Indoor Air Quality – Changing Expectations and the New Norm

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- Building Services Engineering Consultant (MPE) and Air Quality - using latest research to meet practice since 1995.
- Property Operations Mechanical & Electrical Rouse Co. 1985-95.
- ASHRAE Airborne Infectious Disease 2014-2020.
- Vice-Chair Standard 189.1 for the Design of High-Performance Green Buildings (LEED, IgCC).
- Chair, IAQ 2007: International Conference: Healthy and Sustainable Buildings, Baltimore, MD.
- Member MDE Air Quality Control Advisory Council since 1995.

What is Indoor Air Quality?

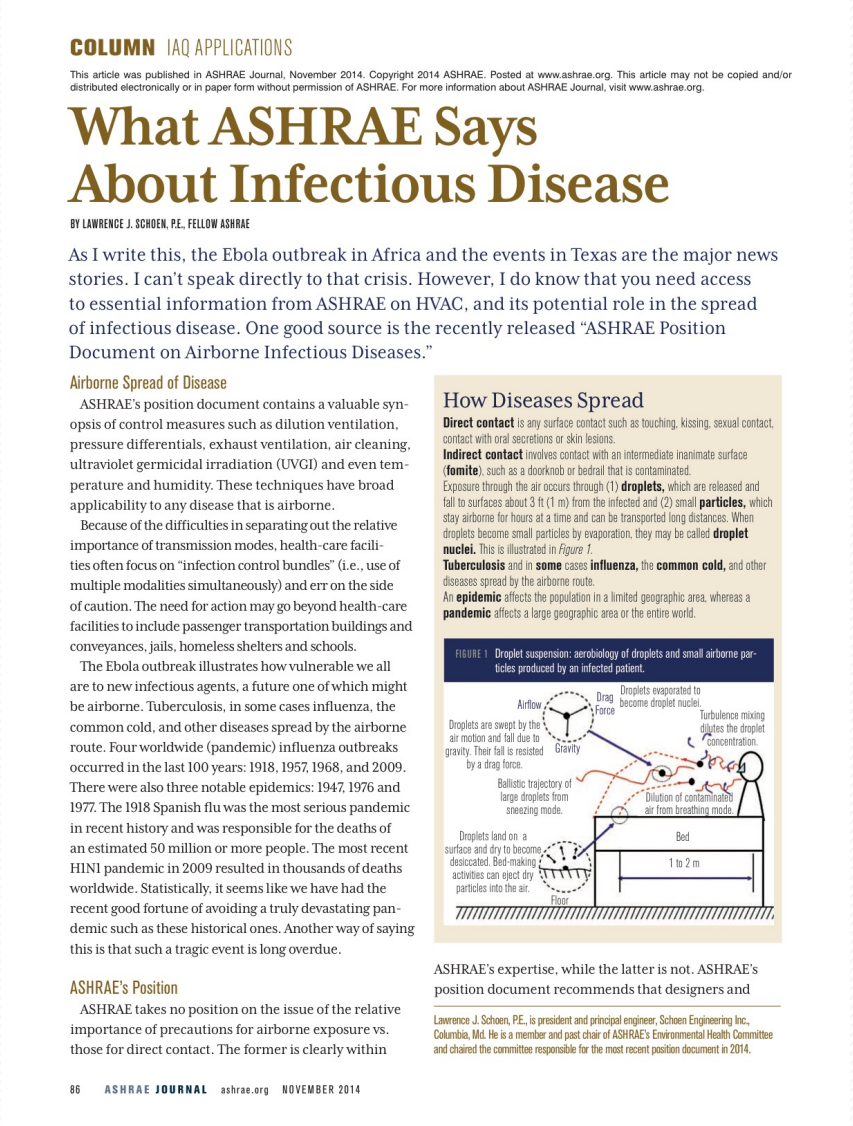
- Only one aspect of Indoor Environmental Quality-IEQ
  - Others: sound, thermal, lighting, views,
- ASHRAE 62.1 and 62.2 (residential) free viewing
- Standards requirements: source control, e.g. smoking, moisture; dilution with *clean* outside air, particle filtration and sometimes gaseous air cleaning
  - Comfort – 80% do not express dissatisfaction with odor and irritation
  - No known contaminants at harmful concentrations
  - No requirement to achieve two above!
- IgCC has high performance req. 189.1 free viewing

ASHRAE Epidemic Task Force Core *Recommendations* January 2021

- Follow regulations, statutes, codes, standards
- MERV 13 or better filters
- Air cleaners w/clear evidence of safety & effectiveness
- Select standalone air cleaners; minimize energy penalty
- Promote mixing of space air, not person to person
- Maintain temperature & humidity
- Verify HVAC function as designed – Standard 62.1 requires OA verification every 5 years
- Run systems when occupied + 3 ACH before occupancy - 1 hour covers many offices, classrooms

ASHRAE Journal, November, 2014, by L. Schoen

- "Statistically, it seems like we have had the recent good fortune of avoiding a truly devastating pandemic such as these historical ones. Another way of saying this is that such a tragic event is long overdue."



COLUMN IAQ APPLICATIONS

What ASHRAE Says About Infectious Disease

BY LAWRENCE J. SCHOEN, P.E., FELLOW ASHRAE

As I write this, the Ebola outbreak in Africa and the events in Texas are the major news stories. I can't speak directly to that crisis. However, I do know that you need access to essential information from ASHRAE on HVAC, and its potential role in the spread of infectious disease. One good source is the recently released "ASHRAE Position Document on Airborne Infectious Diseases."

