Buildings and Air Quality in the Age of COVID and Wildfires

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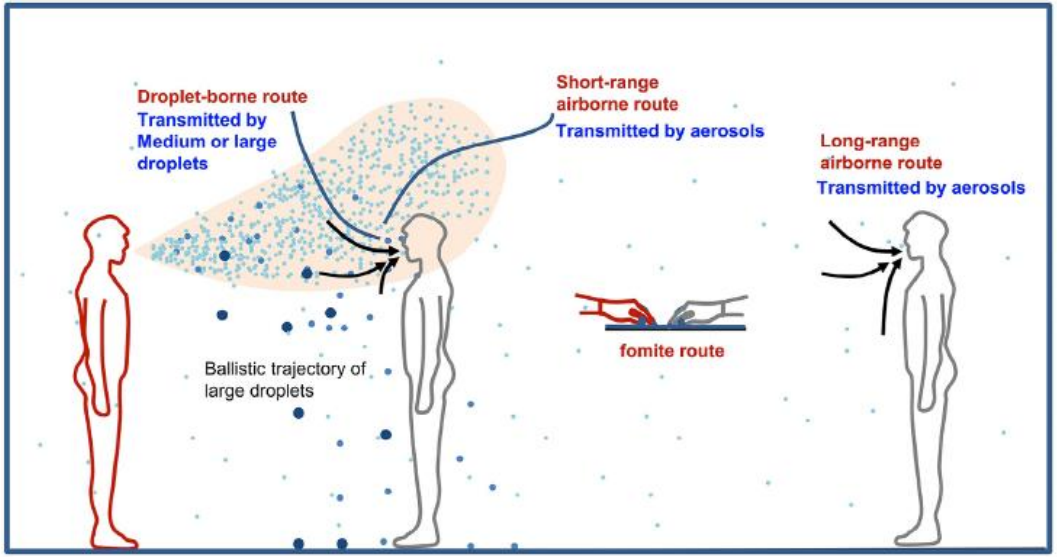
British Columbia Building Envelopes Council
October 30th 2020

What do we know about COVID-19 transmission ?

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

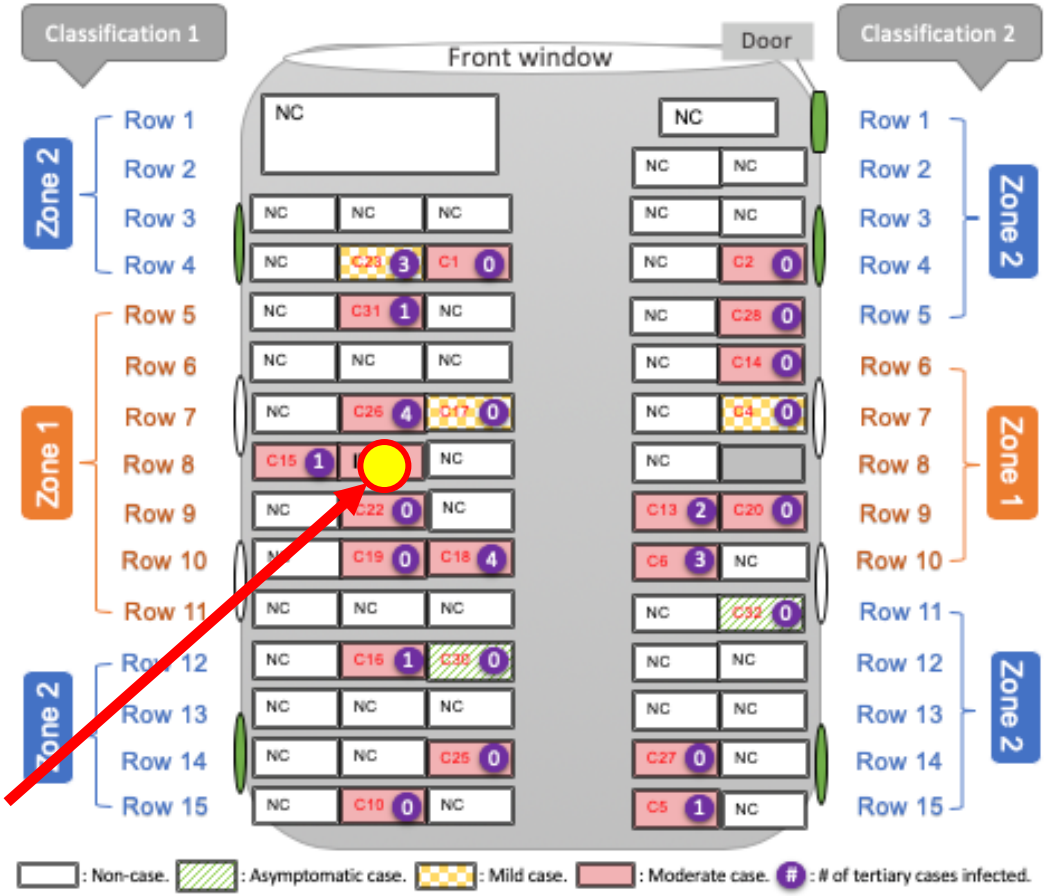
- Respiratory infection (initially)
- Virus in droplets/particles in air
  - In exhaled air from infected people
  - The closer you are to someone the more of their exhausted air you breathe
  - Masks significantly reduce emissions
  - Incubation period typically 5 days – patients most infectious prior to symptoms
  - Practically all transmission happens indoors
  - Risk is higher with more people, less ventilation



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

Transmission on a 100-min bus ride

- Other infected people more than 2 m away
- People within 2m not infected
- implies airborne transmission



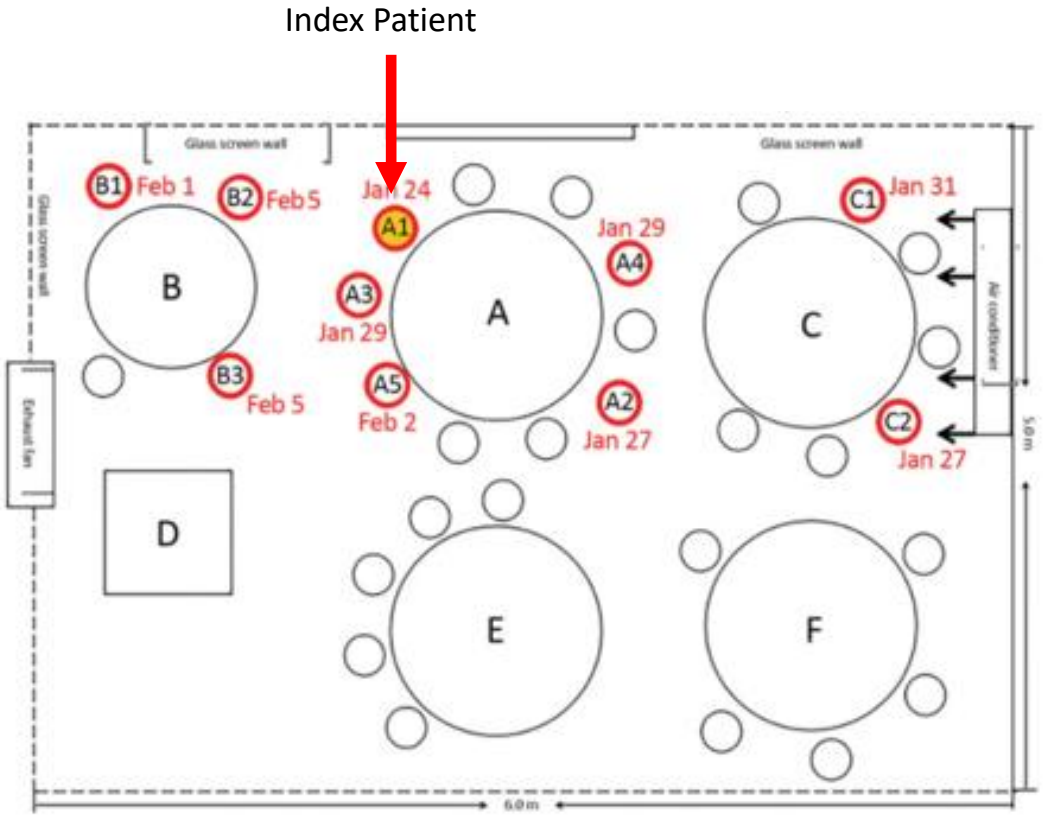
Index Patient

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

Transmission in a Guangzhou restaurant

Asymptomatic Index Patient

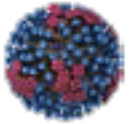
- Shared space for about an hour
- Other infected people more than 2 m away – not direct contact
- Ventilation rates were very low: about 10% of recommended levels



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

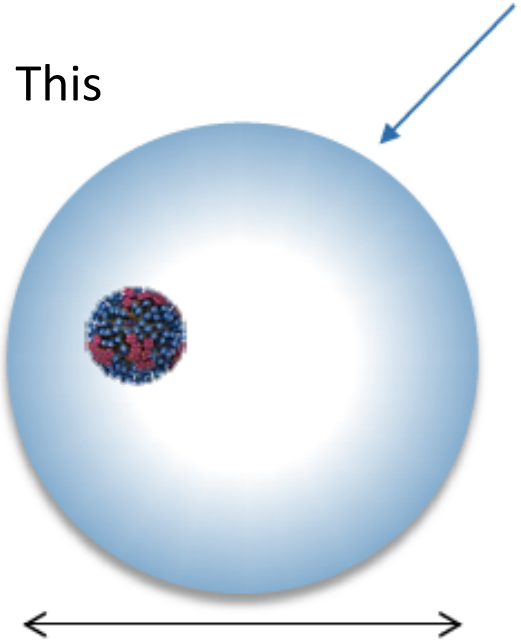
Particle size

Not this



0.1 μm

This



0.5 μm
(0.2-100 μm)

Size determines:

