COVID-19 Science and HVAC Solutions

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Rheem Manufacturing

Association of Energy Engineers

The COVID-19 era

Image from Funvizeo

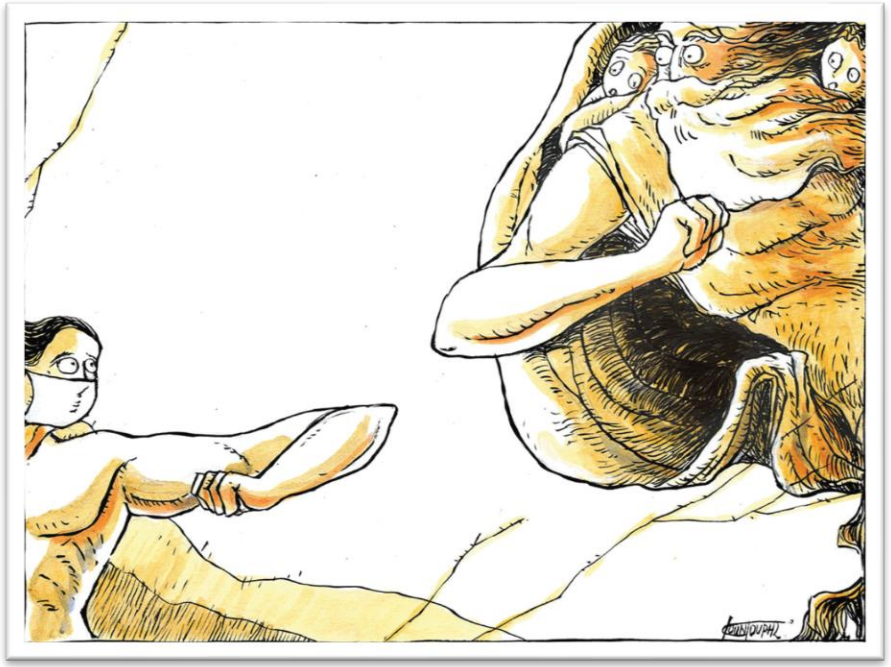
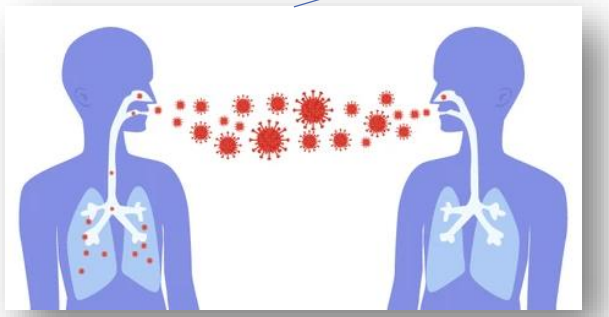


Image by Michael Kountouris on politico

Modes of viral transmission

Modes of viral transmission



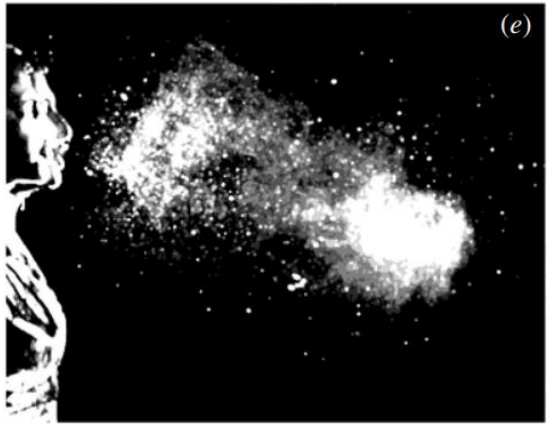
Airborne transmission

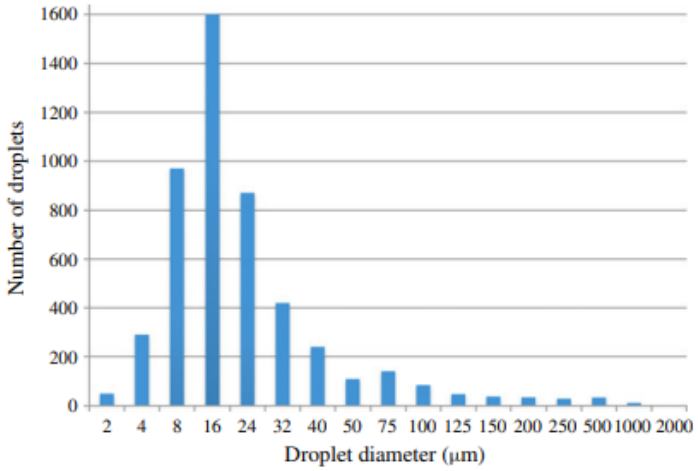
Smaller droplets

Fomite transmission

Larger droplets

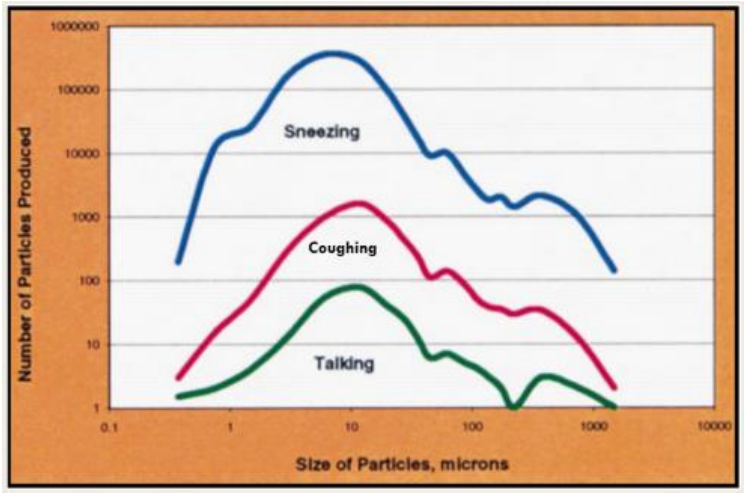
Viral infection sources





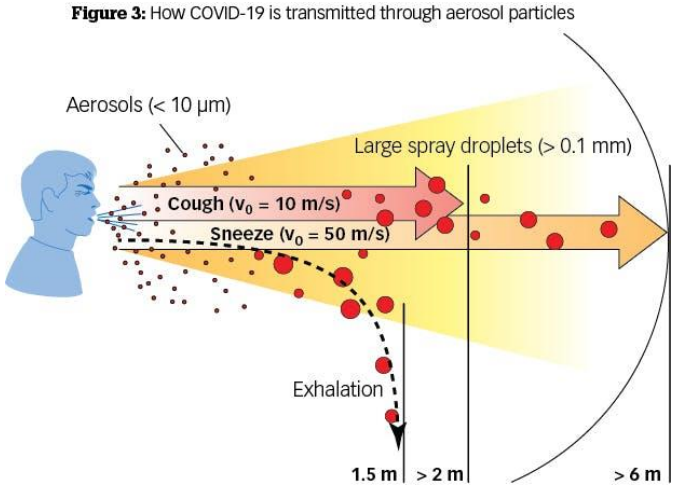
Source: Bourouiba et al. 2014

- Sources – exhalation, talking, coughing, sneezing
- A wide range of droplet size (0.1 – 1000 microns)
- Sneezing can release as many as 1 million droplets



Source: Duguid et al. 1945

Viral transmission through droplets



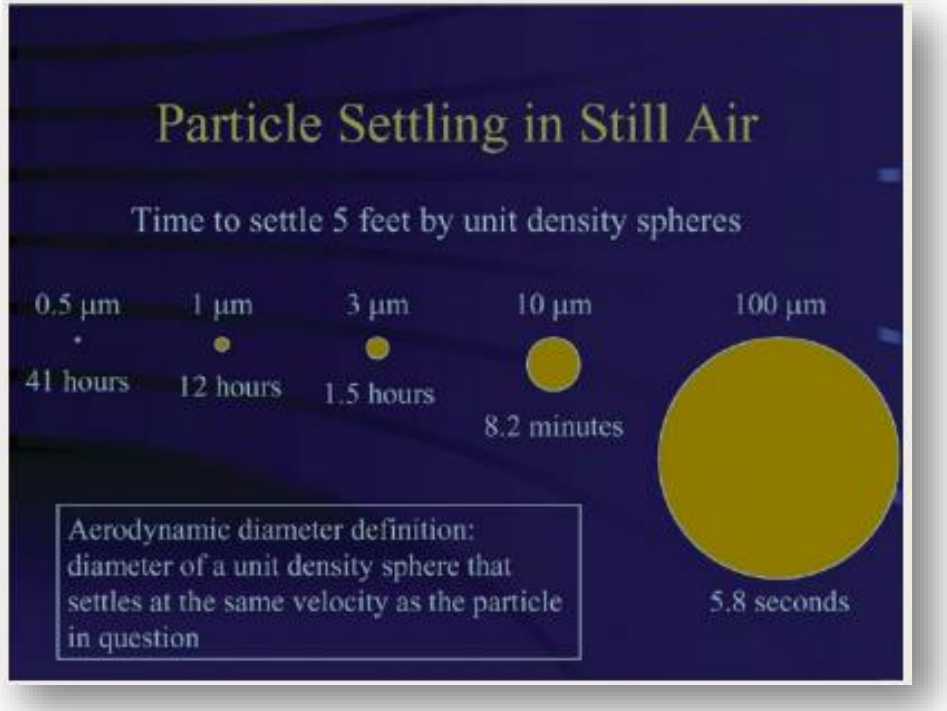
Source: perioimplantadvisory.com

- Larger drops (greater than 100 microns) fall quickly to the ground
- Droplets between 10 and 100 microns evaporate during their travel and are carried to long distances
- Droplets smaller than 10 microns become aerosols and move with the current in the room

