THE LATEST RESEARCH IMPACTING WORKPLACE RE-OCCUPANCY PLANNING

Steve Horwood and Luke Leung

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COVID-19 & Ventilation

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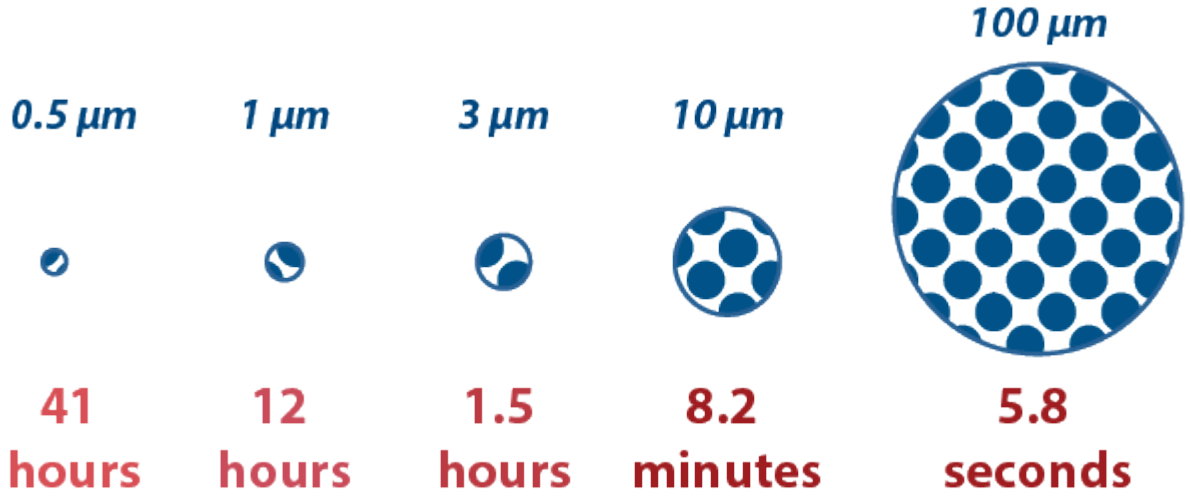
SARS-CoV-2

Time to settle 5 feet by unit density spheres



- Typical droplet size is between 5 to 10 µm
- Naked virus size is in average between 0.06 – 0.15 µm
- Contaminated droplets can float in the air and infect others
- With direct air stream, it is possible contaminated micro droplets can be propelled further in the air or stay suspended longer.

Modes of Transmission

- Infectious droplets (air or surface) are still believed to be the primary route of transmission via
  - Fomite – touch an contaminated area then touch eyes/nose
  - Direct – Exhale infectious droplets to other
  - Local Air – Inhale infectious droplets while still in air
- There is an increase body of researches suggesting the possibility of aerosol path. WHO's July 9th briefing and recent (July) update from EPA.
- We still don't know the required dose of viable virus to infect a healthy person

Is It In My HVAC System?

- Studies had shown traces of SARS-CoV-2 virus RNA throughout the HVAC system in facilities with active COVID-19 patients.
- Samples were taken by following the return air flow from space all the way to the return air damper before the mixing dampers and 25% of the samples were found positive
- However, it does not mean they are still active and the dose is enough to infect a healthy person.
- All we can conclude is it can circulate within HVAC system, but inconclusive on if it can be transmitted through HVAC system.

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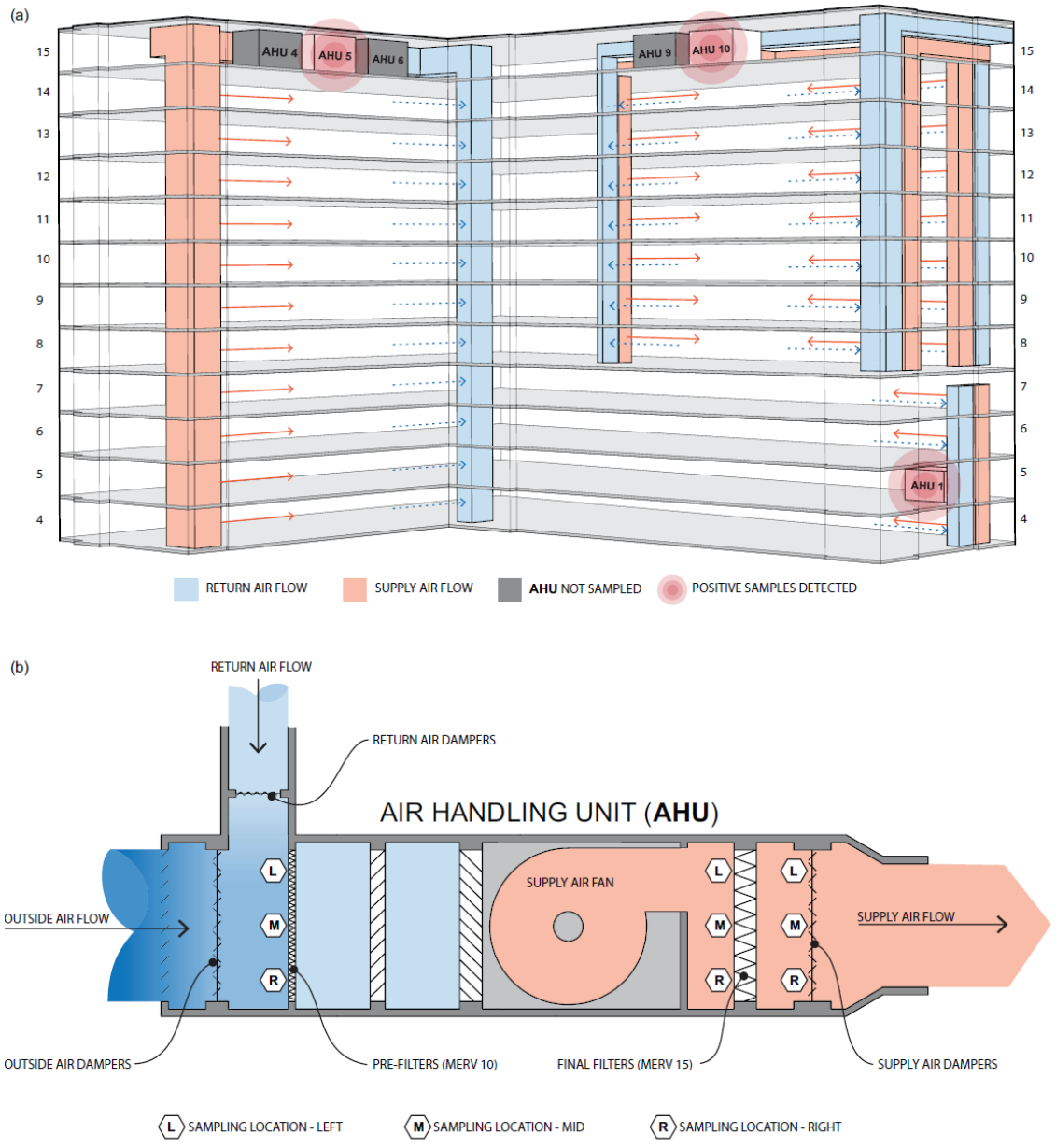
VIRUS FOUND IN AHU

	Pre-Filters		Final Filters		Supply Air Dampers	
	Total Number (n)	Number Positive (%)	Total Number (n)	Number Positive (%)	Total Number (n)	Number Positive (%)
	20	7 (35)	12	2 (16.67)	24	5 (20.8)
Cumulative Gene Copies ($\bar{x}$)	354.8 (34.2)		103.2 (86.2)		342.5 (77.7)	



Identification of SARS-CoV-2 RNA in Healthcare Heating, Ventilation, and Air Conditioning Units
Patrick F. Horve, Leslie Dietz, Mark Fretz, David A. Constant, Andrew Wilkes, John M. Townes, Robert G. Martindale, William B. Messer, Kevin G. Van Den, Wymelenberg

Breakdown of Two Super-spreader Cases

Restaurant in Guangzhou, China (Jan 2020)	Choir Practice in Seattle, USA (Mar 2020)
• Restaurant is a 5-floor building with no windows • Each floor has its own air-conditioner and exhaust fan • Diner's tables were 1 meter apart • Index case patient were asymptomatic • 9 infected cases within 3 clusters • Contaminated droplets were propelled to nearby diner's table by strong direct supply air stream • The restaurant staffs were not infected • Occupants from tables outside of airstream direction did not get infected • Limited physical movement of index patient • No outside air in the AC unit	• 61 choir members met in a church for a 2.5 hours long practice • Index case patient were symptomatic • 87% of attendees were infected (32 confirmed, 20 probable out of 60) • Virus was believed to be aerosolized from loud singing and speaking that contributed to both short-range air transmission and fomite transmission

