Better Buildings Residential Network Peer Exchange Call Series:

Indoor Air Quality and Ventilation in the Current Climate: Perspectives from the Field

June 11, 2020

Agenda and Ground Rules

- Agenda Review and Ground Rules
- Opening Poll
- Residential Network Overview and Upcoming Call Schedule
- Featured Speakers:
  - **Nora Wang**, Pacific Northwest National Laboratory
  - **Lawrence Schoen**, Schoen Engineering
  - **Iain Walker**, Lawrence Berkeley National Laboratory
- Open Discussion
- Closing Poll and Announcements

Ground Rules:

1. **Sales of services and commercial messages are not appropriate** during Peer Exchange Calls.
2. Calls are a safe place for discussion; **please do not attribute information to individuals** on the call.

The views expressed by speakers are their own, and do not reflect those of the Dept. of Energy.

Better Buildings Residential Network

Join the Network

Member Benefits:

- Recognition in media and publications
- Speaking opportunities
- Updates on latest trends
- Voluntary member initiatives
- One-on-One brainstorming conversations

Commitment:

- Members only need to provide *one number*: their organization's number of residential energy upgrades per year, or equivalent.

Upcoming Calls (2nd & 4th Thursdays):

- Jun 25: Remote Energy Efficiency Assessments – the New Normal?
- Jul 09: The New Focus on Health in Buildings
- Jul 23: Energy Efficiency Funding for Residential Programs: Challenges and Opportunities

Peer Exchange Call summaries are posted on the Better Buildings website a few weeks after the call

For more information or to join, for no cost, email bbresidentialnetwork@ee.doe.gov, *or go to* energy.gov/eere/bbrn *& click Join*

Better Buildings

U.S. DEPARTMENT OF ENERGY

Nora Wang
Pacific Northwest National Laboratory

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Healthy Building Initiative

BBRN Peer Exchange: "Indoor Air Quality and Ventilation in the Current Climate: Perspectives from the Field"

June 11, 2020

Nora Wang, Ph.D.

Pacific Northwest National Laboratory

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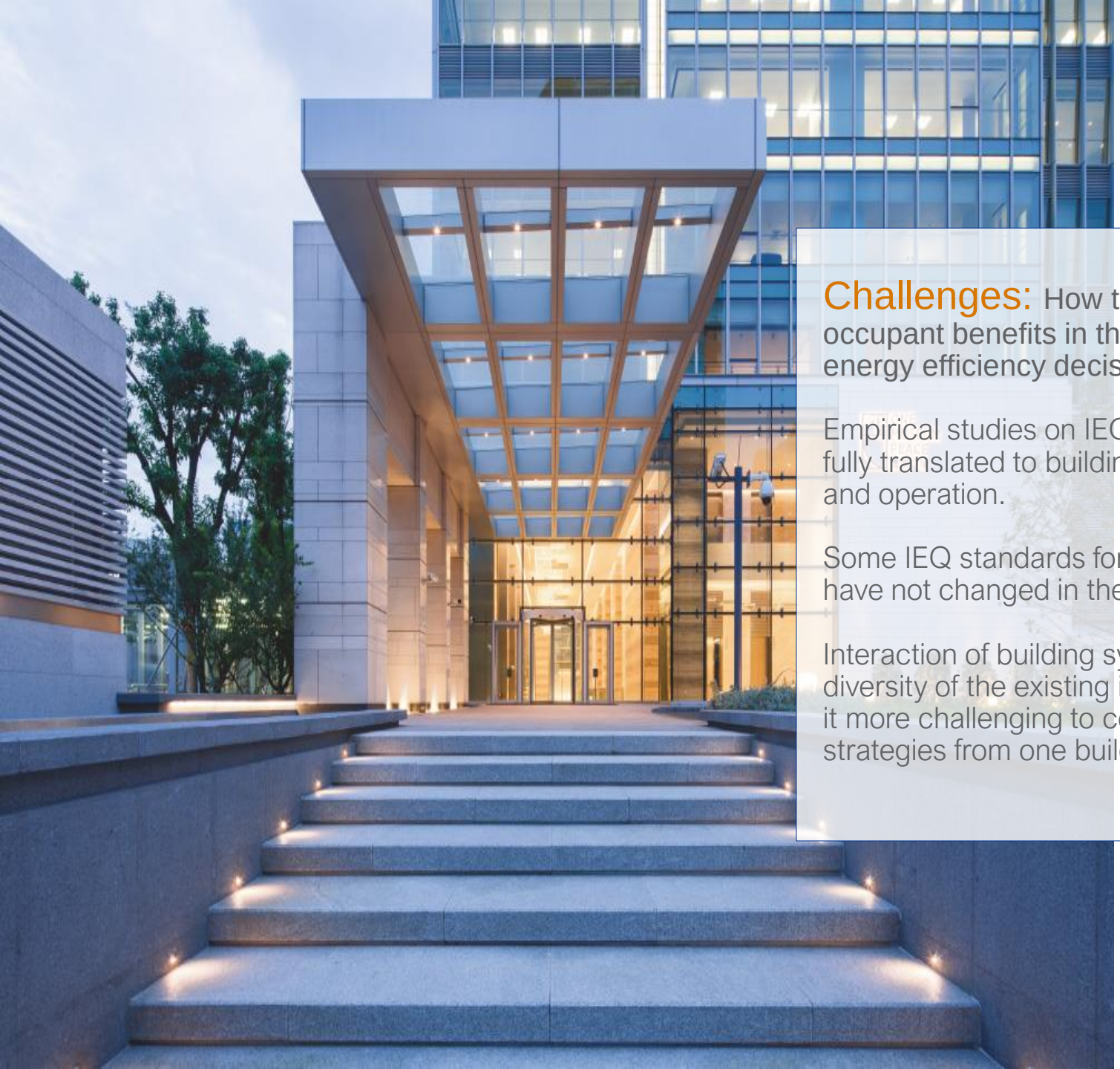
PNNL is operated by Battelle for the U.S. Department of Energy

Value Propositions

Non-energy benefits, such as health and productivity improvements, can have large economic benefits—which are currently unaccounted for in energy efficiency project valuation methodologies.

Leveraging buildings to achieve broader energy goals (demand reduction, smart buildings, building-grid integration) requires gaining knowledge and developing measurement of human outcomes, which represent the best interest of building owners, homeowners, business owners, and building occupants.



Challenges: How to quantify occupant benefits in the context of energy efficiency decision making.

Empirical studies on IEQ have not been fully translated to building system design and operation.

Some IEQ standards for building design have not changed in the past 100 years.

Interaction of building systems and diversity of the existing installations makes it more challenging to copy healthy building strategies from one building to another.

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Objectives

- Integrate occupants' health outcomes with energy efficiency measures.
- Quantify potential financial benefits from productivity gains.
- Develop a toolkit aka "program-in-a-box" (data collection guide, cost-benefit calculator, equipment library) to help facility managers make holistic decisions on building retrofits and operation.

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Industry Landscape

- Guides
- Tools and Services
- Government Programs
- Building Standards and Codes
- Certification Systems
- Academic and Applied Research

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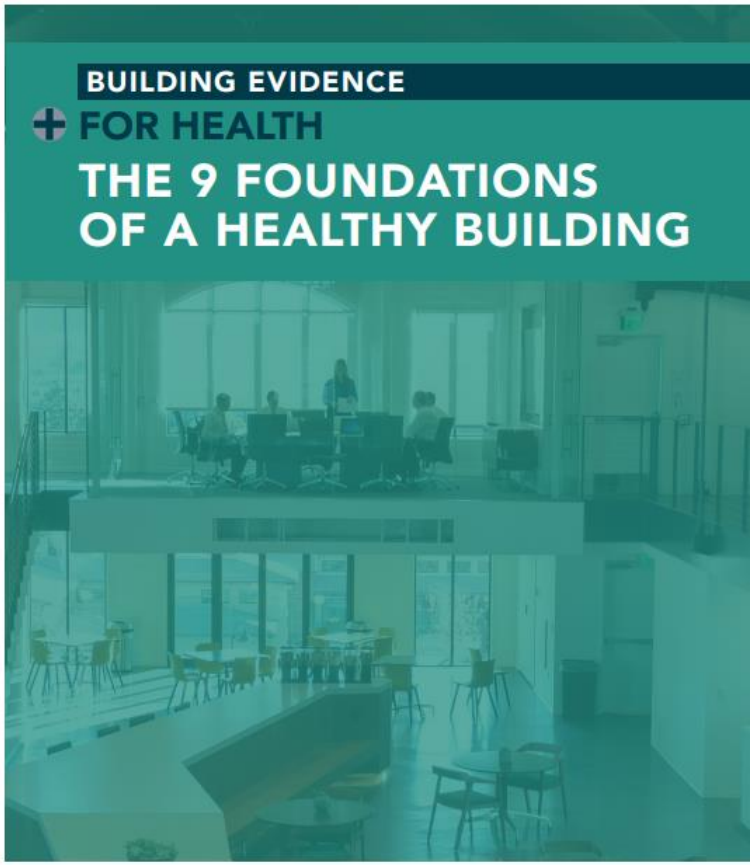
Best Practice Guides and Business Cases

Business cases that have financial returns for general healthy building practices.

https://stok.com/financial-case-for-high-performance-buildings/



HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH Center for Health and the Global Environment