Airborne Spread of Disease

ASHRAE's position document contains a valuable synopsis of control measures such as dilution ventilation, pressure differentials, exhaust ventilation, air cleaning, ultraviolet germicidal irradiation (UVGI) and even temperature and humidity. These techniques have broad applicability to any disease that is airborne.

Because of the difficulties in separating out the relative importance of transmission modes, health-care facilities often focus on "infection control bundles" (i.e., use of multiple modalities simultaneously) and err on the side of caution. The need for action may go beyond health-care facilities to include passenger transportation buildings and conveyances, jails, homeless shelters and schools.

The Ebola outbreak illustrates how vulnerable we all are to new infectious agents, a future one of which might be airborne. Tuberculosis, in some cases influenza, the common cold, and other diseases spread by the airborne route. Four worldwide (pandemic) influenza outbreaks occurred in the last 100 years: 1918, 1957, 1968, and 2009. There were also three notable epidemics: 1947, 1976 and 1977. The 1918 Spanish flu was the most serious pandemic in recent history and was responsible for the deaths of an estimated 50 million or more people. The most recent H1N1 pandemic in 2009 resulted in thousands of deaths worldwide. Statistically, it seems like we have had the recent good fortune of avoiding a truly devastating pandemic such as these historical ones. Another way of saying this is that such a tragic event is long overdue.

ASHRAE's Position

ASHRAE takes no position on the issue of the relative importance of precautions for airborne exposure vs. those for direct contact. The former is clearly within ASHRAE's expertise, while the latter is not. ASHRAE's position document recommends that designers and

How Diseases Spread

Direct contact is any surface contact such as touching, kissing, sexual contact, contact with oral secretions or skin lesions.
Indirect contact involves contact with an intermediate inanimate surface (**fomite**), such as a doorknob or bedrail that is contaminated.
Exposure through the air occurs through (1) **droplets,** which are released and fall to surfaces about 3 ft (1 m) from the infected and (2) small **particles,** which stay airborne for hours at a time and can be transported long distances. When droplets become small particles by evaporation, they may be called **droplet nuclei.** This is illustrated in *Figure 1.*
Tuberculosis and in **some** cases **influenza,** the **common cold,** and other diseases spread by the airborne route.
An **epidemic** affects the population in a limited geographic area, whereas a **pandemic** affects a large geographic area or the entire world.

FIGURE 1 Droplet suspension: aerobiology of droplets and small airborne particles produced by an infected patient.

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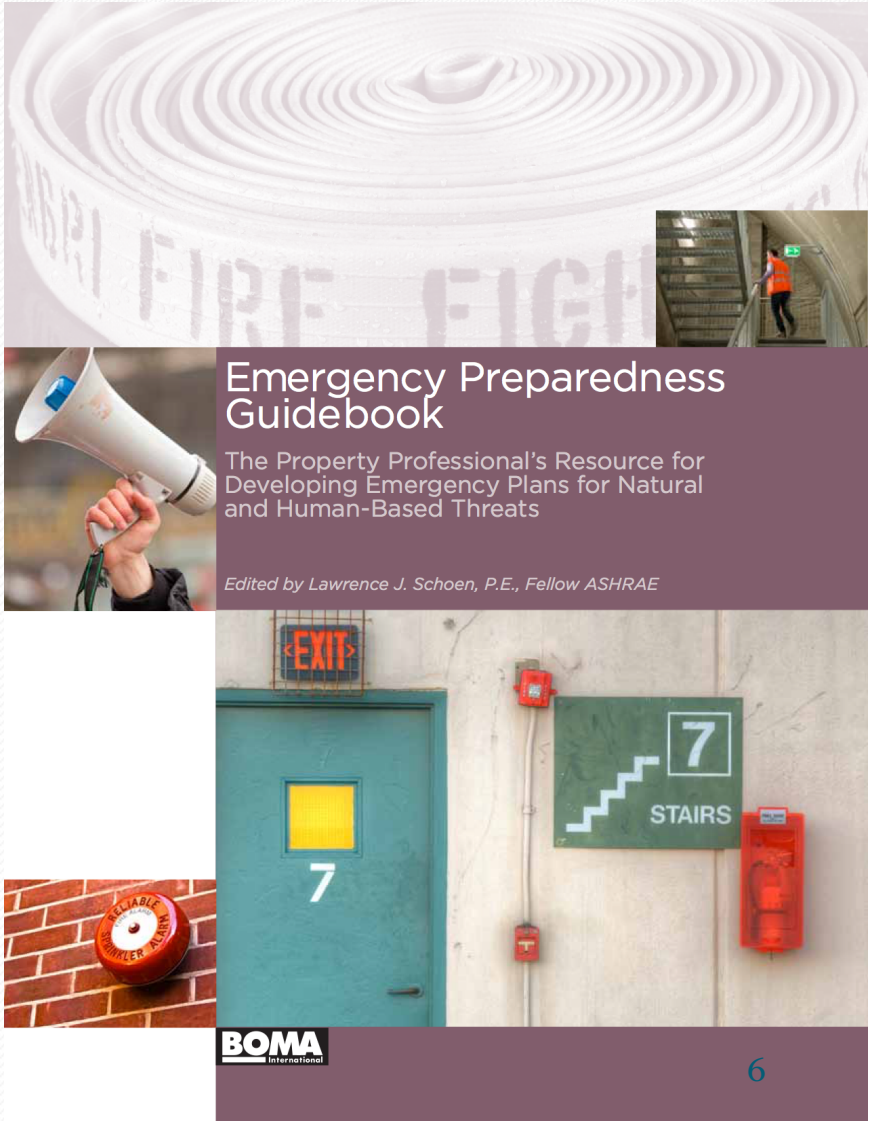
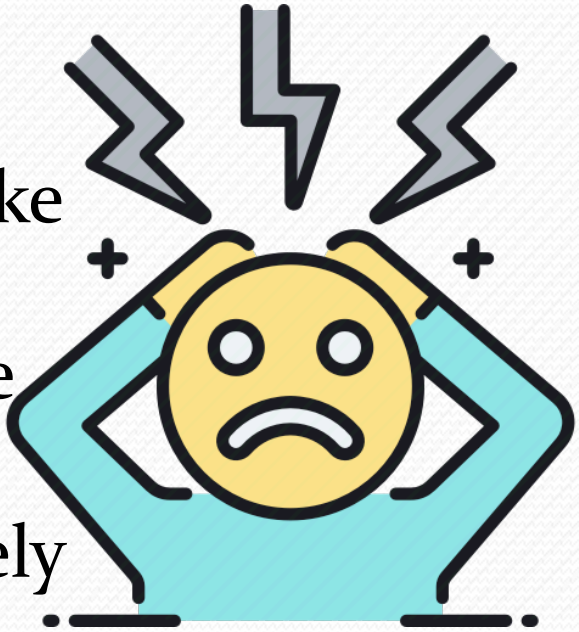
BOMA Emergency Preparedness Guidebook, 2012 by L. Schoen

