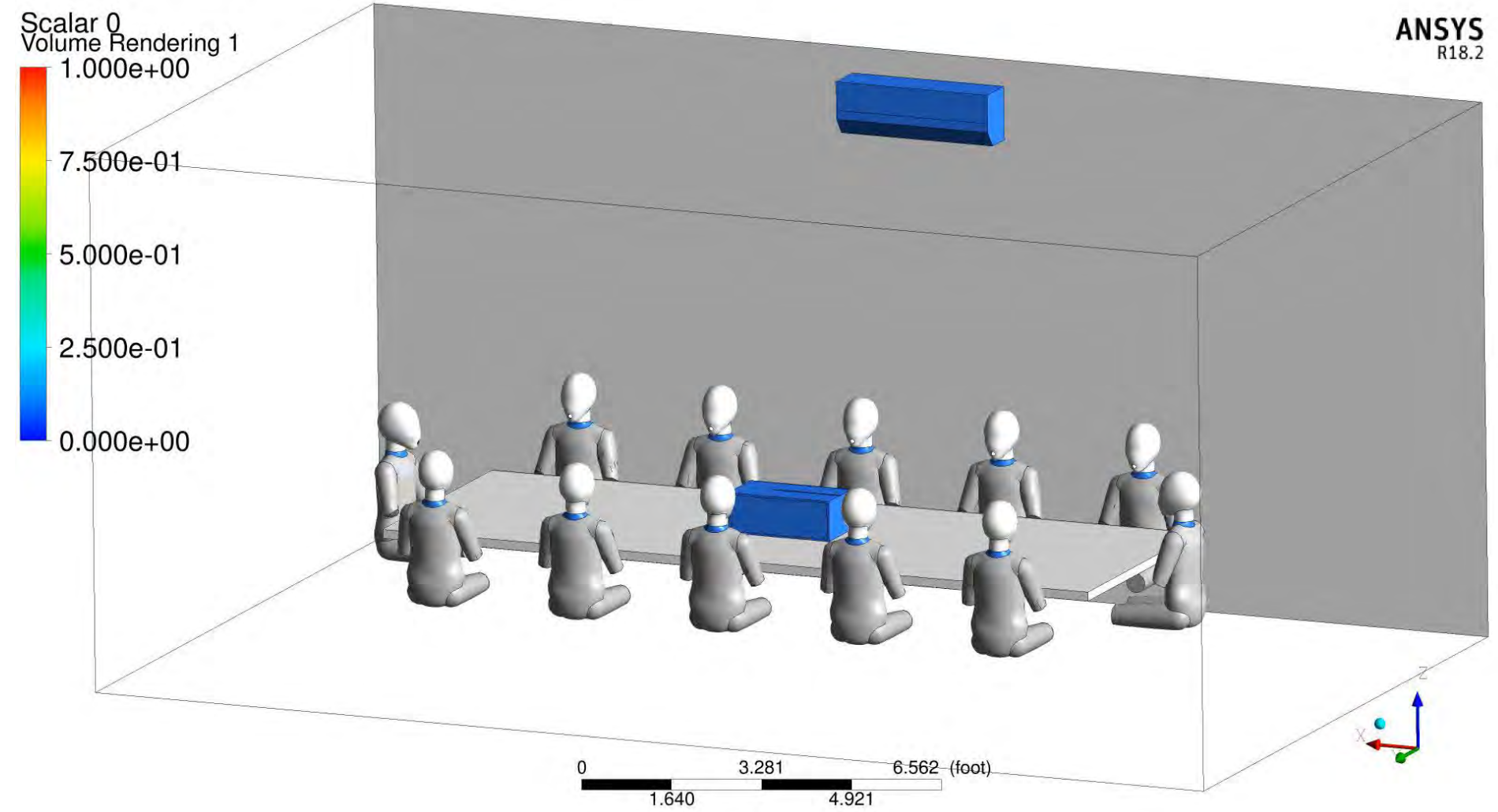
Adding Air Cleaner on the Conference Table