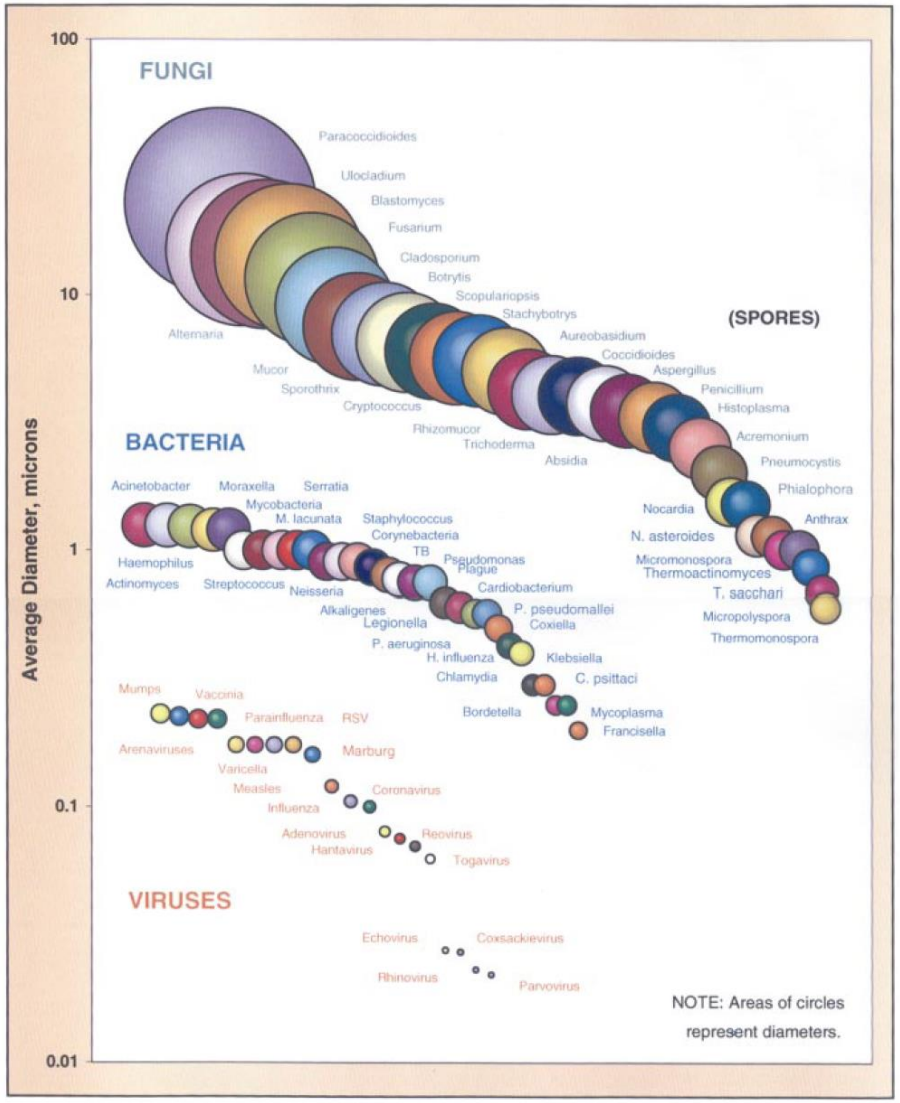
Respiratory droplets from coughs, sneezes can travel beyond 6 feet: study

December 30, 2020 No Comments

CORONAVIRUS



Role of HVAC systems in viral spread

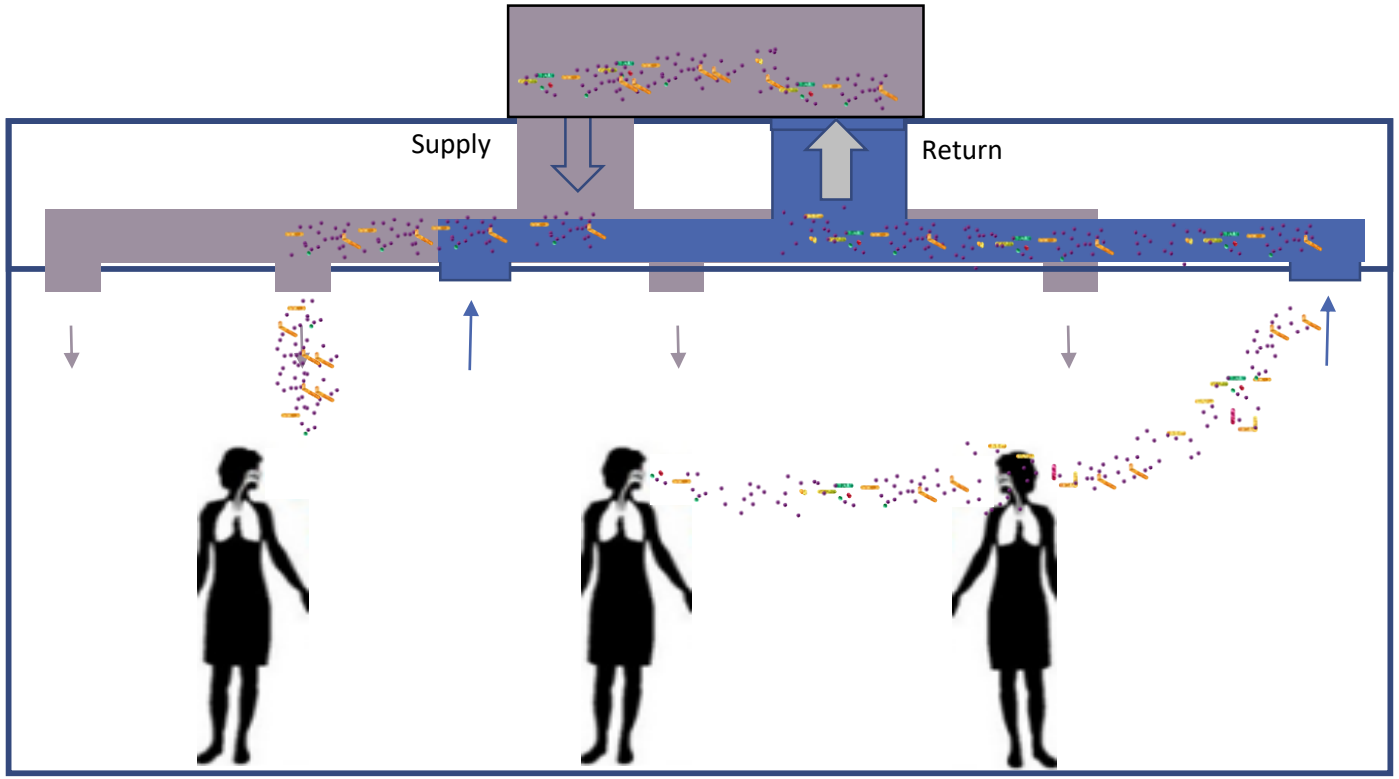


Source: Kowalski et al. 1998

HVAC systems can help spread infection

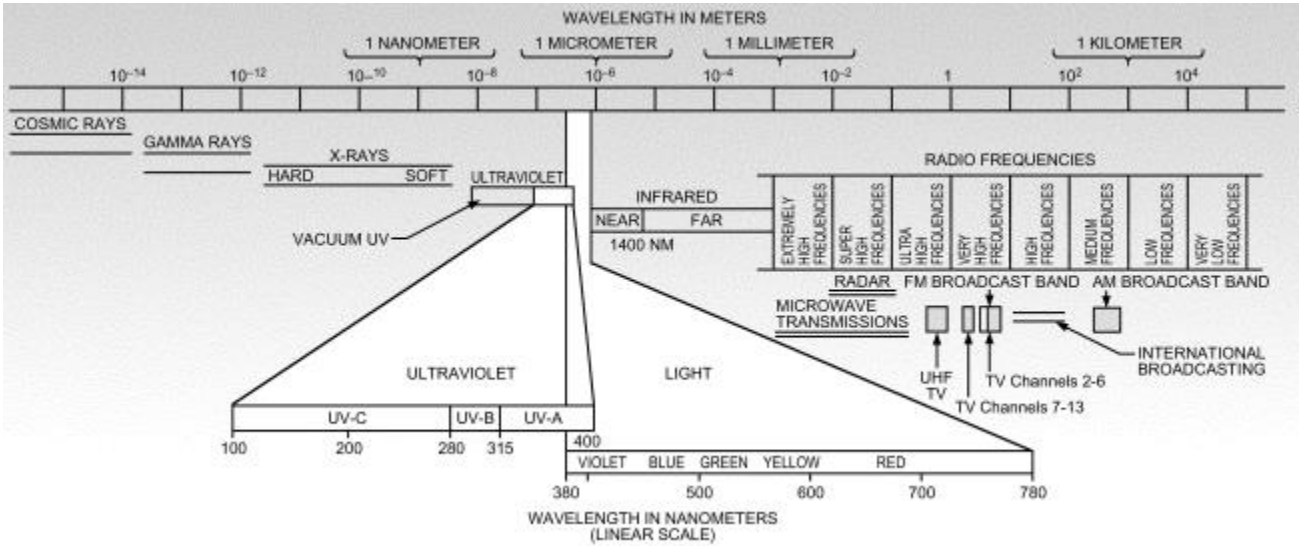
- Poor ventilation causes build up of infectious material
- Air currents disperse viral load