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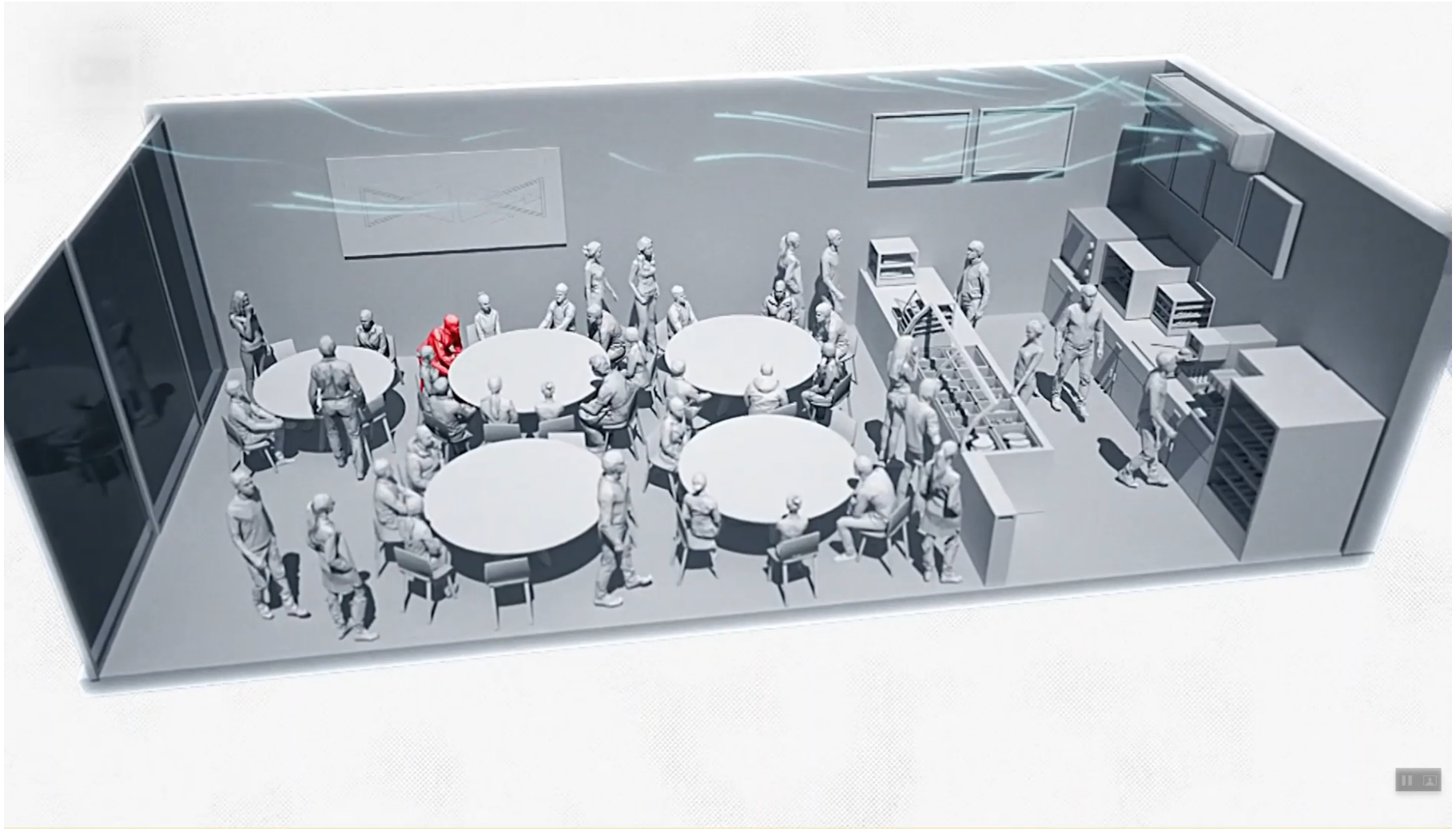
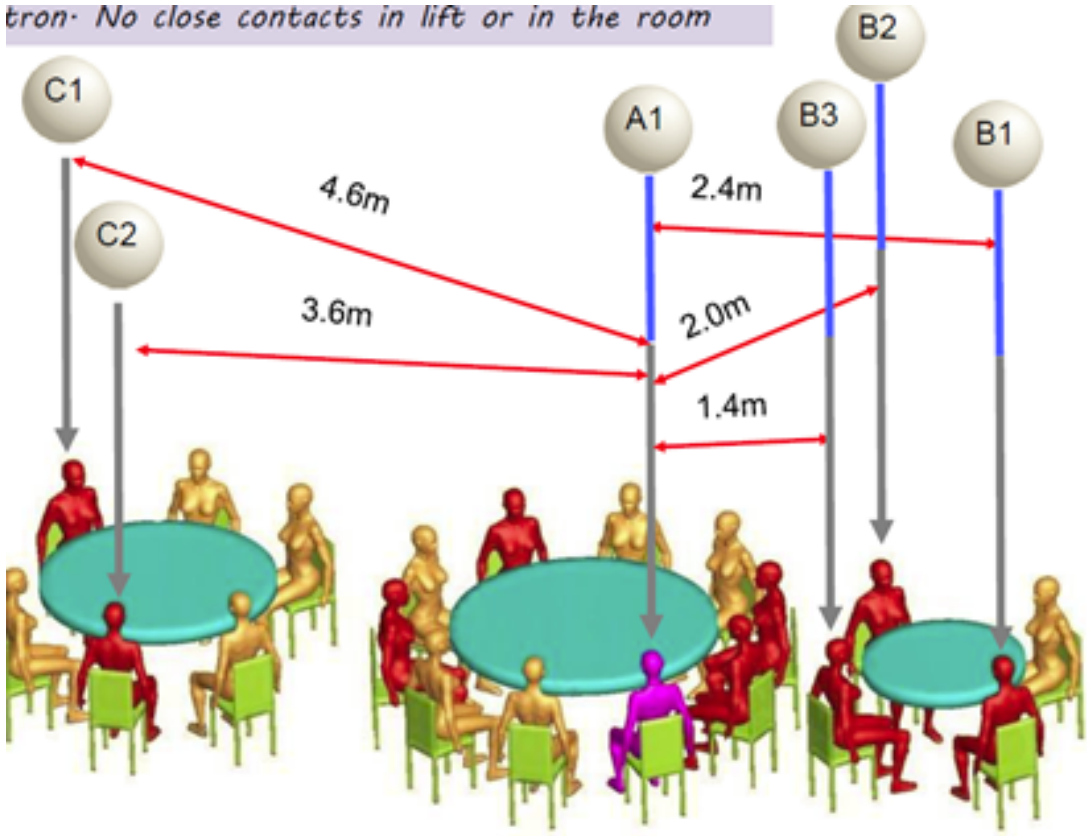
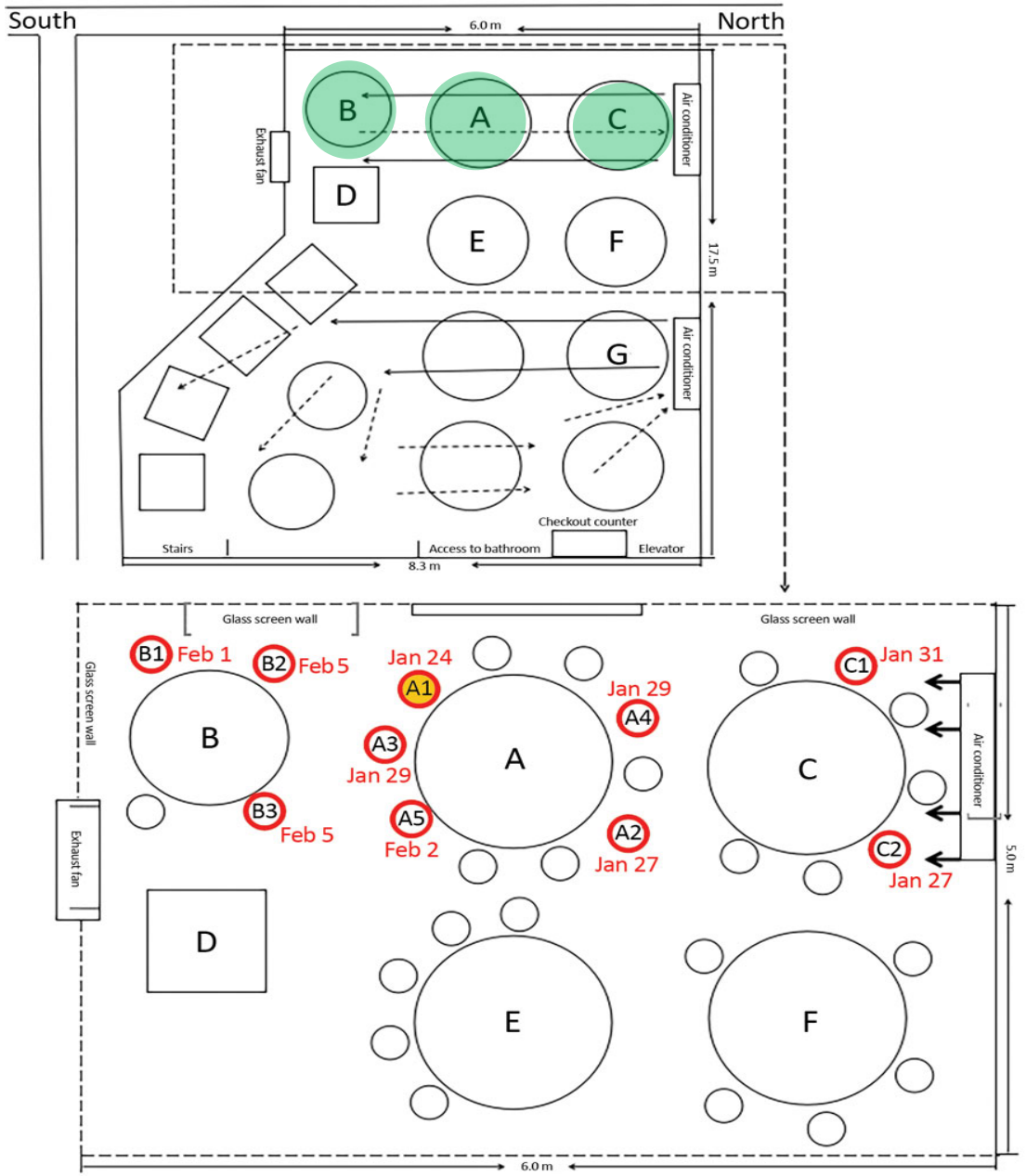
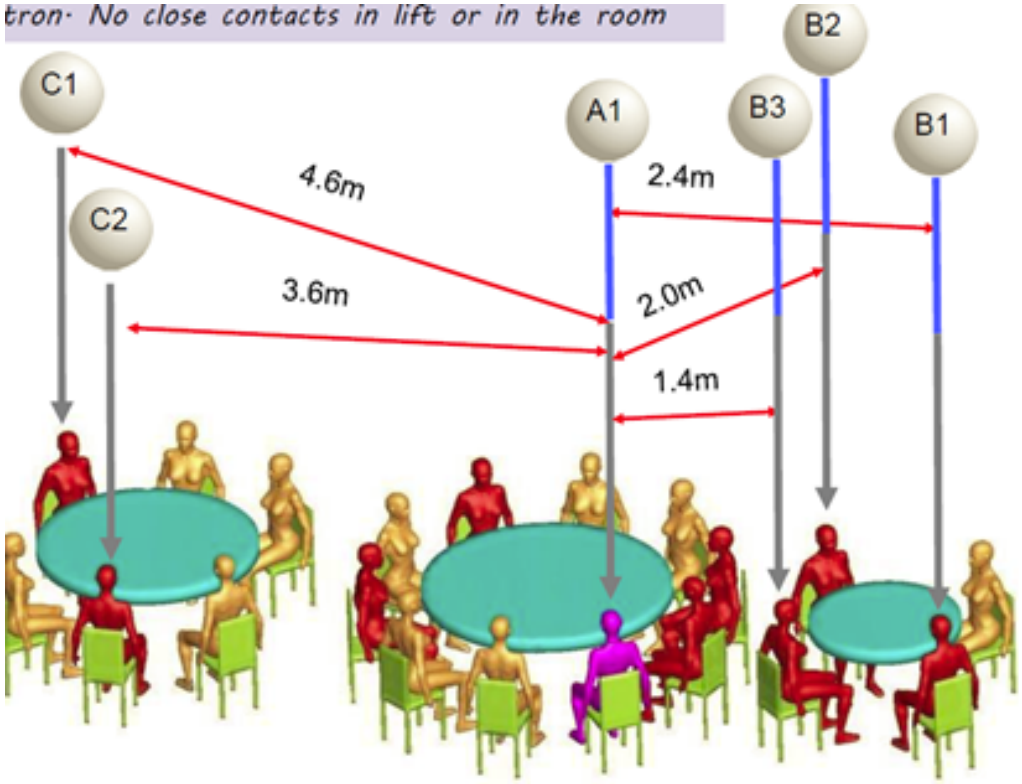