Adding air cleaner to center of table captures the pathogens emitted

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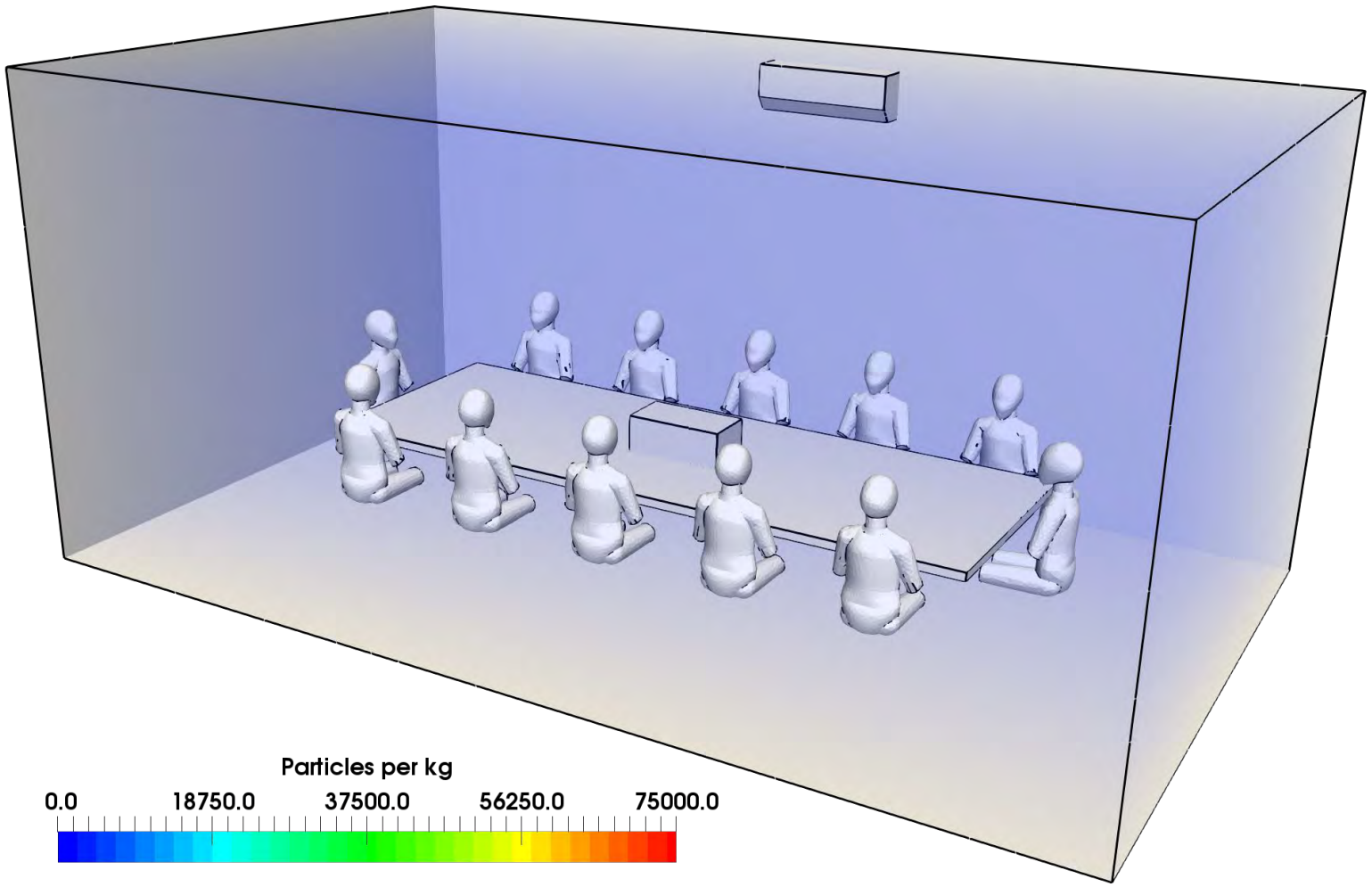
Overall Steady State Pathogen Concentration