HVAC systems recirculate viral aerosol

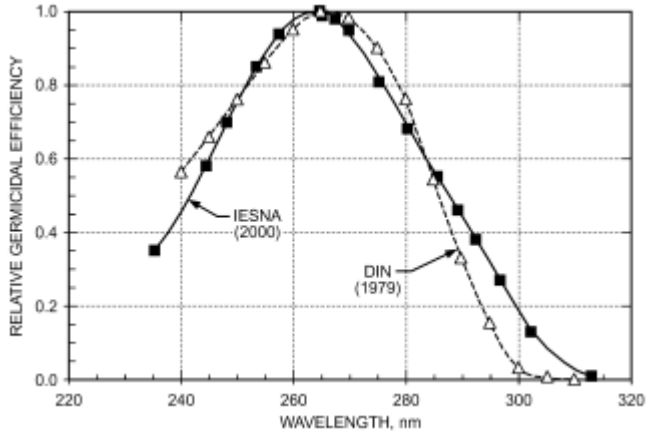


- To reduce operating cost, a certain quantity of air is recirculated by the HVAC system
- This causes build up of contaminants
- It also transports contaminants from one place to another

Ultraviolet light (UV-C) to the rescue

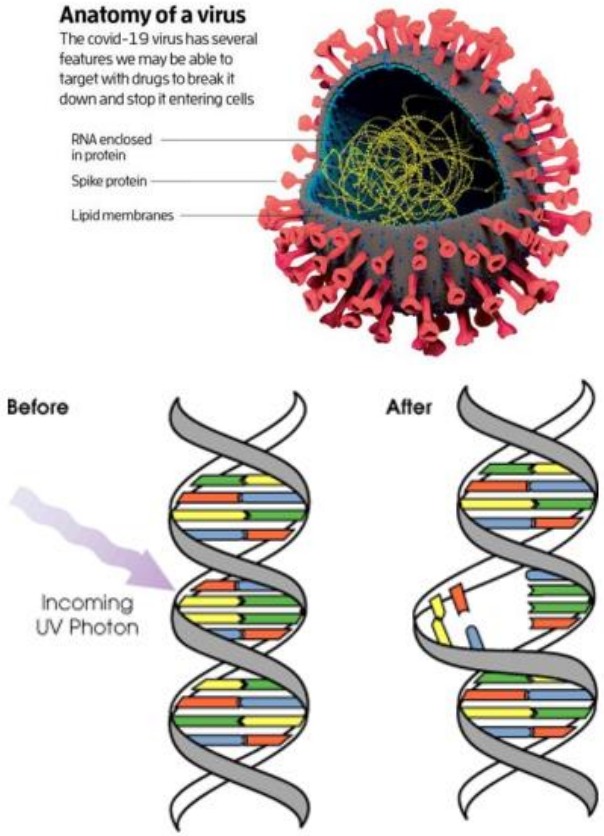


- Ultraviolet light (UV-C) can be used to disinfect air and surfaces
- UV-C ranges from 200 to 280 nm with the peak germicidal efficiency at around 260nm
- It can be used directly in rooms or inside the HVAC ducts to purify the flowing air



Source: ASHRAE – Ultraviolet air and surface treatment

How does UV-C work



- Micro-organisms are highly susceptible to UV-C exposure. UV-C destroys their genetic material

$$\frac{N_s}{N_o} = e^{-KIt}$$

where

N_o = number of bacteria exposed

N_s = number of bacteria surviving after an exposure to UVGI

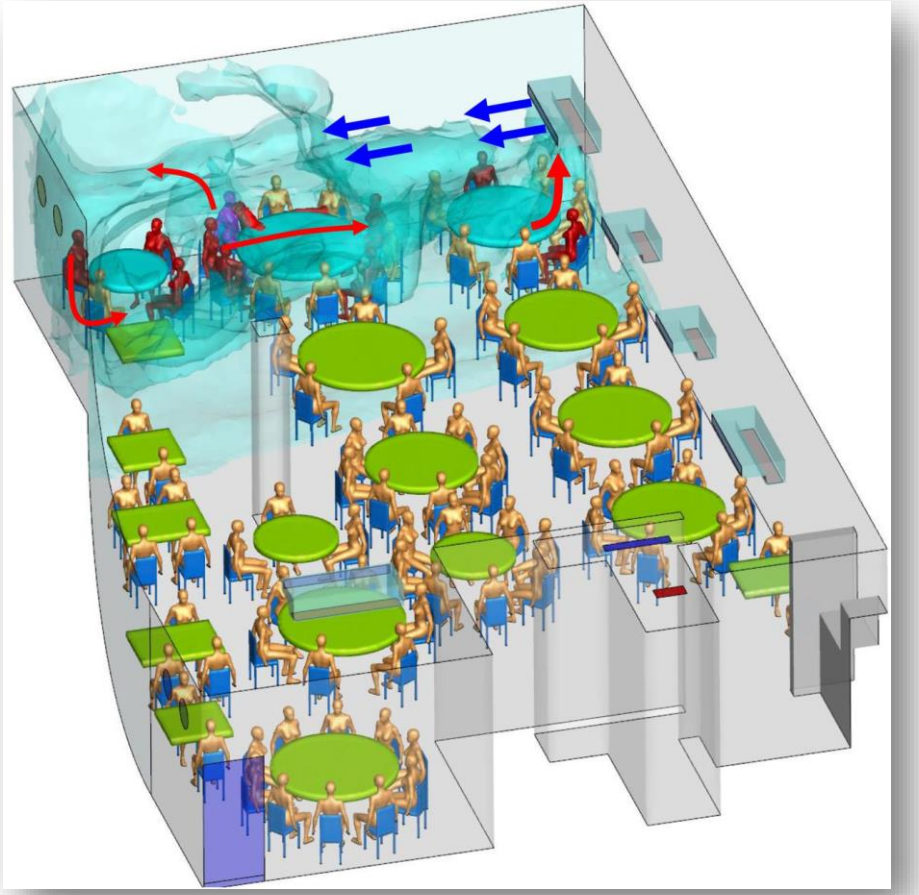
I = UV irradiance, $\mu W/cm^2$

t = time of UV exposure, s (the product, It, is the UVGI dose to the organism)

K = microbe susceptibility factor, $cm^2/\mu W \cdot s$

- Ixt is the dosage of radiation that the micro-organism is exposed to
- With increase in dosage there is an exponential decrease in microbe population
- Coronavirus has a high susceptibility to UV-C

