COVID-19 and Buildings: Re-Occupation After Lockdown

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Learning Objectives

By attending this course, you will learn:

1. What building services engineers need to know about COVID-19.
2. What systems must be checked and restarted after lock down.
3. What equipment should be considered for use when COVID is introduced into a building environment possibly by asymptomatic individuals.
4. What systems should be considered for updating when restoring normalcy.
5. What reliable guidance resources are available to prevent infection spread and re-open buildings with safe and productive environments.

Agenda

1. Corona viruses and COVID-19
2. Hospitals and COVID-19 patients
3. Re-occupation after lockdown
4. Buildings and their engineering systems
5. Updating buildings to restore normality
6. ASHRAE resources available to help

Acknowledgements

- Wade H. Conlan P.E., CxA, BCxP, LEED AP, Hanson Professional Services
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- Jeremy Fauber, PE, CGD, LEED AP BD+C, Senior Mechanical Engineer Heapy
- Rick Hermans, Chair Schools Re-occupation Group, ASHRAE Covid Task Force

Presentation Outline

Human Environments and Health

- Buildings are sophisticated and have complex engineering systems

COVID-19 – What Is It?

- A highly infectious respiratory disease

Re-occupation After a Long Shutdown

- Check test and re-commission/repair equipment and systems

Re-occupation with COVID-19 Still Around

- Measures to take - living with Covid. Could be here for years.

ASHRAE RESOURCES

ASHRAE’s COVID Preparedness Resources Webpage:

ashrae.org/COVID19

COVID-19 Pandemic

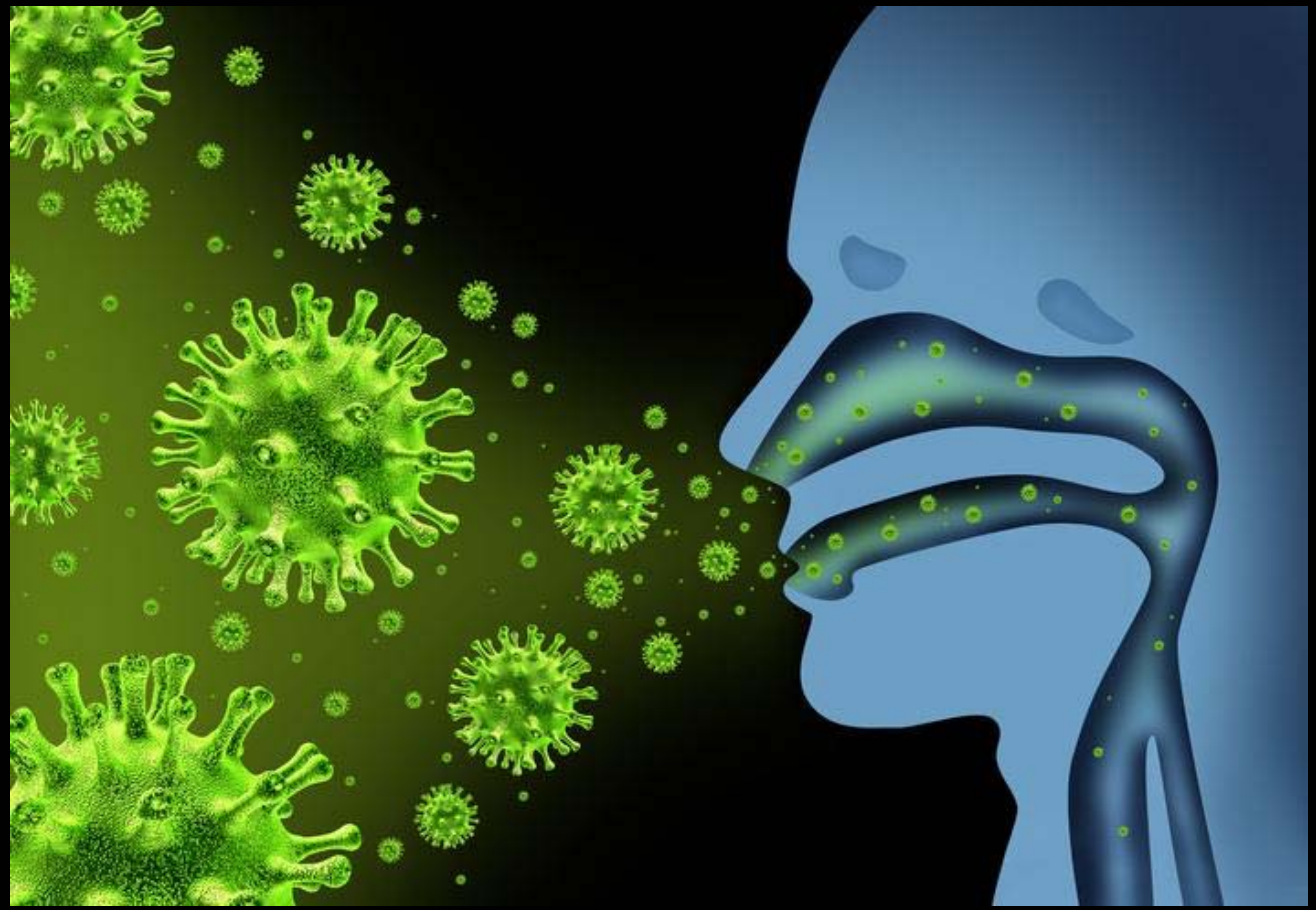
Infection Control Engineer

An infection control engineer is qualified and has experience in ventilation for safe and healthy premises.

- Understands the science – Covid virus and its transmission routes,
- Knows the solutions – what to do to protect people and their spaces
- Carries out site checks and investigations
- Identifies problems
- Finds solutions
- Oversees and signs off works

Coronaviruses, single stranded RNA viruses, have been with us for a long time…

Common cold (30%)
SARS
MERS
COVID-19



UK Government Guidance

Public Health England

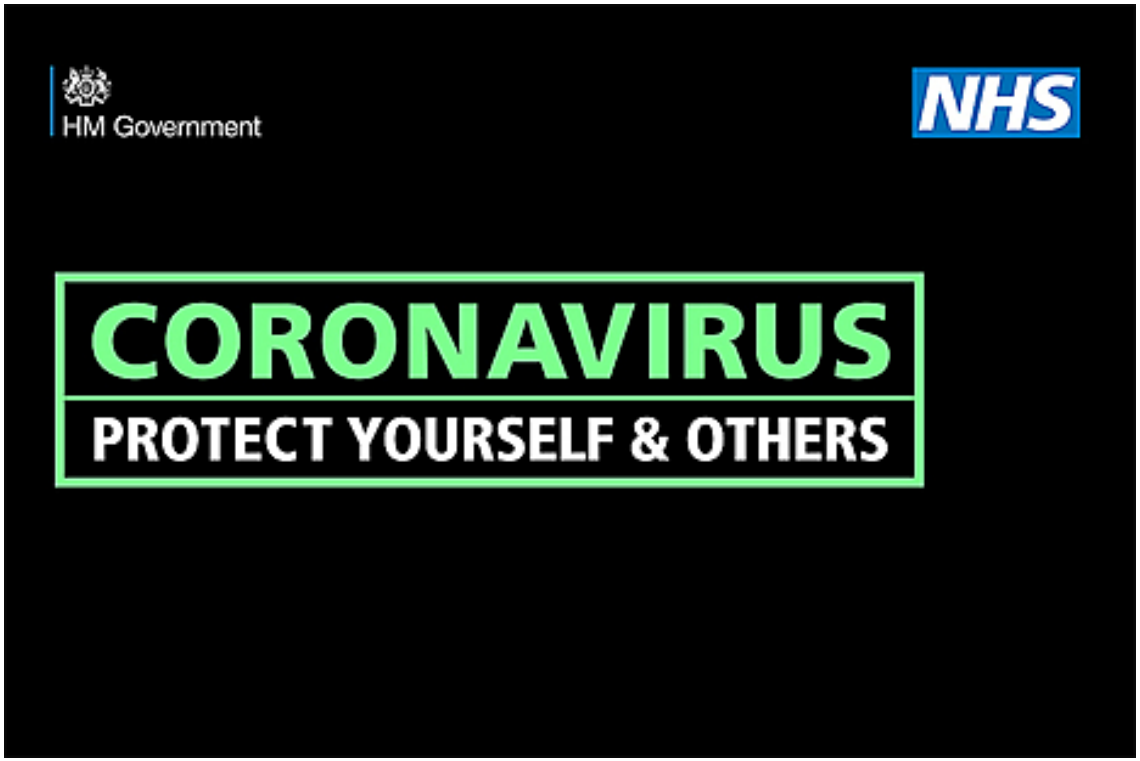
News

https://www.gov.uk/government/collections/coronavirus-COVID-19-list-of-guidance

www.gov.uk/government/organisations/public-health-england

UK Government Guidance

- National Health Service, NHS
- Wide range of guidance
- E.g., Care Homes….



www.gov.uk/government/publications/coronavirus-COVID-19-admission-and-care-of-people-in-care-homes