"There have been about three influenza pandemics in each century for the last 300 years." "… infectious disease outbreak could result in multiple illnesses and deaths … the threat of such medical consequences would trigger public health infection control measures that severely affect operation of facilities, metropolitan areas, nations and the world.



Earlier in Pandemic: What is a Building Operations Team to do?

- Which mode is most important to control? For this novel virus, it can take years to for researchers to know!
- Almost all spread has been from close contact.
- Spread w/o contact has been in densely occupied, poorly ventilated spaces.
- Practical implications: use “infection control bundles” (i.e., use of multiple modalities simultaneously).



Control methods – COVID-19 broad categories

1. Ventilation & filtration by mixing / dilution.
2. Facility disinfection
3. Social distancing, barriers & spacing
4. Masks & for employees: other PPE
5. Personal behavior

- Item 1 is HVAC system

HVAC System Role in COVID-19

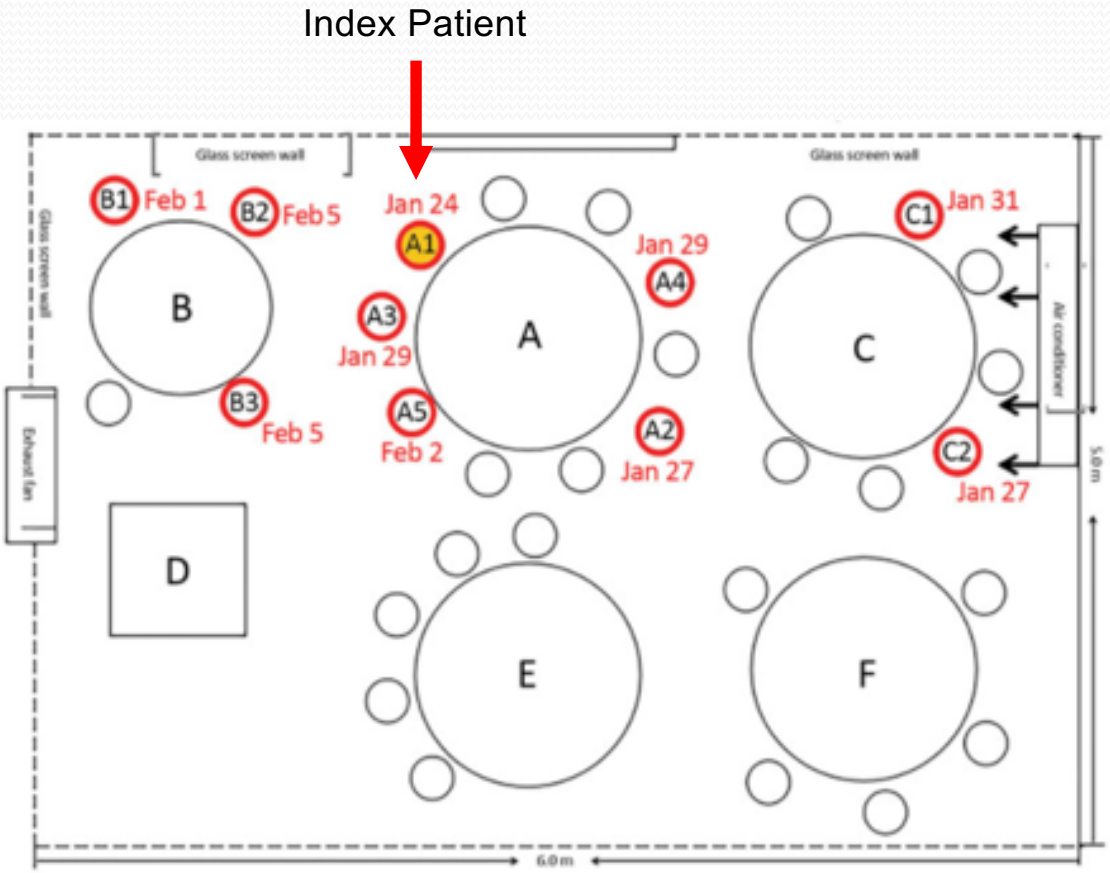
- Most COVID-19 transmission is respiratory

  (Meyerowitz. Transmission of SARS-CoV-2: A Review. *Annals of Internal Medicine* 2021.)
- Transmission through HVAC system possible but not observed.
- THE ABSENCE OF MINIMAL OA & FILTRATION HAS ALLOWED DISEASE TRANSMISSION BY THE HVAC SYSTEM.