Role of HVAC currents in viral transmission



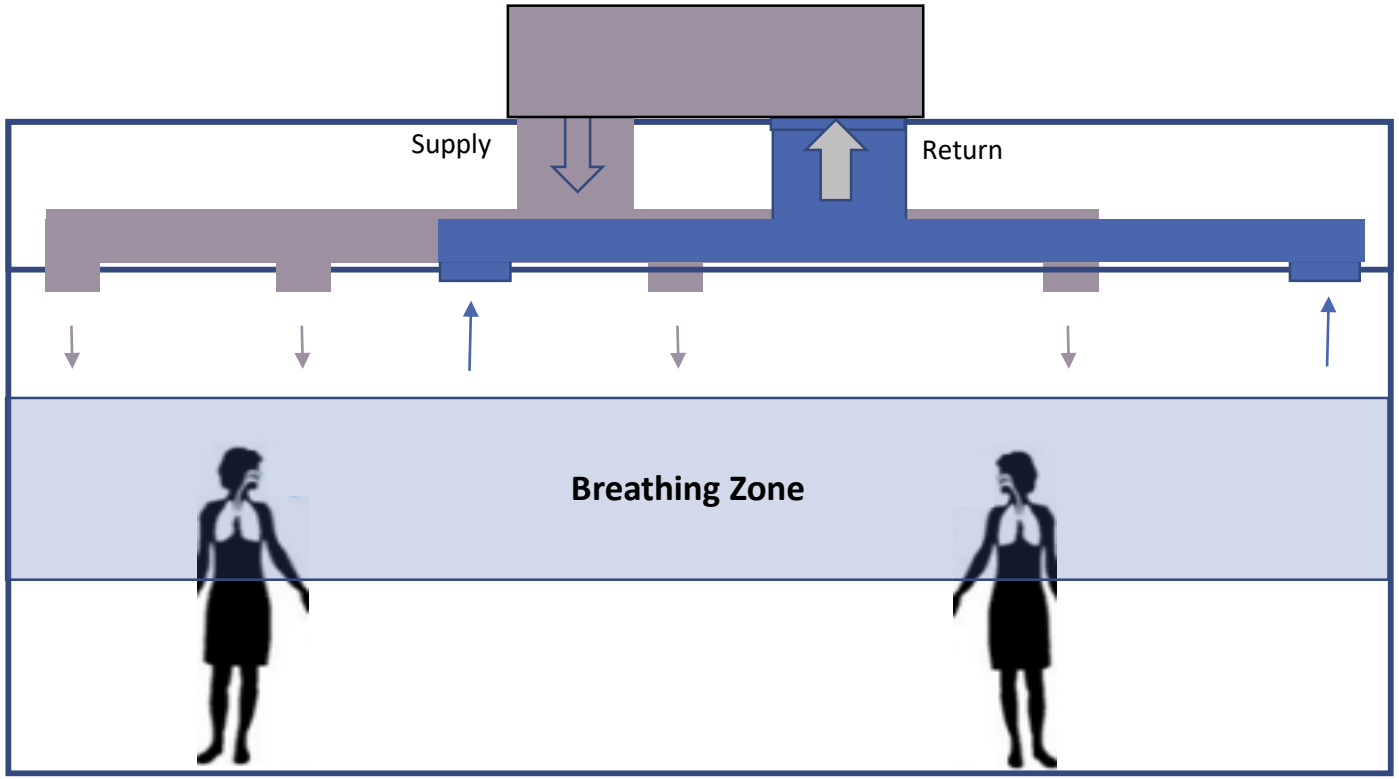
Source: Yuguo Li et al. 2020

Study focusing on aerosol transmission of SARS-CoV-2 in a restaurant in Guangzhou, China

<u>Conclusions</u>

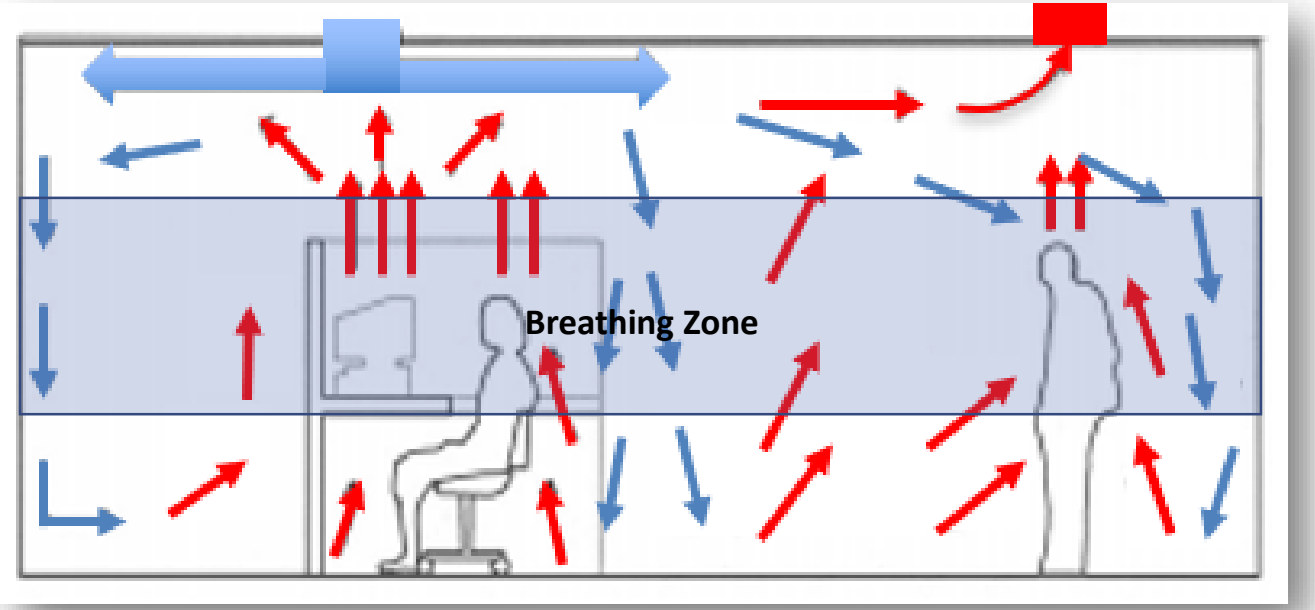
- There was no fomite transmission as there was no contact (more than 6 ft apart)
- Infection distribution was consistent with the aerosol dispersion
- Poor ventilation can result in community spread

The concept of a breathing zone



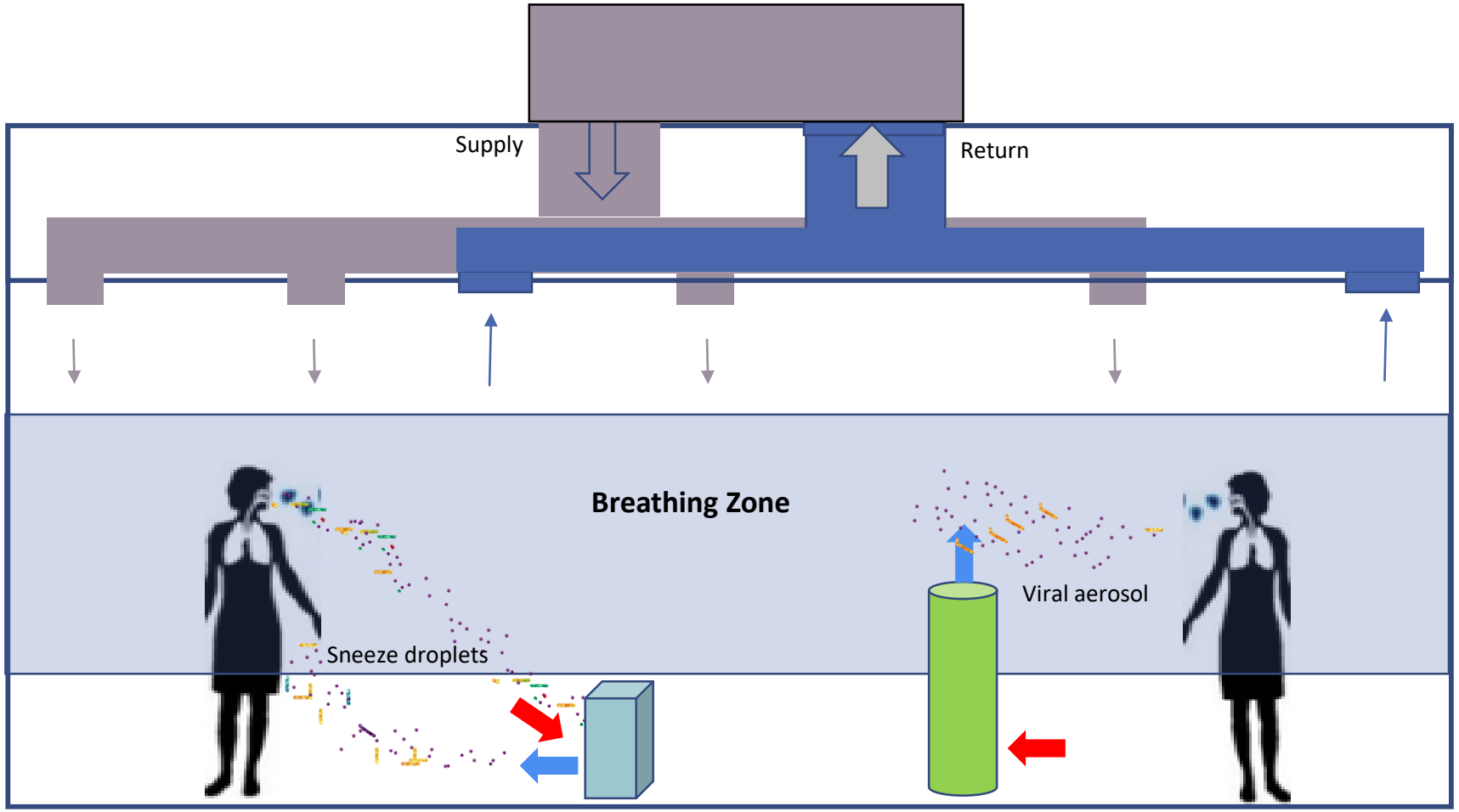
- Breathing zone is hypothetical region around a person's face from where the air is inhaled
- It typically extends from 4 ft – 7 ft
- To prevent any transmission of infection this area needs to be kept clean