NICE Guidance – UK National Institute for Health and Care Excellence

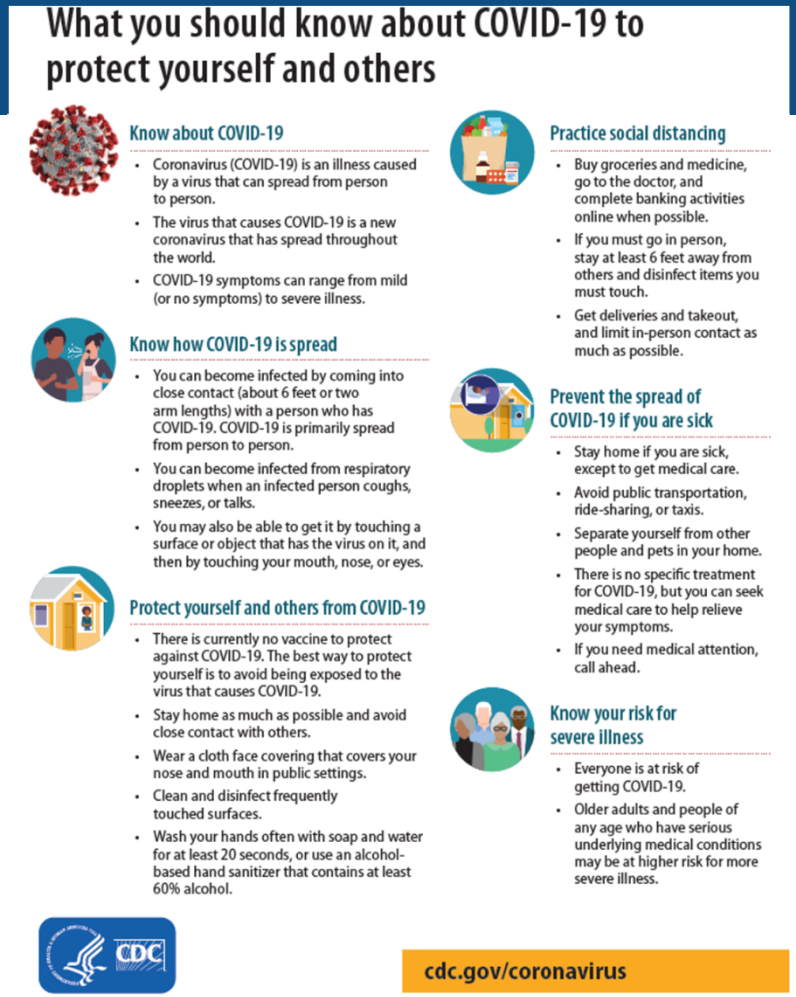
https://www.nice.org.uk/COVID-19

For our COVID-19 products (documents) we have waived our normal licensing requirements for international reuse or reproduction of our content'…UK NICE'

- Rapid guidelines
- Rapid evidence summaries
- Medtech innovation briefings
- Clinical knowledge summaries
- More information

CDC Guidance

US Centers for Diseases Control and Prevention



What you should know about COVID-19 to protect yourself and others

Know about COVID-19

- Coronavirus (COVID-19) is an illness caused by a virus that can spread from person to person.
- The virus that causes COVID-19 is a new coronavirus that has spread throughout the world.
- COVID-19 symptoms can range from mild (or no symptoms) to severe illness.

Know how COVID-19 is spread

- You can become infected by coming into close contact (about 6 feet or two arm lengths) with a person who has COVID-19. COVID-19 is primarily spread from person to person.
- You can become infected from respiratory droplets when an infected person coughs, sneezes, or talks.
- You may also be able to get it by touching a surface or object that has the virus on it, and then by touching your mouth, nose, or eyes.

Protect yourself and others from COVID-19

- There is currently no vaccine to protect against COVID-19. The best way to protect yourself is to avoid being exposed to the virus that causes COVID-19.
- Stay home as much as possible and avoid close contact with others.
- Wear a cloth face covering that covers your nose and mouth in public settings.
- Clean and disinfect frequently touched surfaces.
- Wash your hands often with soap and water for at least 20 seconds, or use an alcohol-based hand sanitizer that contains at least 60% alcohol.

Practice social distancing

- Buy groceries and medicine, go to the doctor, and complete banking activities online when possible.
- If you must go in person, stay at least 6 feet away from others and disinfect items you must touch.
- Get deliveries and takeout, and limit in-person contact as much as possible.

Prevent the spread of COVID-19 if you are sick

- Stay home if you are sick, except to get medical care.
- Avoid public transportation, ride-sharing, or taxis.
- Separate yourself from other people and pets in your home.
- There is no specific treatment for COVID-19, but you can seek medical care to help relieve your symptoms.
- If you need medical attention, call ahead.

Know your risk for severe illness

- Everyone is at risk of getting COVID-19.
- Older adults and people of any age who have serious underlying medical conditions may be at higher risk for more severe illness.

CDC

cdc.gov/coronavirus

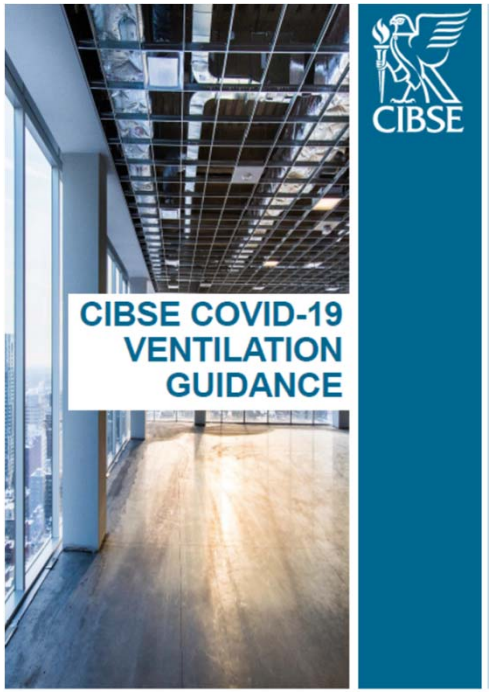
https://www.cdc.gov/coronavirus/2019-ncov/index.html

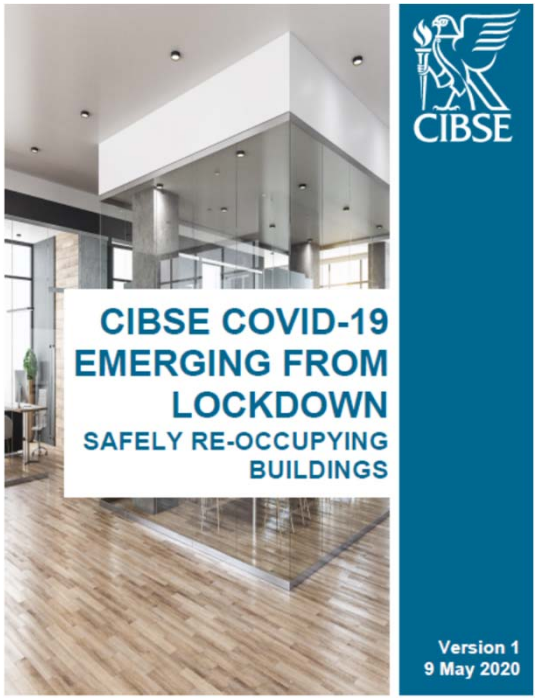
ASHRAE Offers COVID-19 Building Readiness/ Re-opening Guidance

- Use link……..
- ashrae.org/file%20library%/technical%20resources/COVID-19/ashrae-building-readiness.pdf
- Also make use of ASHRAE general guidance documents – ASHRAE position Document on Infectious Aerosols, ASHRAE Position document on Filtration and Air Cleaning

CIBSE Guidance on Re-Opening

www.cibse.org/Coronavirus-(COVID-19)

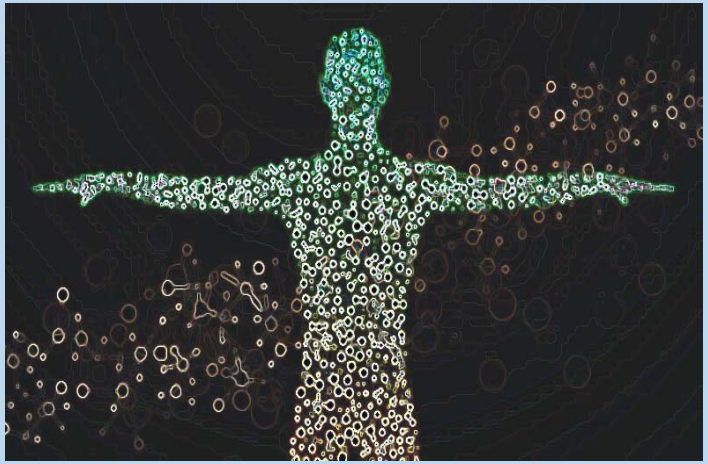


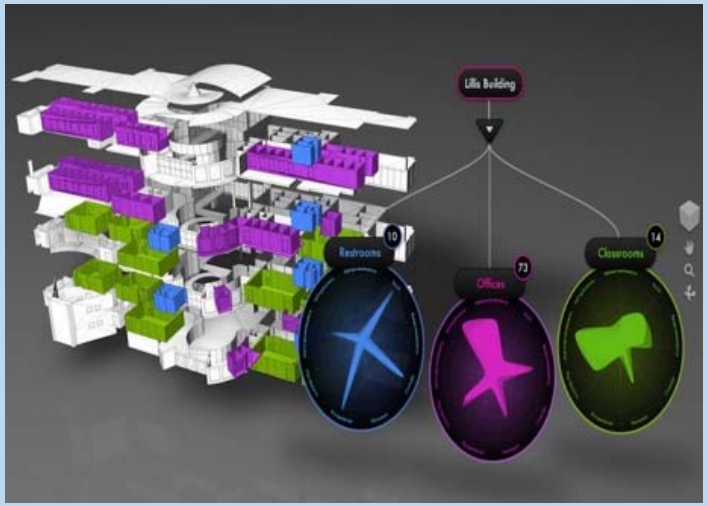


Survival of the fittest

Occupants send their microbes into buildings

Most of this is shedding particles from our natural microbiome (microbes which live on us) which runs in the trillions of cells – and most are not bad or dangerous