tron· No close contacts in lift or in the room
C1
C2
A1
B3
B2
B1
4.6m
3.6m
2.4m
2.0m
1.4m


South
North
6.0 m
B
A
C
Air conditioner
Exhaust fan
D
E
F
17.5 m
G
Checkout counter
Stairs
Access to bathroom
Elevator
8.3 m
Glass screen wall
Glass screen wall
Glass screen wall
B1 Feb 1
B2 Feb 5
B
B3 Feb 5
Exhaust fan
D
Jan 24
A1
Jan 29
A4
A3
Jan 29
A
A5
Feb 2
A2
Jan 27
C1 Jan 31
C
C2
Jan 27
Air conditioner
5.0 m
E
F
6.0 m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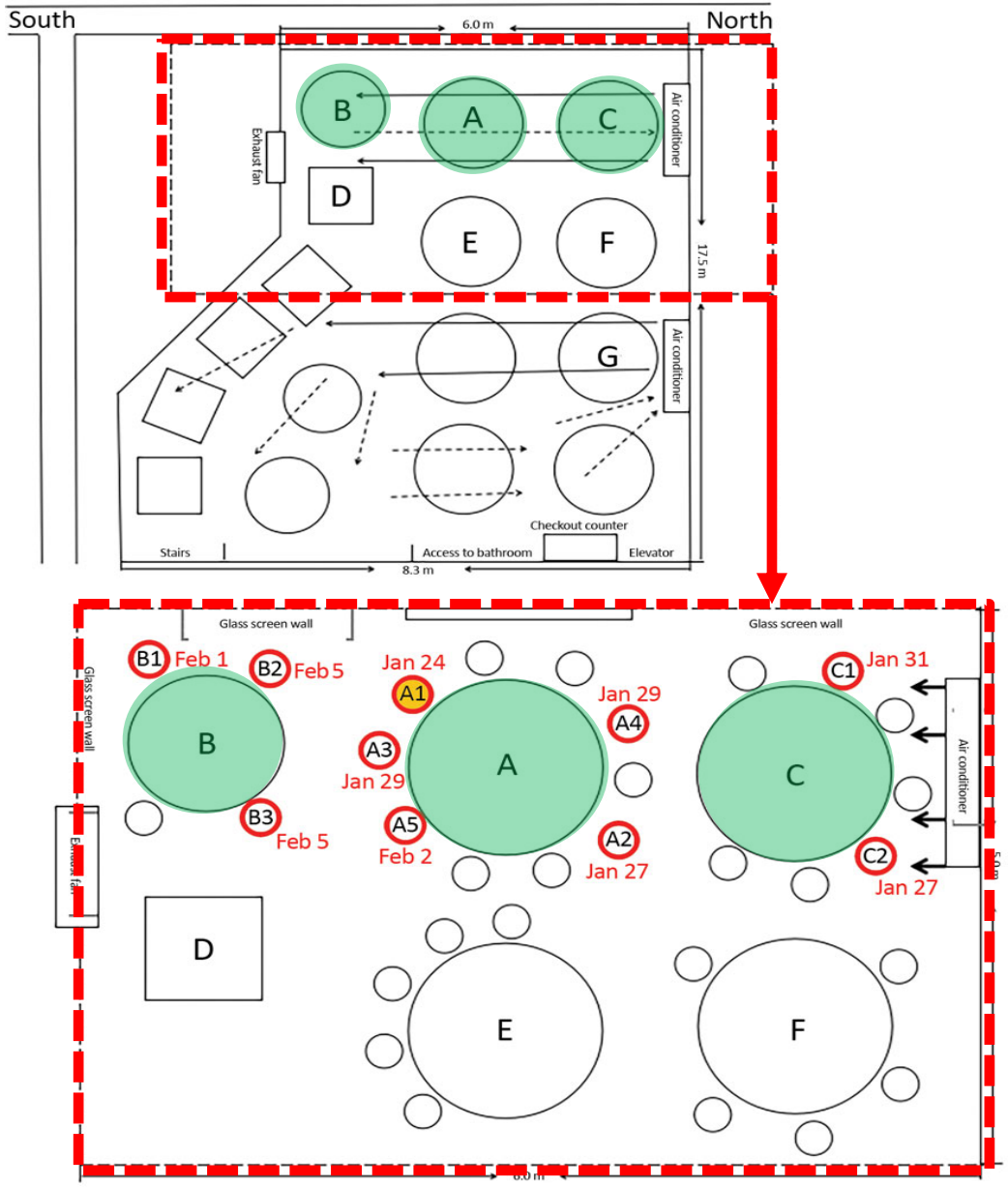
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B1 Feb 1
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B3 Feb 5
A1 Jan 24
A2 Jan 27
A3 Jan 29
A4 Jan 29
A5 Feb 2
C1 Jan 31
C2 Jan 27
Air conditioner
5.0m

Call to Action – Ventilation Unit Operation

Practice the "Do-No-Harm" principle and consider best practice measure against transmission

Goal	Actions	Considerations
Increase Dilution Ventilation	• Open outside air intake wider • Operate ventilation unit longer • Disable DCV control	• Impact on energy consumption relating to cooling/heating • Wear on ventilation unit and consumables • Condition of outside air (i.e. high PM2.5) • Location of outside air intake (i.e. next to pedestrian sidewalk) • Damper Operation (Linkage, Seal, Control, etc.)
Minimize local transmission	• Identify and minimize localized drafty spot • Adjust seating arrangement or air distribution	• Impact on air distribution and total air exchange

COVID-19 & Air Filtration

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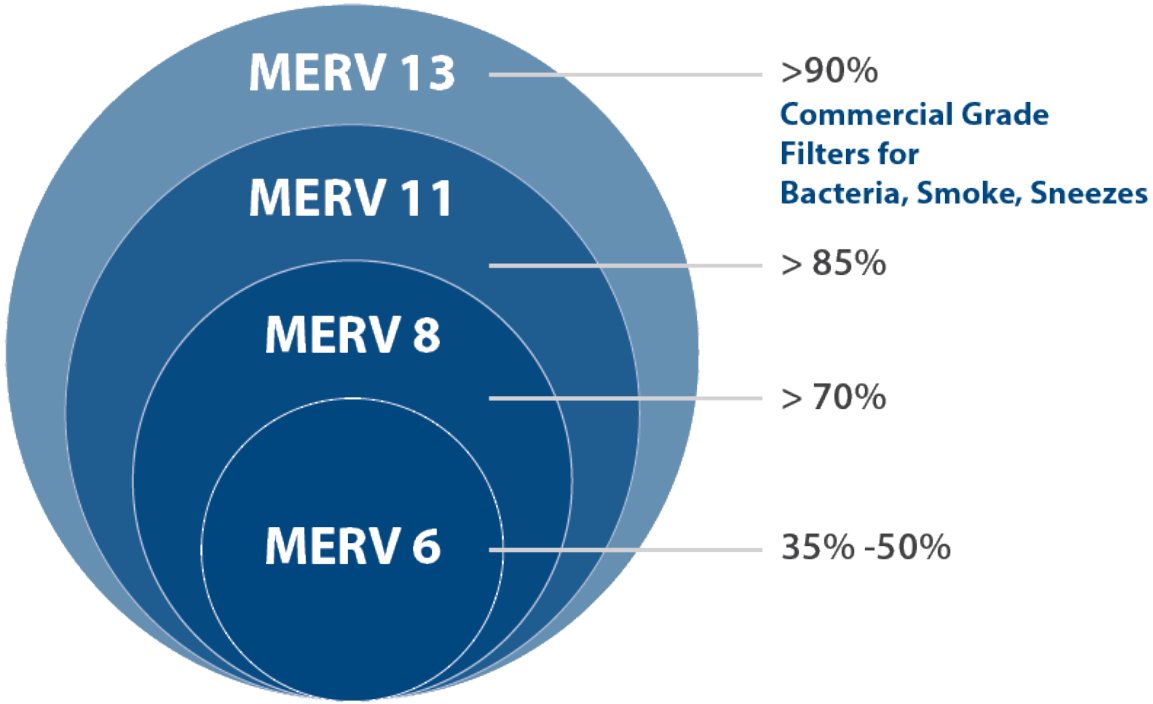
Filters vs. Droplets