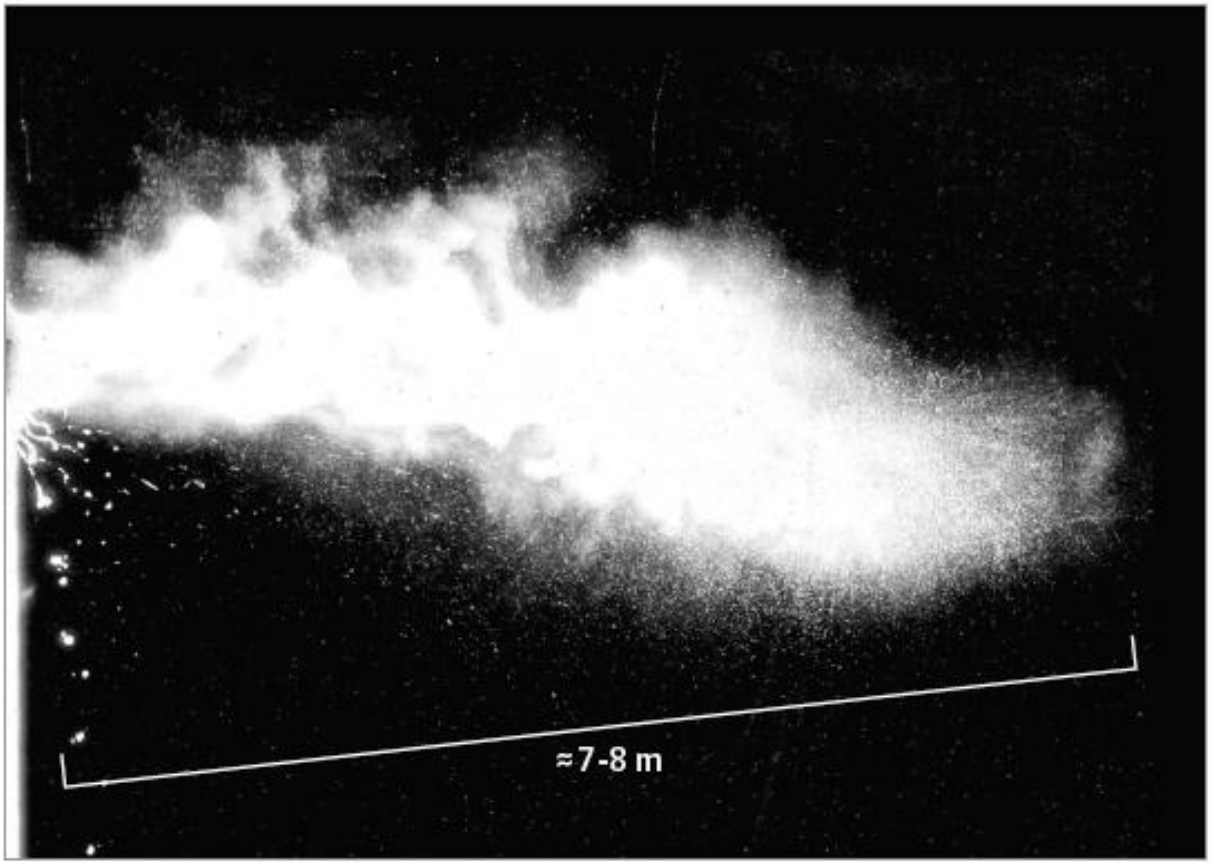
- How long it is airborne (smaller=longer)
- Where it deposits in the respiratory system (smaller=deeper)
- Size changes with time due to evaporation

Half life about one hour in air

People emit a lot of particles

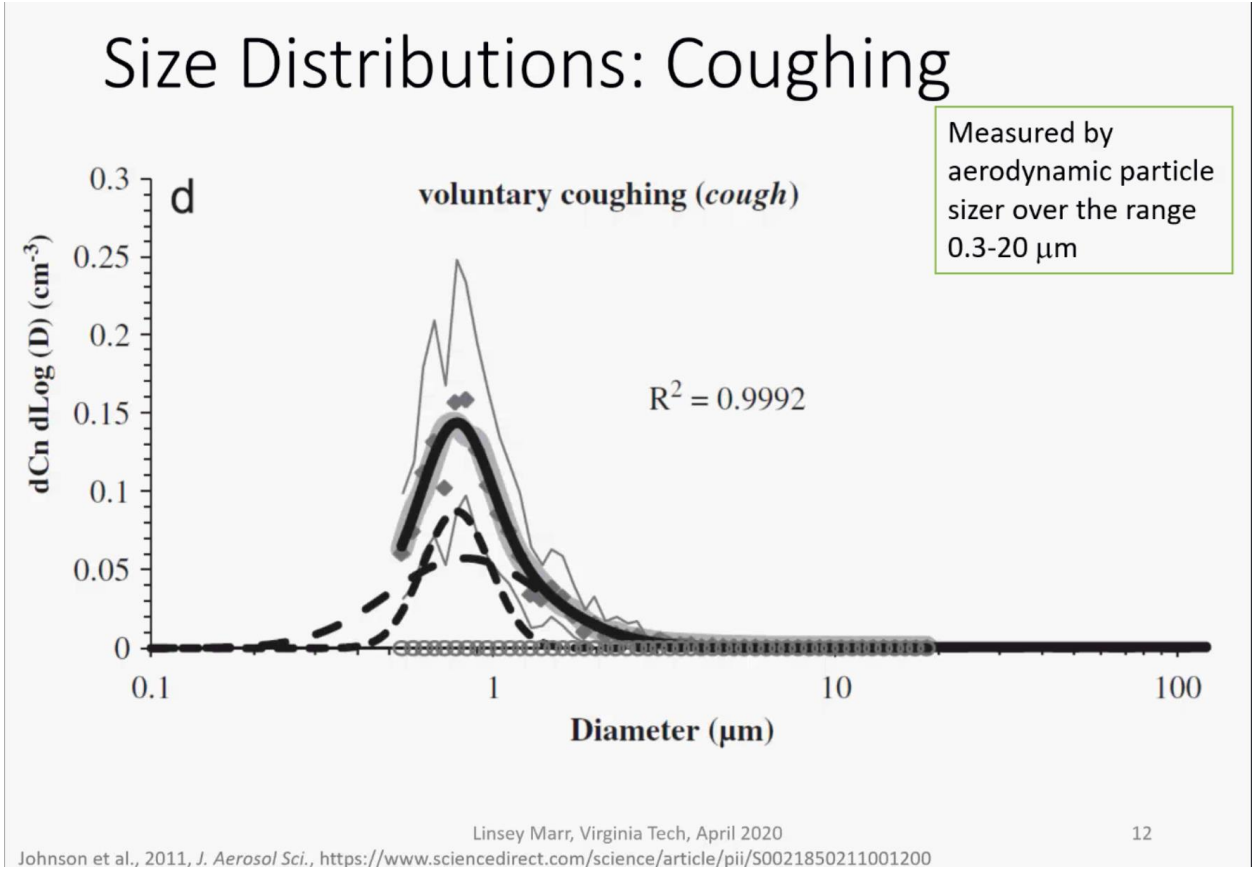
Wearing masks is very important if you are sneezing or coughing!

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

What are the particle sizes of interest?



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

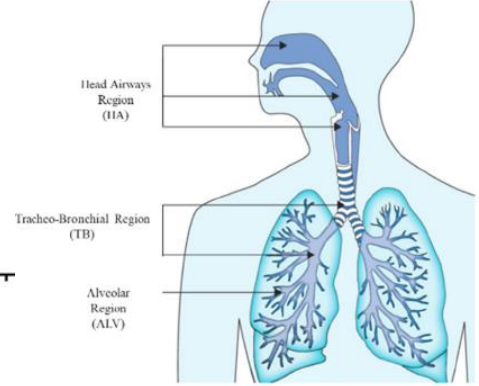
Particle Size

Ongoing discussion:

- More virus in larger particles
- BUT… larger particles don't get far
  - Evaporation, deposition and nasal cavity filtering
- SARS-COV-2 binds to ACE2 surface proteins deep in the lungs/alveoli.

What filter?

- MERV 13 >90% of particles > 1 micron
- Are readily available
- Are affordable
- Help remove ALL harmful particles not just SARS-COV-2
- At MERV 13 level unlikely to need system redesign or introduce large additional fan power requirements
- HEPA not needed!



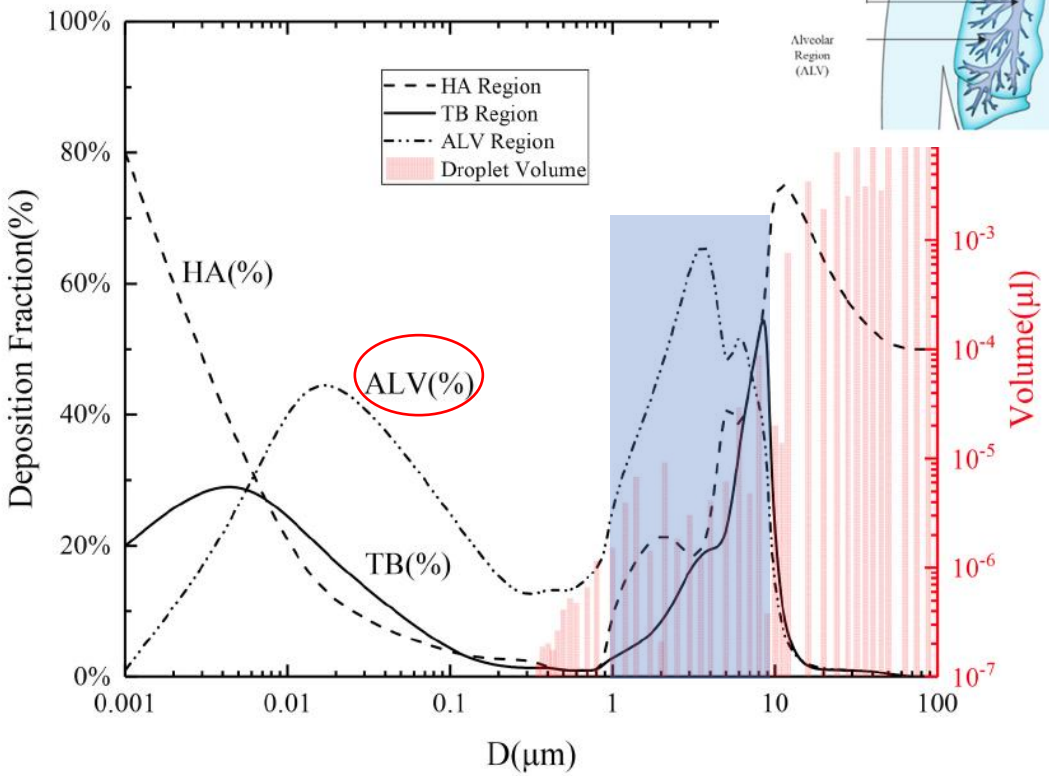


Fig. 7. Transmission risks of droplets with different diameters considering the deposition fraction.