HVAC airflow pattern is important



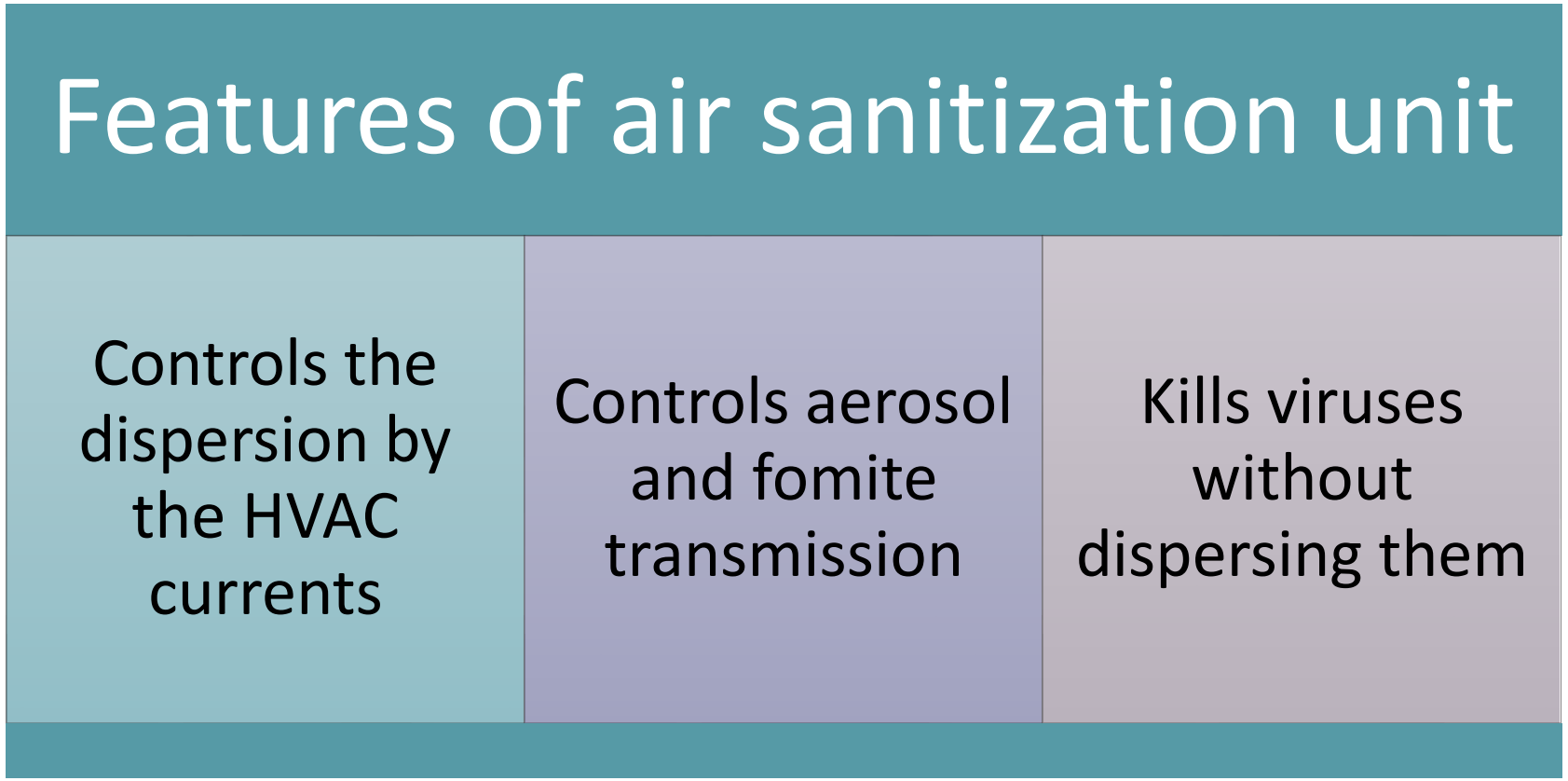
- Mixing ventilation is the most common in open office spaces
- It is designed keeping human comfort in mind
- However, it mixes contaminants with the fresh air in the breathing zone, thus increasing the risk

Current local air sterilization strategies

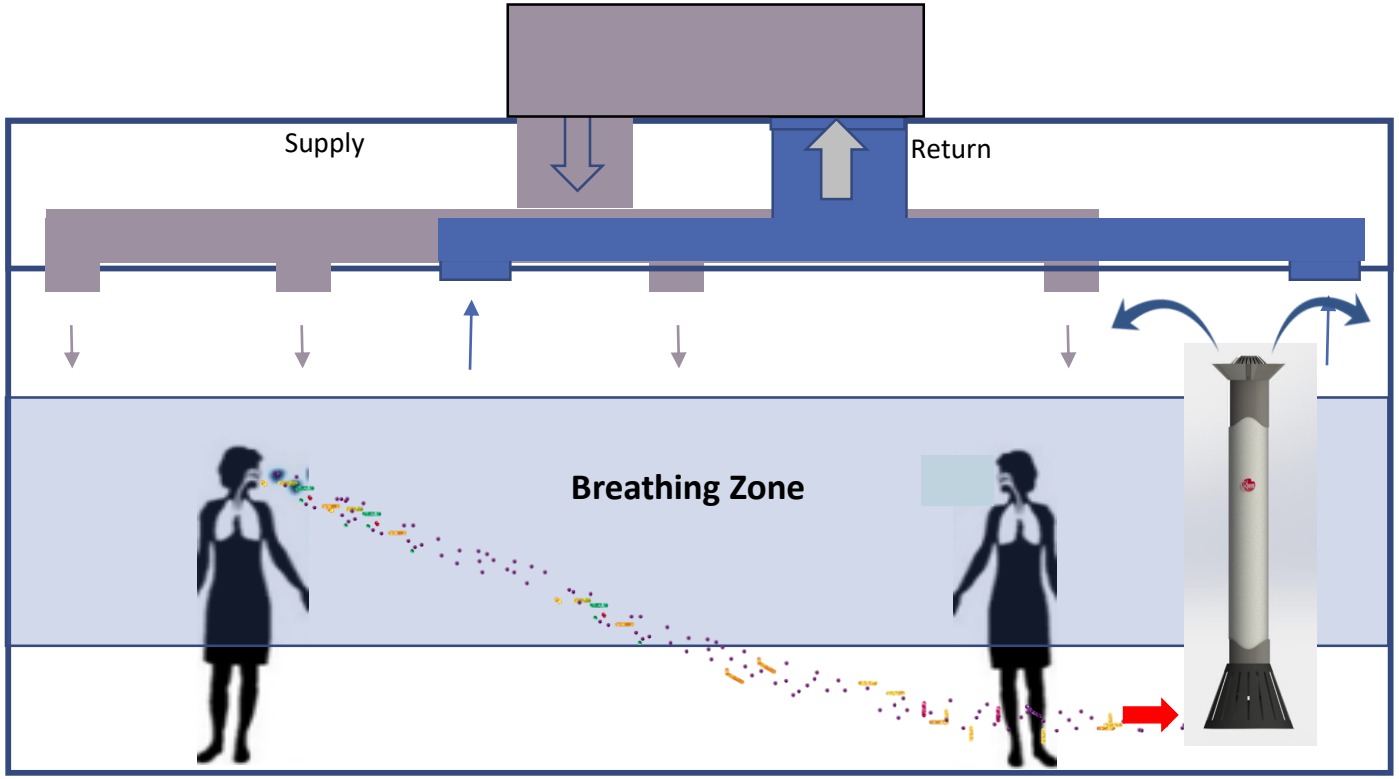


- Any outlet of the sterilization device below or inside the breathing zone aids in dispersing any viral material and transmitting infection

There is a need for better disinfection!