Placing air cleaner on table reducing resulting concentration dramatically

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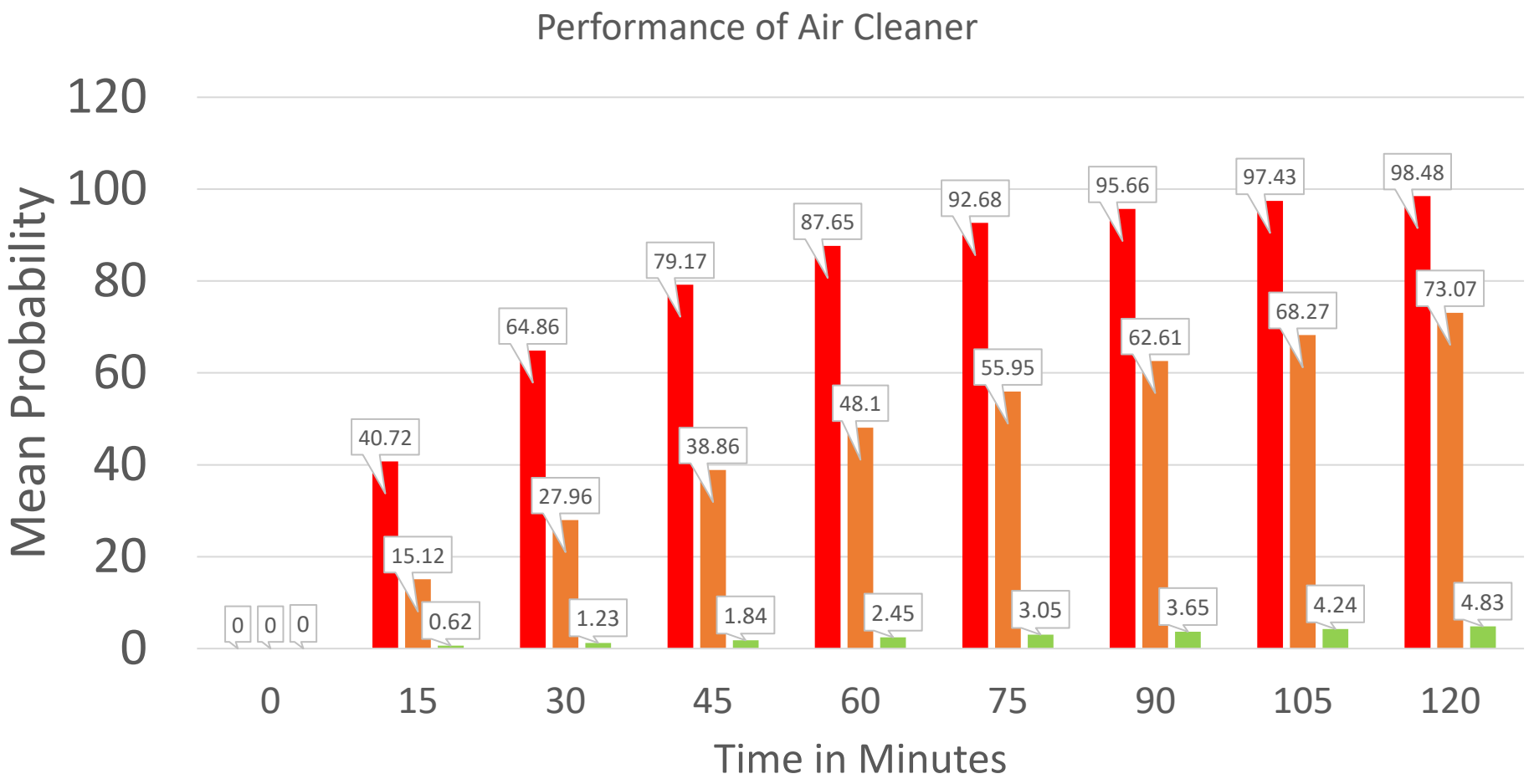
Performance of Air Cleaner

Mean Probability of Transmission for the Occupants



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It’s time for a new definition of “acceptable” IAQ

- Address infection risk to…
  - *Prepare for future novel pandemic diseases*
  - *Reduce impact of seasonal, endemic diseases*
- Why…
  - *Direct health and economic benefits*
  - *Synergy with other IAQ management objectives*

POLICY FORUM

INFECTIOUS DISEASE

A paradigm shift to combat indoor respiratory infection

Building ventilation systems must get much better

By Lidia Morawska, Joseph Allen, William Bahnfleth, Philomena M. Bluyssen, Atze Boerstra, Giorgio Buonanno, Junji Cao, Stephanie J. Dancer, Andres Floto, Francesco Franchimon, Trisha Greenhalgh, Charles Haworth, Jaap Hogeling, Christina Isaxon, Jose L. Jimenez, Jarek Kurnitski, Yuguo Li, Marcel Loomans, Guy Marks, Linsey C. Marr, Livio Mazzarella, Arsen Krikor Melikov, Shelly Miller, Donald K. Milton, William Nazaroff, Peter V. Nielsen, Catherine Noakes, Jordan Peccia, Kim Prather, Xavier Querol, Chandra Sekhar, Olli Seppänen, Shin-ichi Tanabe, Julian W. Tang, Raymond Tellier, Kwok Wai Tham, Pawel Wargocki, Aneta Wierzbicka, Maosheng Yao

Morawska, L., Allen, J., Bahnfleth, W., Bluyssen, P.M., Boerstra, A., Buonanno, G., Cao, J., Dancer, S.J., Floto, A., Franchimon, F. and Greenhalgh, T., 2021. A paradigm shift to combat indoor respiratory infection. *Science*, *372*(6543), pp.689-691.