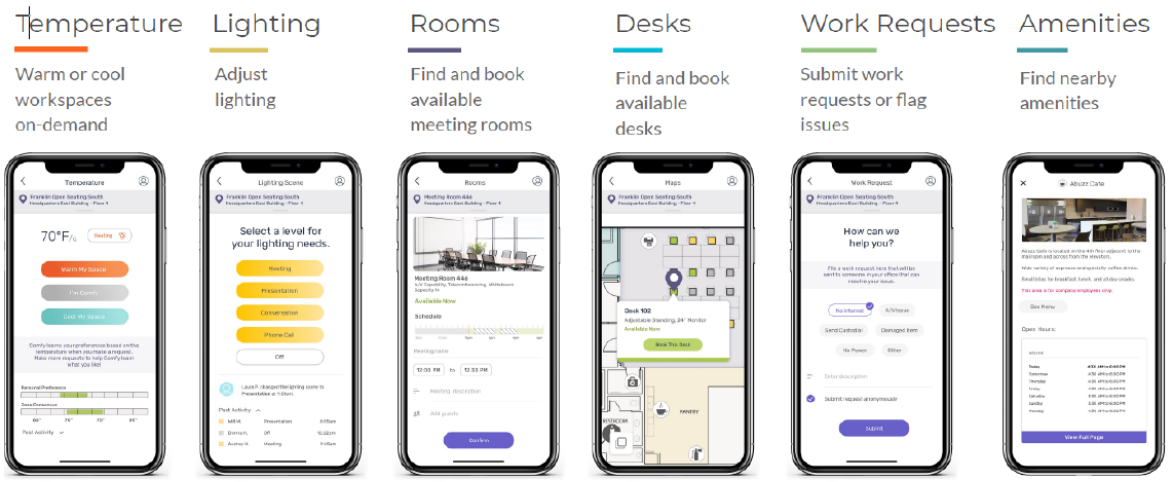
FOR HEALTH forhealth.org

General, high-level guides that overview the principles of healthy building, for example lighting, thermal comfort, acoustics etc.

https://9foundations.forhealth.org/9_Foundations_of_a_Healthy_Building.February_2017.pdf

Tools and Services

- Design services for new buildings or building renovations.
- Healthy building products and technologies (e.g. apps, sensors, building system equipment, cloud analytics).
- Occupancy surveys to identify operation issues with building systems and controls.



www.comfyapp.com

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Government Programs

Upward of 100 existing city, state, and federal green building incentive programs (mostly residential buildings with a focus on low-income public housing).

Fannie Mae

- Fannie Mae financing will reimburse Fitwel certification fees, valued at $750-6,000, for multifamily affordable housing units.
- Intended for borrowers that have incorporated health-promoting design and operational strategies at the property.

mc Pittsburgh, PA

- The City of Pittsburgh, PA offers a sustainable development bonus for commercial LEED-certified buildings including a 20% increase in floor area and height.

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Building Standards and Codes

- ASHRAE, International Code Council (ICC) and Illuminating Engineering Society (IES) release and updates a variety of standards that include IEQ metrics (mostly minimum requirements).
  - For example, ASHRAE Standards 55/62/189, IESNA Lighting Handbook, and International Green Construction Code (IgCC).

- Residential sector standards include:
  - The National Healthy Housing Standard by the National Center for Healthy Housing.
  - Standards developed by the American Public Health Association.

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Certification Systems

- Two prominent certification systems that focus on healthy buildings: WELL Building Standard and Facility Innovations Toward Wellness Environmental Leadership (Fitwel).
  - Fitwel created by GSA and CDC and focuses on amenities, policies, and services for occupants.
  - WELL focuses on building systems, design and operation and has some amenity and policy credits.
- Green building certification systems include provisions for occupant health in addition to sustainability and energy.
  - Of the 126 possible credits in LEED v4.1 BD+C – New Construction, 20 are specifically for occupant comfort, and 12 of those are for IAQ.

LIVING BUILDING CHALLENGE

fitwel℠

U.S. GREEN BUILDING COUNCIL USGBC

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Academic and Applied Research

- Controlled laboratory studies on occupants under different IEQ conditions.
  - Most studies are focused on IAQ (carbon dioxide and ventilation) and temperature.
- Literature review and analysis.
  - Synthesize conclusions from available literature in a certain area healthy building (e.g., ventilation or productivity).
- Theoretical frameworks and evaluation methodologies.
  - For example, sustainability index for healthy buildings, a framework for evaluating ventilation rate effectiveness.
- Technology research and development.
  - For example, IoT sensors and machine-learning algorithm for thermal comfort, testing protocol for identifying sources of VOCs.

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Healthy Buildings Initiative Methodology

- How healthy is my building?
- How to make my buildings healthier?
- How much financial gains to expect from the improved occupants' health and productivity?

In the context of energy efficiency, our "healthy buildings" study includes thermal comfort, air quality, lighting/daylighting and excludes noise, physical activities, and nutrition.

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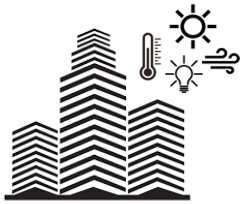
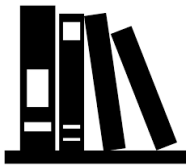
Overview

1. Baseline Health Performance
2. Identify Potential Improvements
3. Corelate to Human Outcomes
4. Investigate Problems & Solutions
5. Outputs:
   Cost Benefit Analysis
   Improvement Recs





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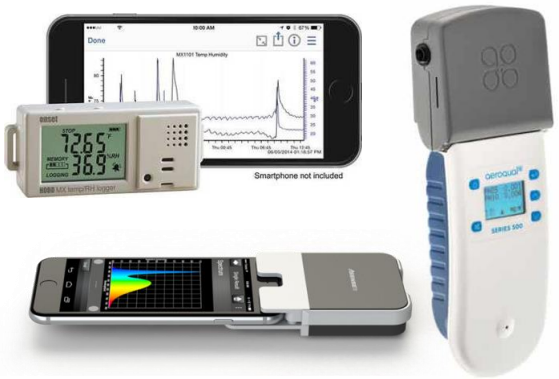
Metrics and Measurement

Category	Baseline Metrics	Diagnosis Metrics
Lighting	Horizontal Illuminance	Task Lighting
		Automatic Dimmers
		Occupancy Sensors and Controls
	Circadian Stimulus	Window Proximity
	Glare (screening Qs)	Glare
Indoor Air Quality	Particulate Matter	Air Filters
		Positive Building Pressure
		Outdoor Air Intake Location
	Carbon Dioxide	Outdoor Airflow Supply
		Ventilation Rate
		Zone Diffuser Obstruction
	VOC (screening Qs)	VOC
Thermal Comfort	Predictive Mean Vote	Temperature Setpoint and Controls
		Manual Controls
		Personal Thermal Devices
		Enclosure Heat Loss/Gain

1

4

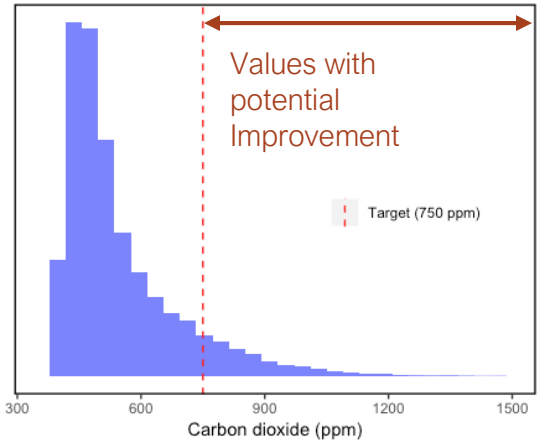
Screening Data
Green cleaning products
Low-emitting materials and equipment
Automatic and manual blinds, shades
Perpendicular desks
Occupant survey question about effectiveness of blinds, shades and source of glare (electric/daylight)



Potential Improvements

2

Baseline measurements are compared with target values to calculate improvement potentials.

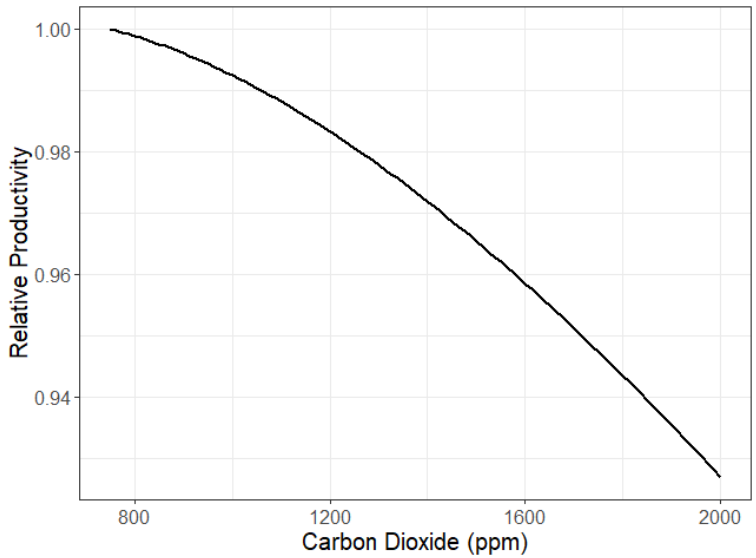


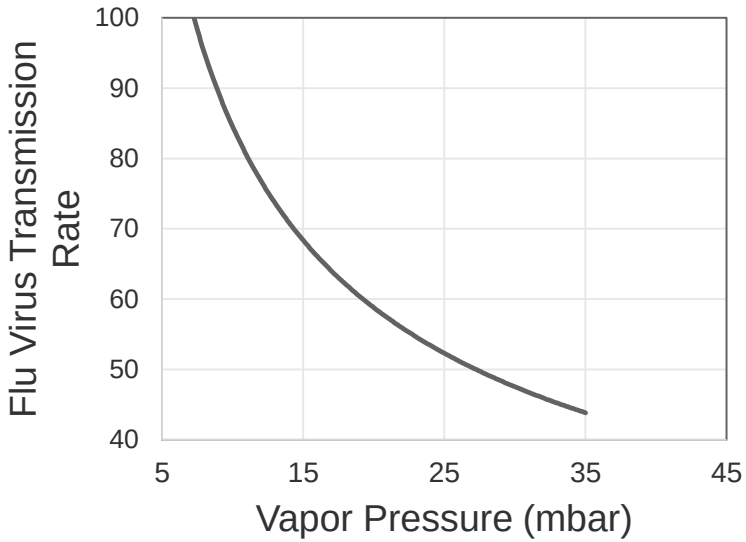
Category	Metric	Units	"Target"	Source
IAQ	PM 2.5	ug/m^3 PM 2.5	12	WELL A05, EPA 24-hr avg
	PM 10	ug/m^3 PM 10	50	WELL A02
	CO_2	ppm	750	WELL A06
	VOC	screening questions	4/7	GSA Total Workplace Scorecard

Correlation to Human Outcomes

3

Correlations were developed for lighting (horizontal illuminance), thermal comfort (PMV), and IAQ (ventilation rate, CO_2), Humidity, and Circadian Stimulus based on published empirical studies.