MERV Rating
Trap particles size 3 to 10 microns



- Typical droplet size is between 5 to 10 µm
- Naked virus size is in average between 0.06 – 0.15 µm
- MERV-13 filters will capture 90% of particles between 3 to 10 µm

MERV Ratings

MERV Rating	Trap particles size 0.03 to 1 microns	Trap particles size 1 to 3 microns	Trap particles size 3 to 10 microns	Typical Application	Notes/ASHRAE Standards
MERV 1 - 4	N/A	N/A	< 20%	Fiberglass/Aluminum Mesh filter for Pollen, Dust Mites, Spray Paint, Carpet Fibres	
MERV 5	N/A	N/A	20% - 35%	Cheap Disposable Filters for Mold Spores, Cooling Dusts, Hair Spray, Furniture Polish	
MERV 6	N/A	N/A	35% - 50%		Minimum ASHRAE Standard for Commercial Application (62.1)
MERV 7	N/A	N/A	50% - 70%		
MERV 8	N/A	N/A	> 70%		Minimum ASHRAE Standard for High Performance Green Building Standard (189.1)
MERV 9	N/A	< 50%	> 85%	Better Box Filters for Lead Dust, Flour, Auto Fumes, Welding Fumes	
MERV 10	N/A	50% - 65%	> 85%		
MERV 11	N/A	65% - 80%	> 85%		Minimum ASHRAE Standard when atmospheric particulate matter is less than 2.5 micrometers, a.k.a. PM2.5 (62.1)
MERV 12	N/A	> 80%	> 90%		
MERV 13	< 75%	> 90%	> 90%	Commercial Grade Filters for Bacteria, Smoke, Sneezes	
MERV 14	75% - 85%	> 90%	> 90%		Recommended by ASHRAE Epidemic Task Force
MERV 15	85% - 95%	> 90%	> 90%		
MERV 16	> 95%	> 95%	> 95%		
MERV 17	99.97%	N/A	N/A	HEPA & ULPA for Viruses, Carbone Dust	HEPA = High-Efficiency Particulate Air
MERV 18	99.997%	N/A	N/A		
MERV 19	99.9997%	N/A	N/A		
MERV 20	99.99997%	N/A	N/A		

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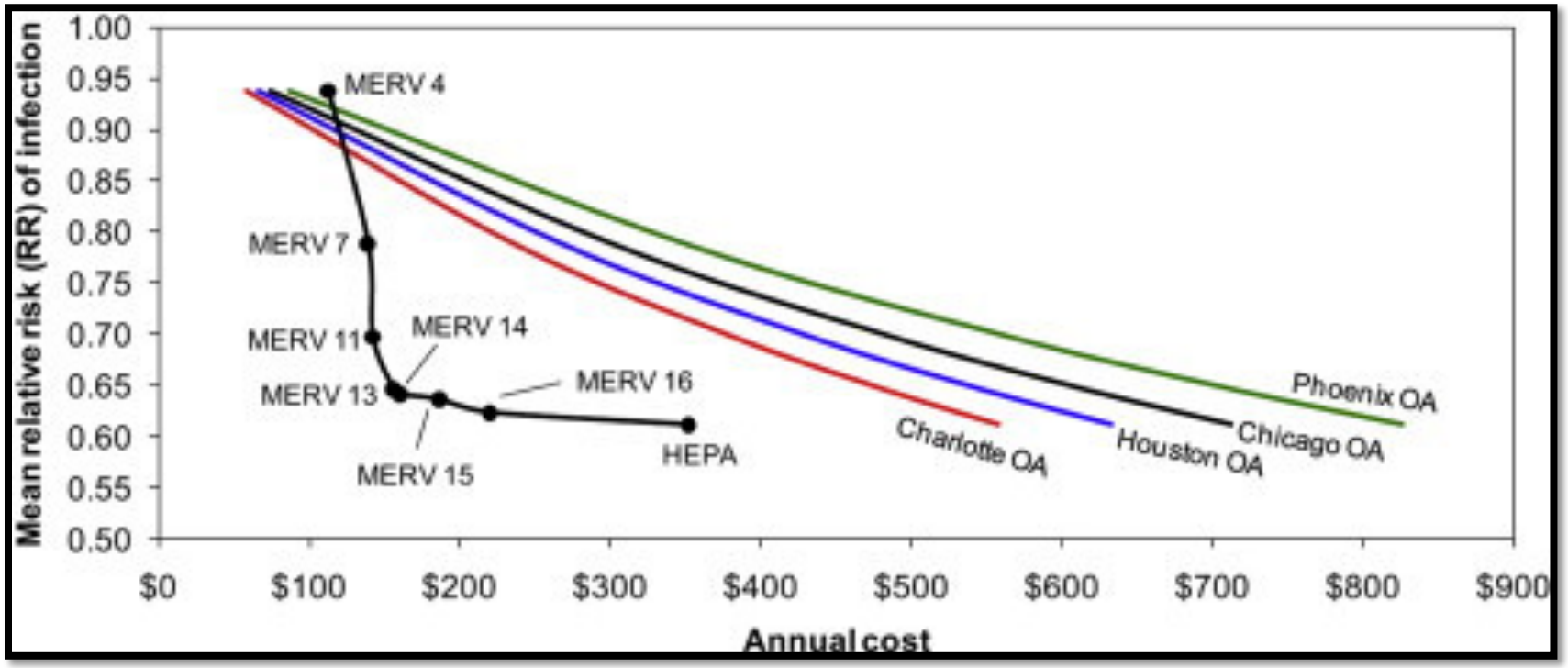
Filter Effectiveness vs. Operation Cost



P. Azimi and B. Stephens, "HVAC filtration for controlling infectious airborne disease transmission in indoor environments: Predicting risk reductions and operational costs," 04 09 2013. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7127325

Call to Action – Filter Upgrade

Practice the "Do-No-Harm" principle and consider best practice measure against transmission

HVAC Contractor	Name	
	Contact	
	Phone/Email	
BAS Contractor	Name	
	Contact	
	Phone/Email	
Air Balancer	Name	
	Contact	
	Phone/Email	
Base Building Engineer	Name	
	Contact	
	Phone/Email	
Base Building Commissioning Agent	Name	
	Contact	
	Phone/Email	

Available Documentations					
Electrical As-built	HVAC As-built	Manufacturer Manual	BAS Schematic	BAS Points list	Air Balancing Report

Notes

Existing Filter						New Filter					
Make:		Model:				Make:		Model:			
Size		Thickness		MERV		Size		Thickness		MERV	
Dirty			Clean			Dirty			Clean		
ΔP Setpoint	ΔP Actual	Supply CFM	ΔP Setpoint	ΔP Actual	Supply CFM	ΔP Setpoint	ΔP Actual	Supply CFM	ΔP Setpoint	ΔP Actual	Supply CFM
Motor RPM	Voltage	Amp	Motor RPM	Voltage	Amp	Motor RPM	Voltage	Amp	Motor RPM	Voltage	Amp

Sample Worksheet to be used for upgrading filter rating, follow ASHRAE recommendation for detail steps. https://www.ashrae.org/technical-resources/building-readiness#practical

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Be Mindful Of……

- The filter will only trap the virus, but not necessary kill it.
- Filters may be contaminated, so removal, bagging and disposal of these filters requires additional safety measures
- The ventilation system may not be designed for the characteristic of higher rating filters. (e.g. air flow, pressure drops, etc.)
- Bypass of filter by gaps around it – 10 mm gap between the filter and duct resulted in a decrease in the ultrafine particle collection efficiency of a MERV 15 filter by ~60%
- Cost Impact – Premium filter can be expensive