COVID-19 Non-contact Transmission

Lunch at restaurant X, Guangzhou, China, Jan. 24, 2020.

- 5 infected at tables adjacent to index person + 4 family at same table as index person.
- No servers or other 68 patrons infected.
- About an hour; 1.5-2.0 cfm/person

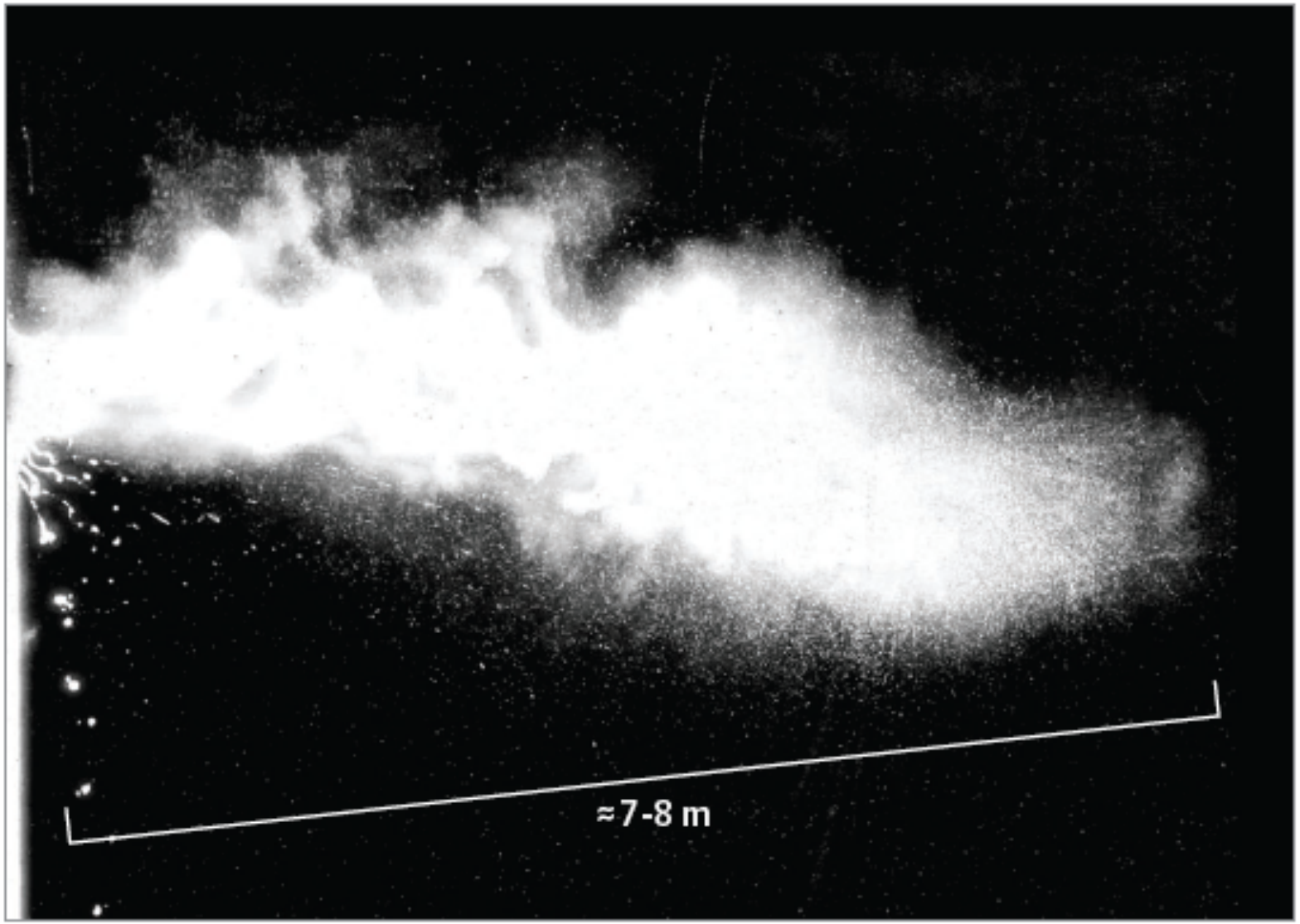


Lu, J. et al. (2020). "COVID-19 Outbreak Associated with Air Conditioning in Restaurant, Guangzhou, China, 2020." Emerging Infectious Disease journal **26**(7).

A cough, singing, or yelling, for instance, over the sound of machinery can produce a plume, too.