What is the Building's Role in reducing infection risk?

Three basic principles:

1. **Source control/Isolation**
    - Isolate infected people (and sensitive people)
    - Exhaust from contaminated rooms (supply to rooms for sensitive people)
    - Air flow direction: from uncontaminated rooms to contaminated rooms to outside
2. **Dilution by ventilation**
    - More ventilation lowers concentrations – reduces amount of virus entering your body
3. **Removal by filtration**
    - Remove virus from air by filtration and return uncontaminated air to the occupied space – lowers concentrations - reduces amount of virus entering your body

A tight envelope allows better control for all these principles

Ventilation

- Outdoor air dilutes indoor contaminants
- Exhausting contaminated air removes contaminants from the building
- How much air is “enough” – as much as you reasonably can…
  - Hospital isolation wards: 12 air changes an hour – not needed in all buildings
  - At least meet minimum flows: ASHRAE 62.1 and 62.2 and CAN/CSA F326 in Canada for residential, CSA Z317.2 for healthcare facilities, local codes… etc.
  - Open windows (be careful in multi-story buildings and commercial buildings due to pressure control issues)
  - Open outdoor air dampers more than the minimum
- Vital to commission & maintain systems

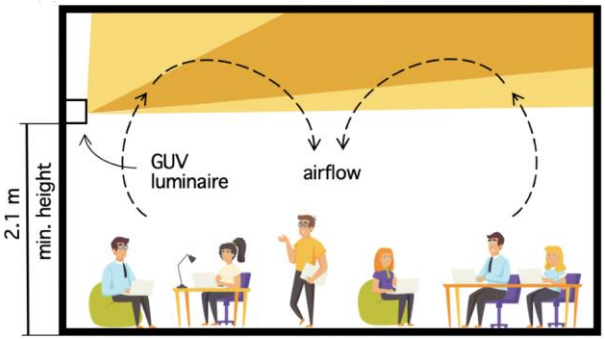
Air Filtering

- Use filters with a rating equal or higher to one of these values:
  - MERV 13
  - FPR 10
  - MPR 1500

- Important to regularly inspect and change filters
- When replacing filters use appropriate PPE (an N95 mask and gloves) and put the old filter in a plastic bag immediately upon removal.

What about UV?

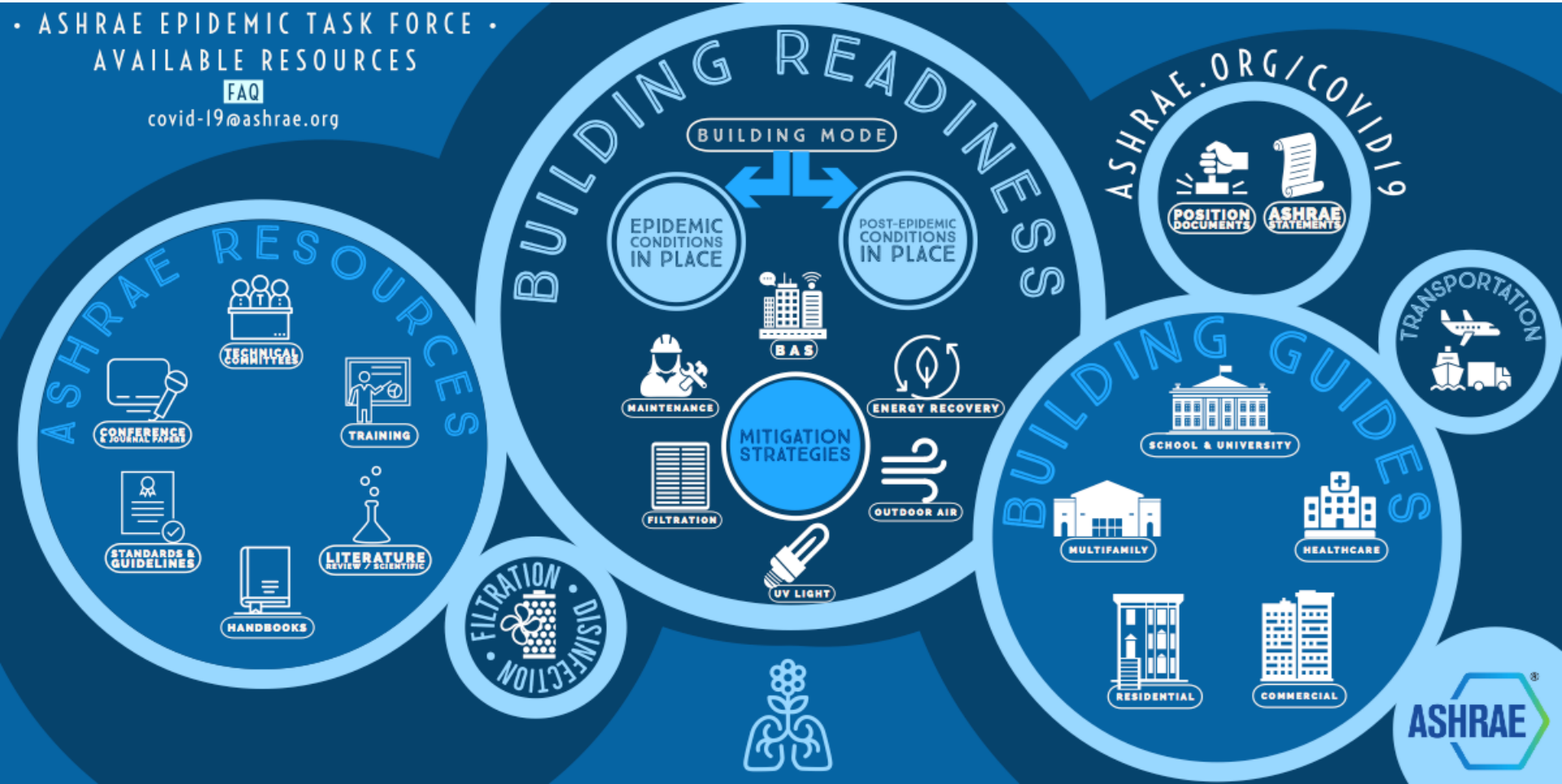
- UV damages DNA – prevents replication
- Needs to be strong enough that you definitely don't want it shining on you
- Best for high-occupancy high-risk applications or where other measures cannot be taken
- In-duct systems
- Ceiling systems integrated with HVAC design to circulate air to/from ceiling and rest of space
- Fan integrated
- Little certification



What about Humidity?

- Few direct studies - many questions about efficacy:
  - VanDoremalen (2020) SARS-COV-2, stable for hours in air at 60% RH
  - VanDoremalen (2013) MERS-COV no reduction in stability at 40% RH over 48 hours
  - Chan (2011) SARS-COV-1 viable on surfaces for 5 days with RH between 40% and 60%
  - US National Academy of Sciences (2020) No evidence of ambient RH link – other factors more important
  - Jüni (2020) Very weak evidence of link with ambient RH (because transmission happens inside spaces)
  - Casanova (2020) gastroenteritis virus (TGEV) and mouse hepatitis virus (MHV) are indeed inactivated in the 40-60%RH range. BUT!... those were surrogates rather SARS-CoV-2.
- These (and other) studies conclude other factors vastly more important than humidity
- Humidity control does not remove virus on time scale of other options: ventilation/filtration.
- Better to keep RH and T in comfort range for occupants and acceptable range for building envelope (>60%RH in winter problematic for building envelopes)

Available Guidance



Some Guidance needs revision?

- *Keep systems running longer hours (24/7 if possible)*
- *Operate systems pre- and post-occupancy to purge the building*

Neither of these are helpful for offices/schools and other spaces not occupied at all times.

1. The virus-laden particles deposit at about 1/h
2. SARS-COV-2 decays in airborne particles at about 1/h

Only 1 in 10:000 left after typical unoccupied time

3. Ventilation at minimum Outdoor Air rates (typical during unoccupied hours) will significantly reduce virus concentrations during 12-16 unoccupied hours
4. Security and cleaning staff need PPE anyway
5. Focus on when you can have the biggest impact

- During occupied hours when there are the most people with a chance of being exposed
- During occupied hours when there is the greatest chance of having an infected individual in the building

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.
- Air flow control –tight envelopes and interior partitions are important

Simpler guidance for homeowners

- **Turn ON your ventilation system if you have one.**

- **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.

Simpler guidance for homeowners

Isolation – infected, quarantined or higher-risk occupants

- Have the person remain in a room that is not shared with anyone else and keep the doors closed.
- Avoid sharing a bathroom.
- If a bathroom must be shared, ensure it is ventilated continuously and pay strict attention to CDC guidance on cleaning shared surfaces.
- Cover/seal heating/cooling air vents in the isolation room. If necessary use portable heaters or room air conditioners to maintain comfort.