https://escholarship.org/content/qt53v69236/qt53v69236.pdf

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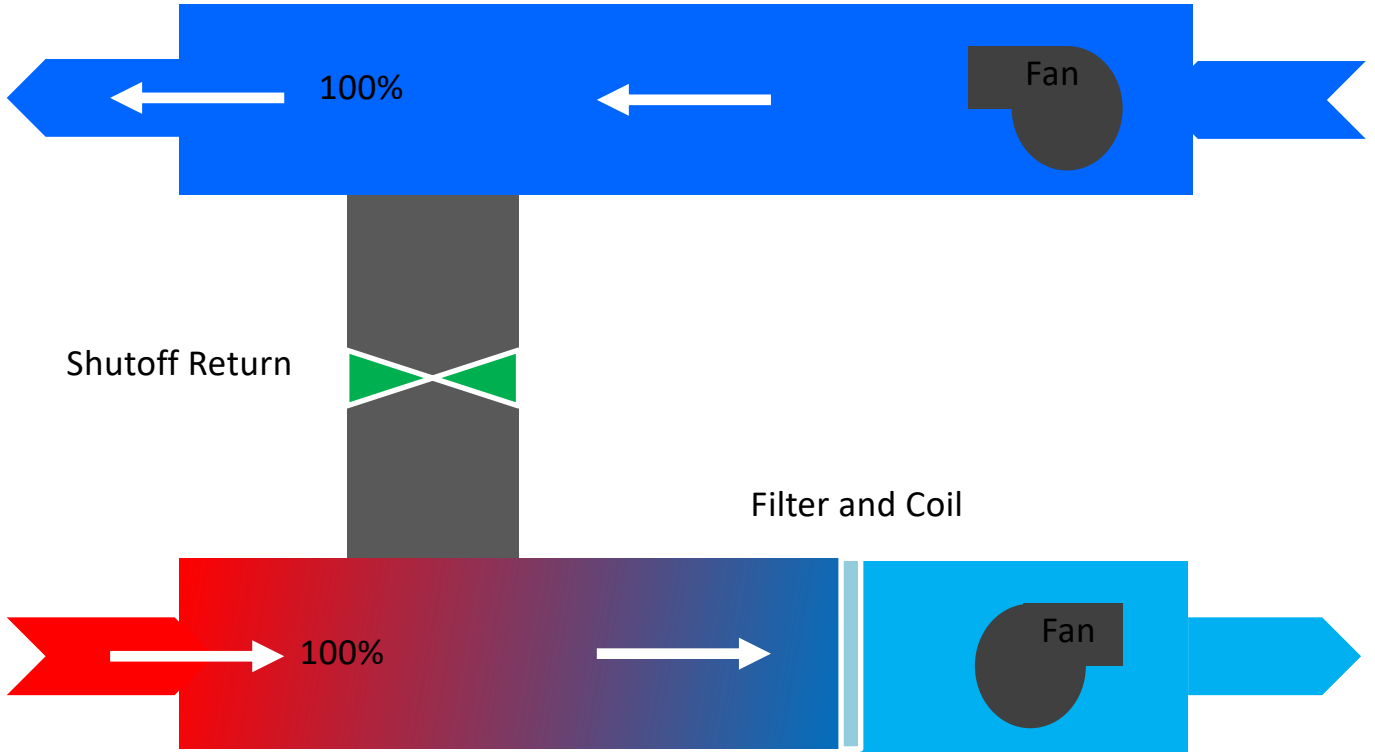
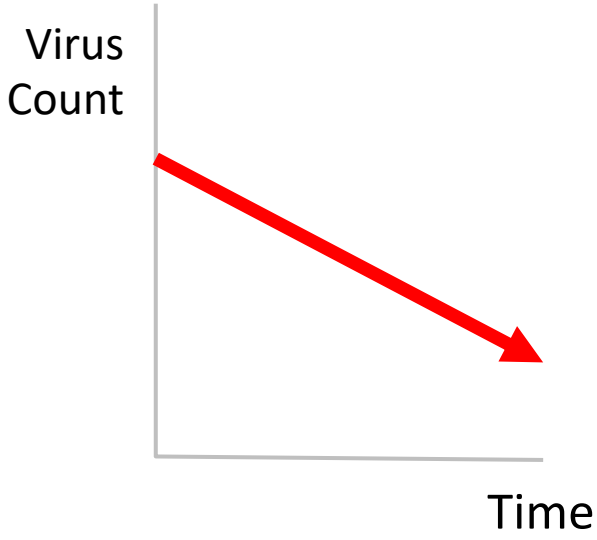
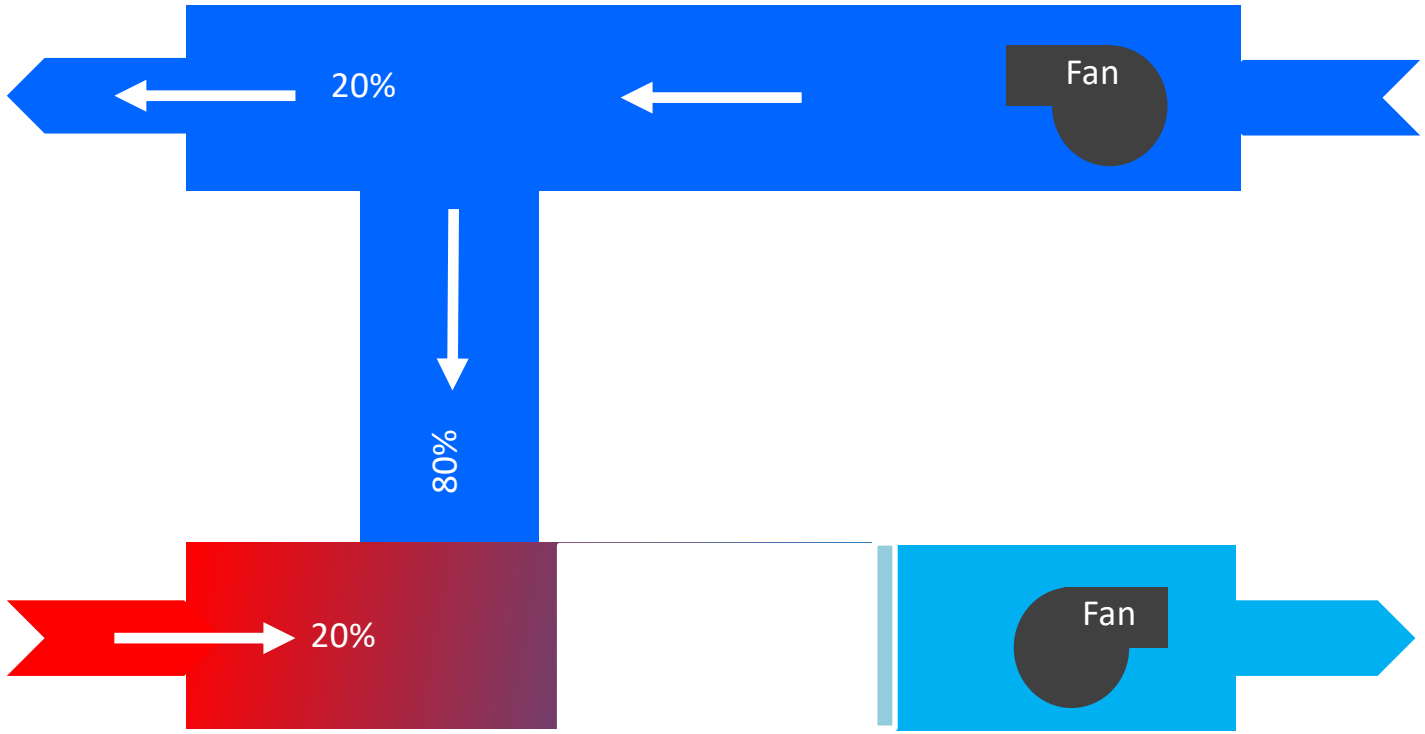
VAV SYSTEM
100% OUTSIDE AIR



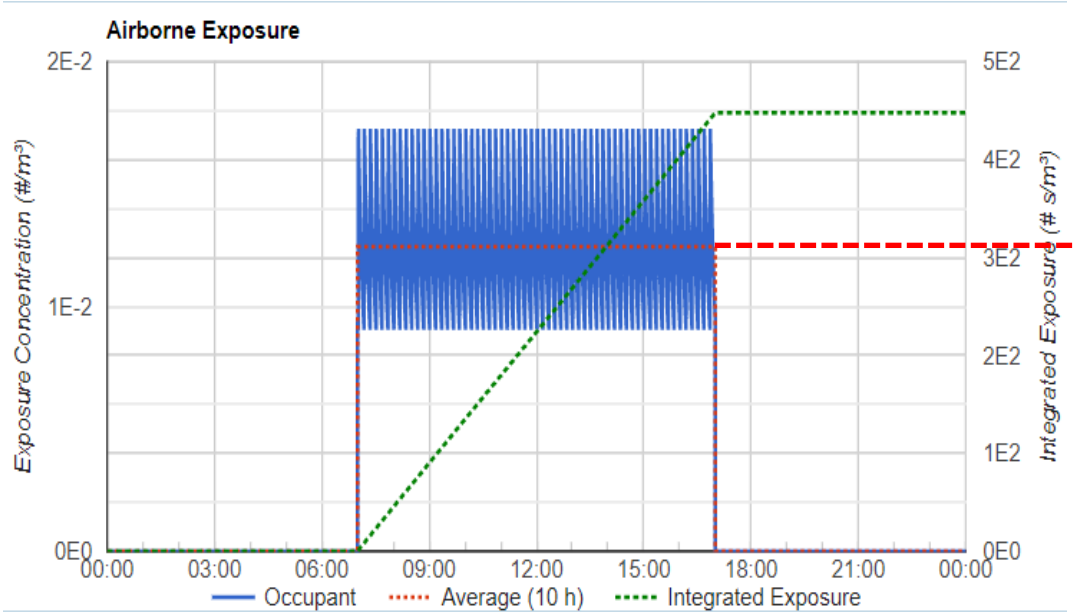
MINIMUM OUTSIDE AIR



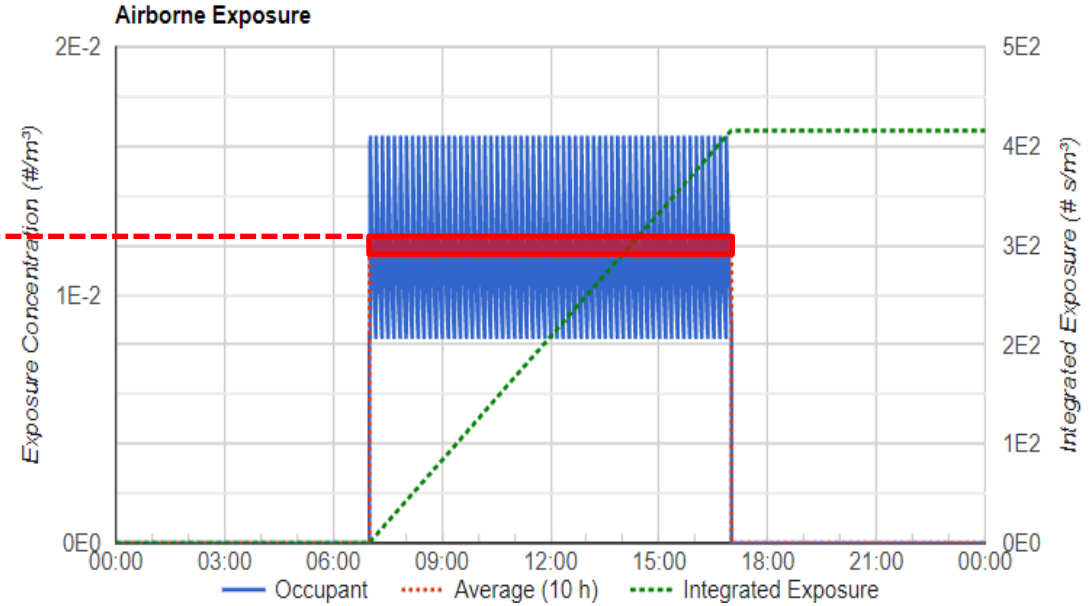


Operate and Maintain the HVAC System

MERV 13 FILTER IS MORE PRACTICAL THAN 100% OUTSIDE AIR



MERV 13 FILTER



100% OUTSIDE AIR

Environmental Condition - Temperature & Humidity

What Do You Know So Far?