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Quantifiable Non-Energy Benefits

5 Example output from pilot building

	Health / Productivity	Energy	Retrofit Capital	Cost-Benefit	
	10-yr NPV	10-yr NPV		10-yr NPV	Benefit / Cost Ratio
IAQ	$0	$57,000	$0	$55, 000	N/A
Thermal Comfort	$3,105,000	-$7,000	-$124,000	$1,884,000	23.3
Electric Lighting	$30,000	-$1,000	-$25,000	$3,000	0.1
Overall	**$3,134,000**	**$44,000**	**-$149,000**	**$2,938,000**	**19.8**

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Multi-family Energy Efficiency Measures with Health Impacts

- Sleep Quality
  - Noise reduction from high-performance windows
  - Circadian regulation from daylighting and circadian-rhythm LED lighting
- Indoor Air Quality
  - Efficient exhaust or ventilation system with particle filtration to remove indoor pollutants and reduce unit-to-unit contamination when opening windows is not feasible
- Thermal Comfort
  - Increased envelope insulation and reduced infiltration to reduce health risks associated with heat stress
  - Energy-efficient heating and cooling equipment makes it more affordable to maintain comfort environment. (Thermal comfort affects sleep quality too.)

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Useful links

- **Healthy Buildings Initiative:**

https://www.pnnl.gov/projects/healthy-buildings

- **Energy and Health Nexus white paper:**

https://www.pnnl.gov/sites/default/files/media/file/EED_0831_BROCH_HealthyBuildings_v4.pdf

- **Case Studies (coming soon)**

https://www.pnnl.gov/healthy-buildings/news-and-publications

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Thank you

Covid-19 : Building Operation Practices

Lawrence Schoen, P.E., Fellow & Life Member, ASHRAE

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U.S. DEPARTMENT OF ENERGY

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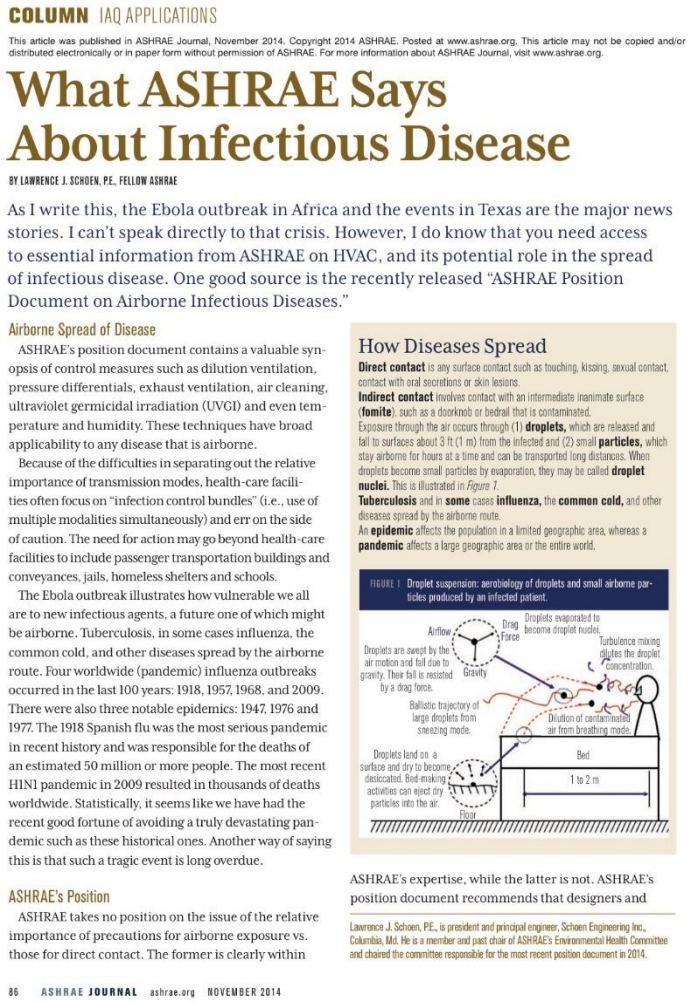
Larry@SchoenEngineering.com

- Property Operations Mechanical & Electrical Rouse Co. – Shopping Centers, Offices, Hotels, Mixed-Use
- Building Services Engineering Consultant (MPE) and Air Quality - using latest research to meet practice since 1995.
- ASHRAE Airborne Infectious Disease Position Document 2014-2020. Reissued as Pos. Doc. On Infectious Aerosols.
- Vice-Chair Standard 189.1 for the Design of High-Performance Green Buildings (LEED, IgCC).
- Past Chair ASHRAE Environmental Health Committee.
- Chair, IAQ 2007: Healthy and Sustainable Buildings.

ASHRAE Journal, November, 2014

- "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.

Lawrence J. Schoen, P.E., is president and principal engineer, Schoen Engineering Inc., Columbia, Md. He is a member and past chair of ASHRAE's Environmental Health Committee and chaired the committee responsible for the most recent position document in 2014.

HVAC System Has Small Role

- SARS-CoV-2 inferences drawn from SARS (2003) and lesser extent from other viruses.
- Non-medical buildings focus of this webinar.
- Preliminary research released, but scientific consensus takes years.
- HVAC systems have roles, though smaller than other interventions.
- Depends on whom you ask……

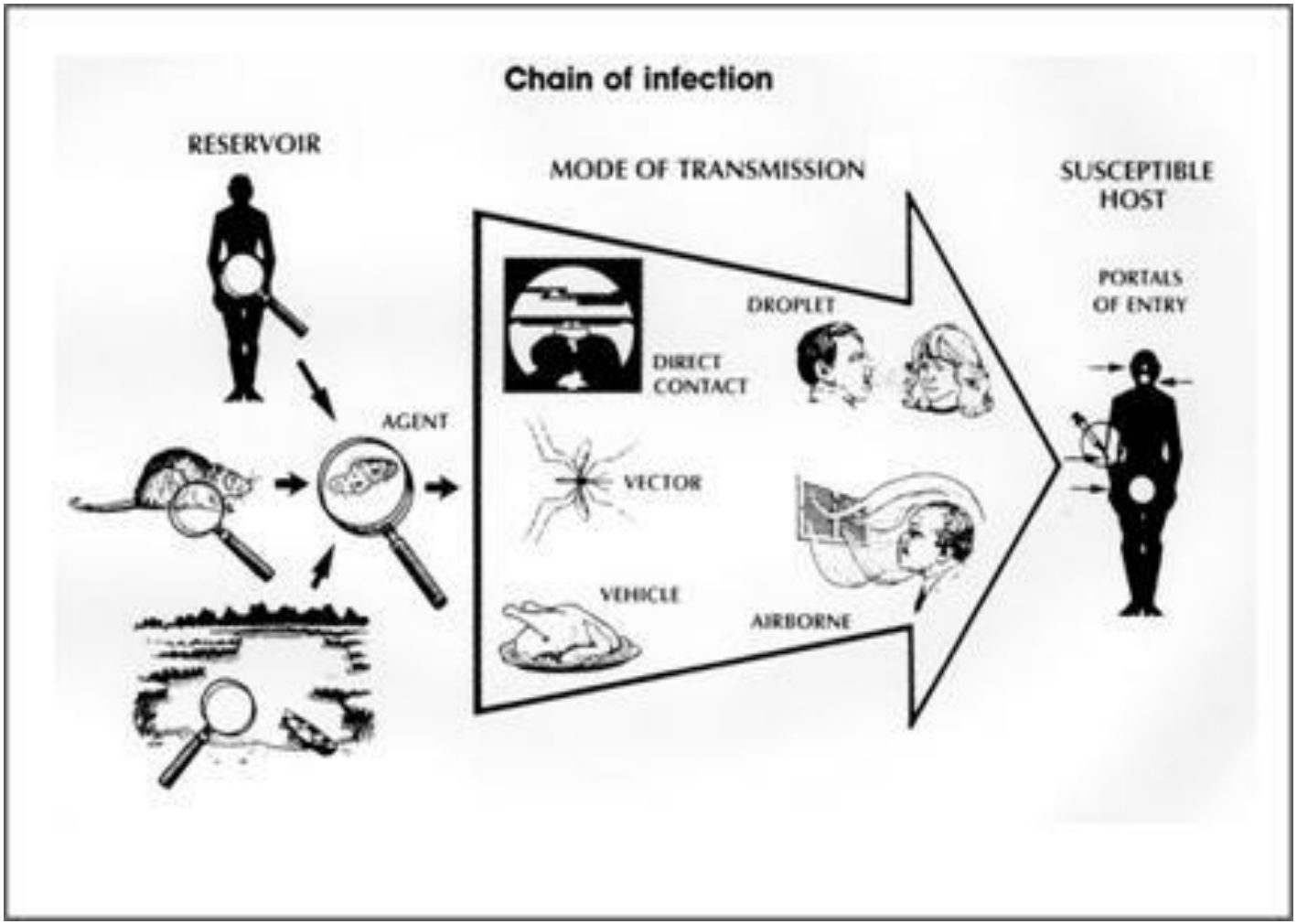
COVID-19 Non-contact Transmission

- 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.
- 100-minute RT bus ride to Buddhist worship in Ningbo city of Zhejiang province, China, Jan. 19, 2020.
  - Bus #2: 23 of 66 passengers infected by one index patient.
  - Bus #1: None infected. All attended the same 150 minute worship event.

System Actions & Policies

- Closing the system is not an option – service is essential. During active transmission:
  - Discourage non-essential occupancy.
  - Screen people at entry.
  - Increase disinfection.
  - Hand sanitation dispensers.
  - Signage to educate public.

Chain of Infection per U.S. CDC



Source: Centers for Disease Control and Prevention. Principles of epidemiology, 2nd ed. Atlanta: U.S. Department of Health and Human Services;1992.

Infectious Disease Transmission

- Transmission to susceptible does not always lead to infection.
- Multiple modes of transmission; predominance of each mode differs by organism.
  - Direct contact person to person (touching)
  - Inanimate object (doorknob, handrail, etc.)
  - Large droplet from person to person (1-2 meters)
  - Aerosol, also called particulate, airborne, spreads like a gas.
- Even the best HVAC system can affect only the latter two.