Air sterilization unit prototype “RM3”



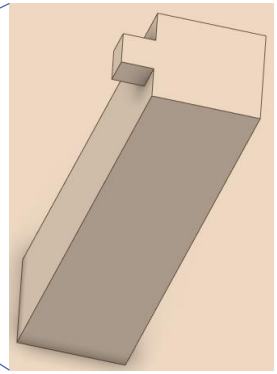
- Important features for an air sanitization device to clean up the breathing zone
  - Air outlet above the breathing zone
  - Air inlet below the breathing zone
  - Velocity and angle of air exit

Computational Simulations

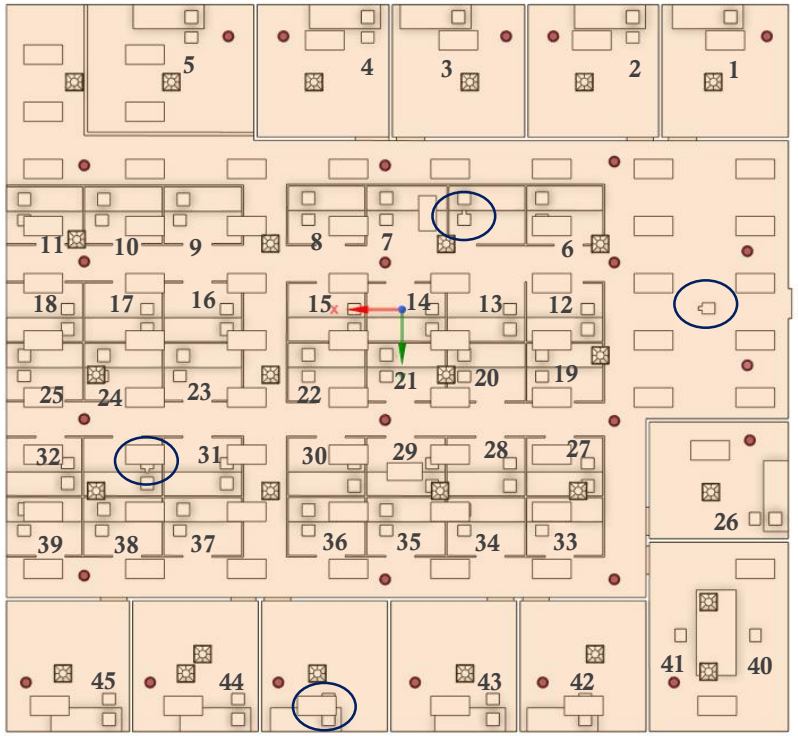
Open office space for airflow studies - I

Rheem office - Montgomery

Supply air diffuser



Return air register



- The Rheem office in Montgomery has 90% air recirculation in the building. Air flow measurements were taken at each diffuser
- 4 infected people have been randomly placed in the simulation to understand the spread of the infection. A small amount of tracer gas was used to mimic viral exhalation from the infected people

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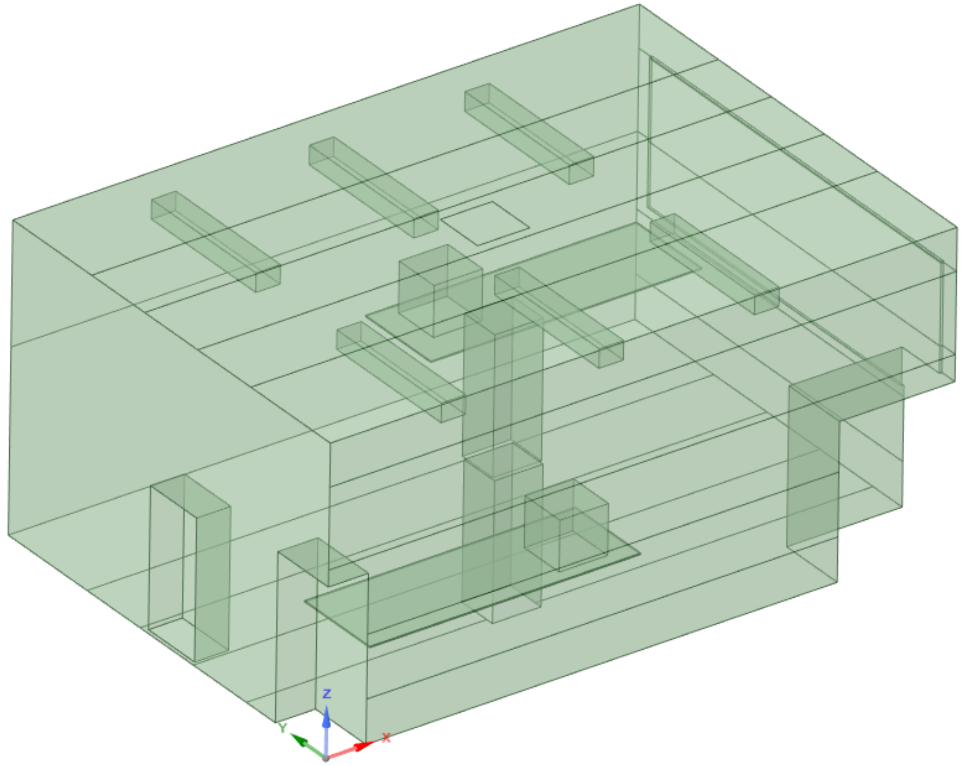
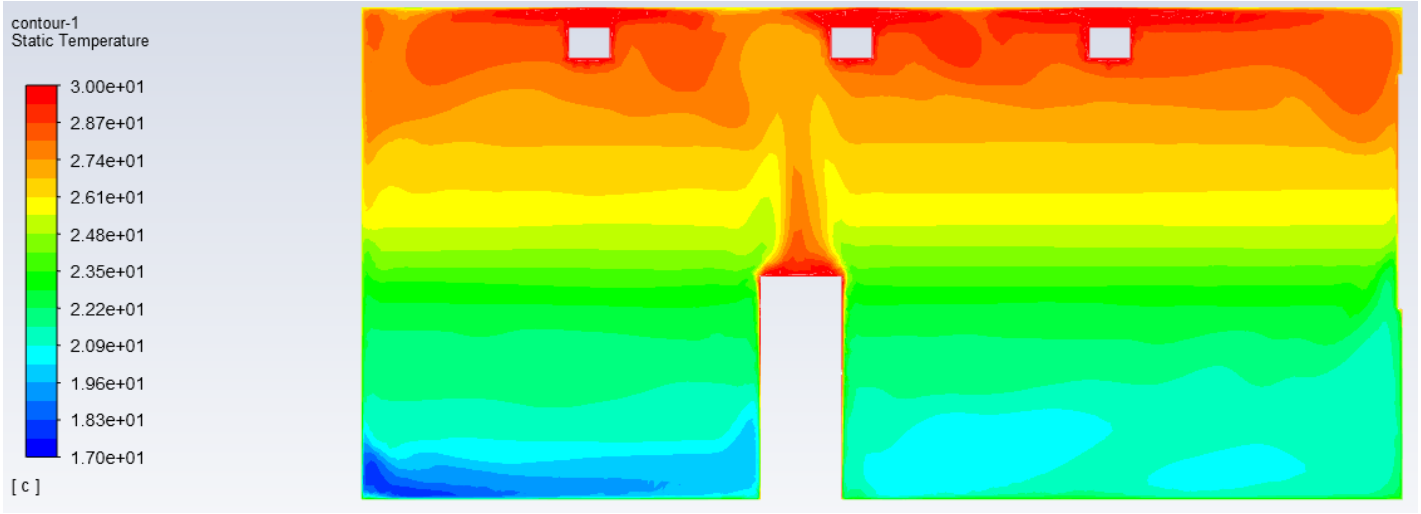
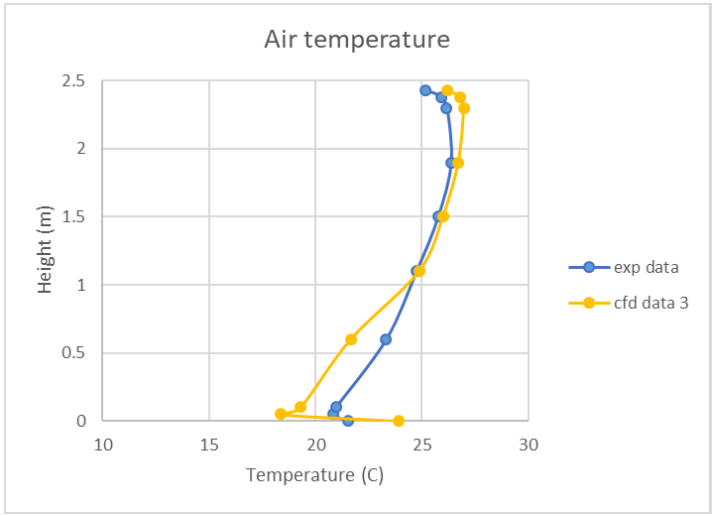
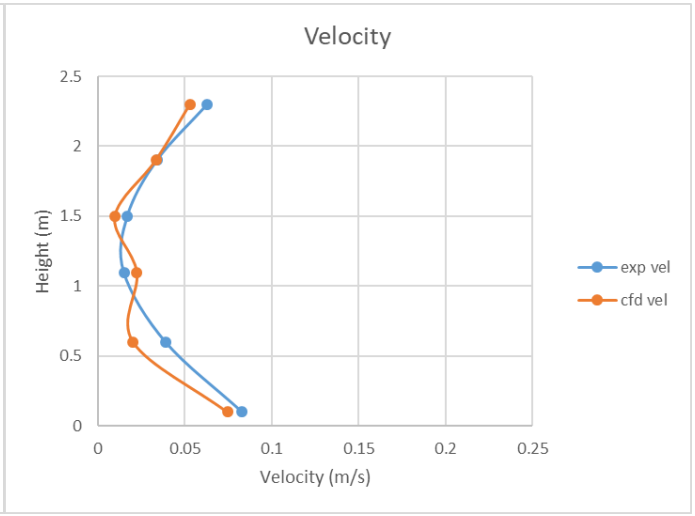
Validation of computational methods