- Studies show a direct correlation between the temperature and humidity to the decay of SARS-CoV-2.
- Optimal relative humidity range to minimizing airborne transmission is between 40%rh to 60%rh
- Higher space temperature reduces decay time of SARS-CoV-2

Surface Decay Calculator (DHS): https://www.dhs.gov/science-and-technology/sars-calculator
Airborne Decay Calculator (DHS): https://www.dhs.gov/science-and-technology/sars-airborne-calculator

Call to Action – Environmental Condition

Practice the "Do-No-Harm" principle and consider best practice measure against transmission

Goal	Actions	Considerations
Maintain optimal space RH between 40% to 60%	• Verify operation of humidifiers • Install humidifiers as required • Modify HVAC humidity control sequence and set points • Verify and calibrate accuracy of all humidity sensors	• Impact on energy consumption relating to humidification & de-humidification • Occupant Comfort • Original intent use of space • Wear/tear on ventilation unit and consumables • Condition of outside air humidity • Location of outside air intake
Increase space temperature	• Modify HVAC temperature control sequences & set points • Verify calibrate accuracy of all temperature sensors	• Impact on energy consumption relating to heating and cooling • Occupant Comfort • Wear/tear on ventilation unit and consumables • Condition of outside air temperature • Location of outside air intake

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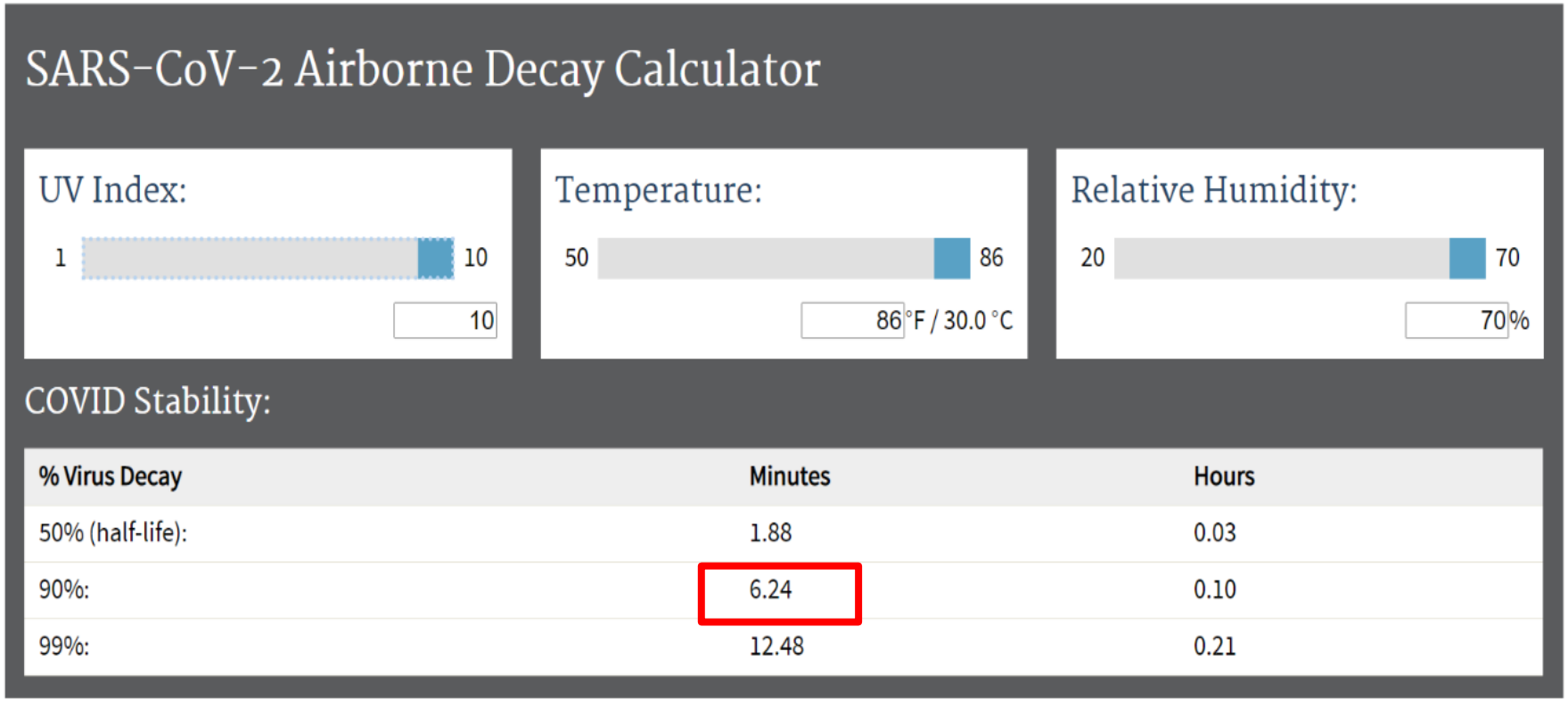
Review Indoor and Outdoor Environment

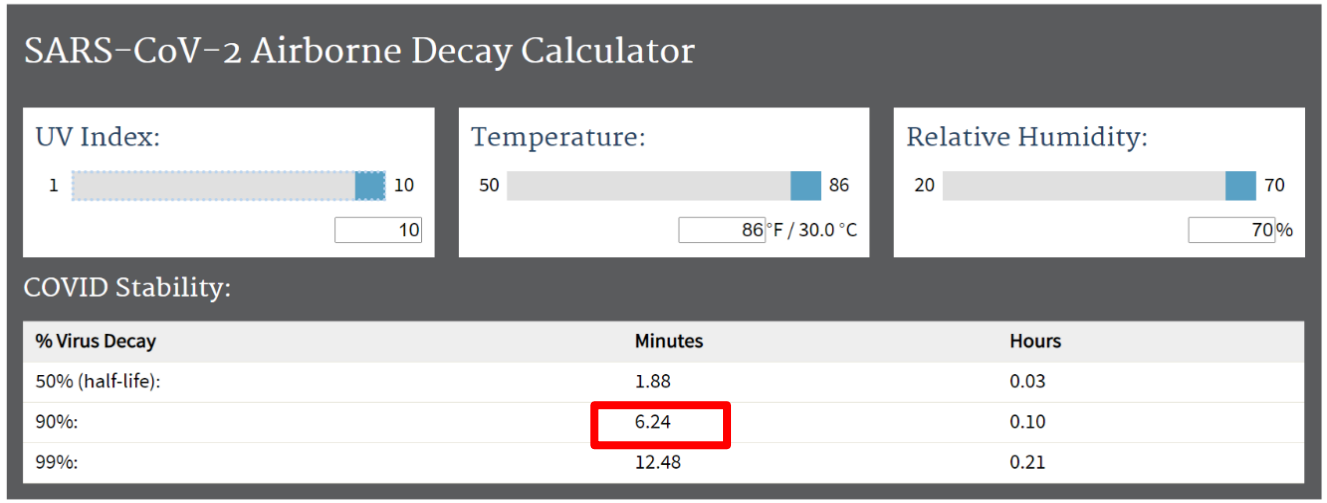
SARS-COV2 AIRBORNE DECAY CALCULATOR

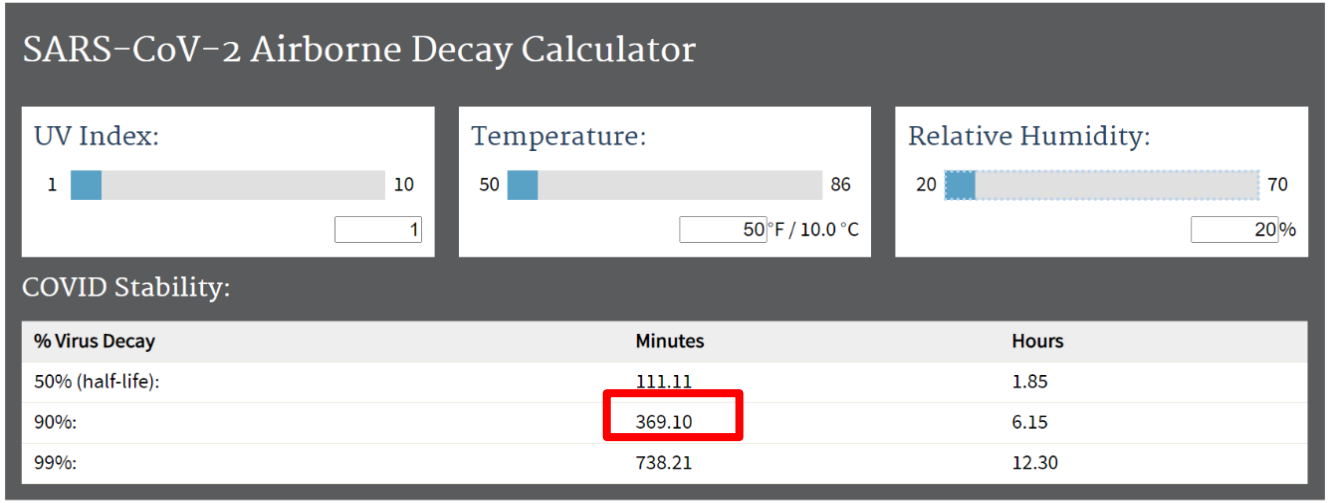


% Virus Decay	Minutes	Hours
50% (half-life):	1.88	0.03
90%:	6.24	0.10
99%:	12.48	0.21