- Wear masks.
- Avoid yelling esp. at close distance (use electronic communication or gestures)

Figure. Multiphase Turbulent Gas Cloud From a Human Sneeze



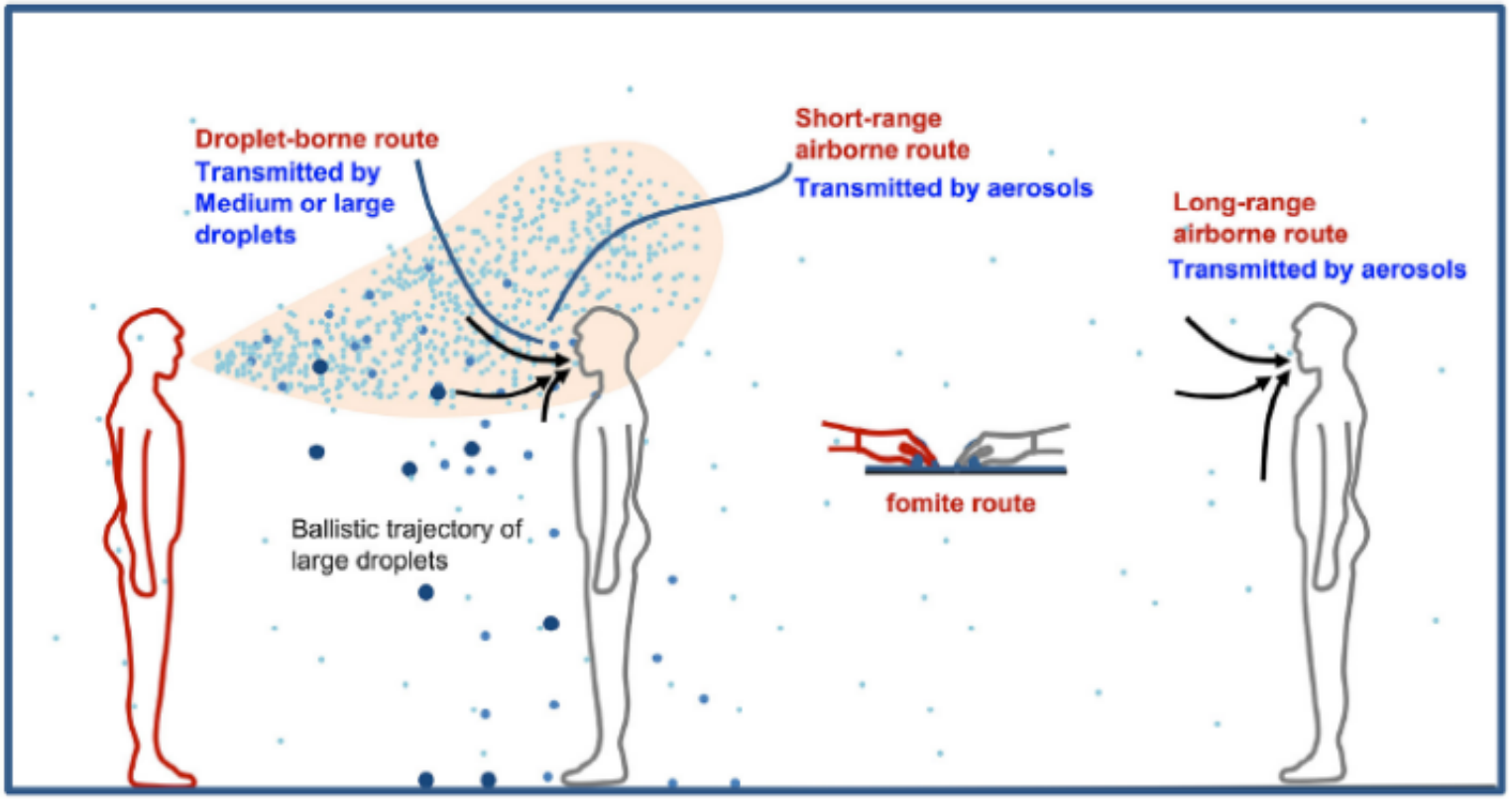
Bourouiba. Turbulent Gas Clouds and Respiratory Pathogen Emissions: Potential Implications for Reducing Transmission of COVID-19. JAMA online March 26, 2020