- Flow of air was simulated in the room along with the thermal interaction with all the bodies
- Velocity and temperature measurements were compared against the simulation data to validate the CFD methods

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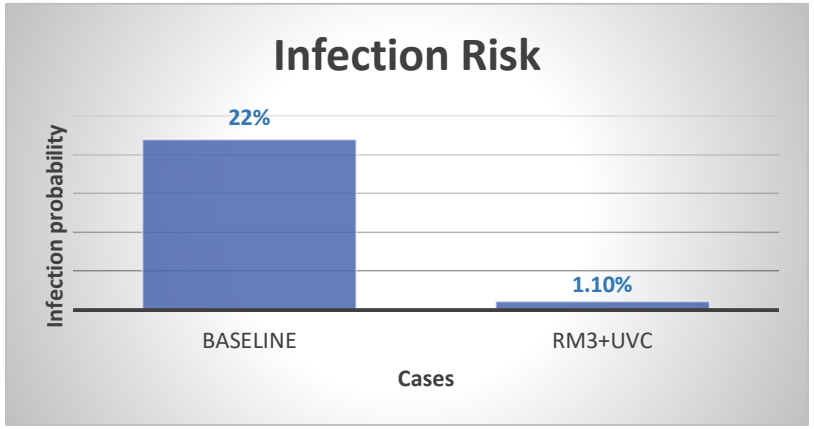
Quantifying infection risk

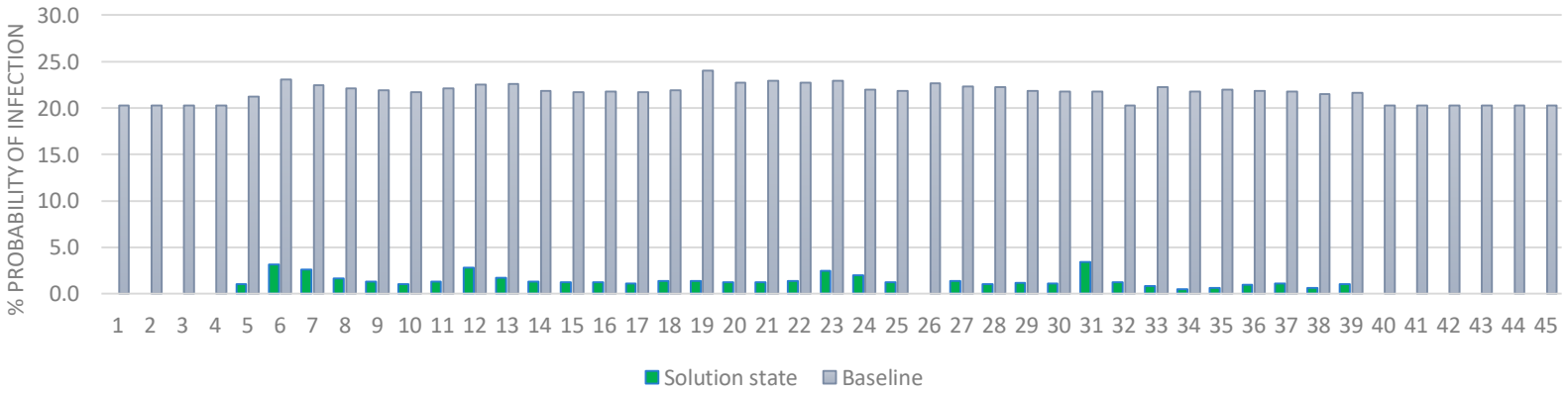


$$P = \frac{D}{S} = 1 - e^{-Iqpt/Q}$$

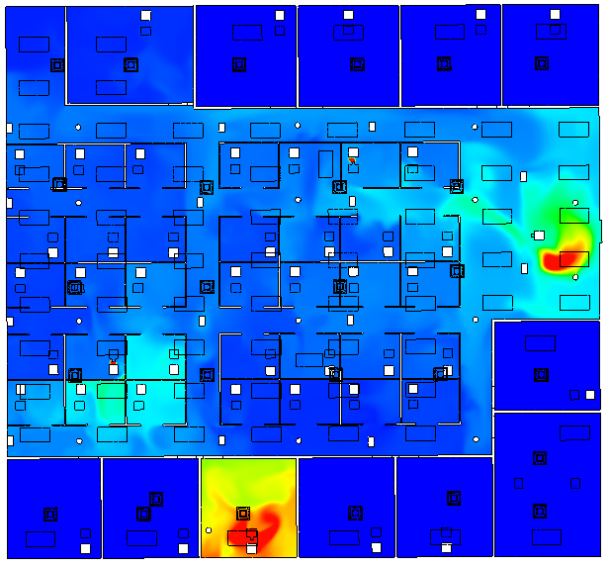
This equation quantifies the risk of infection to healthy people due to airborne transmission

- *P*: the probability of infection
- *D*: number of infected
- *S*: number of susceptible
- *I* : number of infector
- *q*: quanta produced by one infector (quanta/h)
- *p*: pulmonary ventilation rate of each susceptible (m^3/h), for seated person or doing light activity indoor p = 0.3 m^3/h [1]
- *t*: the duration of exposure (h)
- Q: room ventilation rate (m^3/h)

- **The risk of airborne transmission has reduced by almost 20 times**



The index numbers here represent the noninfected office occupants



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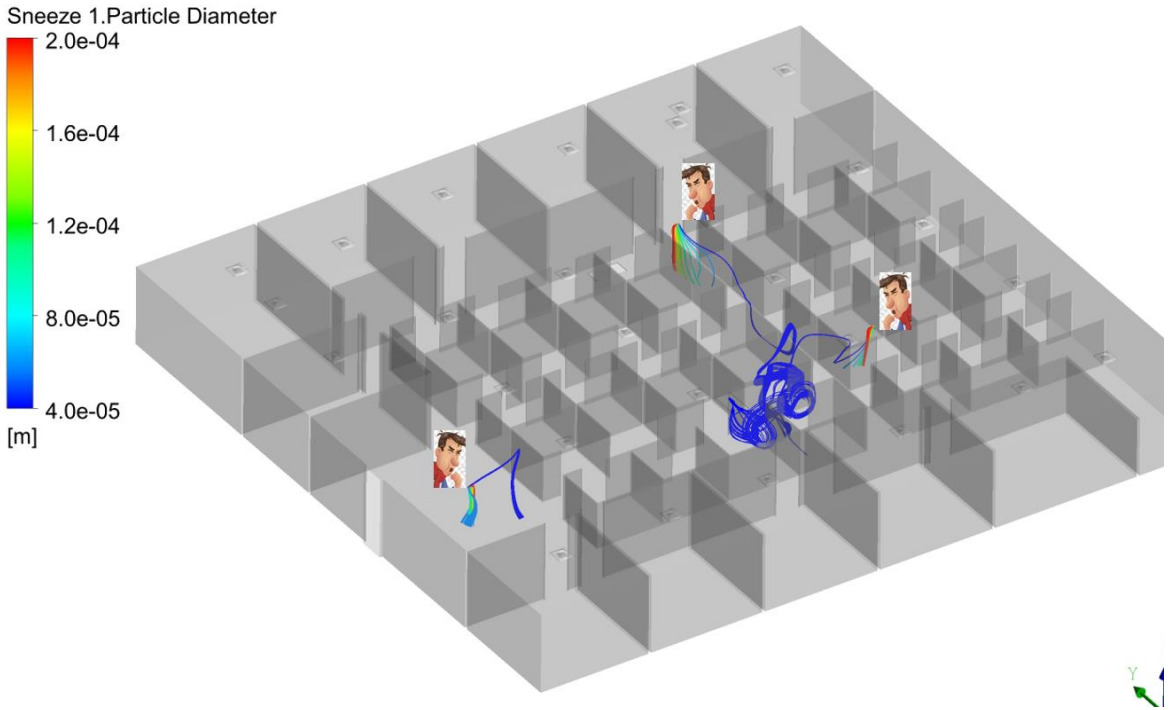
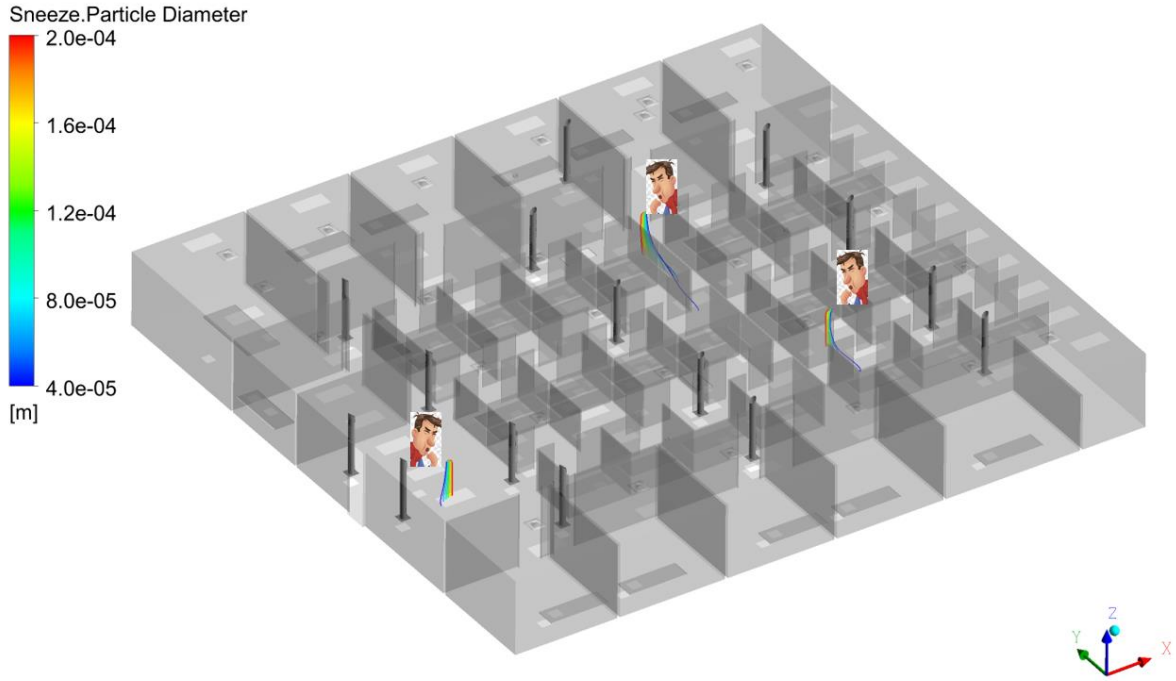
Dispersion of sneeze droplets