Review Indoor and Outdoor Environment

SARS-COV2 AIRBORNE DECAY CALCULATOR





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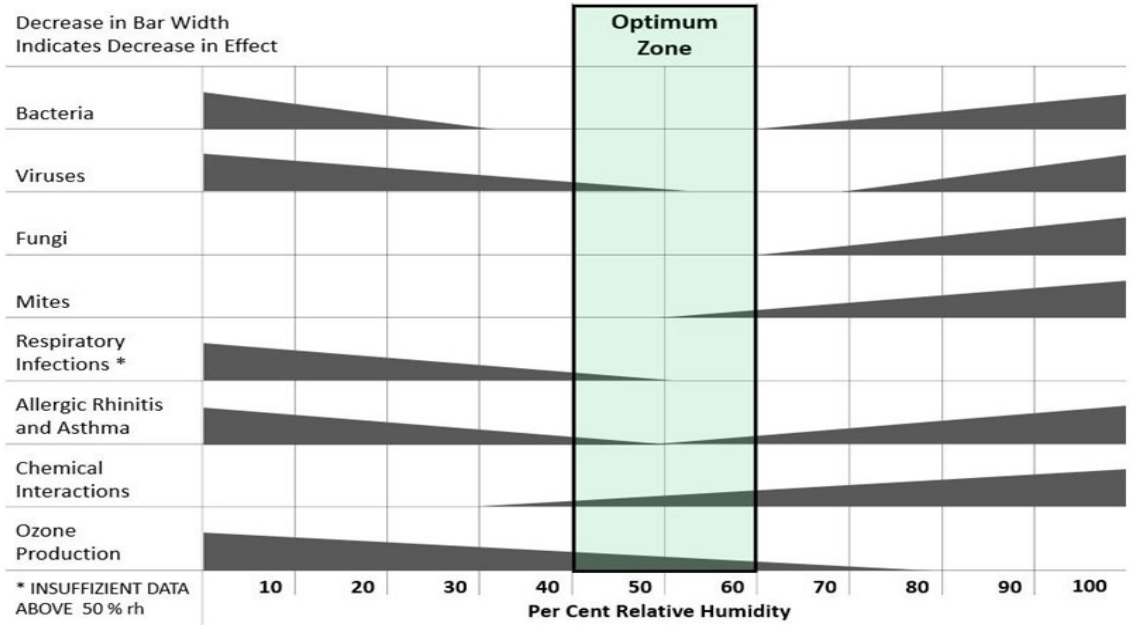

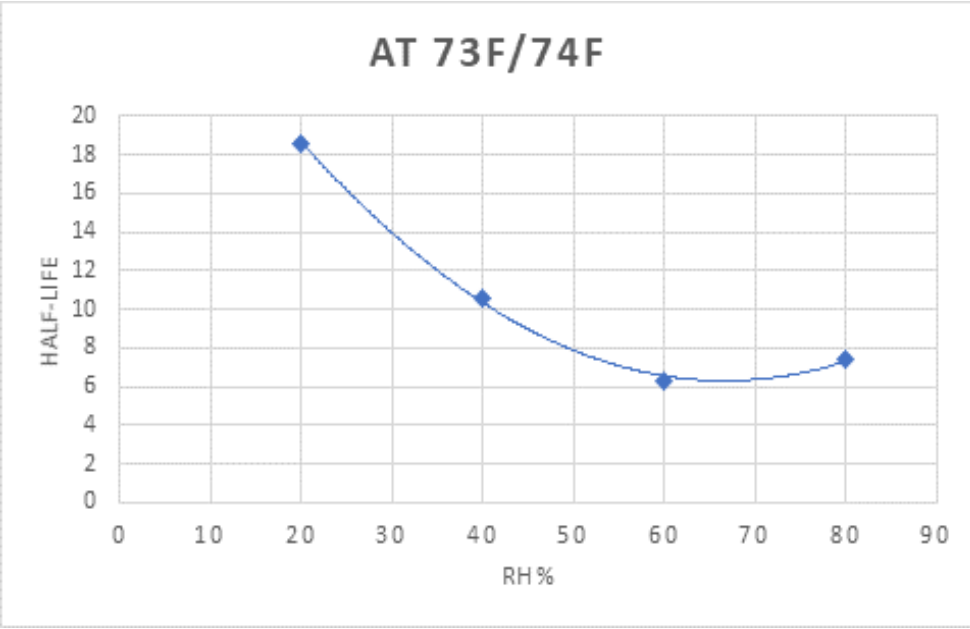

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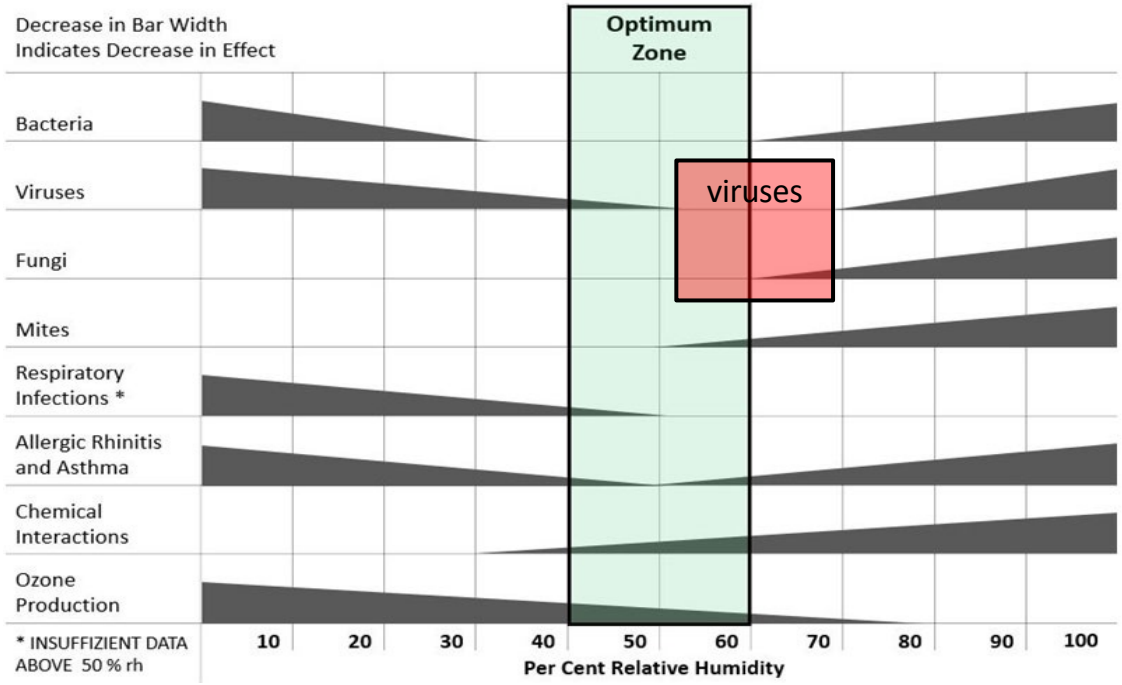