HVAC ORGANIZATIONS HAVE TAKEN CONSERVATIVE POSITIONS

ASHRAE

Transmission of SARS-CoV-2 through the air is *sufficiently likely* that airborne exposure to the virus should be controlled. Changes to building operations, including the operation of heating, ventilating, and air-conditioning systems, can reduce airborne exposures.

REHVA

At this date we *need all efforts* to manage this pandemic from all fronts…

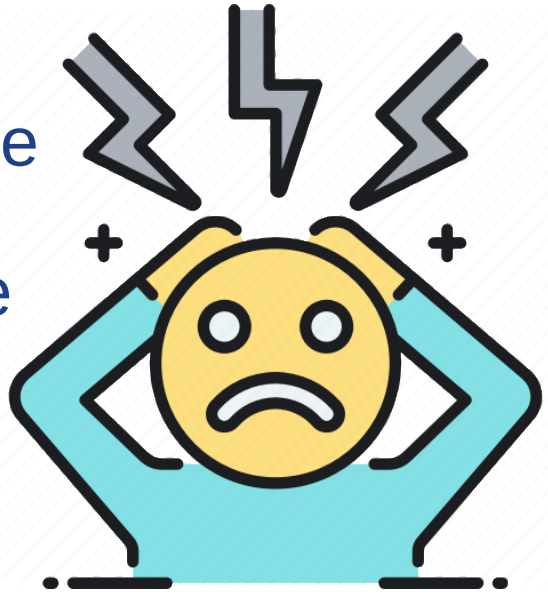
(T)ake a set of measures that help to also control the airborne route in buildings

ASHRAE Reopening Guidance (May 7,2020).

- HVAC programming to flush 2 hours pre and post occupancies. Operate exhaust fans and open outside air dampers.
- If no capacity to treat large quantities of outside air and when outside air conditions are moderate, open all windows for a minimum of two hours before reoccupation.
- Run the system on minimum outside air when unoccupied.
- "Key elements of a strategy to limit the spread of the COVID-19 virus are to perform needed heating, ventilating and air conditioning (HVAC) system maintenance, including filter changes, and to run HVAC equipment, prior to re-occupancy," -Bill Bahnfleth

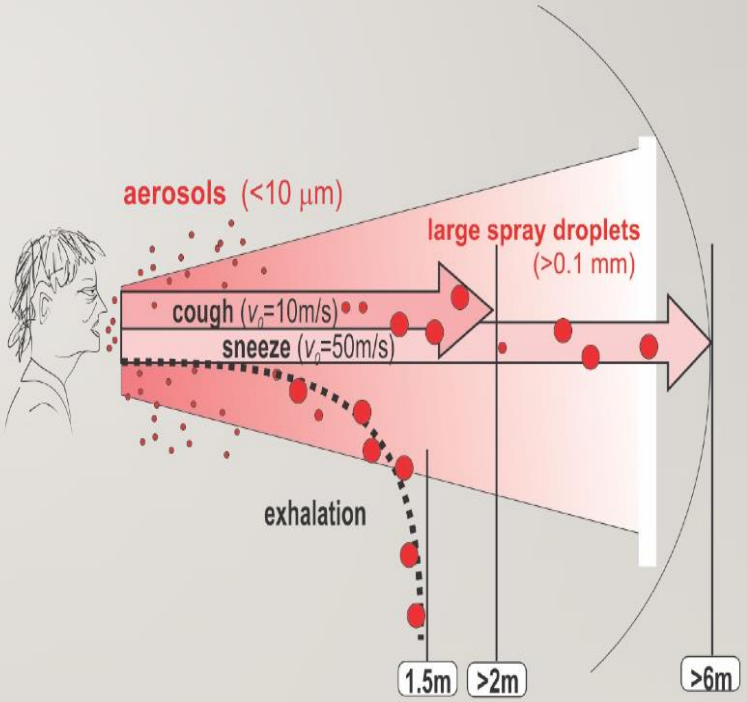
What is a Building Operations Team to do?

- 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).



6 RESPIRATORY AEROSOL DYNAMICS

- "Large" droplets settle before travelling long distances
- "Small" droplets/aerosols remain airborne longer, may travel significant distances
- Various definitions of boundary between small and large –~ 60 µm initial diameter, 10 µm final diameter



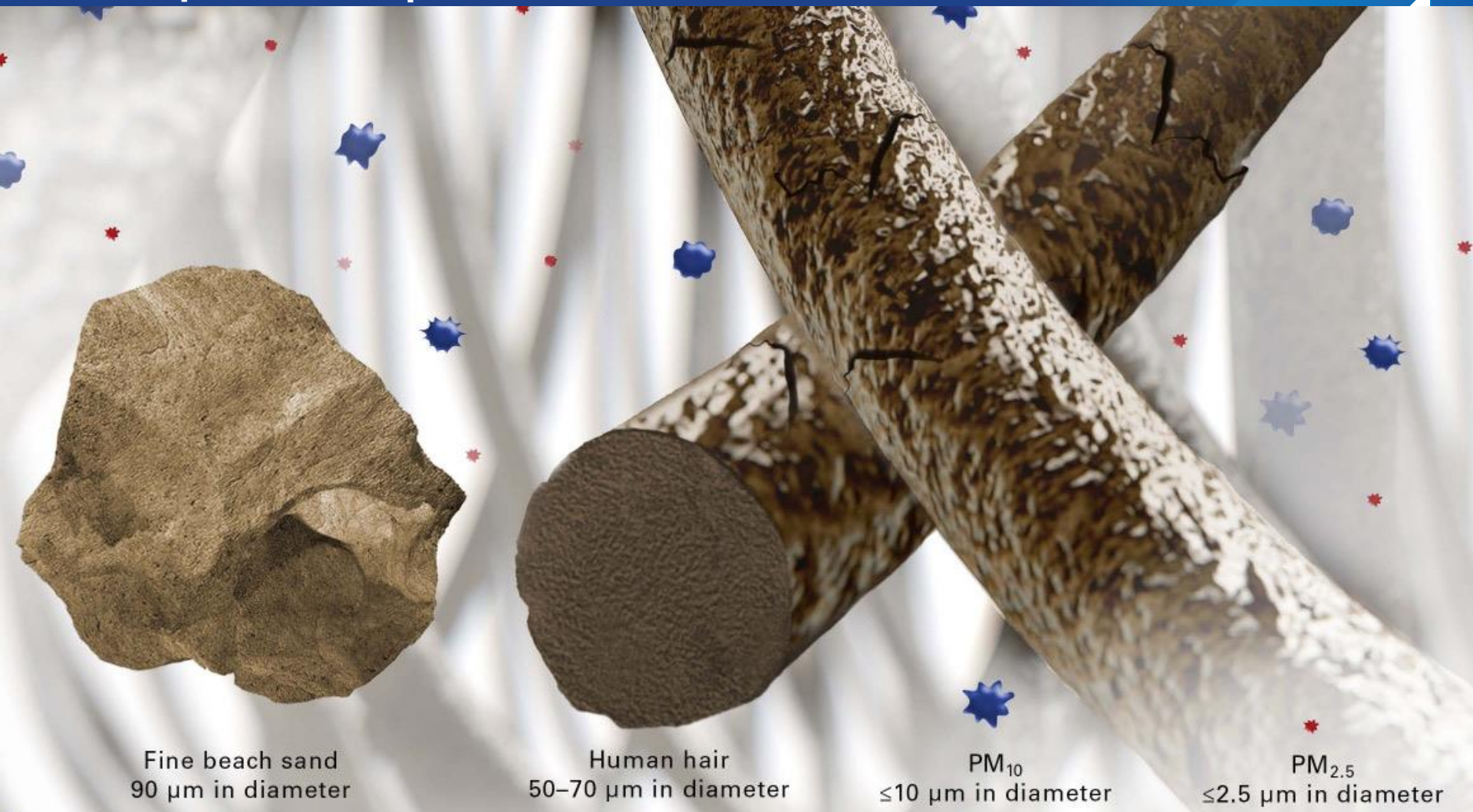
Airborne Transmission

- 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.

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 (ASHRAE MERV-9, EU F5) or higher).
- For central systems with MERV-13, F7 or higher, seal edges.
- Keep systems running longer hours to enhance above.
- Keep humidity above 30% when possible (caution in cold climates! – extended periods below freezing).
- Keep humidity below 60^0 F dew point.
- 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	

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 over-humidify in winter.
- Don’t use ozone generator.
- Electronic air cleaners difficult to compare to media and may emit ozone.

Specialized Actions for High Risk Occupancies

(e.g., crowded rooms or areas likely to have infected

- Upper room ultraviolet germicida irradiation (UVGI).