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NEW WHO AIR QUALITY GUIDELINES SET CLEAR GOALS TO HELP IMPROVE AIR QUALITY FOR ALL

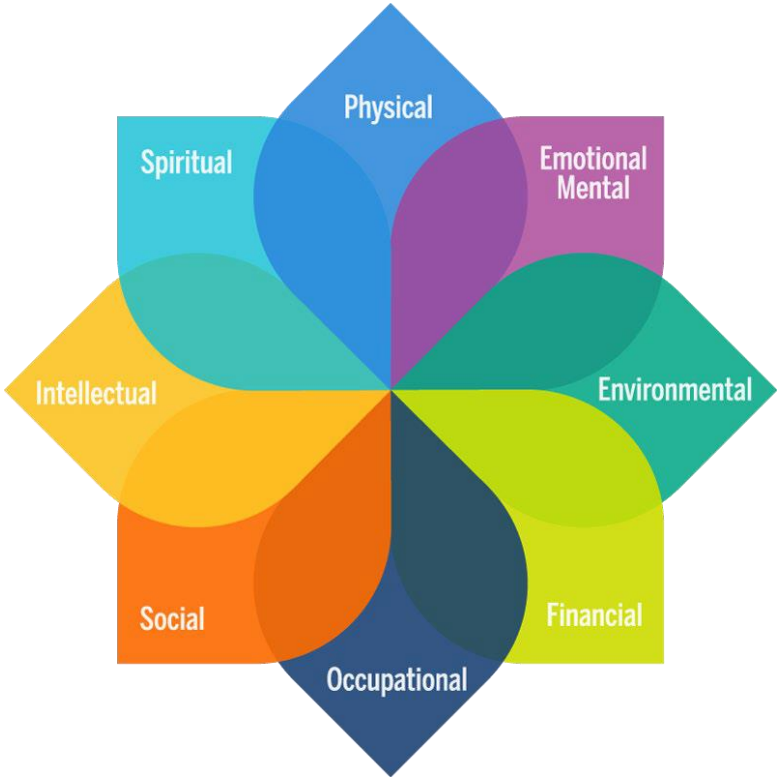
WHO Air Quality Guidelines set goals to protect millions of lives from air pollution.