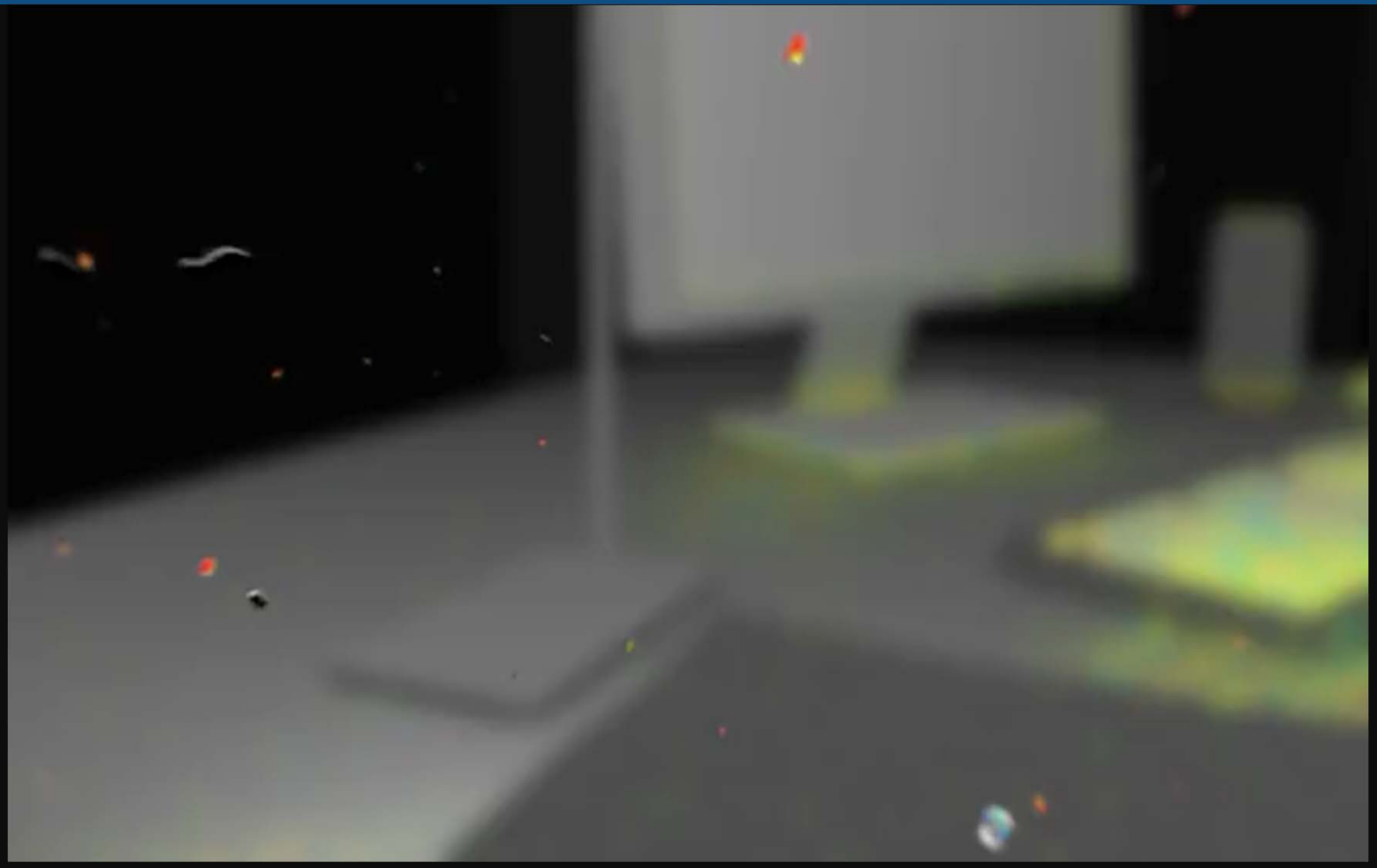




Indoor environments determine which microbes will survive and interact with occupants

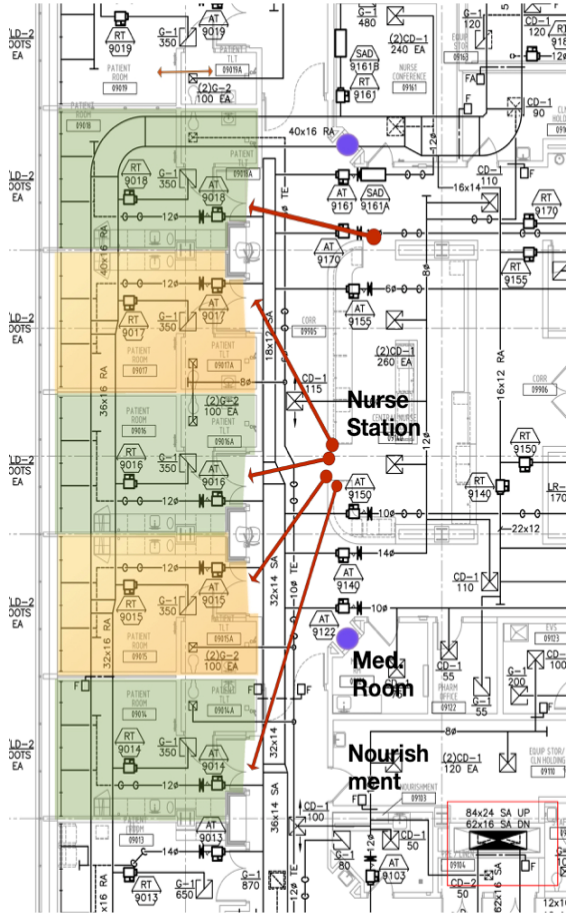
A closer look at our surroundings

Gibbons SM. 2016, The built environment is a microbial wasteland, mSystems 1(2):e00033-16. d



Do indoor HVAC factors contribute to infections?

Research studies show the risks. Refer to Stephanie Taylor, M.D., M. Arch., ASHRAE DL



Patient room data *VS.* **Patient and Hospital Acquired Infections HAIs**

Temperature

Staff & visitor hand cleaning

Room pressurization

Lux

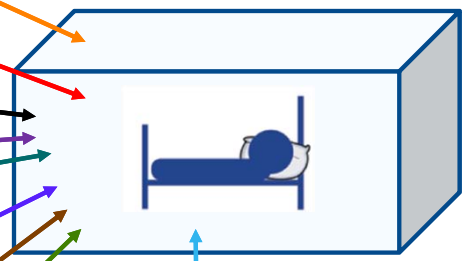
CO_2 level

Relative humidity,
Absolute humidity

Room traffic

Room air changes

Outdoor air fractions



8 million room data points **~ 300 patient outcomes**

Some infections are spread through the air

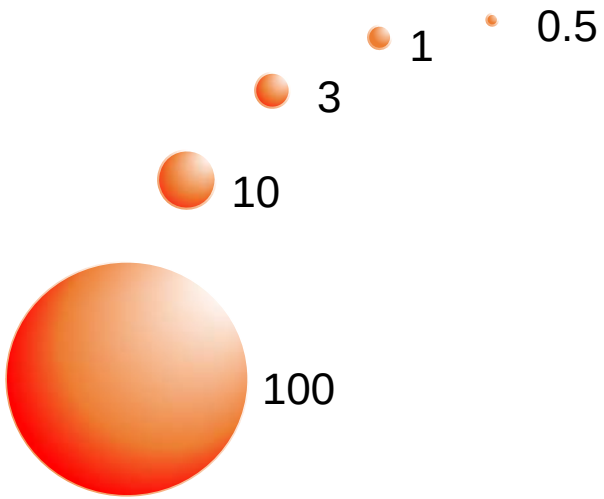
- HVAC systems can assist spread infection – or can stop it.
- HVAC Engineers control indoor environment and therefore some of these factors affecting infection risk.
- COVID-19 is spread by droplets from mouth.
- Large droplets – above 10 micron – fall to surfaces within 3 metres and can be spread by touch.
- Small droplets – less than 10 micron – float in airstream and can drift a long way – 10 metres plus.
- Large droplets can become small as they evaporate moisture and then stay floating.

Infectious droplets shrink, travel far and evade surface cleaning when the air is dry

Droplet diameter in microns (um)

Float time

Droplets emitted from mouth vary from large – 100 micron - to very small - 0.5 micron. Large land on surfaces but small can float away and behave like an aerosol floating in airstream.



41 hours – 21 days

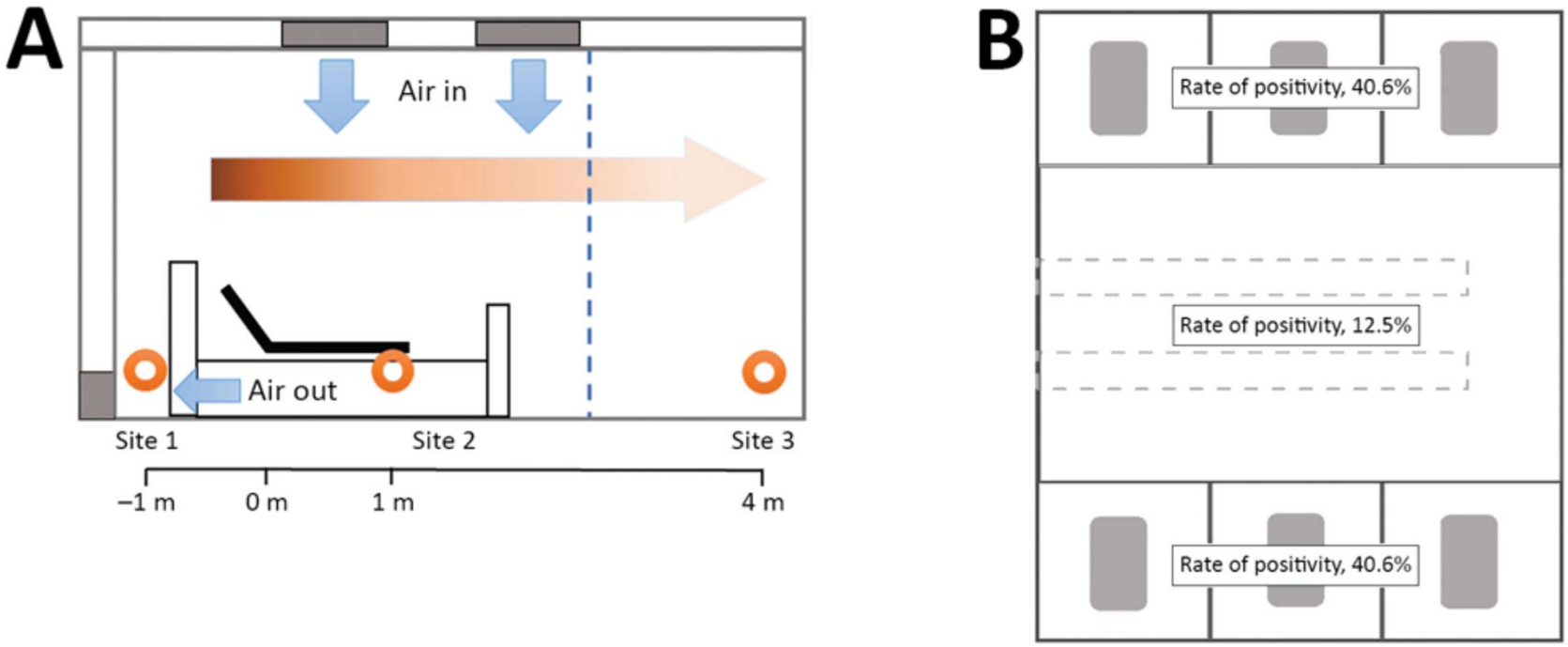
1.5 hours

6 seconds

Distance travelled: 1m 10m+

What determines if this cough will infect others?