Sneeze particles move outside of the 6ft Social distancing zone !!

- **Sneeze particles stay *<u>within</u>* the 6ft social distancing zone**

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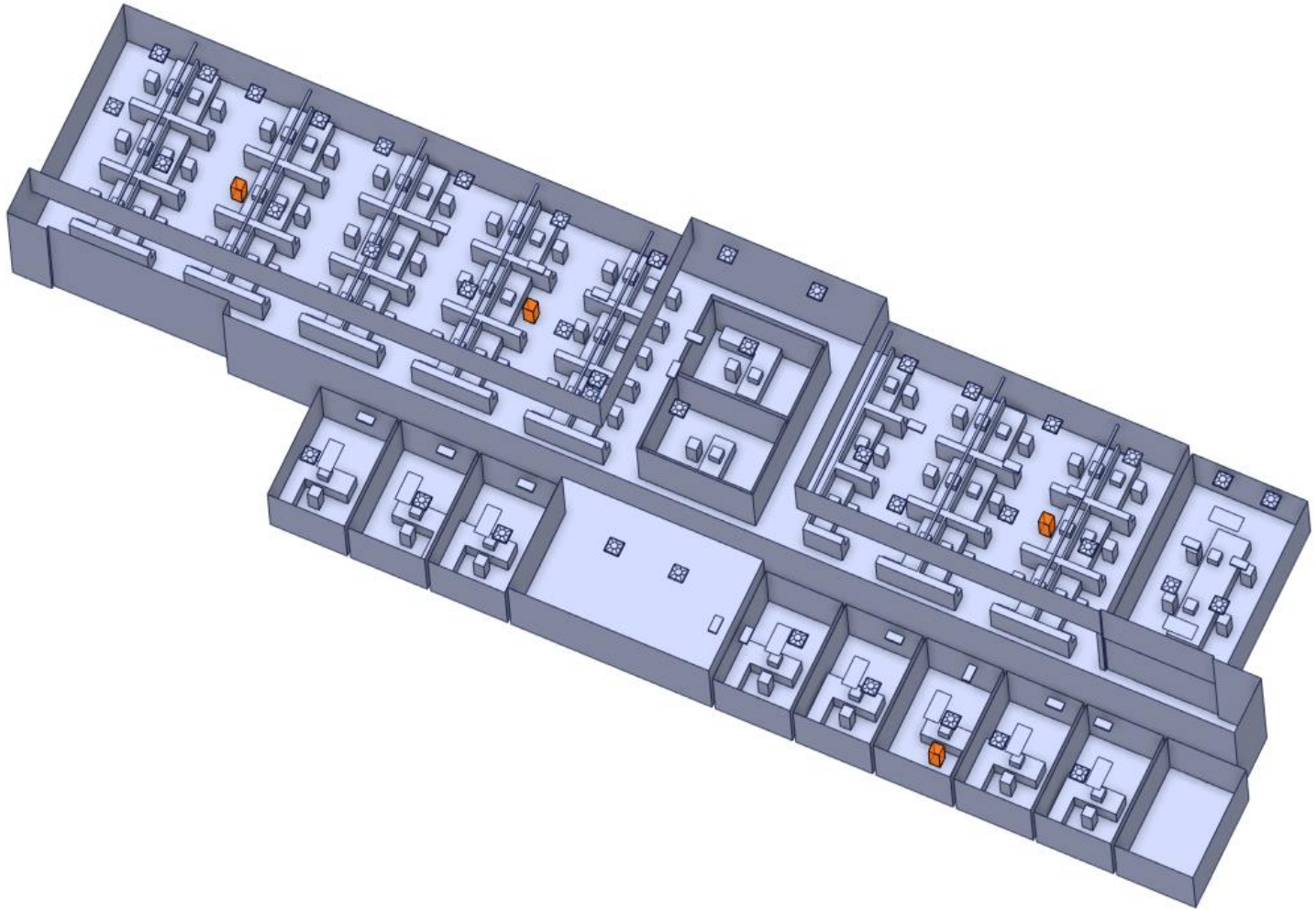
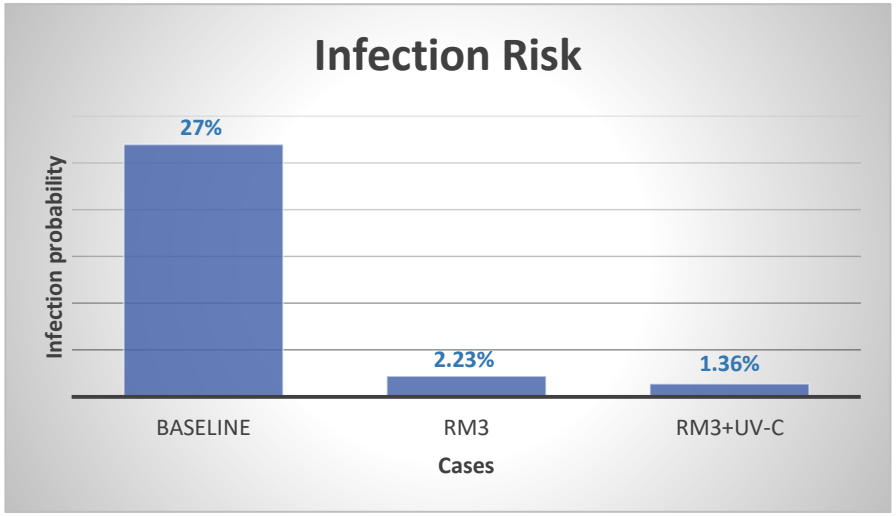
Open office space for airflow studies - II





Conclusions

- In indoor settings, the 6 feet rule does not necessarily work
- HVAC systems can aid in spreading infection even with fresh air
- Installing UV-C lights alone does not solve the problems.
- The airflow pattern from an air purifying unit is important
- Important features for an air sanitization device to clean up the breathing zone are -
    - Air outlet above the breathing zone
    - Air inlet below the breathing zone
    - Velocity and angle of air exit

Thank you!

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› Sustain Cities Soc. 2021 Dec;75:103408. doi: 10.1016/j.scs.2021.103408. Epub 2021 Sep 29.

Effective ventilation and air disinfection system for reducing coronavirus disease 2019 (COVID-19) infection risk in office buildings

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Affiliations – collapse

Affiliations

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PMID: 34603942 PMCID: PMC8479514 DOI: 10.1016/j.scs.2021.103408

Free PMC article

Abstract

During the COVID-19 pandemic, an increasing amount of evidence has suggested that the virus can be transmitted through the air inside buildings. The ventilation system used to create the indoor environment would facilitate the transmission of the airborne infectious diseases. However, the

Appendix

Air sterilization unit “RM3”

US Patent No.: 11,129,918

- RM3 is a commercial air sanitization unit
- It has an average area coverage of 300 ft2
- The specially designed outlet prevents any contaminant in the surrounding air from being dispersed
- The outlet and intake together establish a flow that ensures maximum contaminant removal efficiency