Airborne transmission

Short range:
- 6 ft separation
- Wear a mask

Long Range:
- Dilute/Ventilate
- Filter

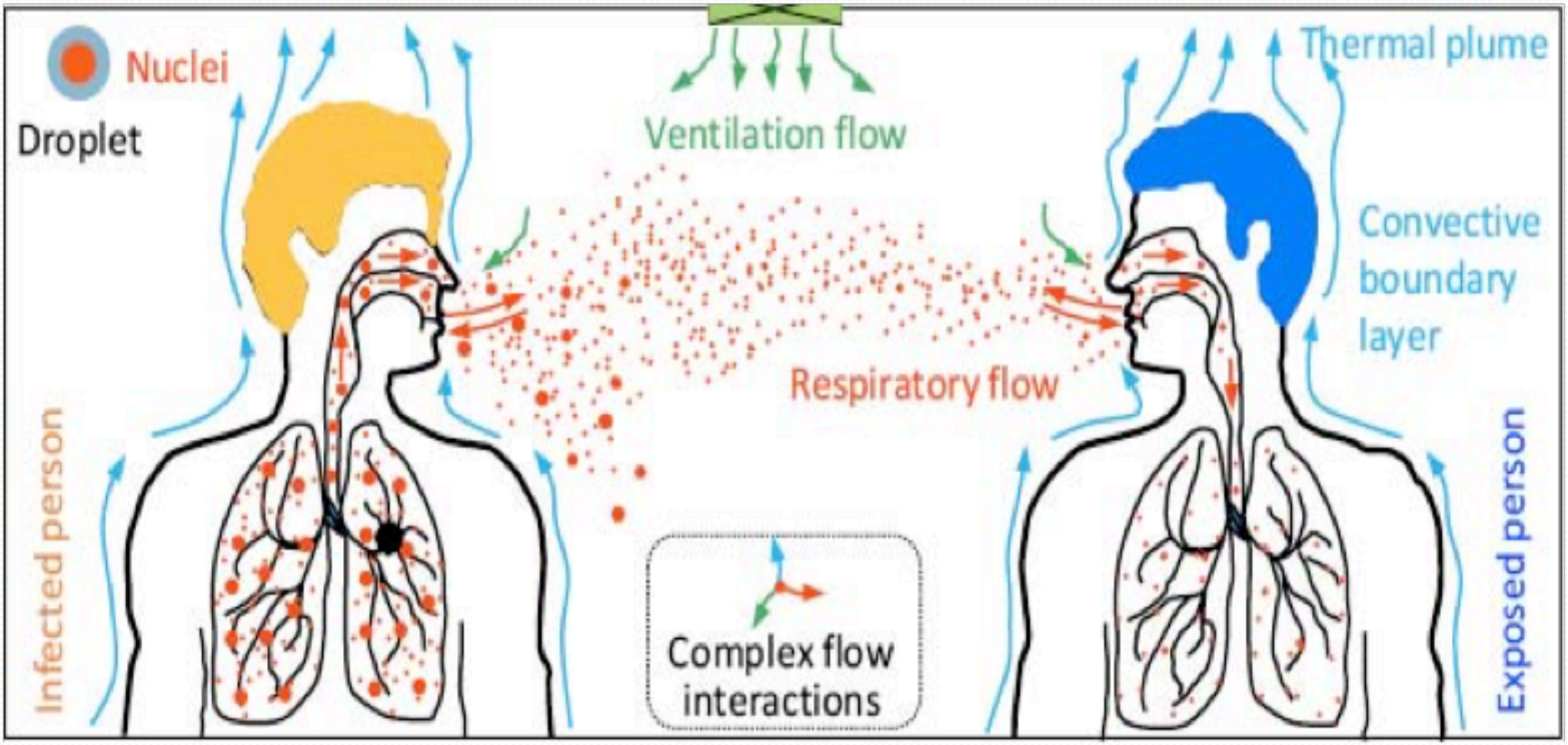
The HVAC part



- Large droplets (>100 μm) : Fast deposition due to the domination of gravitational force
- Medium droplets between 5 and 100 μm
- Small droplets or droplet nuclei, or aerosols (< 5 μm): Responsible for airborne transmission

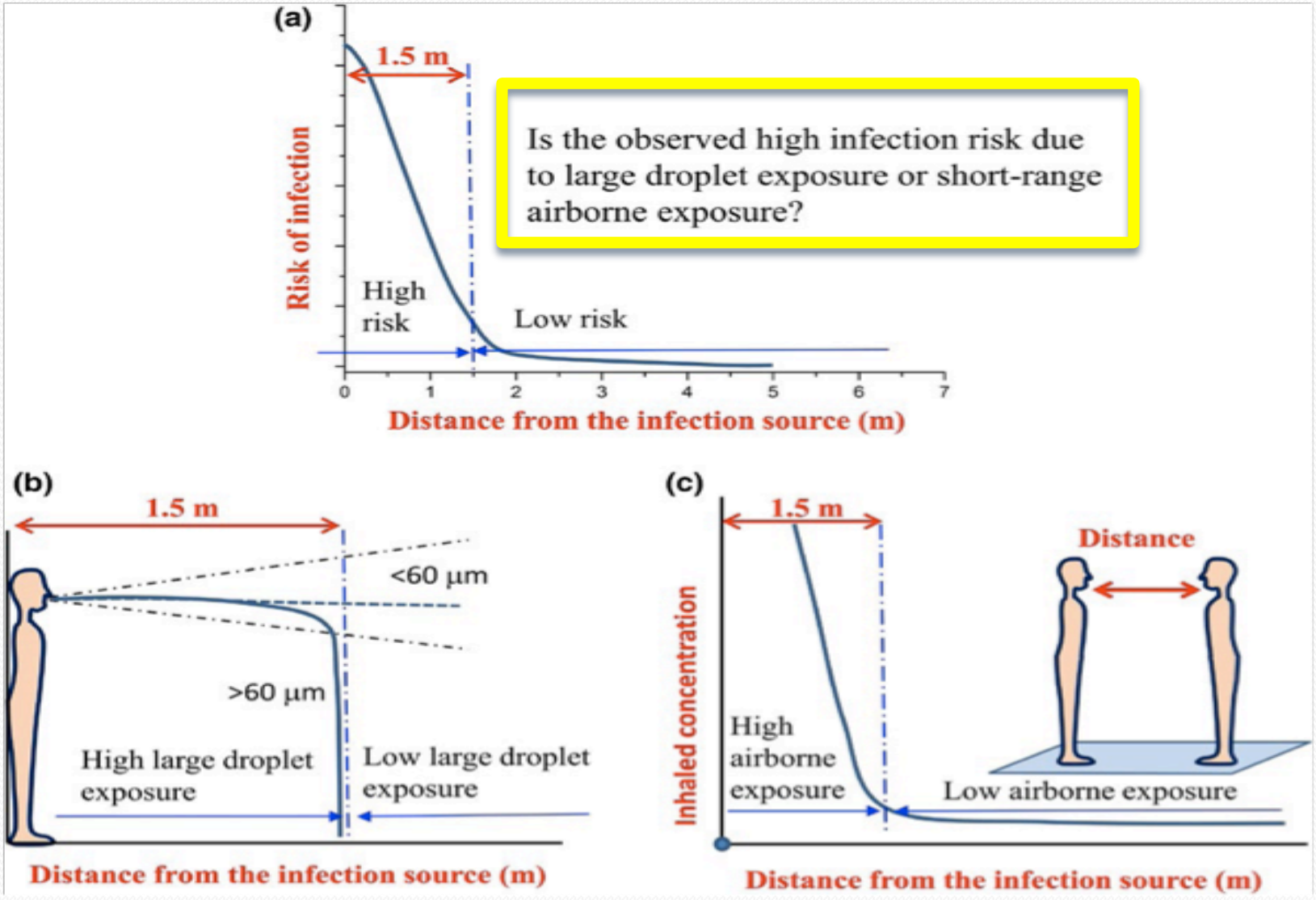
Wei and Li. Airborne spread of infectious agents in the indoor environment. American Journal of Infection Control 44 (2016) S102-S108