The air and surfaces in Wuhan ICU with COVID-19 were widely contaminated by the virus up to 14 feet away



Guo Z-D, Wang Z-Y, Zhang S-F, Li X, Li L, Li C, et al. Aerosol and surface distribution of severe acute respiratory syndrome coronavirus 2 in hospital wards, Wuhan, China, 2020. Emerg Infect Dis. April 10.

When can we go back to normality ?

Re-Occupation After COVID

- Buildings have been locked down for long periods – over 10 weeks.
- Clean, repair/maintain, check and possibly re-commission all of the engineering systems serving the building.
- Take steps to prevent Covid 19 transmission – infection control measures.
- Risk assessment, training and behavioral changes .

The Risks

- Sick buildings risks – due to lack of use and build up of dust/dirt.
- Failure of plant and equipment.
- Security.
- Fire safety.
- Energy wastage.
- As occupants return there is a risk of COVID-19 virus transmission from anyone infected – leading to sickness, some deaths, and possible further lockdowns (if infection rate rises fast).
- Occupant productivity affected by enforced changes.

Getting Out of Lockdown

- Phased end to lockdown
- Concerns of a second wave of Covid transmission
- Covid could be here ‘for years’
- Covid vaccine research – but could 18 months to safe vaccine
- 1 step at a time approach – prioritization of controls
- Governments are in control

BESA SFG-30 Maintenance & Task Schedules: Mothballing & Recommissioning of Buildings

- Building Fabric Elements
- Building Management System (BMS)/Controls
- Catering Services
- Chilled Water Systems
- Compressed Air Systems
- DX Cooling Plant
- Electrical Systems
- Emergency Lighting
- Fire Alarm Systems
- Gas Supply
- Heating Systems
- Oil Supply
- Lighting and Lighting Systems
- Motors, Generators, UPS's and Battery Systems
- Pipework (All Systems)
- Refrigerant Gases
- Security Monitoring and Access Systems
- Swimming Pools
- Transformers and Substations
- Ventilation Plant
- Water Hygiene Services
- Water Services - Fire Protection and Domestic Supply Systems

https://www.sfg20.co.uk/whats-new/sfg30-mothballing-reactivation-out-now/

Various Versions Around

Versions being developed by Engineering companies – many for sharing

Bringing buildings to life

COVID-19 BCP

Building Reoccupation Strategy

Water Systems

Although Covid 19 is not known to infect water systems, there is a risk where water systems have not been stagnant for a long time.

During the coronavirus (COVID-19) outbreak, water system stagnation can occur due to lack of use and lead to risk of Legionnaires' disease

Employers and all people in control of premises have a duty to identify and control risks associated with legionella.

Due to this increased risk of Legionella UK HSE has launched a new website to provide information and guidance –

https://www.hse.gov.uk/news/legionella-risks-during-coronavirus-outbreak.htm

CIBSE TM13 gives guidance on minimising risk of legionella

ASHRAE Standard 188- 2018 Legionellosis: Risk Management for Building Water Systems

ASHRAE Guideline 12-2020, *Managing the Risk of Legionellosis Associated with Building Water Systems*

Water - Legionella

ESCMID Study Group for Legionella Infections - ESGLI - 'Guidance for managing Legionella in building water systems during the COVID-19 pandemic'

ASHRAE Standard 188- 2018 Legionellosis: Risk Management for Building Water Systems

ASHRAE Guideline 12-2020, *Managing the Risk of Legionellosis Associated with Building Water Systems*

ESGLI Guidance Sheets

14th April 2020
The European Study Group for Legionella Infections - ESGLI, has drafted some excellent specific guidance for managing legionella in specific settings. These are aimed at building operators in three sectors: Hospitals, Nursing/Care homes and other buildings.

ESGLI Guidance for managing Legionella in nursing & care home water systems during the COVID-19 pandemic
ESGLI Guidance for managing Legionella in hospital water systems during the COVID-19 pandemic
ESGLI Guidance for managing Legionella in building water systems during the COVID-19 pandemic

Hot and Cold Water Systems

- ✓ If used infrequently- flush weekly to prevent water stagnation.
- ✓ If you cannot do this ensure systems are cleaned and disinfected before the building is occupied.

For further guidance read:

- ✓ Legionnaires' disease. The control of legionella bacteria in water systems - Approved Code of Practice and guidance (L8 ACOP)
- ✓ Legionnaires' disease - Technical guidance (HSG274 Part 2) (PDF)
- ✓ ASHRAE Standard 188
- ✓ ASHRAE Guideline 12-2020, *Managing the Risk of Legionellosis Associated with Building Water Systems*
- ✓ ESGLI Guidance Sheets, https://www.legionellacontrol.org.uk/news/94/

Cooling Towers and Evaporative Condensers

Legionella rules requires plans in place - safe systems of work continue during any shutdown

This includes

trained personnel carry out essential checks and monitoring

chemical supplies are maintained and dosed

- If cooling towers and evaporative condensers are likely **to be out of operation** for:
- **up to a month** - isolate fans, but circulate biocidally-treated water around the system for at least an hour each week
- **more than a month** - drain down the systems and clean and disinfect them. Clean and disinfect the systems again before refilling and returning to operation

Legionnaires' disease. The control of legionella bacteria in water systems - Approved Code of Practice and guidance (L8 ACOP)
Legionnaires' disease - Technical guidance (HSG274 Part 1) - Portable Document Format

BMS Systems

- Pre-shutdown - should backup all databases, programs, schedules, setpoints, etc and store off site or on the cloud before making any changes
- See building readiness guidance on ASHRAE website for BAS/BMS recommendations and assessment.
- Check to ensure that BMS operation is as expected
- Implement any changes regarding ventilation rates, building opening times, etc, due to Covid changes to achieve safe usage
- Plant operating times may need to be extended to accommodate changes to working hours and shift patterns

Air Systems

Adequate ventilation required in all occupied areas.

Ventilation rates should not be reduced if occupancy reduces - but maintained to mitigate any risk of airborne transmission – i.e. dilution important.

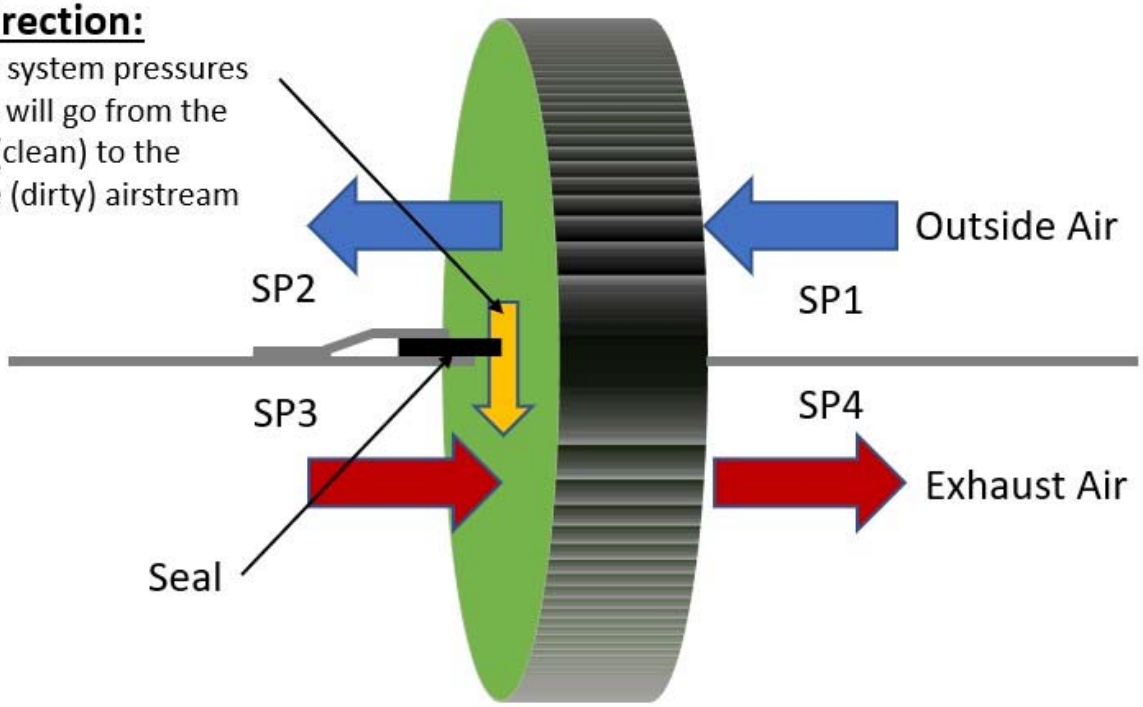
Guidance is to INCREASE fresh air rate to dilute and remove any Covid droplets - but depends on system and needs engineer input to each case.

- ***Covid additional works***
- Add higher filtration level – if AHU allows. See ASHRAE guidance
- Add UVC air cleaning (See ASHRAE Reducing Infectious Disease Transmission with UVGI course (https://register.gotowebinar.com/recording/8373797400651662856)
- Note – if UVC used it should be possible to stick with previous filters
- Add humidifier to control RH (Dry Climates) – see later slide.
- Disable demand control ventilation strategies while in pandemic mode
- Other such as add 2 hour flushing periods pre and post occupancy.