Simpler guidance for homeowners

If anyone in your home is sick or required to quarantine

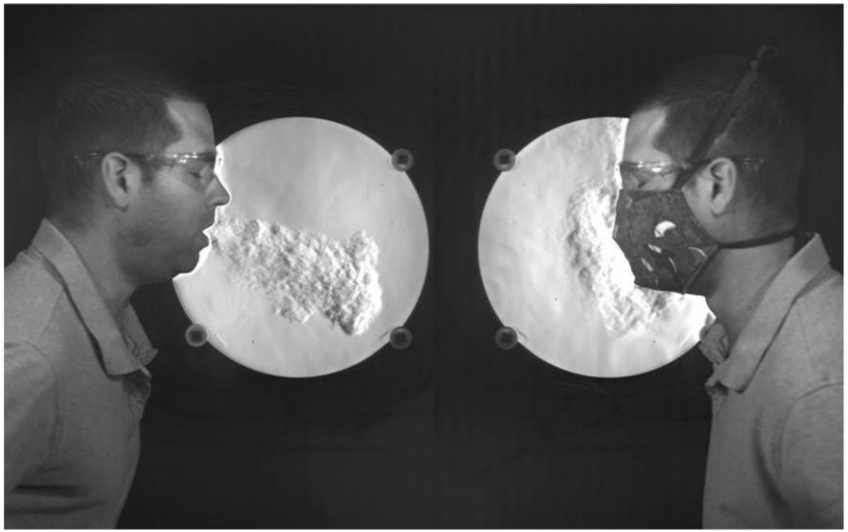
Use a fan to exhaust air *from the room* occupied by the sick person *to outside*.

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

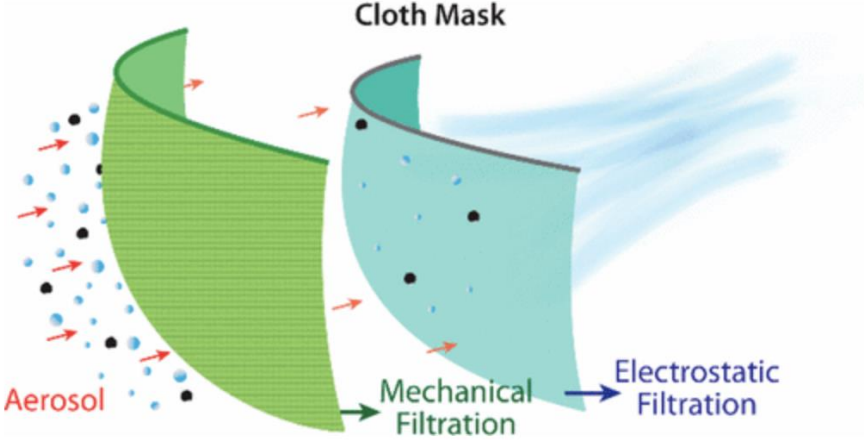
What do masks do?

- Reduce the *velocity* of air expelled during breathing, talking, sneezing, and/or coughing
- Expelled air won't travel as far

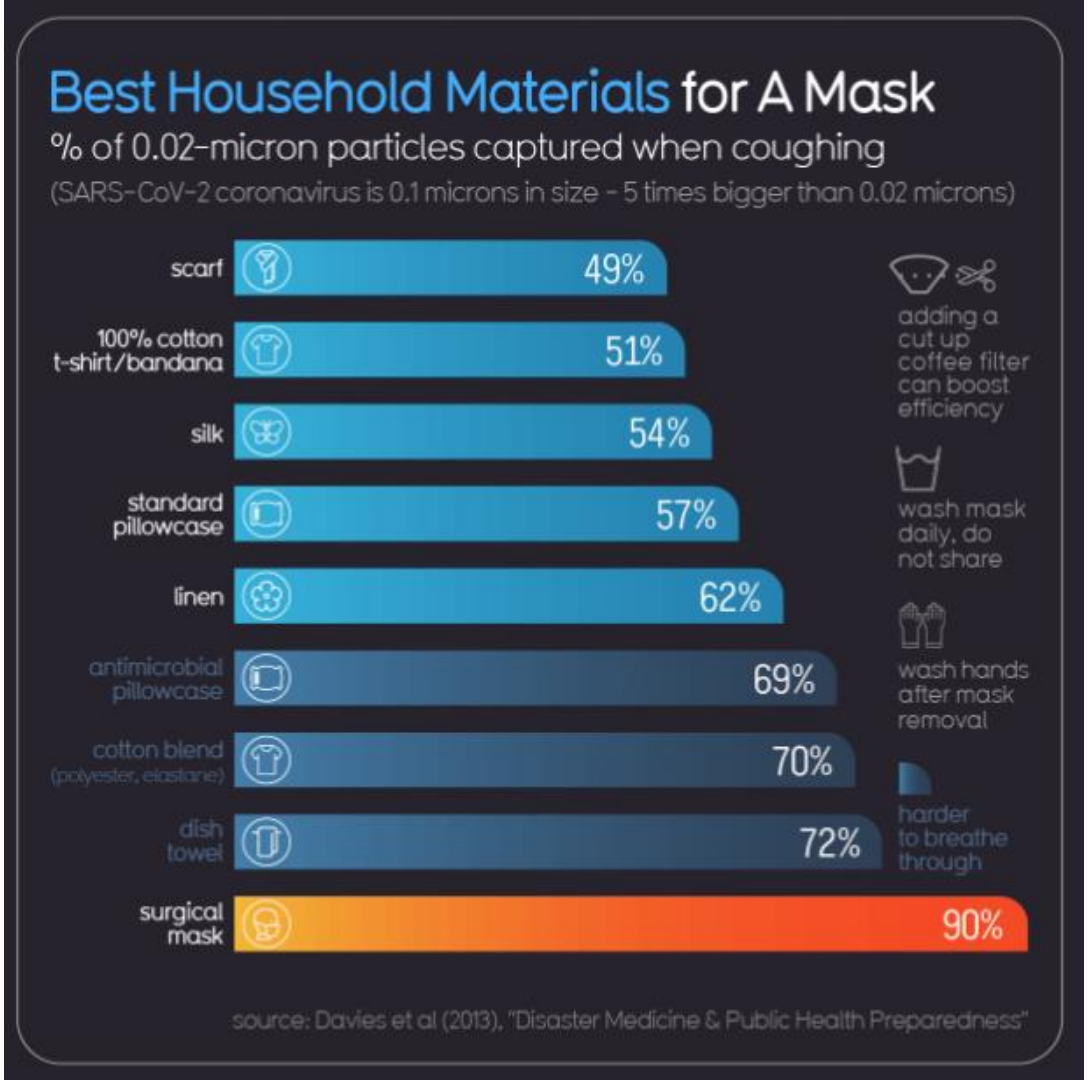


A visualization from NIST illustrates airflow when coughing, but it does not show the movement of virus particles (Staymates, 2020)

Masks can also *filter* respiratory particles of various sizes. And particle filtration can work in two directions: filtering particles during exhalation (which protects others) and filtering particles during inhalation (which protects yourself).



Depiction of aerosol filtration efficiency mechanisms for a fabric mask material (Konda et al. 2020)



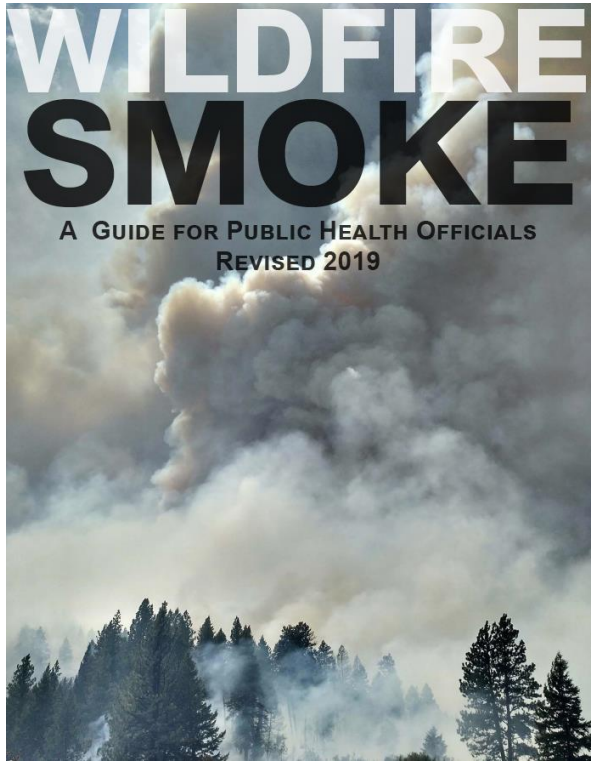
https://informationisbeautiful.net/visualizations/covid-19-coronavirus-infographic-datapack/

Wildfires and air quality

The view from Berkeley Lab

The view from Iain's house (September 9th)

Wildfires and Air Quality

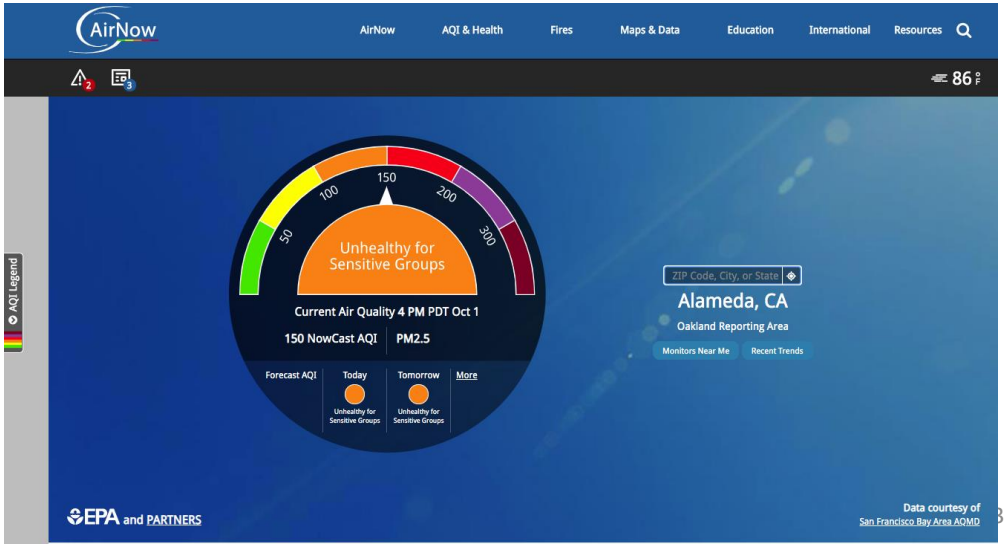


Biggest concern is particles

- Action levels: AQI> 100 for sensitive population
- AQI>150 for everyone
- Typically indoors is half outdoors – building envelope provides filtration