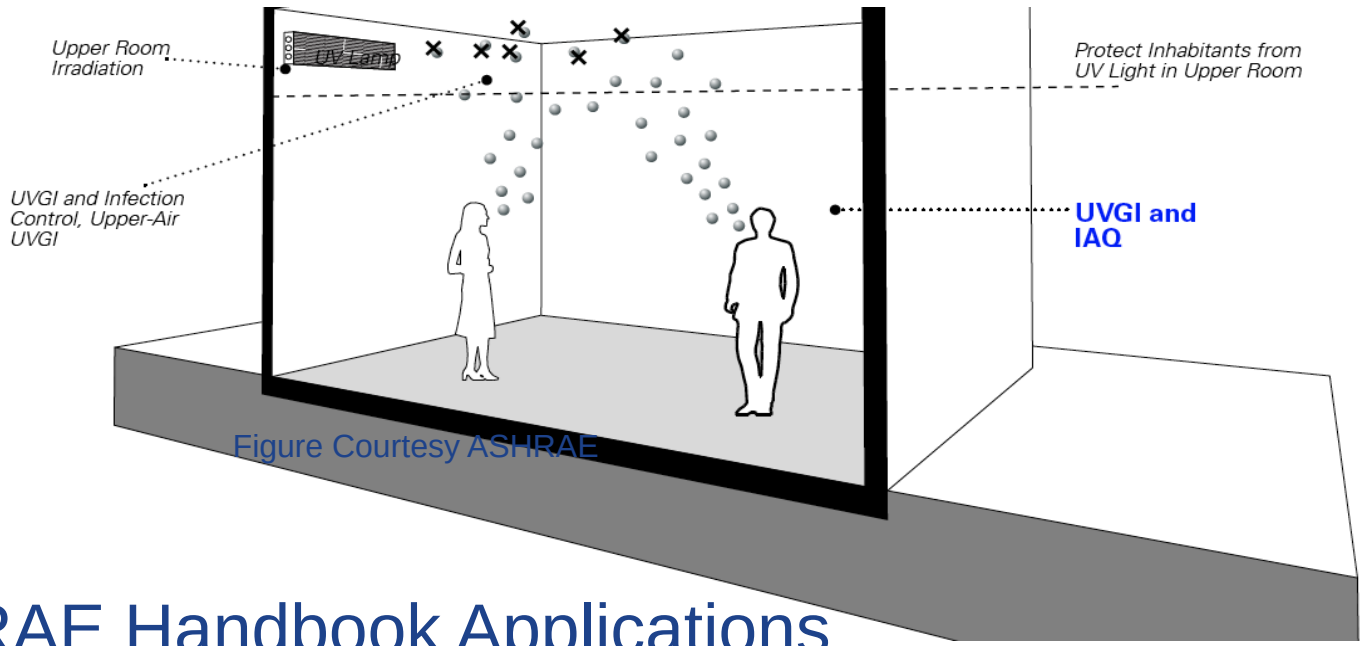


Figure Courtesy ASHRAE

- See ASHRAE Handbook Applications Chapter 62.

Figure 7. Upper-Air UVC Treating Congregate Setting (TUSS Project, St. Vincent's Hospital, New York City)

PRACTICAL IMPLICATIONS: TEMPERATURE AND HUMIDITY

- Possible concerns about humidification and temperature manipulation to control infection risk
  - Different responses for different pathogens
  - Risk of moisture damage/mold growth
  - May reduce effectiveness of UVGI
  - May adversely affect comfort
- No *specific* recommendation but, practitioners are encouraged to apply the evidence on a case by case basis

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.
- HVAC system is NOT the first line of defense.
- For more information, consult ASHRAE, Journal Newsletter, March 24, 2020, Handbooks, BOMA, ULI, etc.

Summary

- Take basic steps: HVAC system is ”icing” on cake.
- Keep systems with outside air and filtration running, lengthen hours.
- Improve filtration & increase outside air if clean.
- Possibly humidify to 30% in cold weather. Low humidity indoors occurs only when outside < 40^0F.
- High limit for humidity: < 60^0F dew point.
- Ultraviolet and other advanced techniques for crowded rooms and those likely to have infected individuals.
- Questions: Larry@SchoenEngineering.com

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Home IAQ and COVID19

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11-Jun-2020

What do we know about COVID-19 transmission and how do we know it?

The disease COVID19 is transmitted by the SARS-CoV-2 virus.

Look at knowledge from previous similar respiratory viruses: SARS (2003) and MERS (2009).

Case studies of transmission via contact tracing or outbreaks.

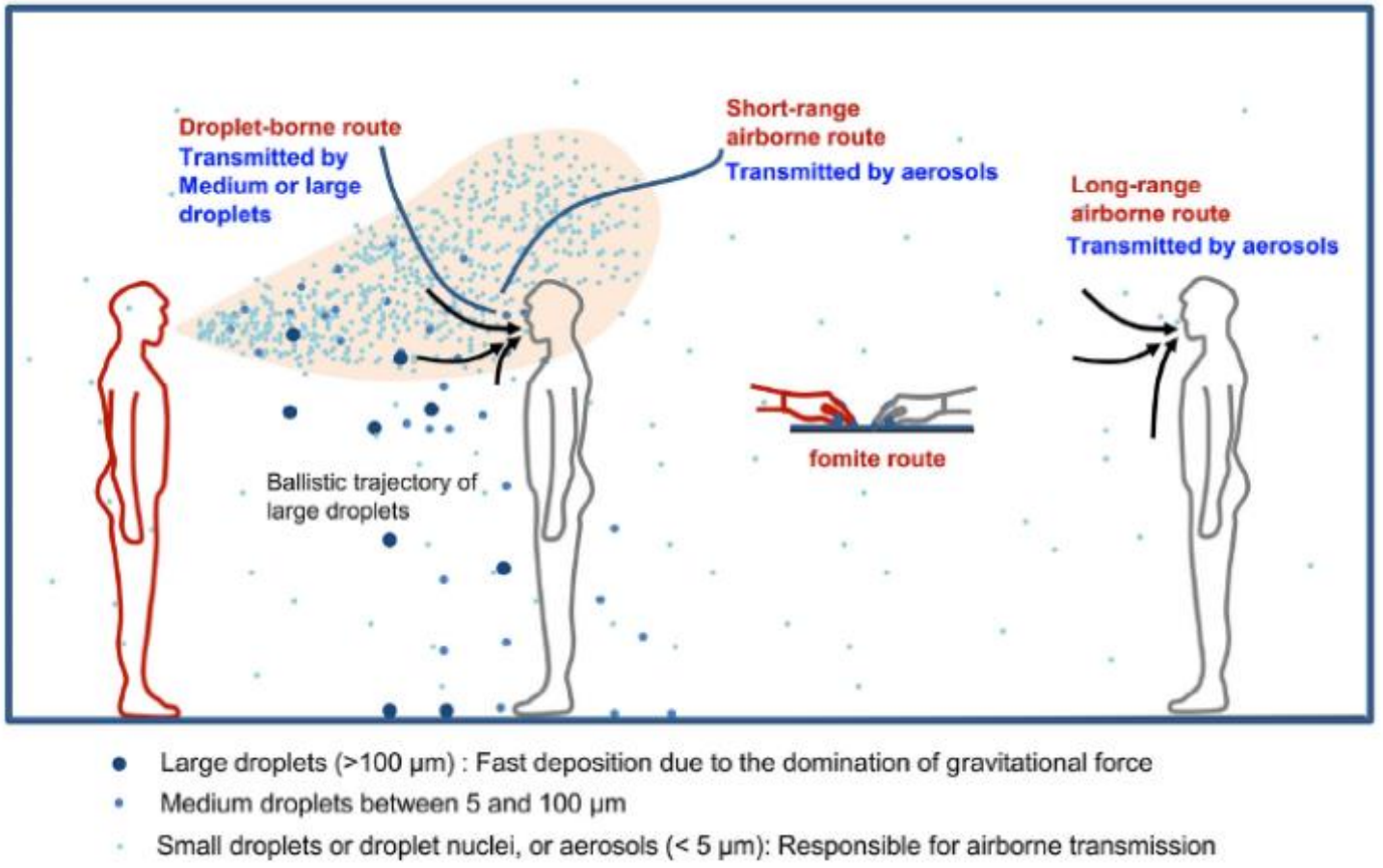
Using the physics and biology of virus emissions and transport through the environment to estimate infectious dose

Airborne transmission

Short range:
- 6 ft separation
- Wear a mask

Long Range:
- Isolate
- Dilute/Ventilate
- Filter

The IAQ part



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

Transmission at Choir Rehearsal in Washington

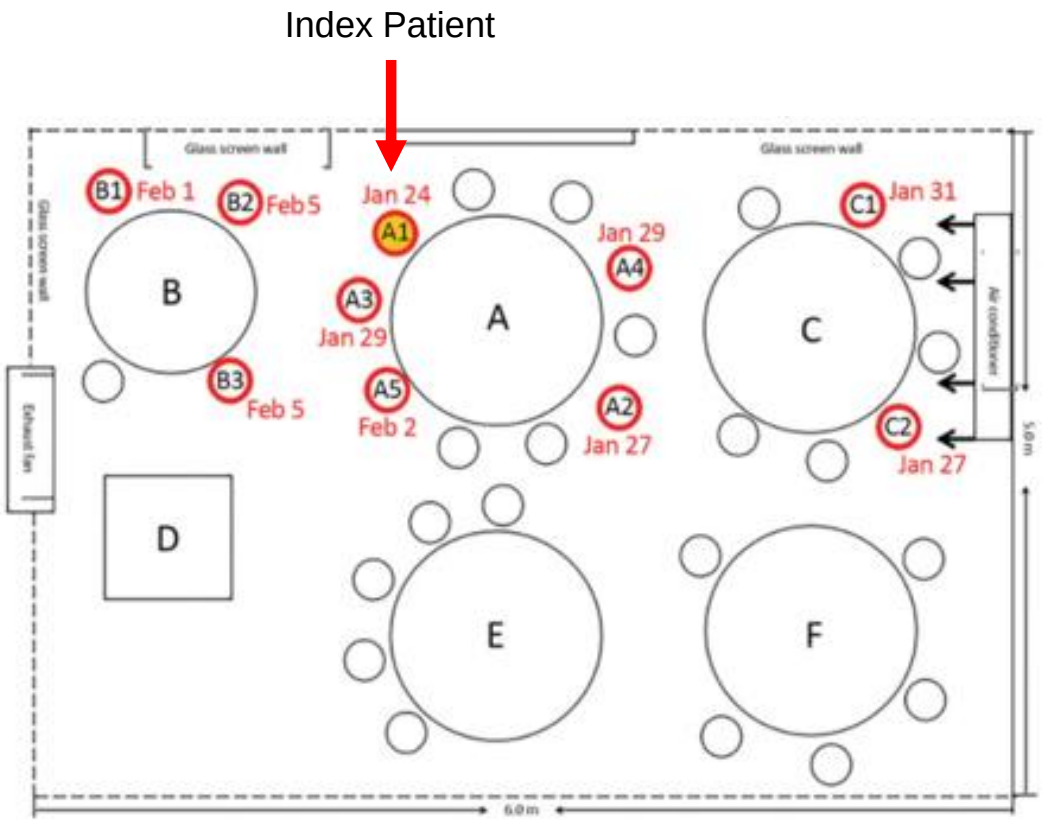
60 members of a choir in Mt. Vernon WA attended rehearsal on March 10.
As of April 2, 45 were ill, 28 tested positive, 2 died. (CNN)

"During the entire rehearsal, no one sneezed, no one coughed, no one there appeared to be sick in any way," one member said to KIRO.