Mixing is not complete



Source: Ai & Melikov. /Airborne spread of expiratory droplet nuclei between to occupants of indoor environments: A review. *Indoor Air* 2018.

Many assume short range exposure results from droplets

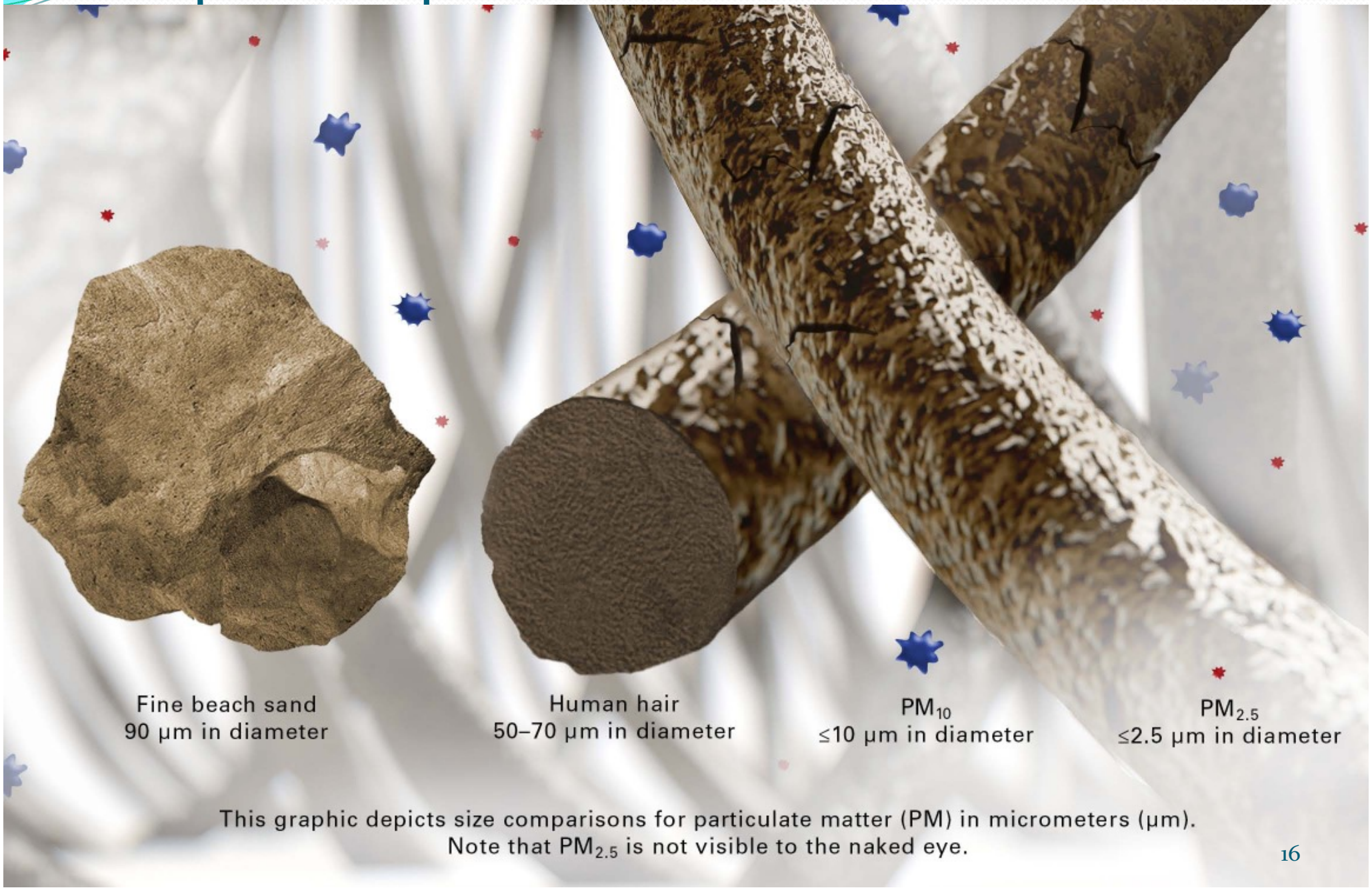


Source:
Liu, Li et al. Short-range airborne transmission of expiratory droplets between two people. *Indoor Air* 2017.

HVAC System Strategies in non-healthcare Buildings – Offices, Retail, Hotel, Education, etc.

- Increase outdoor air ventilation; disable energy saving controls that reduce outside air, e.g., CO_2 demand vent.
- If 100% outdoor air not possible (some recirculation), improve air filter ratings.
- For central systems with MERV-13, F7 or higher, seal edges.
- Keep systems running longer hours, continuously while occupied, to enhance above.
- Use portable room air cleaners with HEPA filters especially if ventilation poor or outside air has high level of PM 2.5.