What's new

- A lot more fires for longer
- Better sensor/data networks
- Conflict with indoor contaminant (SARS-COV-2)dilution by ventilation



Wildfire Solutions

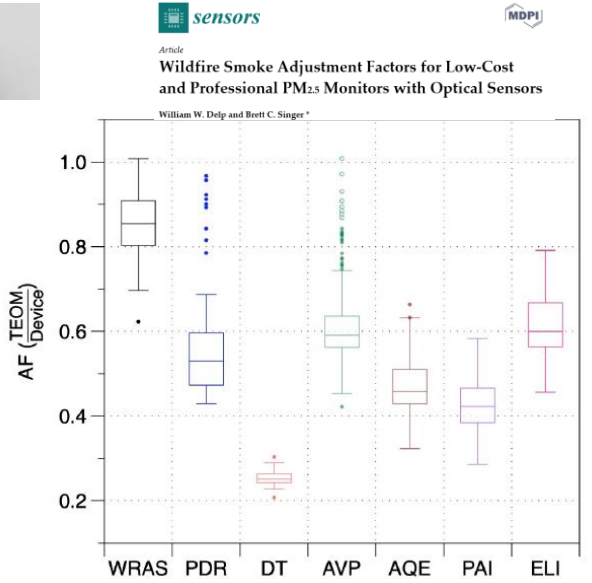
- Minimize outdoor air unless outdoor air filtered: At least MERV 13 on air intakes
- May still be an odor issue or chemical irritants on very high polluting days
- No open windows
- Recirculate air through good filters – MERV 13 minimum
  - Can be central forced air systems and/or stand-alone room air cleaners
  - DIY – box fans

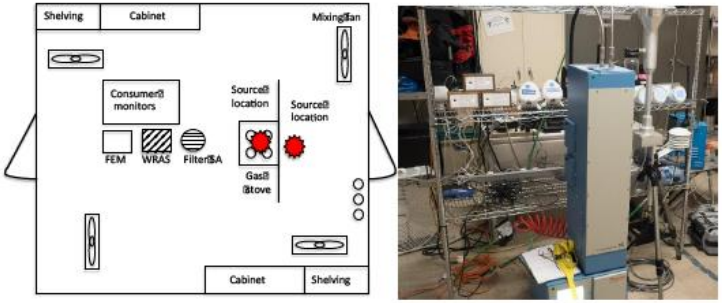
A tight envelope is a better filter. In new home about MERV 10-13

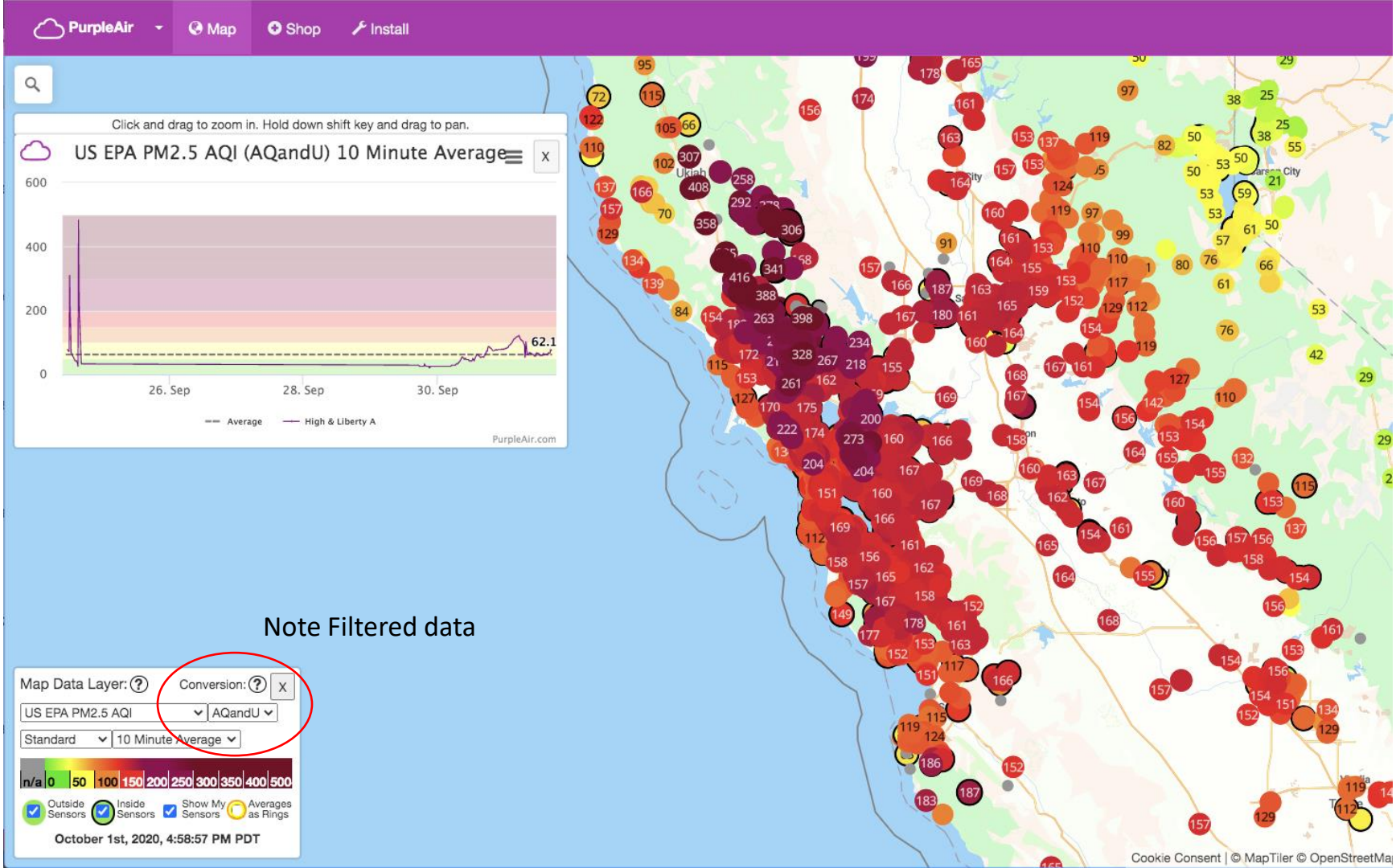
A tight envelope helps control building air flows making these strategies more effective

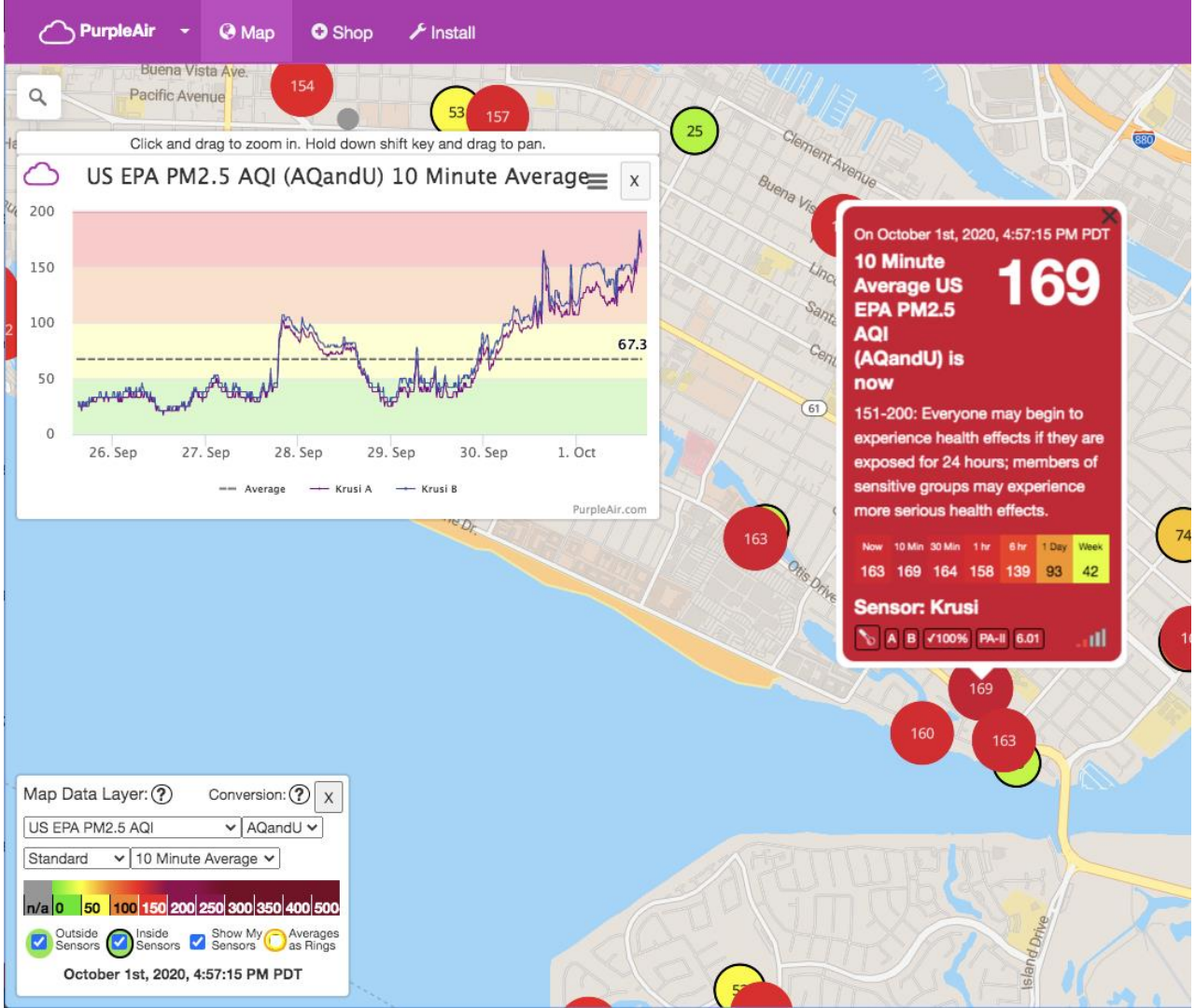
Wildfire Solutions

- Affordable sensors for decision making
  - Automated building controls
  - When to send everyone home???
  - Lots of new products and research
- Low cost monitors are OK –but need converting
- If there's lots of ash need to clean outdoor coils , air intakes, PV systems, etc.