Transmission in a Hong Kong restaurant

Asymptomatic Index Patient

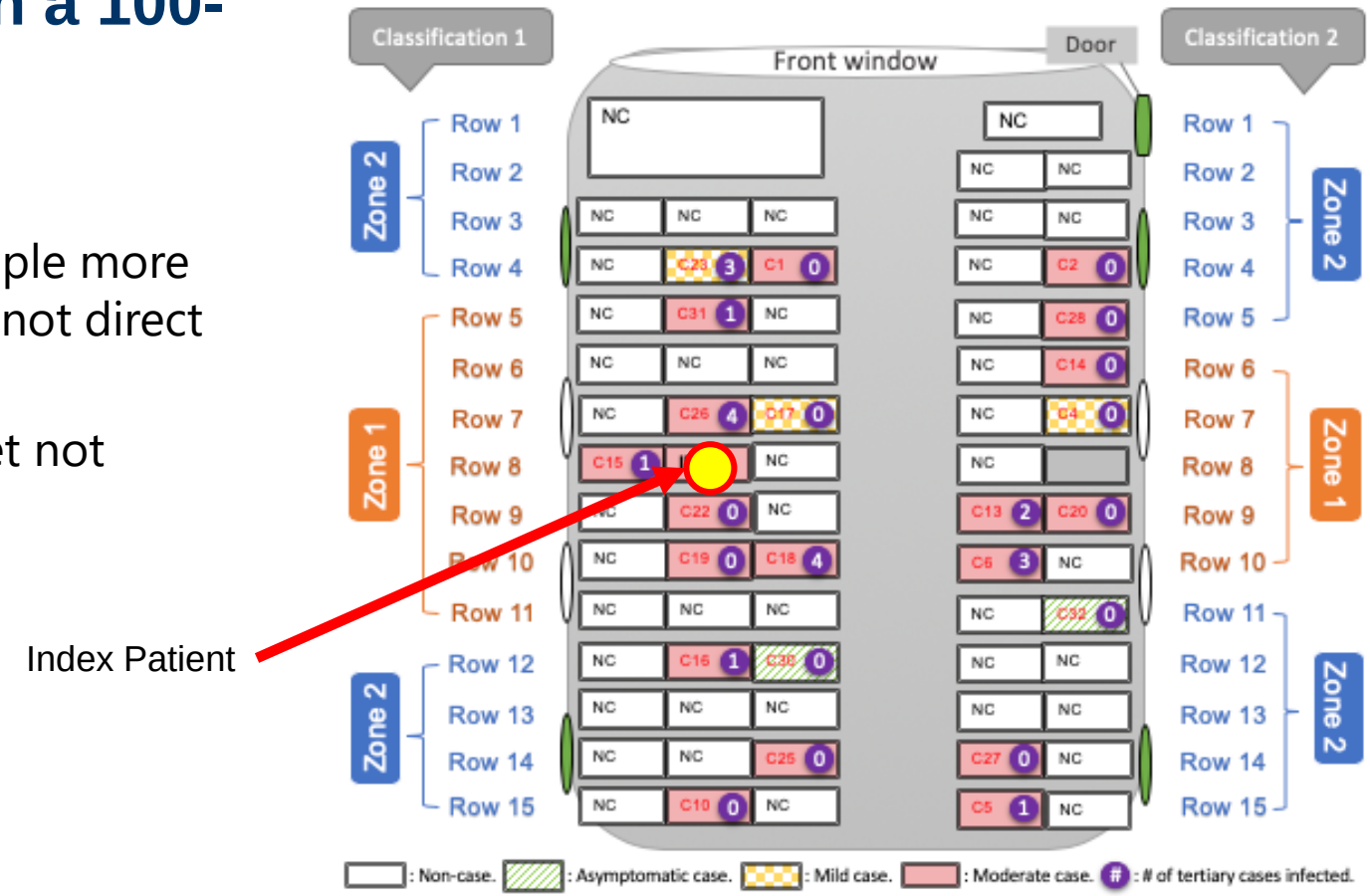
- Shared space for about an hour
- Other infected people more than 6 feet away – not direct contact
- Ventilation rates were very low: about 10% of recommended levels



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

Transmission on a 100-min bus ride

- Other infected people more than 6 feet away – not direct contact
- People within 6 feet not infected

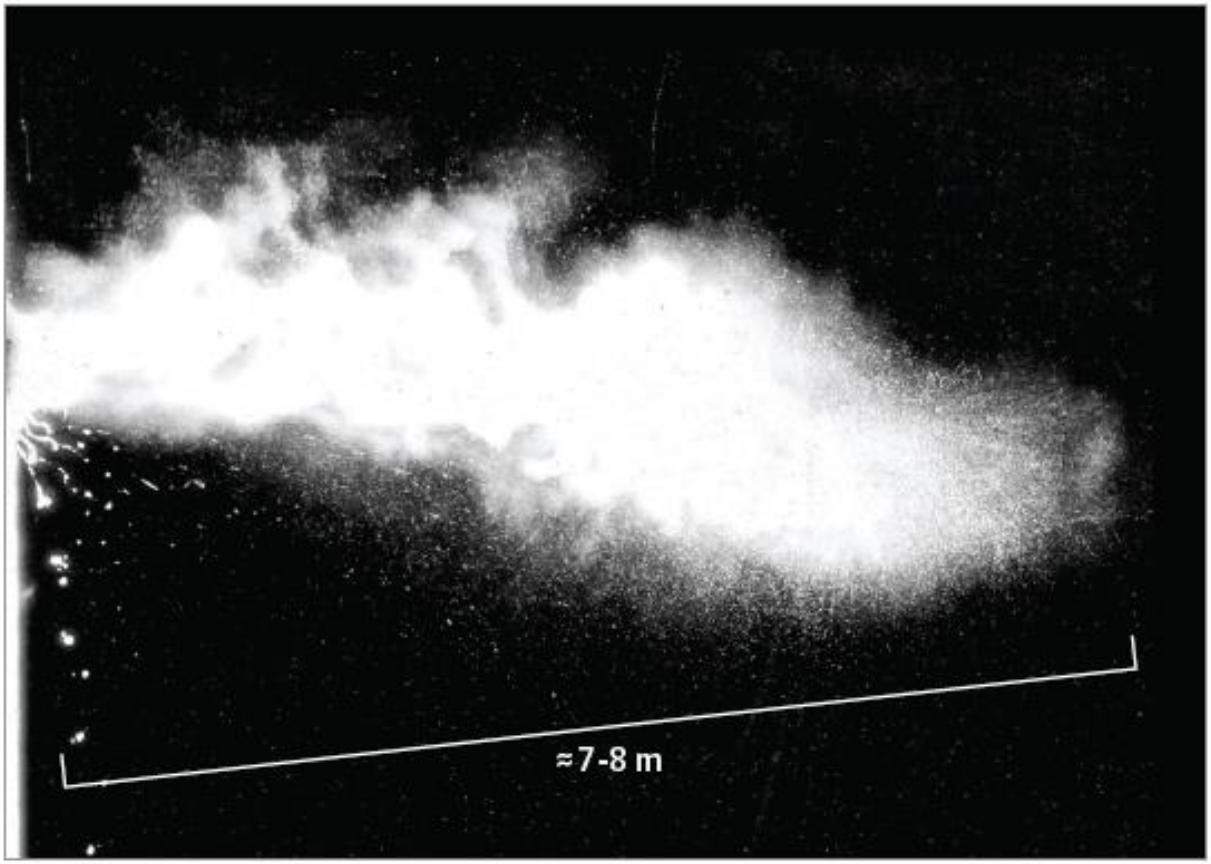


Shen, Ye et al. PREPRINT. Airborne Transmission of COVID-19: Epidemiologic Evidence from Two Outbreak Investigations (March 10, 2020). Available at SSRN: https://ssrn.com/abstract=3567505 or http://dx.doi.org/10.2139/ssrn.3567505

Sneezes and coughs have their own momentum

Wearing masks is very important if you are sneezing or coughing!

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

Large droplet travel was acknowledged in 1934

Wells WF. On air-borne infection study II. Droplets and droplet nuclei.
Am J Epidemiol 20:6118.

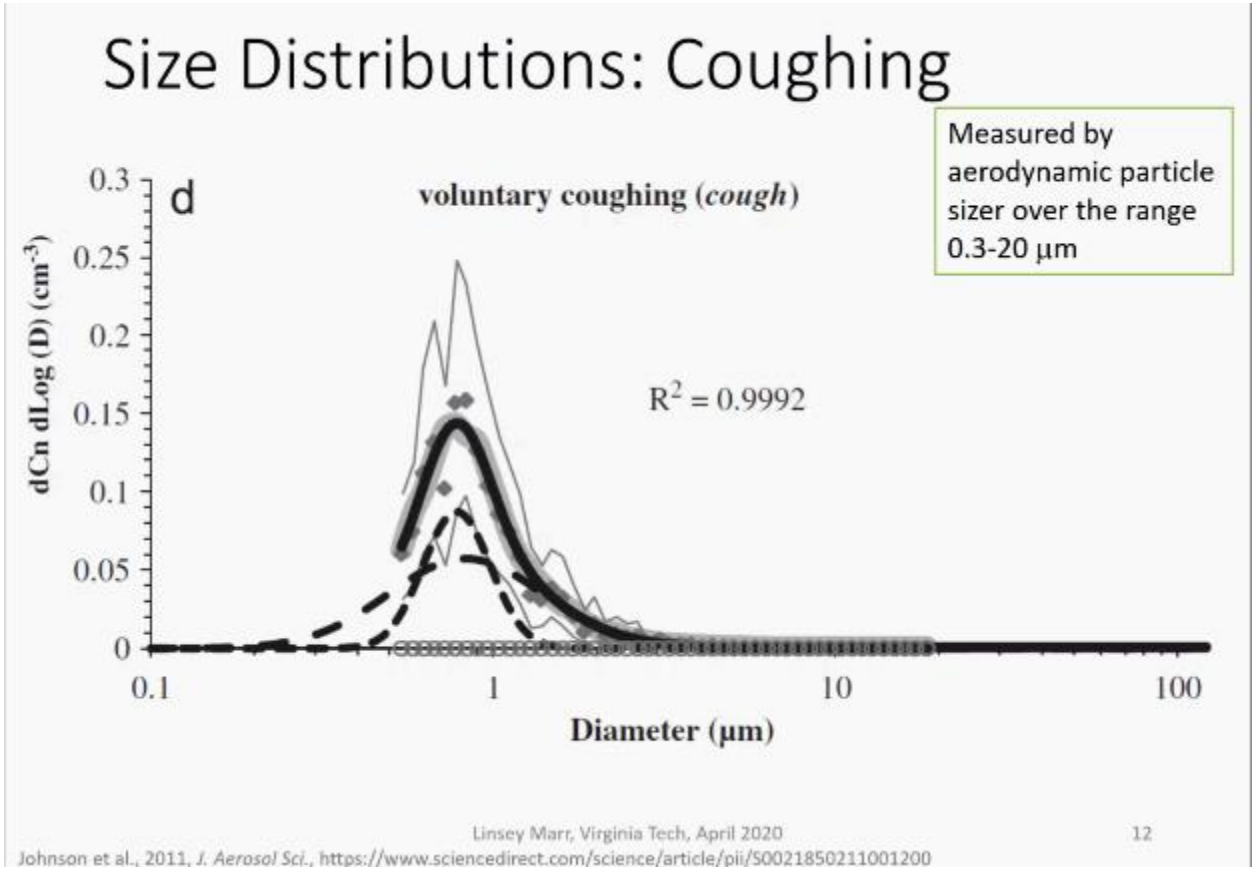
Particles of diameters 1-3 μm remained suspended almost indefinitely…