Energy Recovery Ventilation Systems

Seal Leakage Going In Proper Direction:

With proper system pressures seal leakage will go from the supply side (clean) to the exhaust side (dirty) airstream



Energy Recovery Ventilation Systems

Evaluation for Leakage

- Leaving Supply static pressure (P2) should be at least 0.5 in. w.g. greater than the entering return airstream static pressure (P3) measured near the wheel surfaces. This means there is a positive static pressure differential.

- Positive pressure differential means the pressure at the supply outlet (P1) of the wheel is higher than the exhaust inlet of the wheel.

- If there is a driving force for exhaust air transfer to the supply (P2 greater than P1), ask the ERV manufacturer for an EATR prediction. Provide the manufacturer the following information, at minimum: SP1, SP2, SP3, Rotation Speed, Purge Angle (if one is used) and Leaving Supply Airflow Volume.

- Request the estimated exhaust air transfer as a volume rate (e.g. in CFM or L/s) at the specific operating condition.

- To determine the Leaving Supply Airflow Volume, measure it directly if possible.

Cooling Systems

- Refrigerants may have leaked
- Check for pressure
- Where leaks have occurred the system must be refilled using an approved refrigerant. If the system had R22 or other banned substance, a suitable ‘drop in’ alternative refrigerant must be used.
- Check cooling coil for fouling. Flush system through and treat water
- For water based systems, make sure all air is vented, system is full, chemical treatment is applied
- Check P-trap on condensate line

Electrical Systems

Electrical safety checks are required under the Electricity at Work Regulations 1989 & BS7671 (18th edition electrical regulations)

Competent person to test and certificate

Advice after shutdown…….

- https://www.eca.co.uk/CMSPages/GetFile.aspx?guid=cf50f8e8-7809-49d1-8f47-fa47e3267556

- NFPA 70B Recommended Practice for Electrical Equipment Maintenance.

Emergency Lighting

Must be tested and demonstrated to work fully and effectively

Batteries checked by conducting a full 3 hour test.

Check emergency generators - and the batteries that start them and automatic transfer switches.

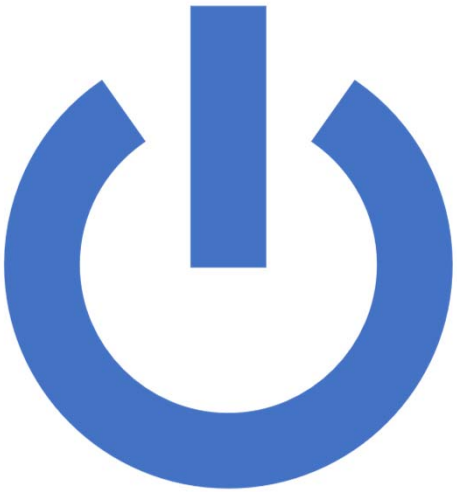
BS5266-1 *Emergency lighting* and BS EN 50172 *Escape Lighting*

Society of Light and Lighting Guidance in Lighting Guide 12 on Emergency Lighting.

Gas Safety Inspections

- Inspections and maintenance – essential requirement (legal).
- Especially unvented gas appliances.
- Not suspended due to the coronavirus.
- Keep test certificates up to date.
- Insurance may void if not.

Portable Appliances



- Establish safety of portable appliances such as kettles, microwaves, etc.
- Portable appliance testing (PAT) system.
- However, use of such appliances should be carefully considered as they present a potential risk of transmission via surface contact.

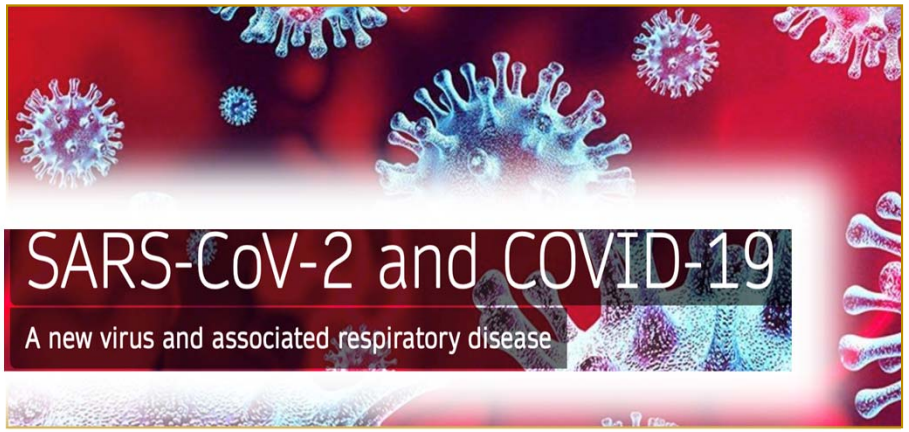
Specialist Services and Equipment

Expert advice should be sought in relation to specialist services…

- Generators
- UPS systems
- Catering equipment
- Process cooling
- Fume extract systems
- Other

Living with COVID-19

- COVID-19 is here to stay – could be 2 years or more.
- Lockdown is expensive.
- Lockdown is unhealthy too.
- Need to get back to normality.
- Re-occupy buildings.
- Stay safe and healthy.
- Meet people safely.



Engineering Covid Safe Environments

Contact transmission

Note – recent CDC position statement that fomite transfer is not significant …but good to be conservative – take no risks

- Surface transmission
- Cleaning
- Contact
- Social (physical) distancing
- PPE - including masks

Airborne transmission

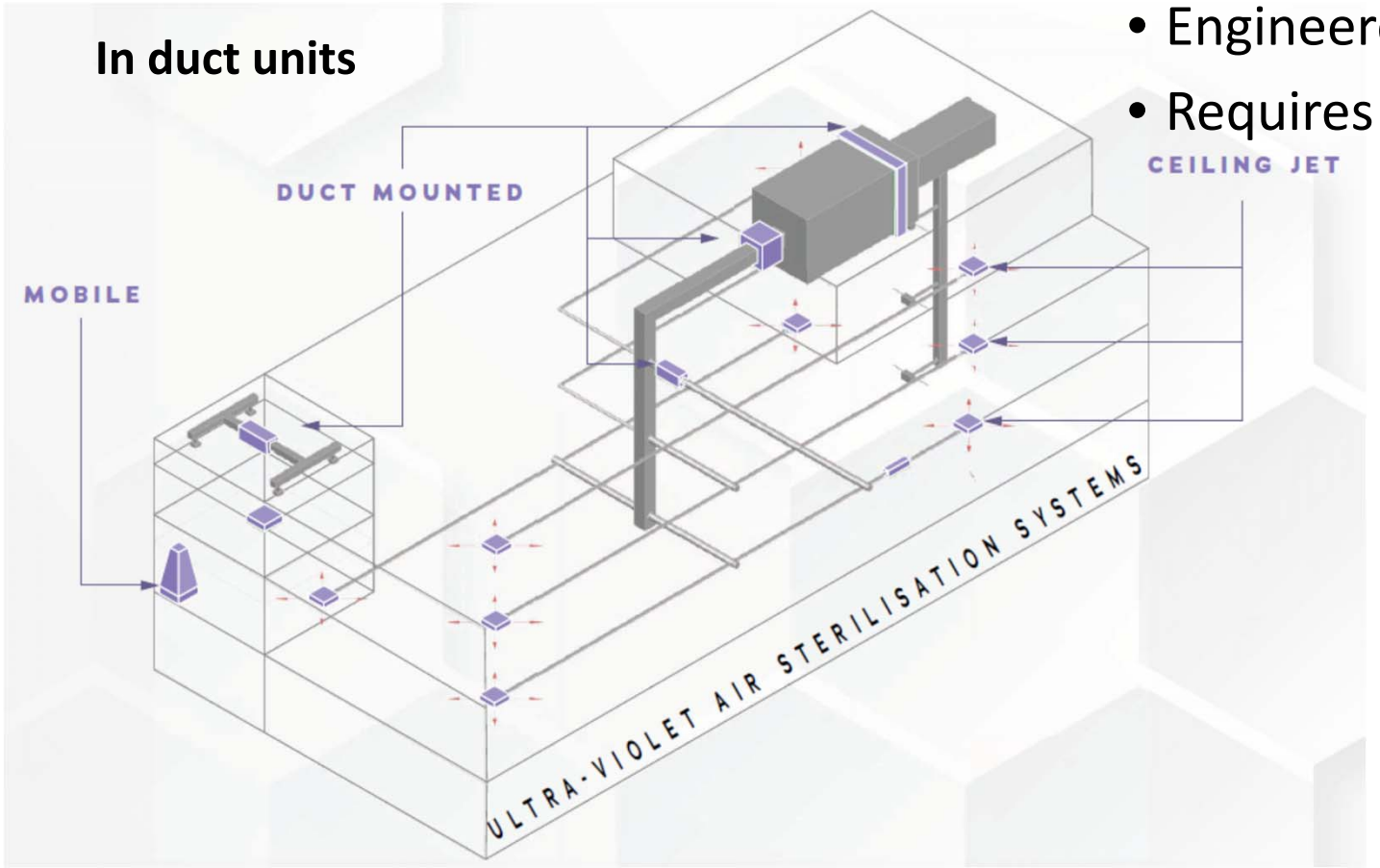
Droplets and aerosols

- Ventilation
- Air sterilisation – UV
- Air cleaning – MERV 13 to 14 filters. HEPA better but needs engineer to confirm if possible and cost effective
- Humidity control
- Masks

Outside the building - Coronavirus dies in SUNLIGHT in minutes

- **Study by US Department of Homeland Security**
- **Officials say transmission of the killer virus WILL decrease in summer**
- **Sunlight, temperature and humidity all detrimental to the virus**
- **Ultraviolet light = sterilizing effect - radiation damages virus's genes**
- **William Bryan, science advisor to DHS**

UV options – Upper room (in ceiling), mobile floor mounted, or bespoke in ducted systems



- Engineered solution
- Requires installation

UV Kills Corona Virus – UV in Duct Option

UV in series with a lower efficiency filter can be quite effective and low cost.