PurpleAir
Map
Shop
Install
Click and drag to zoom in. Hold down shift key and drag to pan.
US EPA PM2.5 AQI (AQandU) 10 Minute Average
600
400
200
0
62.1
26. Sep
28. Sep
30. Sep
Average
High & Liberty A
PurpleAir.com
Note Filtered data
Map Data Layer:
Conversion:
US EPA PM2.5 AQI
AQandU
Standard
10 Minute Average
n/a 0 50 100 150 200 250 300 350 400 500
Outside Sensors
Inside Sensors
Show My Sensors
Averages as Rings
October 1st, 2020, 4:58:57 PM PDT
Cookie Consent | © MapTiler © OpenStreetMap


PurpleAir
Map
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Buena Vista Ave
Pacific Avenue
Clement Avenue
Otis Drive
Island Drive
Click and drag to zoom in. Hold down shift key and drag to pan.
US EPA PM2.5 AQI (AQandU) 10 Minute Average
200
150
100
50
0
67.3
26. Sep
27. Sep
28. Sep
29. Sep
30. Sep
1. Oct
Average
Krusi A
Krusi B
PurpleAir.com
On October 1st, 2020, 4:57:15 PM PDT
10 Minute Average US EPA PM2.5 AQI (AQandU) is now
169
151-200: Everyone may begin to experience health effects if they are exposed for 24 hours; members of sensitive groups may experience more serious health effects.
Now 10 Min 30 Min 1 hr 6 hr 1 Day Week
163 169 164 158 139 93 42
Sensor: Krusi
A B ✓100% PA-II 6.01
Map Data Layer:
Conversion:
US EPA PM2.5 AQI
AQandU
Standard
10 Minute Average
n/a 0 50 100 150 200 250 300 350 400 500
Outside Sensors
Inside Sensors
Show My Sensors
Averages as Rings
October 1st, 2020, 4:57:15 PM PDT

Ventilation, COVID-19 and Wildfires: At what point do we reduce outdoor air?

- With good (MERV 13 or better) filters on supply air systems – no need to reduce outdoor air
  - For healthcare/elder care facilities its imperative to have better filtration due to higher COVID sensitivity
- General guidance for buildings without good supply filtration:
  - if exposure to outdoor air would cause an immediate problem (acute exposure) rather than long-term (chronic) then reduce outdoor air
    - If AQI > 150
    - For sensitive population, if AQI >100
  - Use good filters – room air cleaners really work well

What about the future?

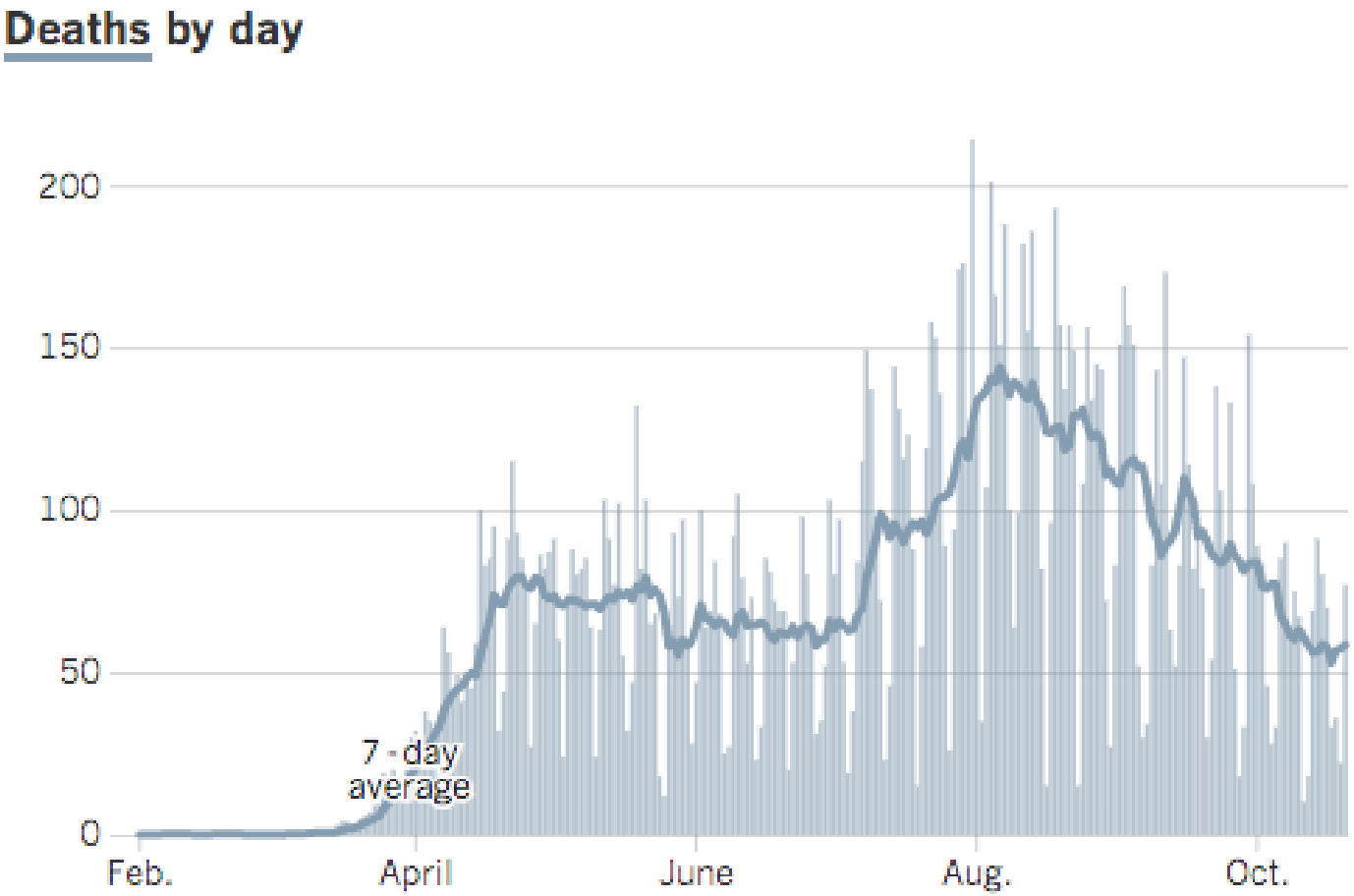
Given that:

- Wildfires are here to stay
- COVID-19 might be around for a while and there is related *increased interest in how public health relates to IAQ*

1. Envelope airtightness matters.
   - A tight envelope is a good filter
   - A tight envelope lets us control air flows
2. Buildings need an alternative to open windows for ventilation
3. More focus on filtration/air cleaning
4. Sensors and controls will become integrated into HVAC/Envelopes
5. We will need to use low-emitting materials in construction

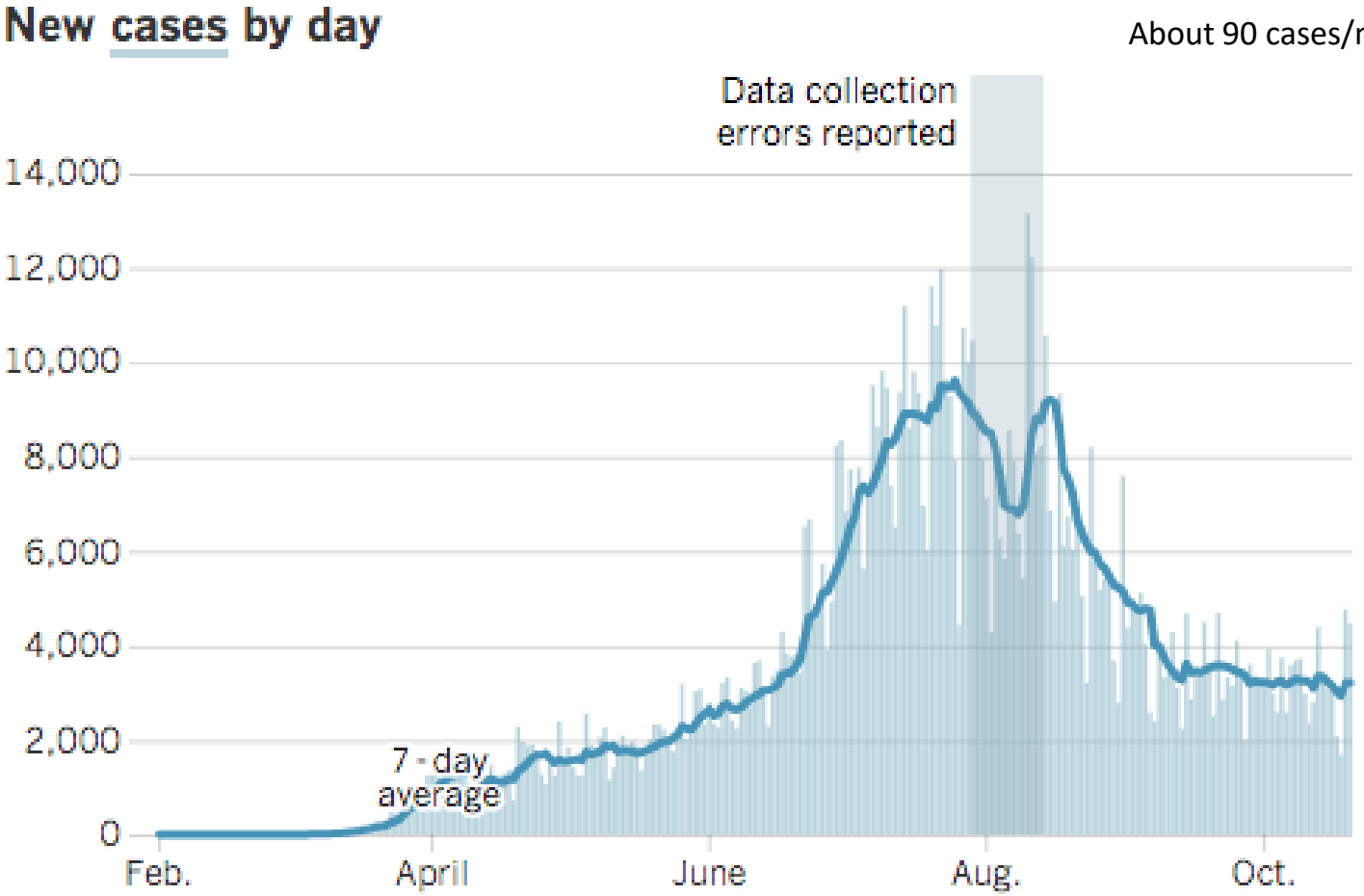
How are we doing at controlling COVID-19?