10 μm droplets took 17 minutes to fall 3 m (10 feet) to the floor

20 μm droplets took 4 minutes,

100 μm droplets took 10 seconds

What are the particle sizes of interest?

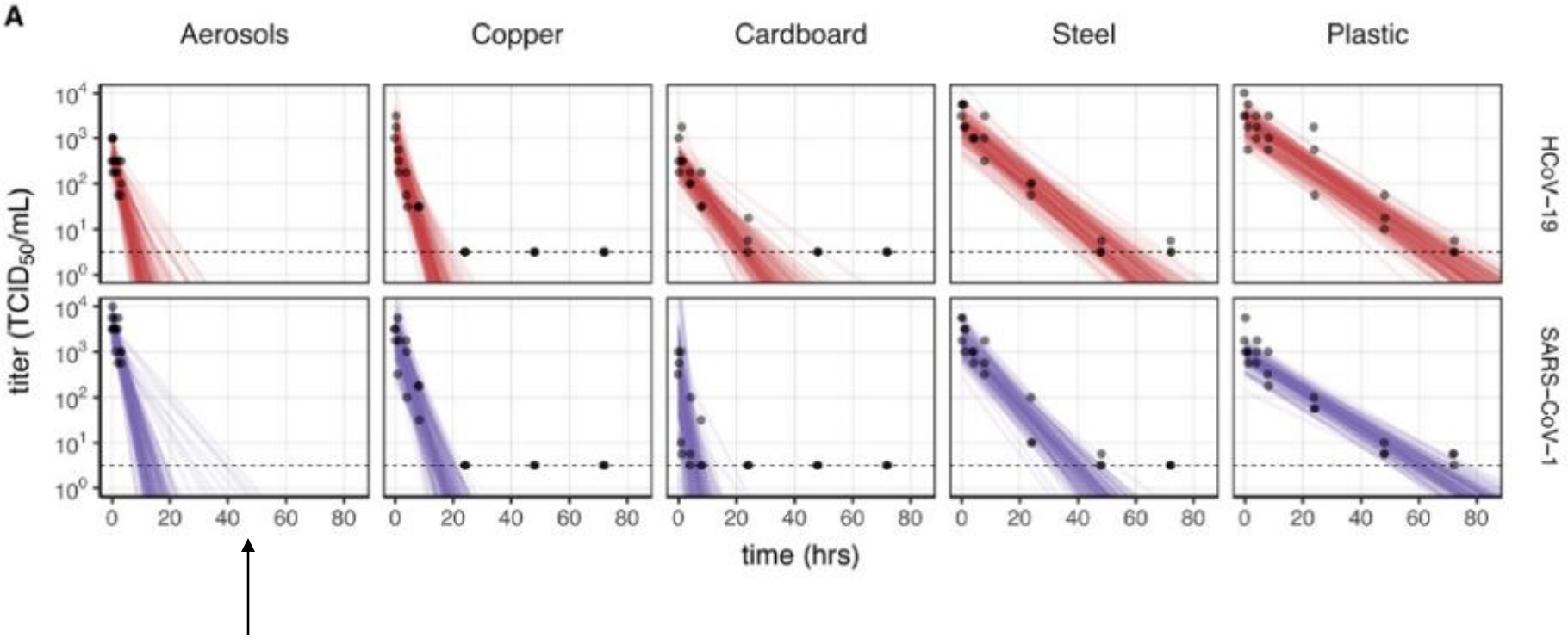


Breathing and talking: similar distribution but about half the amount emitted

Almost all particles remain airborne ”almost indefinitely”

Filters need to capture particles less than 1 micron in diameter = MERV 13 or better

Virus viable in aerosols for hours, longer on some surfaces



Airborne half life about 2-3 hours

van Doremalen et al. (2020). "Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1." New England Journal of Medicine **382**(16): 1564-1567.

Conclusion: We need to address Home IAQ to reduce infection risk

An hour or two is plenty of time for infection to take place

Asymptomatic people can transmit the virus

Direct proximity does not always result in an infection

Direct proximity not required for transmission

The virus can be transmitted through the air

ASHRAE: *Transmission of SARS-CoV-2 through the air is sufficiently likely that airborne exposure to the virus should be controlled. Changes to building operations, including the operation of heating, ventilating, and air-conditioning systems, can reduce airborne exposures*.

What can you do in a home?

- **Isolate**
  - Isolate infected or higher-risk people
  - Exhaust from contaminated rooms
  - Air flow direction: from uncontaminated rooms to contaminated rooms to outside
- **Dilute**
  - More ventilation lowers concentrations – reduces amount of virus entering your body
- **Filter**
  - Remove virus from air by filtration and return uncontaminated air to the occupied home

If no-one in your home is sick

- Turn ON your ventilation system if you have one.
  - The most common ventilation systems are exhaust fans designed to run continuously and located in a laundry room or bathroom, heat recovery systems that both supply and exhaust air and fresh air supply systems usually connected to the forced air heating and cooling system.

- Open windows.
  - If it is too hot, cold, windy or rainy then don’t open your windows.
  - Avoid using windows that are within 10 feet of neighbors' open windows
  - If seasonal allergies are a problem for anyone in the home, or during extreme outdoor events such as wildfires, keep windows closed and filter the air as much as possible.

- If you can’t do either of these, then run a bath or kitchen exhaust fan or a range hood continuously or as much as possible. In a home with natural draft gas appliances, do not run ALL exhaust fans in your home at the same time unless your home has been tested by a home performance contractor to be safe under these operating conditions.

If no-one in your home is sick

If you have or can install a good filter in your heating/cooling system, use the thermostat to run the fan continuously on low speed if possible or intermittently using “circulate” or similar setting.

- **Very filters will have a rating equal or higher to one of these values:**
  - **MERV 13**
  - **FPR 10**
  - **MPR 1500**

When replacing your filter use a mask and gloves and put the old filter in a plastic bag immediately upon removal.

If no-one in your home is sick

Other IAQ issues:

- Avoid overly dry indoor air (<20% RH), to stay healthier and better able to resist infection. Use a humidifier in cold weather.
- Run some water for a few seconds in all sinks/tubs/showers to stop sewer gas entry.
- When using the toilet, turn on exhaust fan when entering (if not on already), close the toilet lid before flushing, and leave exhaust fan on for at least a few minutes.
- Avoid respiratory irritants: no smoking, caution with candles, vent gas burners. Use your range hood when cooking.

If anyone in your home is sick or required to quarantine

If possible, have the sick person remain in a room that is not shared with anyone else and keep the door(s) closed.

If possible, avoid sharing a bathroom with the sick person.

If a bathroom must be shared, ensure it is ventilated continuously and pay strict attention to CDC guidance on cleaning shared surfaces.

Use a fan to exhaust air from the room occupied by the sick person to outside.

- If the bedroom has a master bathroom with a fan, turn it on and leave any doors between the master bathroom and the bedroom open.
- Otherwise put a fan in a window and make sure it draws air from the room and blows it outside.

If anyone in your home is sick or required to quarantine

Cover/seal heating/cooling air vents in the patient's room. If necessary use portable heaters or room air conditioners to maintain comfort.

Upgrade HVAC air filter.

Use a room air cleaner in the other occupied rooms; follow EPA Guidance for room air cleaner selection and use.

https://www.epa.gov/sites/production/files/2018-07/documents/guide_to_air_cleaners_in_the_home_2nd_edition.pdf

If someone in your home is at higher risk of infection

Follow CDC guidance on what "higher risk" means. Generally, this applies to the elderly and people with existing health problems.

So long as the higher risk person is NOT infected

- Isolate sensitive occupants: if possible provide them with their own bedroom and bathroom and keep the door(s) closed.
- Use a fan to draw air from outside into the room of the higher risk person.
  - Put a fan in a window and make sure it blows into the room.
  - Only do this if it does not create uncomfortable conditions in the room
- Cover/seal heating/cooling air vents in the patient's room. If necessary use portable heaters or room air conditioners to maintain comfort.
- Upgrade the HVAC air filter
- Use a room air cleaner in the higher risk person's room; follow EPA Guidance for room air cleaner selection and use.