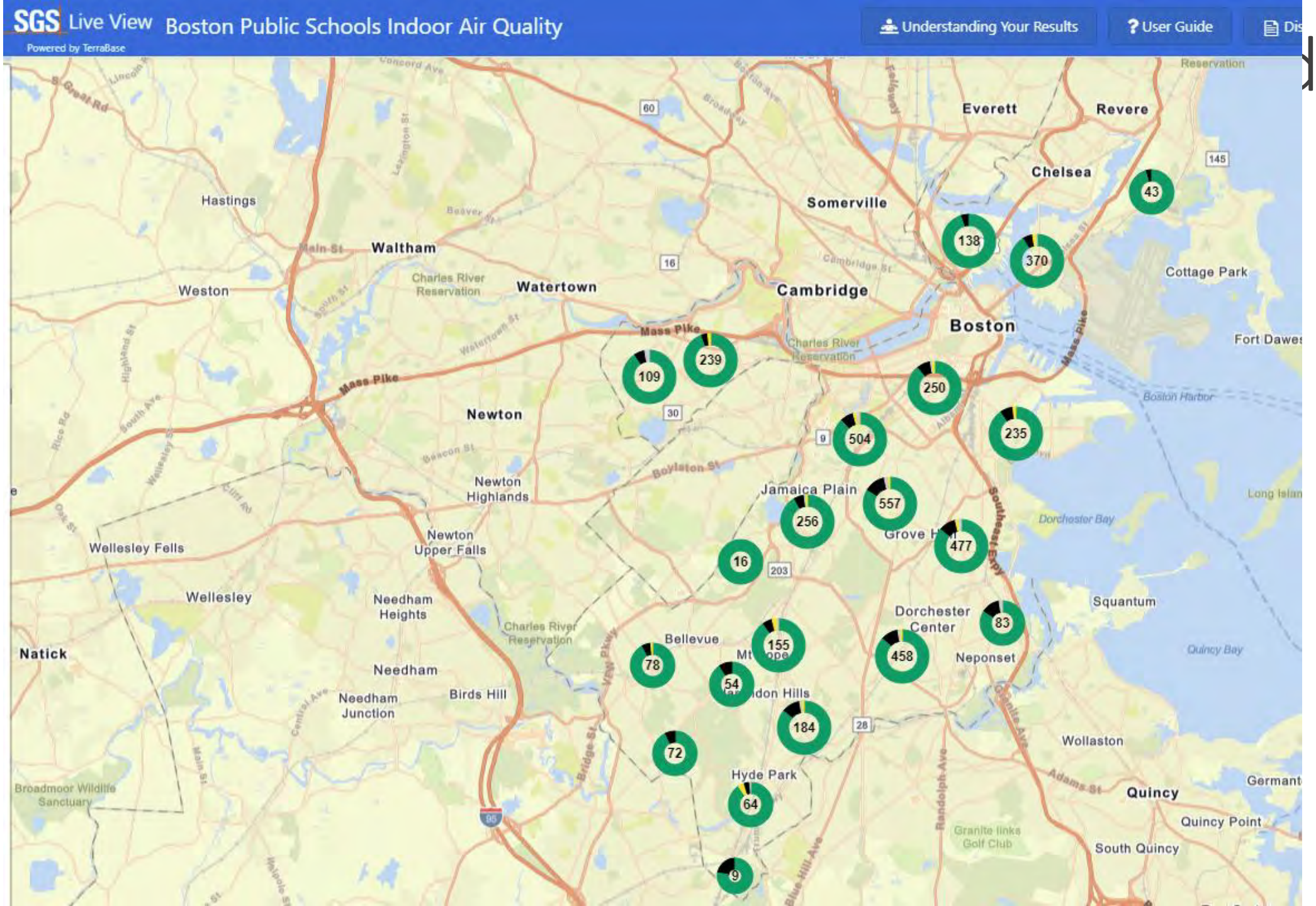
CLEAN AIR FOR HEALTH #AirPollution World Health Organization

New definition of “acceptable” IAQ Health and Wellness

Healthy Buildings

Wellness




SGS Live View
Powered by TerraBase
Boston Public Schools Indoor Air Quality
Understanding Your Results
User Guide
Everett
Revere
Chelsea
Somerville
Cambridge
Boston
Watertown
Waltham
Weston
Hastings
Newton
Newton Highlands
Newton Upper Falls
Wellesley Falls
Wellesley
Needham Heights
Needham
Needham Junction
Birds Hill
Natick
Broadmoor Wildlife Sanctuary
Charles River Reservation
Mass Pike
Jamaica Plain
Grove Hall
Dorchester Center
Bellevue
Hyde Park
Cottage Park
Fort Dawes
Boston Harbor
Dorchester Bay
Squantum
Quincy Bay
Neponset
Wollaston
Quincy
Quincy Point
South Quincy
Germant
Granite links Golf Club
43
138
370
239
109
250
504
235
557
256
16
477
83
155
458
78
54
184
72
64
9

Need to overcome some barriers

- Scientific justification not persuasive to all
- Economic justification not understood
- Split incentives
- Likely need for policy and standard changes – regulatory aversion
- Workforce education needed
- Perception of increased professional liability
- Perceived conflict with energy and environment – “not sustainable”

Air Cleaners Inc
“Cleaning The Air That We Share”

Businesses and Consumers will Drive Change

NEWS + FEATURES:TECH NEWS NOVEMBER 29, 2021

Lawsuit Over Indoor Air Quality at Connecticut School Settled for $500,000

The original report cites 'poor building conditions' responsible for student injuries and declining health.

Words by: DesignWell staff • Photos by: Jeanette Ross

Summary

- We've been stuck in a paradigm for decades that institutionalizes mediocre IAQ
- The Covid-19 pandemic has created strong motivation to redefine IAQ goals to address health and resilience
- The technology exists to implement a new paradigm
- The potential benefits are large
- The is a growing understanding of the importance of IAQ in the general public

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Personal Choices You can Make

Be Sensitive to these four items when entering indoor spaces

- *People*
  - How many people are in the room?
- *Place*
  - How large is the room?
  - Air Cleaners?
- *Time*
  - How long are you staying in the room?
- *Space*
  - How much distance is there between people?

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"Cleaning The Air That We Share"

Thank You!

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