LA Times California dashboard



LA Times California dashboard

About 90 cases/million people



British Columbia COVID-19 Dashboard

Filter Dashboard Values by Health Authority: All | Interior | Fraser | Vancouver Coastal | Vancouver Island | Northern

Total Cases
11,189

Laboratory Diagnosed	Epi-Linked
10,982	207

Currently Hospitalized
72

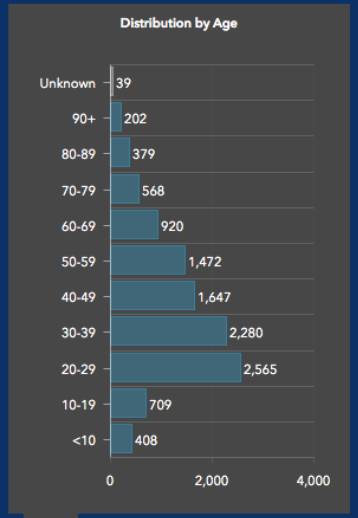
Total to Date: 880

Currently Admitted to ICU
26

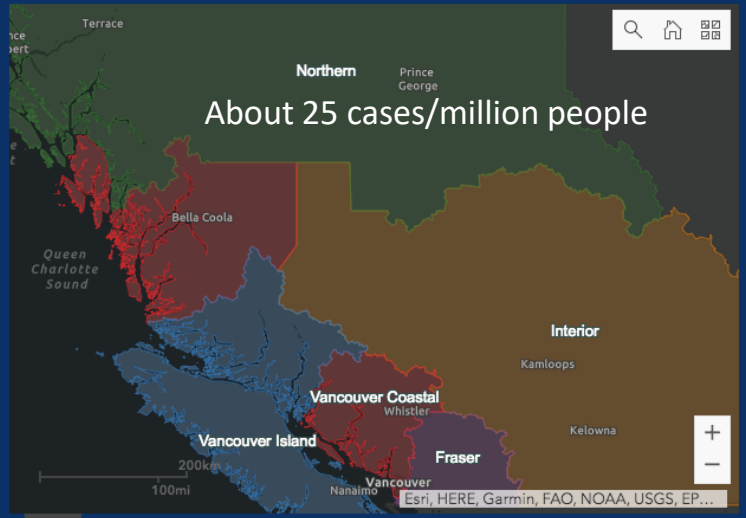
Confirmed Deaths
251

Recovered
9,387

Last Update
10/16/2020, 4:30 PM



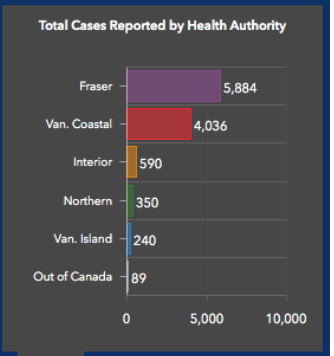
Age | Sex



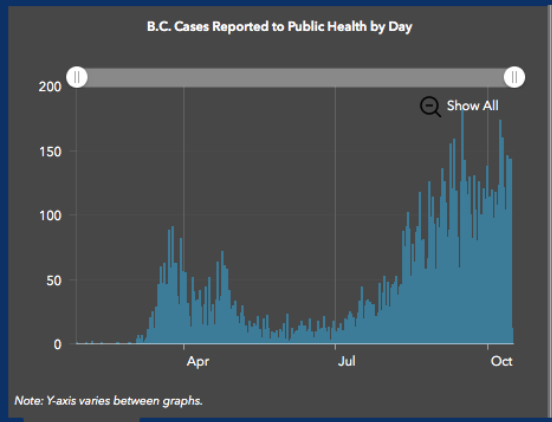
Map | International Comparison

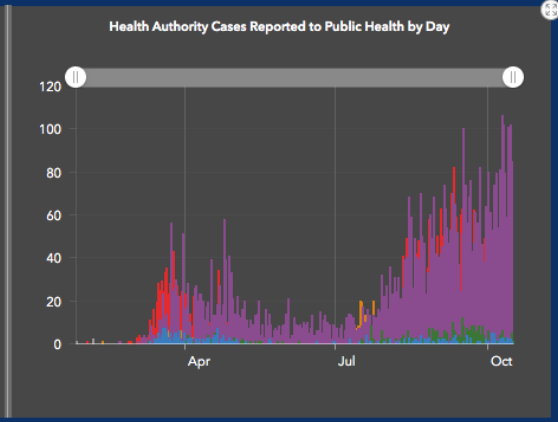
New Cases
155

Active Cases
1,513



Cases | New | Active | List





Cases by Day | New Tests | Turn-Around | Positivity

Total Tests
703,402

New Tests
10,855

B.C. Testing Rate	Canadian Testing Rate
104,749	223,552
People per 1,000,000	People per 1,000,000

Data notes, terms of use, disclaimer and limitations of liability

The following data notes define the indicators presented on the public dashboard and describe the data sources involved. Data changes daily as new cases are identified, characteristics of reported cases change

Provincial Health Services Authority

BC Centre for Disease Control

Thanks for listening

iswalker@lbl.gov

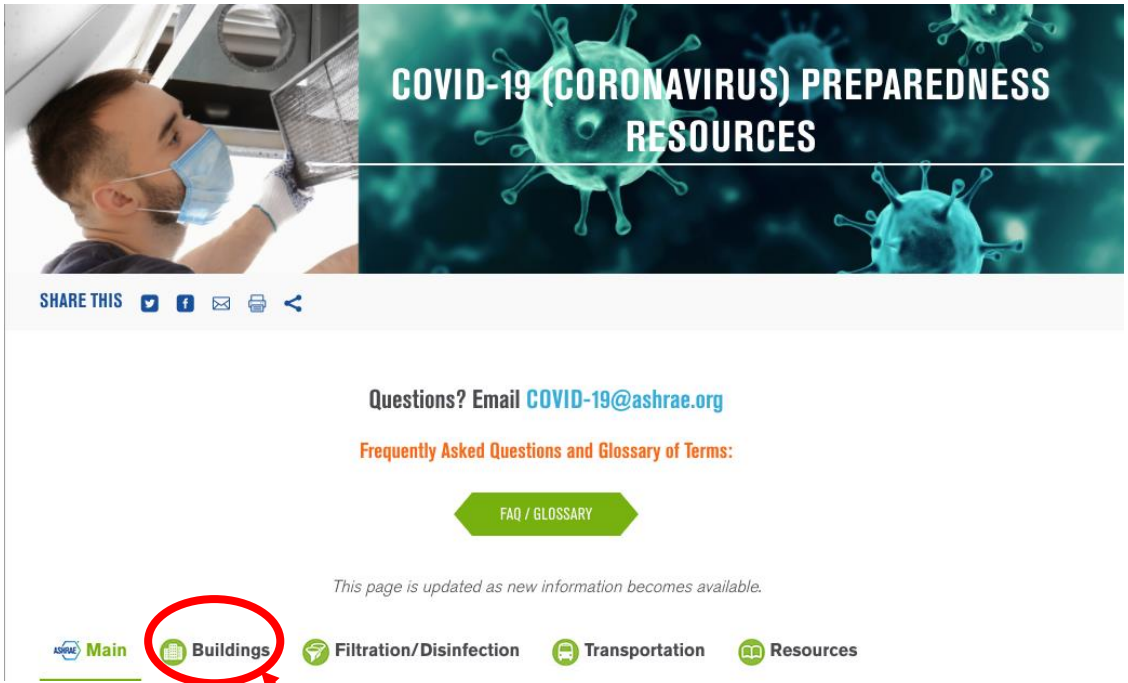
Additional slides

ASHRAE Guidance

- Control humidity in 40-60% range + temperatures in ASHRAE 55 comfort range
  - In cold climates be aware of potential surface condensation
- Consider use of upper-room UVGI lamps where there are large assemblies of people
- Add duct- or air-handling-unit-mounted, upper room, and/or portable UVGI
- Improve central air and other HVAC filtration to MERV13 or the highest level achievable
- Increase outdoor air ventilation, disable demand-controlled ventilation and open outdoor air dampers to 100% as indoor and outdoor conditions permit
- Add portable room air cleaners
- Aim for lower CO_2 : between 800 and 1000 ppm

Key Resources - ASHRAE

- https://www.ashrae.org/covid19



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

Impact of climate and public health interventions on the COVID-19 pandemic: a prospective cohort study

Peter Jüni MD, Martina Rothenbühler PhD, Pavlos Bobos MSc, Kevin E. Thorpe MMath, Bruno R. da Costa PhD, David N. Fisman MD, Arthur S. Slutsky MD, Dionne Gesink PhD

Cite as: *CMAJ* 2020. doi: 10.1503/cmaj.200920; early-released May 8, 2020

Applied and Environmental Microbiology, May 2010, p. 2712–2717 Vol. 76, No. 9
0099-2240/10/$12.00 doi:10.1128/AEM.02291-09

Effects of Air Temperature and Relative Humidity on Coronavirus Survival on Surfaces[▽]

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Hindawi Publishing Corporation
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Research Article

The Effects of Temperature and Relative Humidity on the Viability of the SARS Coronavirus

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CORRESPONDENCE

Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1

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RAPID COMMUNICATIONS

Stability of Middle East respiratory syndrome coronavirus (MERS-CoV) under different environmental conditions