Other issues for Multi-Family Buildings

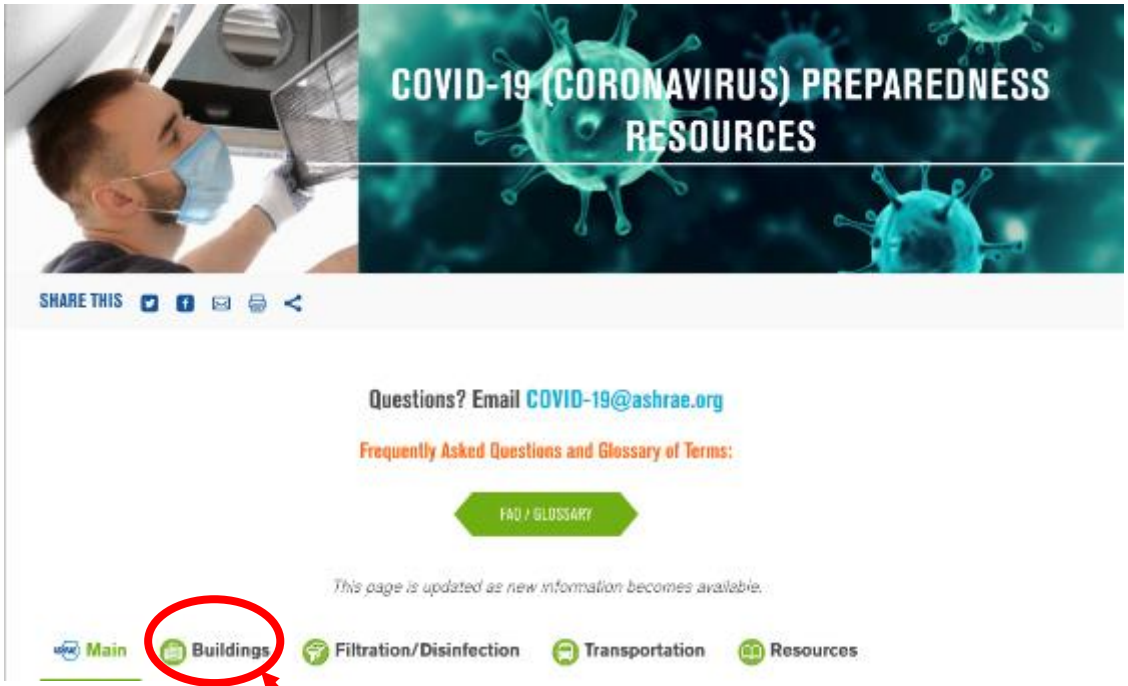
- Maintenance staff should check/replace/fix all backflow dampers in venting systems.
- Maintenance staff should check all plumbing stacks, vents and drains to ensure that air cannot enter homes from the sewer system.
- Run some water for a few seconds in all sinks/tubs/showers to stop sewer gas entry.
- Exhaust air from units with infected occupants.
- Do not open windows within 10 feet of an open window of a neighboring apartment?
- Ensure that common space ventilation systems are operating correctly and comply with ASHRAE 62.1.
- Upgrade air filtration in both common areas and dwelling units in both ventilation and heating/cooling systems.

Future home upgrades

- **Add (or upgrade) a ventilation system to at least ASHRAE 62.2**
- **Upgrade your central forced air system:**
  - Two or four inch inch filter slots/holders
  - Better air handler/furnace blower for continuous operation
- **In Multifamily Buildings**
  - Air seal dwelling units (<0.2 cfm50/sq.ft. @ 50 Pa recommended)

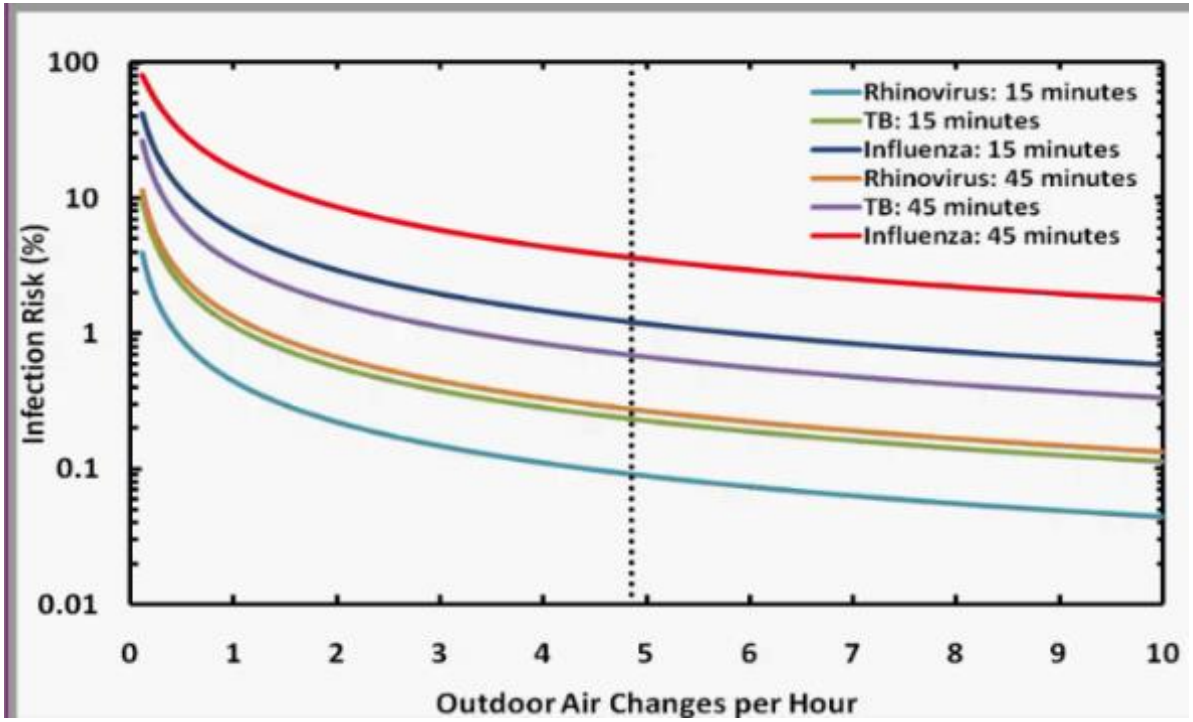
Key Resources - ASHRAE

https://www.ashrae.org/covid19



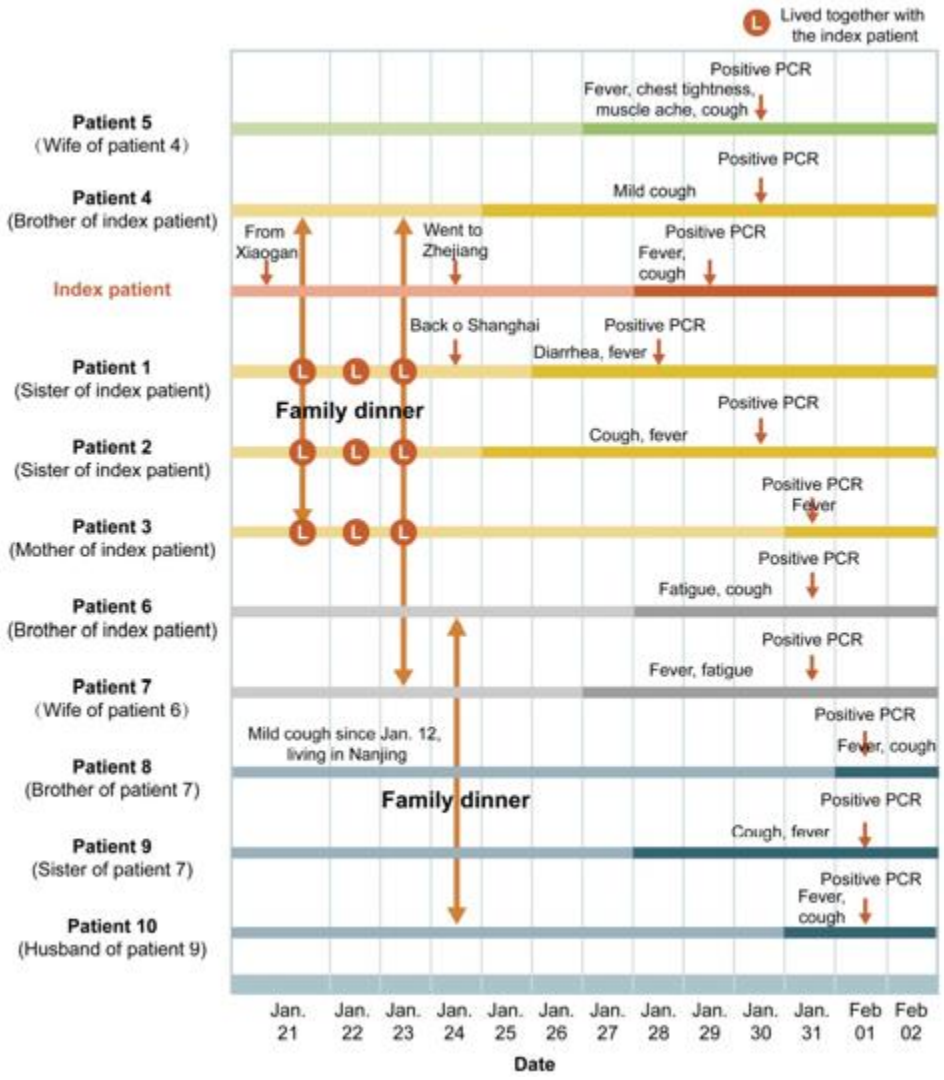
Click this link for info on residences, commercial buildings, schools, health care facilities

Thanks for listening



Knibbs et al. *American Journal of Infection Control*, 39: 866-872, 2011

BERKELEY LAB



Serial transmission in a family

Huang, R., et al. (2020). "A family cluster of SARS-CoV-2 infection involving 11 patients in Nanjing, China." The Lancet. Infectious diseases: S1473-3099(1420)30147-X.

Study of outbreaks in China found that 80% were from household members

Qian, H., T. Miao, L. Liu, X. Zheng, D. Luo and Y. Li (2020). "Indoor transmission of SARS-CoV-2." medRxiv: 2020.2004.2004.20053058.

Explore the Residential Program Solution Center

Resources to help improve your program and reach energy efficiency targets:

- Handbooks - explain *why* and *how* to implement specific stages of a program.
- Quick Answers - provide answers and resources for common questions.
- Proven Practices posts - include lessons learned, examples, and helpful tips from successful programs.
- Technology Solutions NEW! - present resources on advanced technologies, **HVAC** & **Heat Pump Water Heaters**, including installation guidance, marketing strategies, & potential savings.

https://rpsc.energy.gov

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