See ashrae.org/covid:
-includes 2 ASHRAE Handbook chapters (download in Resources tab/Handbook)
-one hour short course (Bahnfleth) recording and slides (download in Resources tab/Training)

IES CR-2-20-V1

Illuminating ENGINEERING SOCIETY

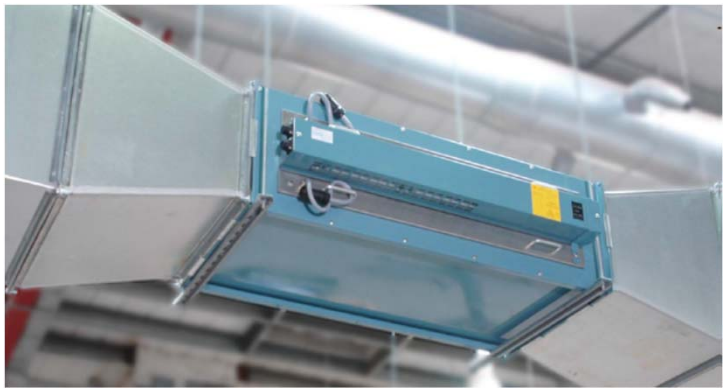
IES Committee Report:

Germicidal Ultraviolet (GUV) – Frequently Asked Questions

Authoring Committee: IES Photobiology Committee

This Committee Report has been prepared by the IES Photobiology Committee in response to the 2020 COVID-19 pandemic, with the specific goal of providing objective and current information on germicidal ultraviolet irradiation (UVGI) as a means of disinfecting air and surfaces. The IES provides this information freely and will update it periodically, as more information becomes available.

Publication of this Committee Report has been approved by the IES Standards Committee April 15, 2020 as a Transaction of the Illuminating Engineering Society. (www.ies.org)



UV in Duct

- Requires modifications to install UV unit into ductwork.
- Must have room for regular lamp replacement.
- Electrical supplies.
- Safeguards if duct is opened for cleaning etc – lights failsafe off.

Upper Room (ceiling) UV Unit in Each Patient Area

CEILING-JET AIR STERILISATION UNIT

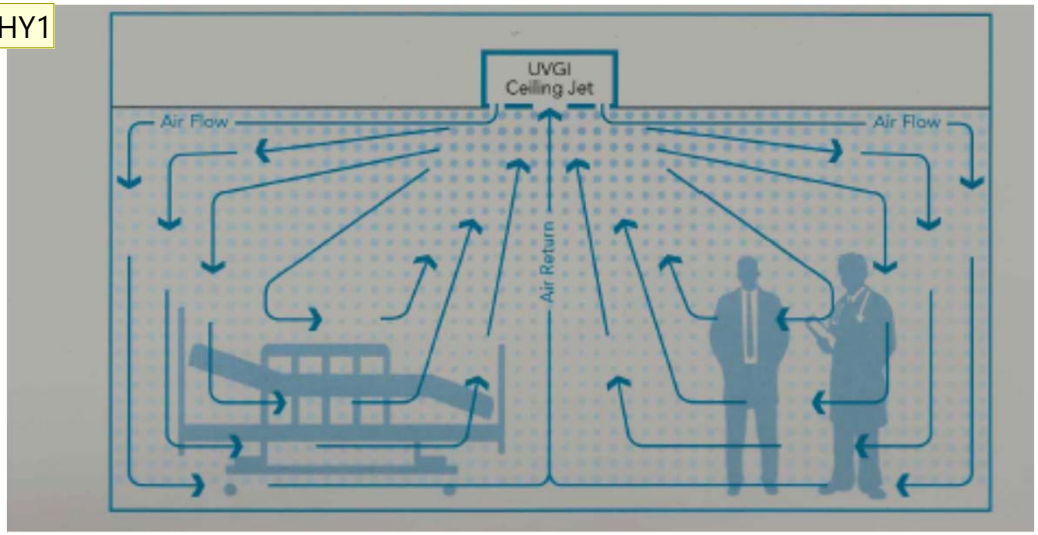
ASU 5000

This ceiling mounted device sterilises indoor air through localised recirculation, specifically for individual rooms and treatment spaces. The directional air-jet system gently agitates all the room air, dissipating areas of high bacterial concentration. The displaced air is drawn back in to the ceiling unit for further UV dosing and recirculated as often as necessary, the treated air being jetted back in to the room minus the harmful microorganisms.

Using the latest air movement technology, the ASU 5000 model silently creates maximum air distribution, utilising the minimum air quantity, to reduce areas of microorganism manifestation.

Replaces a standard ceiling tile, or is available with a surface-mounted cover.

HY1



The air jets mix air and create air return into the UV lamps which kill corona virus

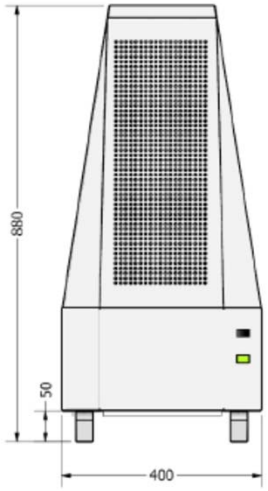
Slide 51

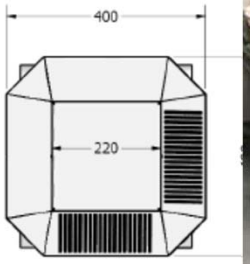
HY1 Shodul we hide the model number?

Hassan Younes, 6/5/2020

Mobile UV unit in each patient area

Mobile UVGI unit, 3ft high, on wheels, with electrical plug



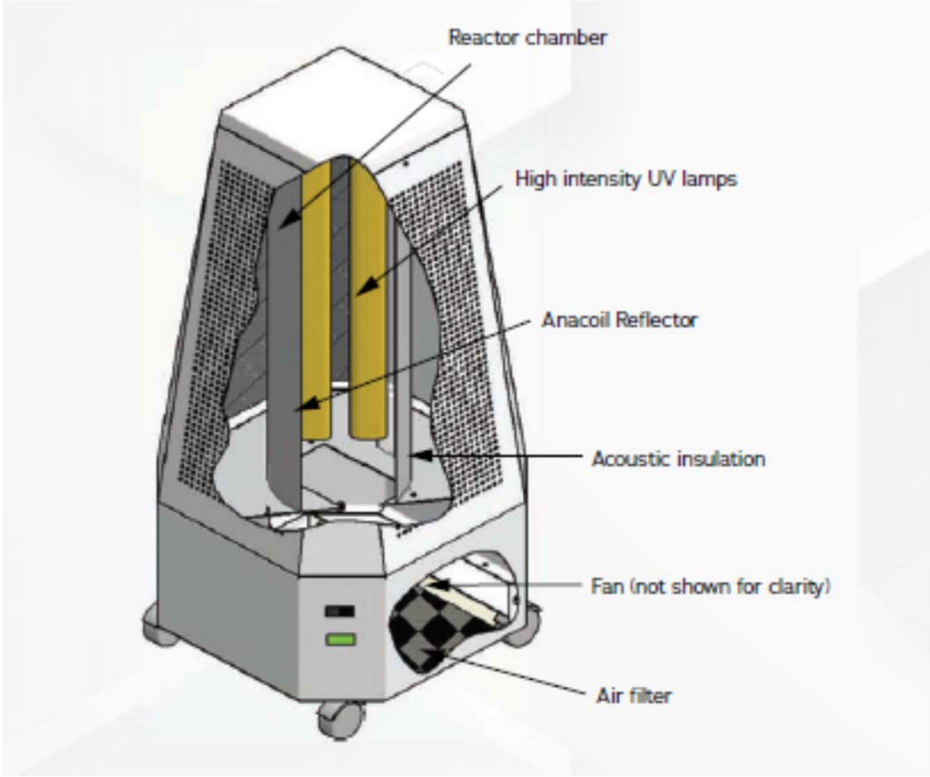


UV and filter

- Select a ‘good’ filter that removes AT LEAST 90% of virus containing particles
- So 10% penetrates the filter
- UV device inactivates, say, 85% of remaining viral content, the overall penetration is

= (1-0.9)(1-0.8) = 0.02 = 2%.

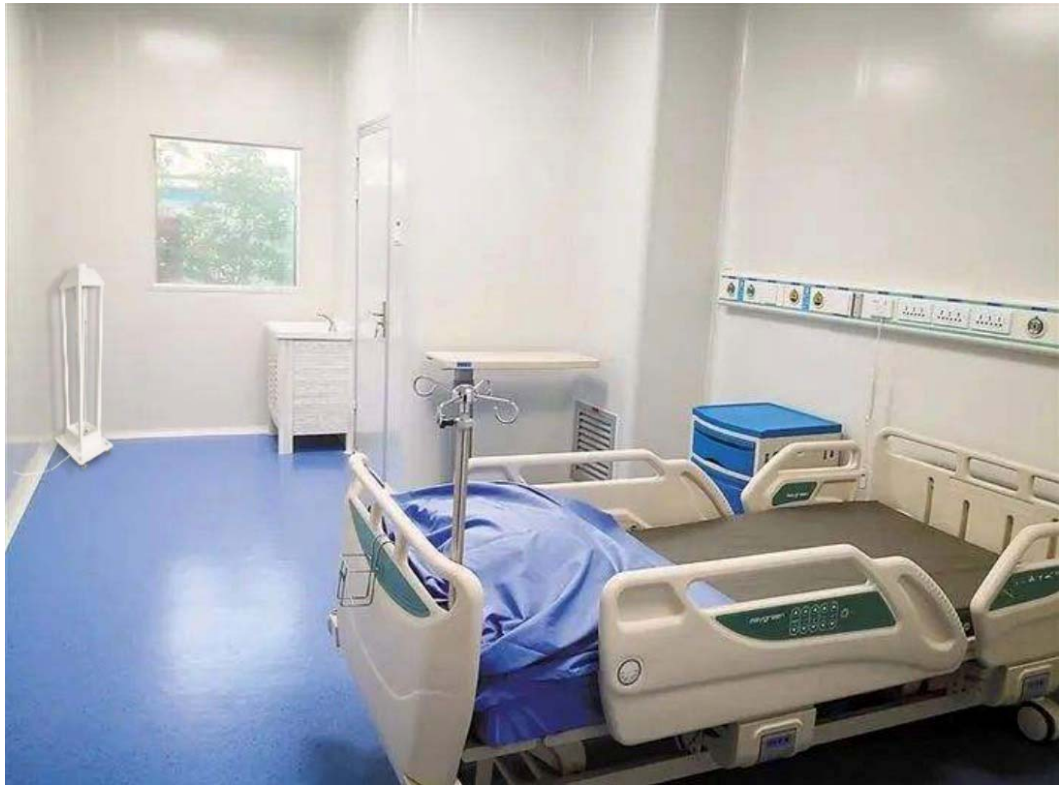
Overall removal = 98%



Not recommended - mobile UV ‘in room’ unit with exposed UV lamp

Product from China which shines UV in patient rooms

- UV light shines onto surfaces to kill virus
- Switches OFF by occupancy detection
- Misses locations out of direct sightlines
- Cannot use when people – and patients - are in – due to UV risk
- Not an effective way to do room disinfection with UV – better technology available