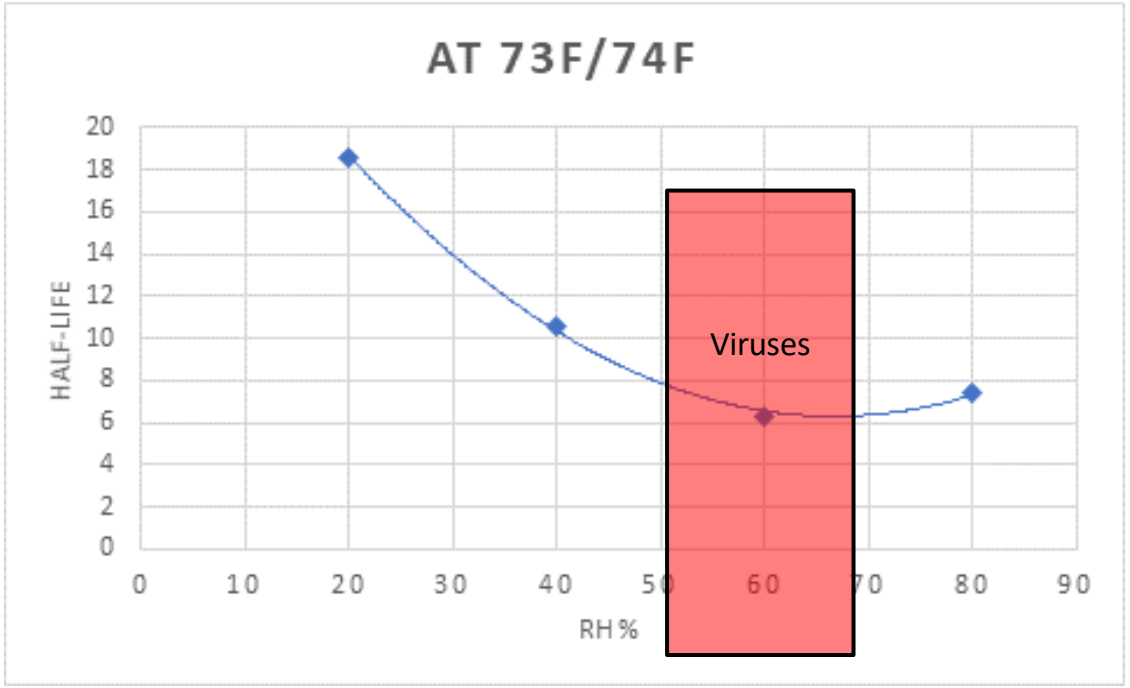

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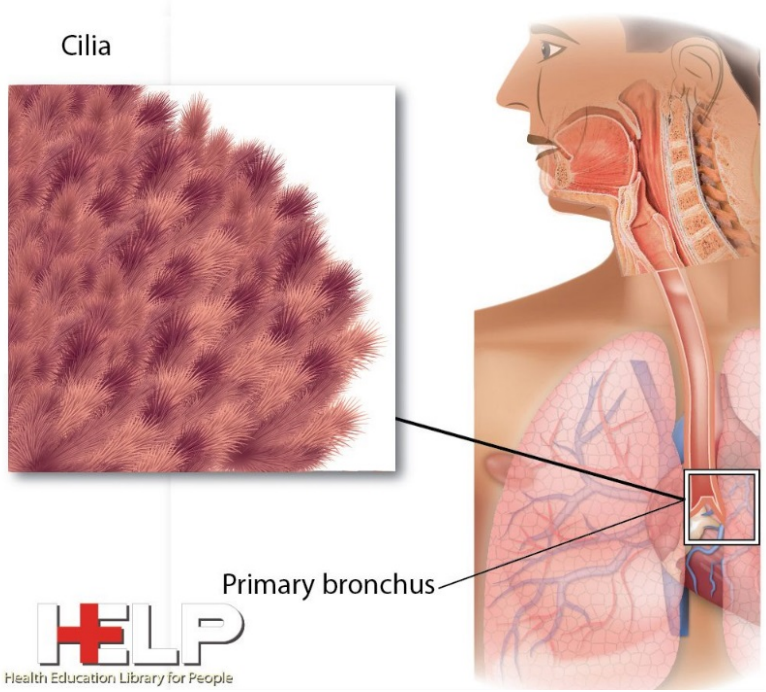
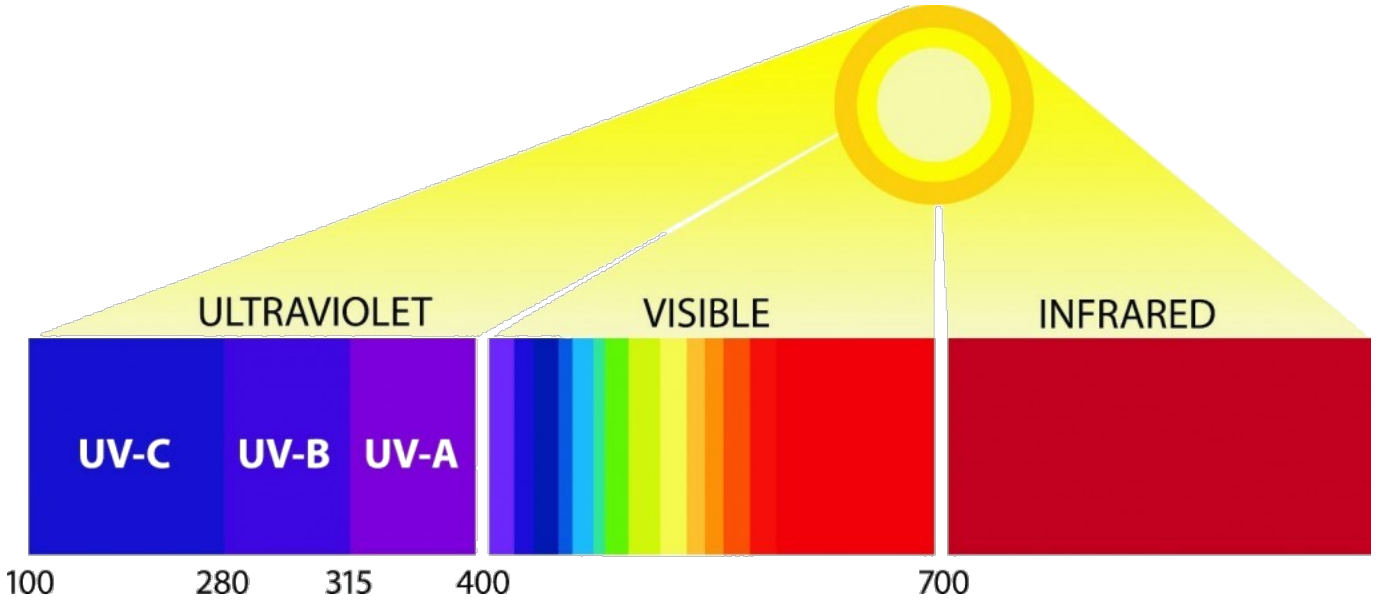


Call to Action – Indoor Environment Quality Dashboard

- Simple monitor only mini-BAS
- Leverage existing infrastructure if available
- Expand beyond T/RH/CO2
- Can have both measured indexes or calculated indexes
- Additional trending and analytics to gain additional insight

Ultraviolet Germicidal Irradiation (UVGI)

Few Facts About UV



- The shorter the wavelength, the higher the disinfection effectiveness (i.e. UV-C is better than UV-A)
- UV-C photons penetrate cells and damage the nucleic acid, rendering the pathogen incapable of reproduction, or microbiologically inactive.
- The longer the exposure the higher the effectiveness
- COVID-19 related data is still limited but there is a definite correlation to the decay of SARS-CoV-2.

Airborne Decay Calculator (DHS): https://www.dhs.gov/science-and-technology/sars-airborne-calculator

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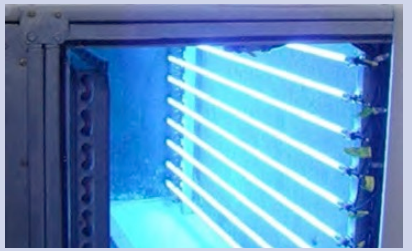
Call to Action – Adding UVGI

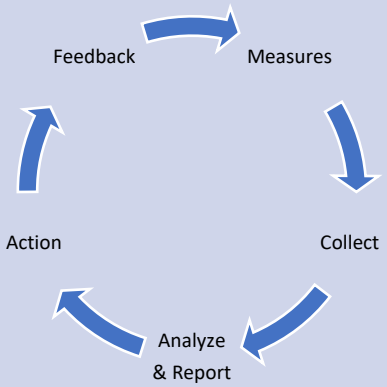
Practice the "Do-No-Harm" principle and consider best practice measure against aerosol transmission

Disinfection	Installation	Considerations	Sample
In-duct Air	In ventilation system/ductwork, targeting air	• Airflow can limit the effectiveness of UV.	
In-duct Surface	In ventilation system next to high-pathogen surfaces, targeting surface	• For cooling coils, drain pans, etc.	
Space	Any space as required can target both air and surface	• Use a schedule to accommodate occupancy • Use portable unit if the retrofit option is not feasible • When using during occupied hours, additional measures are required for occupant's health & safety	

Other Considerations

Other Building Systems

Practice the "Do-No-Harm" principle and consider best practice measure against aerosol transmission

BAS	Plumbing	Electrical
• Ensure all sensors are calibrated and control devices are operational • Confirm system capability for data trending and archiving • Backup your DDC system database. • Practice action driven data collection and analytics 	• Ensure domestic water system continue to circulate water with temperature above 60C • During the previous SARS-CoV-1 epidemic, virus could be transmitted through plumbing traps, although no similar evidence relating to SARS-CoV-2, precaution should be taken by keeping plumbing traps full of water	• Stagger the restart of building equipment to even out spikes on electrical demand • Preventative service such as thermography

Sample Recommended Pilot Project

Sample Pilot Project For Distributed Retail

Action	Expected Outcome	Resources	Measure, Validate, C.I	Concerns & Notes
Dilution Ventilation	• Increased overall IAQ & lower harmful particulate concentration • Most effective combined with enhanced filtration	• $500/sensor • Additional programming and installations are required	• Adjust & document changes made on outdoor air intake • Monitor and trends supply and return CO2 to understand the effectiveness of dilution	• Dilution is occurring naturally through building openings • Leverage local weather services to understand outdoor condition
Enhanced Filtration MERV 13	• Removal of ***micron size*** particulate such as SARS-CoV-2	• Cost increase varies based on qty and frequency (e.g. $500/yr)	• Monitor PM2.5/5/10 levels in space • Local surface swab testing • Pressure drop across filter	• Consider air distribution configuration (% of return air?) • System capability for higher MERV
Temperature Control	• Maintain a balance of optimal environment for mitigating virus spread	• <1 hour Programming & Configuration ($200)	• Trend space temperature	• Occupant comfort – implement in stages
Humidity Control	• Maintain space humidity between 40-60 %rh	• Cost varies based on existing infrastructure (CAPEX)	• Trend space humidity	• Lack of existing humidification equipment
Enhanced Sanitation Hand Held Swabbing	• Safer high touchpoint surfaces	• $ 1,500 / location • $ 240 / year	• Validates surface pathogen count. • Informs frequency and quality	

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Sample Pilot Project For Distributed Retail

Action	Expected Outcome	Resources	Measure, Validate, C.I	Concerns & Notes
Occupancy Counting	• Collect occupancy pattern to inform hard/soft services	• $1,000 / entry • Programming & Configurations	• Total active occupants in building • Align activities/measures appropriately based on occupancy	• Integration to existing building system
Thermal Screening	• Insight of occupant well-being • Prediction of seasonal illness	• $450/month/location (36 months)	• Occupant body temperature	• Non-intrusive measuring up to 10 entrants concurrently
IAQ Dashboard	• Validation, Informed Control, Informed Risk Management, Increased Communication	• TBD depending on existing infrastructure	• All IEQ related data that can be captured and normalized into one platform	• Existing infrastructure

Selected Next Step

- Pilot location 1 – Dorval Branch (full control installed)
- Pilot location 2 – 1x local branch (with no digital control)

References

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