Size demarcation of respiratory aerosols 2.5 - 10 µm compared to Human Hair



This graphic depicts size comparisons for particulate matter (PM) in micrometers (µm).
Note that $PM_{2.5}$ is not visible to the naked eye.

Performance of Various MERV Filters

MERV Level	Dust Spot %	Typical Particulate Filter Type	% 0.3-1 µm	% 1-3 µm	% 3-10 µm	Example Filter
1	N/A	Low-efficiency fiberglass and synthetic media disposable panels, cleanable filters	Too low efficiency to be applicable to ASHRAE Standard 52.2 (ASHRAE 2007) determination			
2	N/A					
3	N/A					
4	N/A					
5	N/A	Pleated filters, cartridge/cube filters, and disposable multi-density synthetic link panels			20-35	
6	N/A				36-50	
7	25%-30%				50-70	
8	30%-35%				>70	
9	35%-40%	Enhanced media pleated filters, bag filters of either fiberglass or synthetic media, rigid box filters using lofted or paper media		>50	>85	
10	50%-55%			50-65	>85	
11	60%-65%			65-85	>85	
12	70%-75%			>80	>90	
13	80%-85%	Bag filters, rigid box filters, minipleat cartridge filters	>75	>90	>90	
14	90%-95%		75-85	>90	>90	
15	>95%		85-95	>90	>90	
16	98%		>95	>95	>95	

Airborne Transmission

- Droplet (large) vs. small particle (aerosol).
- Someone who coughs, sneezes or even talks or sings, releases both large and small.
- Large droplets fall to surface in 1-2 meters.
- Size demarcation 2.5 – 10 µm - opinions vary but principle is important –aerosol spreads like a gas
- Concentration of aerosol inversely proportional (-3rd power) to distance.
- Droplet or aerosol can infect, so maintain 1-2 meters.

Limitations of dilution / mixing ventilation

- If mixing is not complete, then local effects must be considered. UV has similar limitation.
- If local effects result not only from large droplets, but also from higher exposure to aerosol, then more localized ventilation may assist.
- One concept is known as personalized ventilation (PV) and personalized exhaust (PE).
- How might this be done effectively in theaters, restaurants, classrooms etc.?

Use Caution

- Don't turn off ventilation systems
  - Exception: first disinfect system where infected individuals have been present.
  - Exception: systems with inadequate outside air or inadequate filtration.
  - Exception: major outdoor contamination.
- Don't use ozone generator.
- Electronic air cleaners difficult to compare to media and may emit ozone.

Building Operation

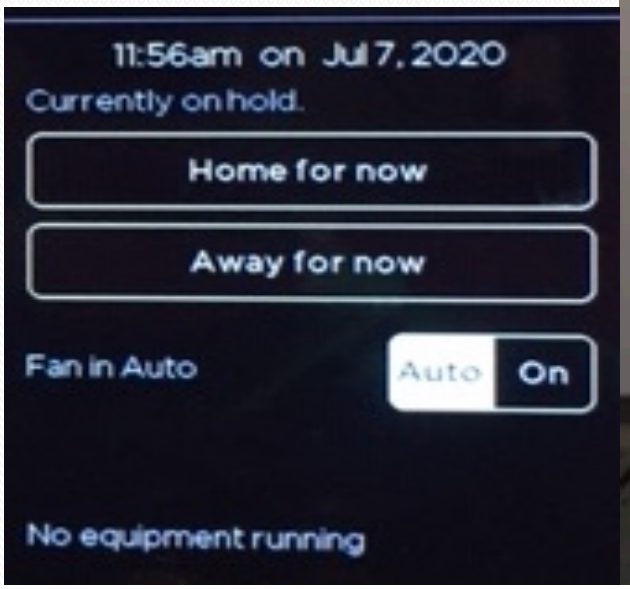
- Know the building and its systems
- Consider type of occupancy:
  - Known persons or unknown?
  - Densely occupied?
  - Fixed or transient?
  - Unknown infected?
  - Informed or uninformed? General public?
- Risk can be reduced but not eliminated.

Building Operation Details

- Visually check outdoor air (OA) intake and damper.
- Measure OA: ASHRAE Standard 62.1 @ 5 yr. intervals.

Building Operation Details

- Check for, or measure air to each room.
- Disable carbon-dioxide (CO_2) based demand-controlled ventilation (DCV).
- HVAC system runs continuously for dilution ventilation with outdoor air. This could be as simple as setting the thermostats to “Fan on”.
- NOT THIS ----------→



Building Operation Details

- VAV systems require consultation with engineer to calculate required air flow and VAV box minimum setting.
- Technician to re-set minimum.
- May require changing temperature settings at air handler and outside air “tracking.”

TABLE 403.3—continued
MINIMUM VENTILATION RATES

OCCUPANCY CLASSIFICATION	OCCUPANT DENSITY #/1000 FT^2 [a]	PEOPLE OUTDOOR AIRFLOW RATE IN BREATHING ZONE, R_p CFM/PERSON	AREA OUTDOOR AIRFLOW RATE IN BREATHING ZONE, R_a CFM/FT^2 [a]
Offices			
Conference rooms	50	5	0.06
Office spaces	5	5	0.06
Reception areas	30	5	0.06

Building Operation Details

- MERV-13 filter in central air handler.
- Good edge seal.

Summary

- Check the systems to see that outside air damper is open, and recirculated air goes through filters MERV-13 or better.
- Keep systems with outside air and filtration running, lengthen hours.
- Improve filtration & increase outside air if clean.
- Questions: Larry@SchoenEngineering.com