Mobile UV ‘in ward area’ unit with exposed UV lamp

Not recommended - mobile UV ‘in room’ unit with exposed UV lamp

- Vertical unit 3ft high in corridor
- Switches OFF by occupancy detection – could be switched off more than on
- UV light shines onto surfaces to kill virus
- Misses locations out of direct sightlines

ASHRAE Handbook UV Chapter 62

- Ultra Violet light sterilises air by ‘killing’ bacteria and viruses
- UV is harmful to humans so must always be shielded from view/body
- UV performance depends on intensity and dwell time
- So air must pass close to lamps and at slow speed

CHAPTER 62

ULTRAVIOLET AIR AND SURFACE TREATMENT

Fundamentals 62.1
Terminology 62.3
UVGI Air Treatment Systems 62.5
HVAC System Surface Treatment 62.9
Energy and Economic Considerations 62.10
Room Surface Treatment 62.11
Safety 62.12
Installation, Start-Up, and Commissioning 62.13
Maintenance 62.14

ULTRAVIOLET germicidal irradiation (UVGI) uses short-wave ultraviolet (UVC) energy to inactivate viral, bacterial, and fungal organisms so they are unable to replicate and potentially cause disease. UVC energy disrupts the deoxyribonucleic acid (DNA) of a wide range of microorganisms, rendering them harmless (Brickner et al. 2003; CIE 2003). Early work established that the most effective UV wavelength range for inactivation of microorganisms is between 220 and 280 nm, with peak effectiveness near 265 nm. The standard source of UVC in commercial systems is low-pressure mercury vapor lamps, which emit mainly near-optimal 253.7 nm UVC. Use of germicidal ultraviolet (UV) lamps and lamp systems to disinfect room air and air streams dates to about 1900 (Reed 2010). Riley (1988) and Shechmeister (1991) wrote extensive reviews of UVC disinfection. Application of UVC is becoming increasingly frequent as concerns about indoor air quality increase. UVC is now used as an engineering control to interrupt the transmission of pathogenic organisms, such as *Mycobacterium tuberculosis* (TB), influenza viruses, mold, and potential bioterrorism agents (Brickner et al. 2003; CDC 2002, 2005; GSA 2010; McDevitt et al. 2008; Rudnick et al. 2009).

UVC lamp devices and systems are placed in air-handling systems and in room settings for the purpose of air and surface disinfection (Figure 1). Control of bioaerosols using UVC can improve indoor air quality (IAQ) and thus enhance occupant health, comfort, and productivity (ASHRAE 2009; Menzies et al. 2003). Detailed descriptions of UVGI components and systems are given in Chapter 17 of the 2016 *ASHRAE Handbook—HVAC Systems and Equipment*. Upper-air (also commonly called upper-room) devices are installed in occupied spaces to control bioaerosols (e.g., suspended viruses, bacteria, fungi contained in droplet nuclei) in the space. In-duct systems are installed in air-handling units to control bioaerosols in recirculated air that may be collected from many spaces, and to control microbial growth on cooling coils and other surfaces. Keeping the coils free of biofilm buildup can help reduce pressure drop across the coils and improve heat exchanger efficiency (therefore lowering the energy required to move and condition the air), and eliminates one potential air contamination source that could degrade indoor air quality. UVC is typically combined with conventional air quality control methods, including dilution ventilation and particulate filtration, to optimize cost and energy use (Ko et al. 2001).

This chapter discusses these common approaches to the application of UVC products. It also surveys the most recent UVC design guidelines, standards, and practices and discusses energy use and economic considerations for the application of UVC systems. Photocatalytic oxidations (PCOs), another UV-based HVAC application, are not discussed in this chapter, but are addressed in Chapter 47 of this volume.

The preparation of this chapter is assigned to TC 2.9, Ultraviolet Air and Surface Treatment.

1. FUNDAMENTALS

Ultraviolet energy is electromagnetic radiation with a wavelength shorter than that of visible light and longer than x-rays (Figure 2). The International Commission on Illumination (CIE 2003) defines the UV portion of the electromagnetic spectrum as radiation having wavelengths between 100 and 400 nm. The UV spectrum is further divided into UVA (wavelengths of 400 to 315 nm), UVB (315 to 280 nm), UVC (280 to 200 nm), and vacuum UV (VUV; 200 to 100 nm) (IESNA 2000). The optimal wavelength for inactivating microorganisms is 265 nm (Figure 3), and the germicidal effect decreases rapidly if the wavelength is not optimal.

UV Dose and Microbial Response

This section is based on Martin et al. (2008).

UVGI inactivates microorganisms by damaging the structure of nucleic acids and proteins at the molecular level, making them incapable of reproducing. The most important of these is DNA, which is responsible for cell replication (Harm 1980). The nucleotide bases (pyrimidine derivatives thymine and cytosine, and purine derivatives guanine and adenine) absorb most of the UV energy responsible for cell inactivation (Diffey 1991; Setlow 1966). Absorbed UV photons can damage DNA in a variety of ways, but the most significant damage event is the creation of pyrimidine dimers, where two adjacent thymine or cytosine bases bond with each other, instead of across the double helix as usual (Diffey 1991). In general, the DNA molecule with pyrimidine dimers is unable to function properly, resulting in the organism’s inability to replicate or even its death (Diffey 1991; Miller et al. 1999; Setlow 1997; Setlow and Setlow 1962). An organism that cannot reproduce is no longer capable of causing disease.

UVGI effectiveness depends primarily on the UV dose (D_{UV}, $\mu J/cm^2$) delivered to the microorganisms:

$$D_{UV} = It \quad (1)$$

where I is the average irradiance in $\mu W/cm^2$, and t is the exposure time in seconds (note that 1 J = 1 W/s). Although Equation (1) appears quite simple, its application can be complex (e.g., when calculating the dose received by a microorganism following a tortuous path through a device with spatial variability in irradiance). The dose is generally interpreted as that occurring on a single pass through the device or system. Although the effect of repeated UV exposure on microorganisms entrained in recirculated air may be cumulative, this effect has not been quantified, and it is conservative to neglect it.

The survival fraction S of a microbial population exposed to UVC energy is an exponential function of dose:

$$S = e^{-kD_{UV}} \quad (2)$$

where k is a species-dependent inactivation rate constant, in $cm^2/\mu J$. The resulting single-pass inactivation rate η is the complement of S:

$$\eta = 1 - S \quad (3)$$

62.1

HEPA Filter

- HEPA rated at removal of 99.97% + of 0.3 micron particles
- Viral load is trapped in filter and must be removed periodically as a biohazard.

Stephanie Taylor, MD, M Arch

Harvard Medical School
ASHRAE Distinguished Lecturer
Taylor Healthcare Consulting, CEO

Indoor Air Hydration

The game changer to staying healthy during COVID-19 and beyond!

An important study just published explains this

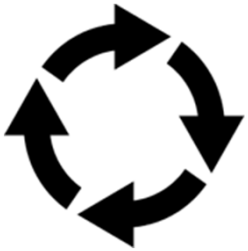
"Low ambient humidity impairs barrier function and innate resistance against influenza infection."

Eriko Kudo, Eric Song, Laura Yockey, Tasfia Rakib, Patrick Wong, Robert Homer, Akiko Iwasaki