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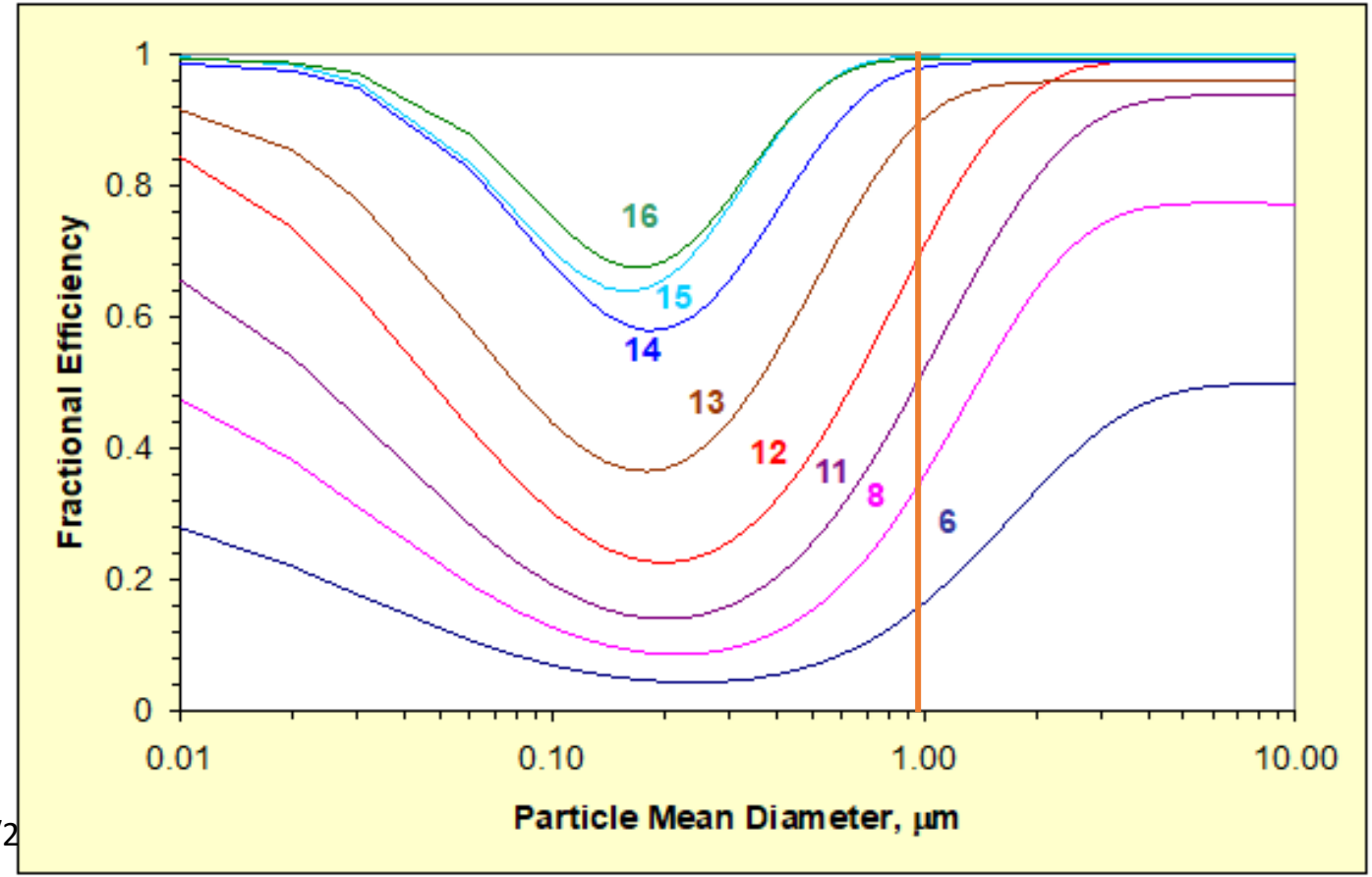
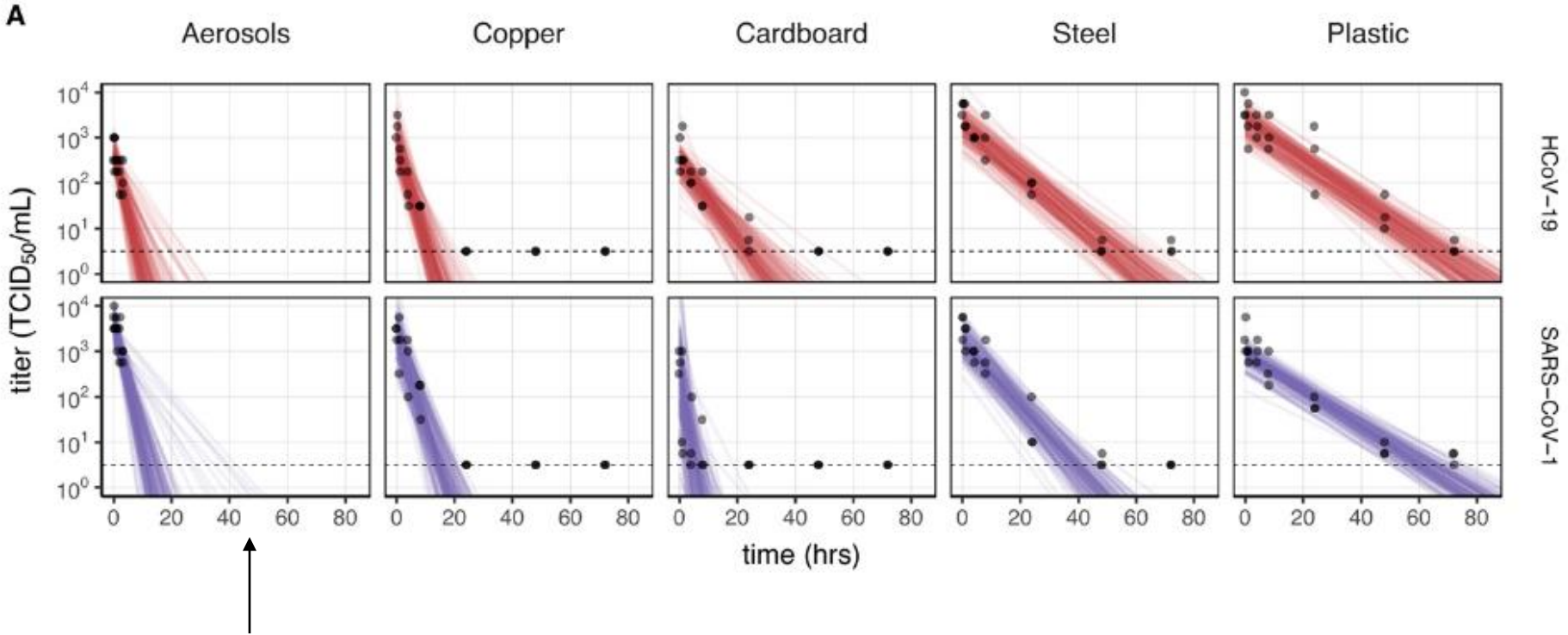
MERV ratings for filters



Virus viable in aerosols for hours, longer on some



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.

Mask material: cotton seems to be better

Table 1. Filtration Efficiencies of Various Test Specimens at a Flow Rate of 1.2 CFM and the Corresponding Differential Pressure (ΔP) across the Specimen[a]

	flow rate: 1.2 CFM		
	filter efficiency (%)		pressure differential
sample/fabric	<300 nm average ± error	>300 nm average ± error	ΔP (Pa)
N95 (no gap)	85 ± 15	99.9 ± 0.1	2.2
N95 (with gap)	34 ± 15	12 ± 3	2.2
surgical mask (no gap)	76 ± 22	99.6 ± 0.1	2.5
surgical mask (with gap)	50 ± 7	44 ± 3	2.5
cotton quilt	96 ± 2	96.1 ± 0.3	2.7
quilter's cotton (80 TPI), 1 layer	9 ± 13	14 ± 1	2.2
quilter's cotton (80 TPI), 2 layers	38 ± 11	49 ± 3	2.5
flannel	57 ± 8	44 ± 2	2.2
cotton (600 TPI), 1 layer	79 ± 23	98.4 ± 0.2	2.5
cotton (600 TPI), 2 layers	82 ± 19	99.5 ± 0.1	2.5
chiffon, 1 layer	67 ± 16	73 ± 2	2.7
chiffon, 2 layers	83 ± 9	90 ± 1	3.0
natural silk, 1 layer	54 ± 8	56 ± 2	2.5
natural silk, 2 layers	65 ± 10	65 ± 2	2.7
natural silk, 4 layers	86 ± 5	88 ± 1	2.7
hybrid 1: cotton/chiffon	97 ± 2	99.2 ± 0.2	3.0
hybrid 2: cotton/silk (no gap)	94 ± 2	98.5 ± 0.2	3.0
hybrid 2: cotton/silk (gap)	37 ± 7	32 ± 3	3.0
hybrid 3: cotton/flannel	95 ± 2	96 ± 1	3.0

[a]The filtration efficiencies are the weighted averages for each size range—less than 300 nm and more than 300 nm.

Particle filtration efficiencies of mask materials (Konda et al. 2020)

What about Humidity?

- Few direct studies - many questions about efficacy:
  - VanDoremalen (2020) SARS-COV-2, stable for hours in air at 60% RH
  - VanDoremalen (2013) MERS-COV no reduction in stability at 40% RH over 48 hours
  - Chan (2011) SARS-COV-1 viable on surfaces for 5 days with RH between 40% and 60%
  - US National Academy of Sciences (2020) No evidence of ambient RH link – other factors more important
  - Jüni (2020) Very weak evidence of link with ambient RH
  - Casanova (2020) gastroenteritis virus (TGEV) and mouse hepatitis virus (MHV) are indeed inactivated in the 40-60%RH range. BUT!... those were surrogates rather SARS-CoV-2.
- These (and other) studies conclude other factors vastly more important than humidity Does not remove virus on time scale of other options: ventilation/filtration.
- Better to keep RH and T in comfort range for occupants and acceptable range for building envelope (>60%RH in winter problematic for building envelopes)