Proceedings of the National Academy of Sciences, USA. May 19, 2019

Pathogen infectivity is high when RH < 40%

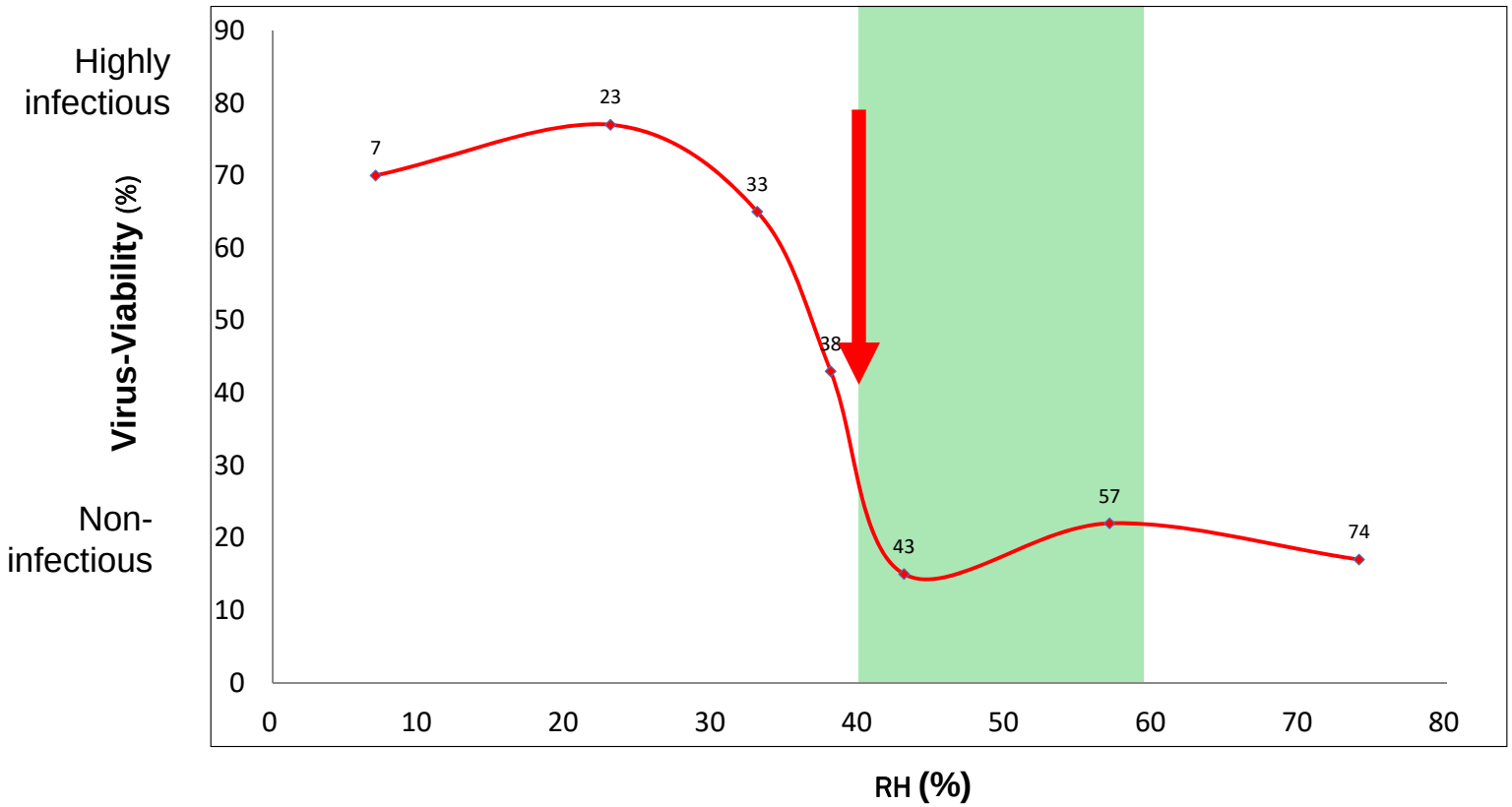
Greater aerosol transmission



Evasion from surface cleaning through resuspension

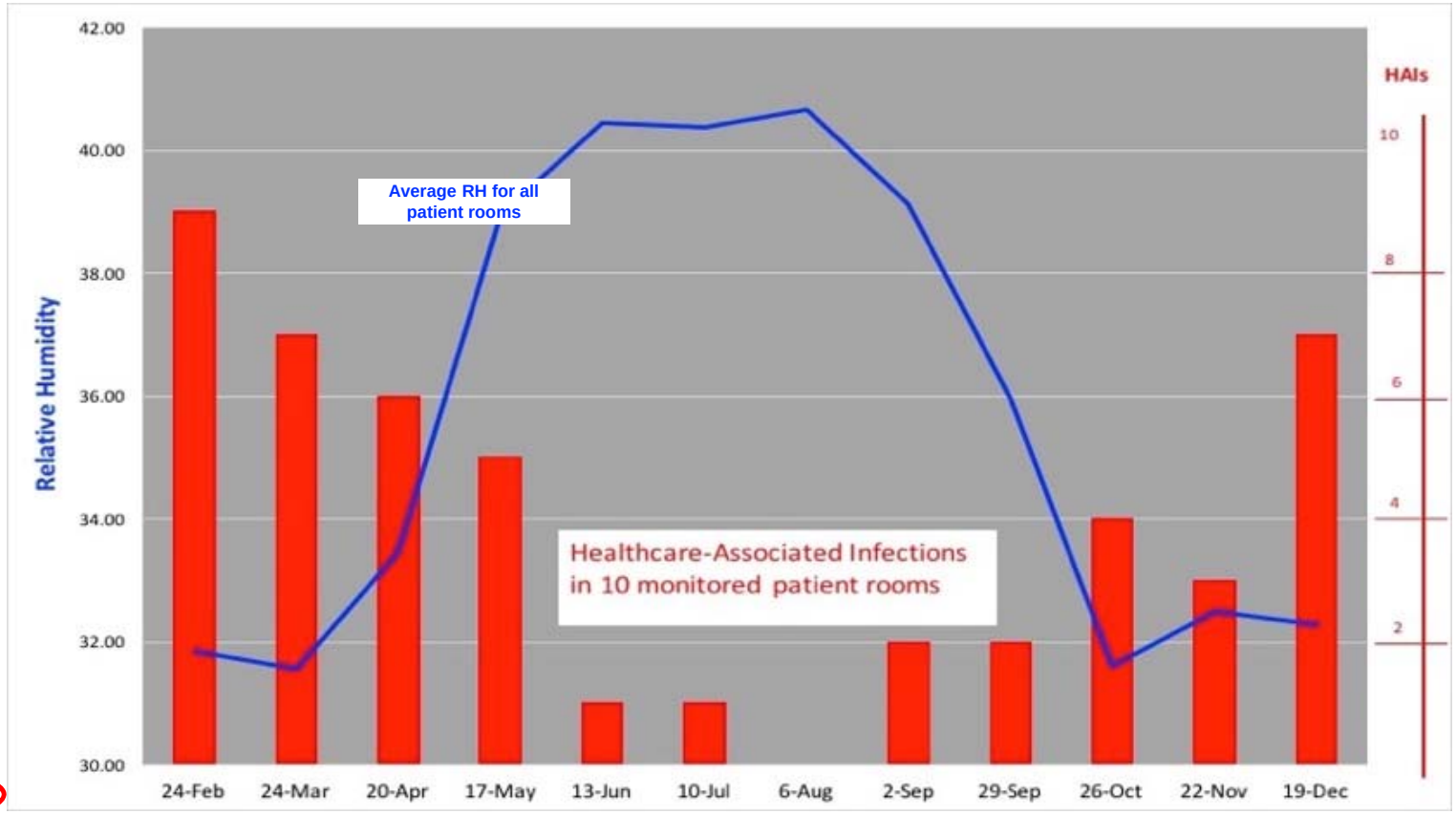
Increased survival and virulence of pathogens

Influenza A virus is more infectious when RH is below 40%



Noti 2007

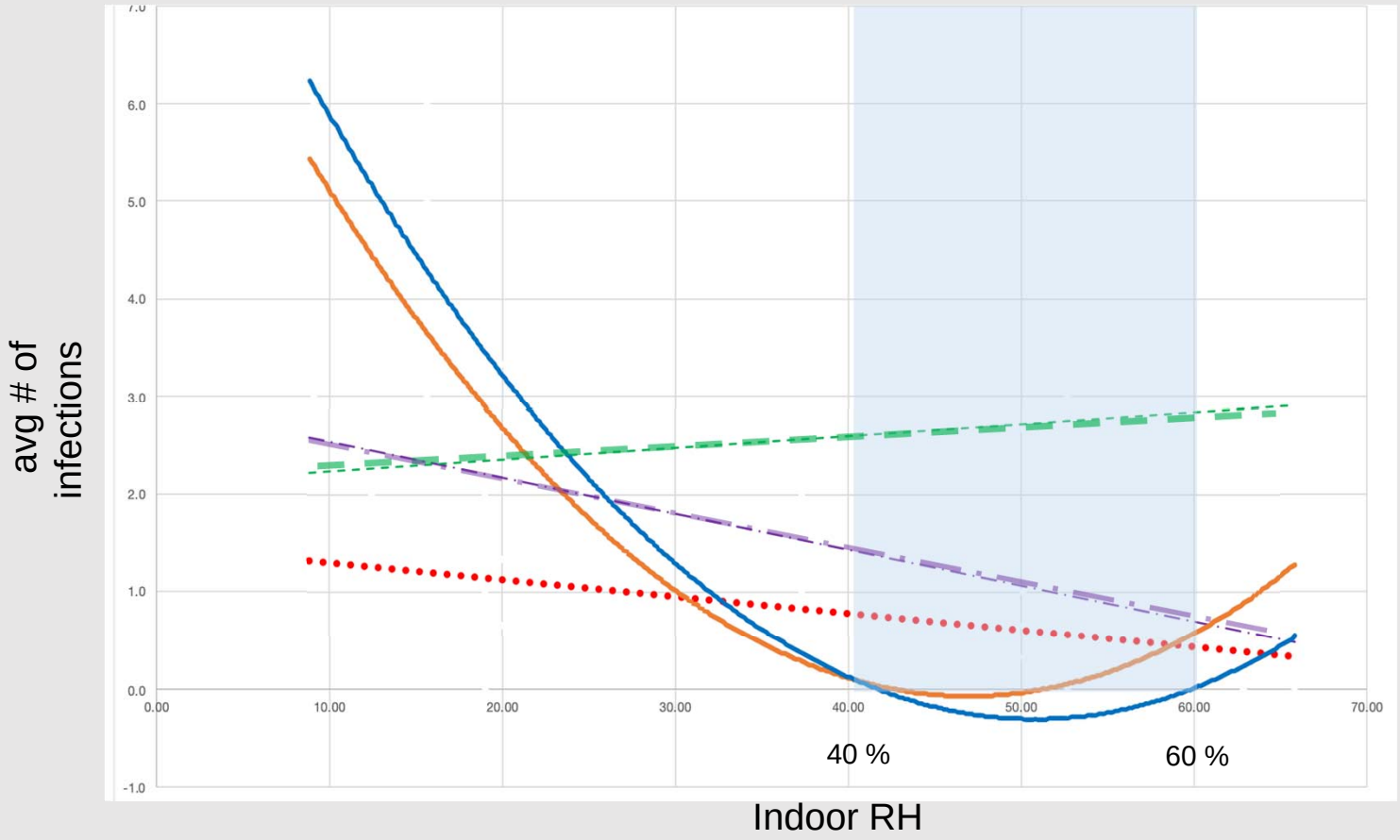
As patient room RH went down, infections went up!



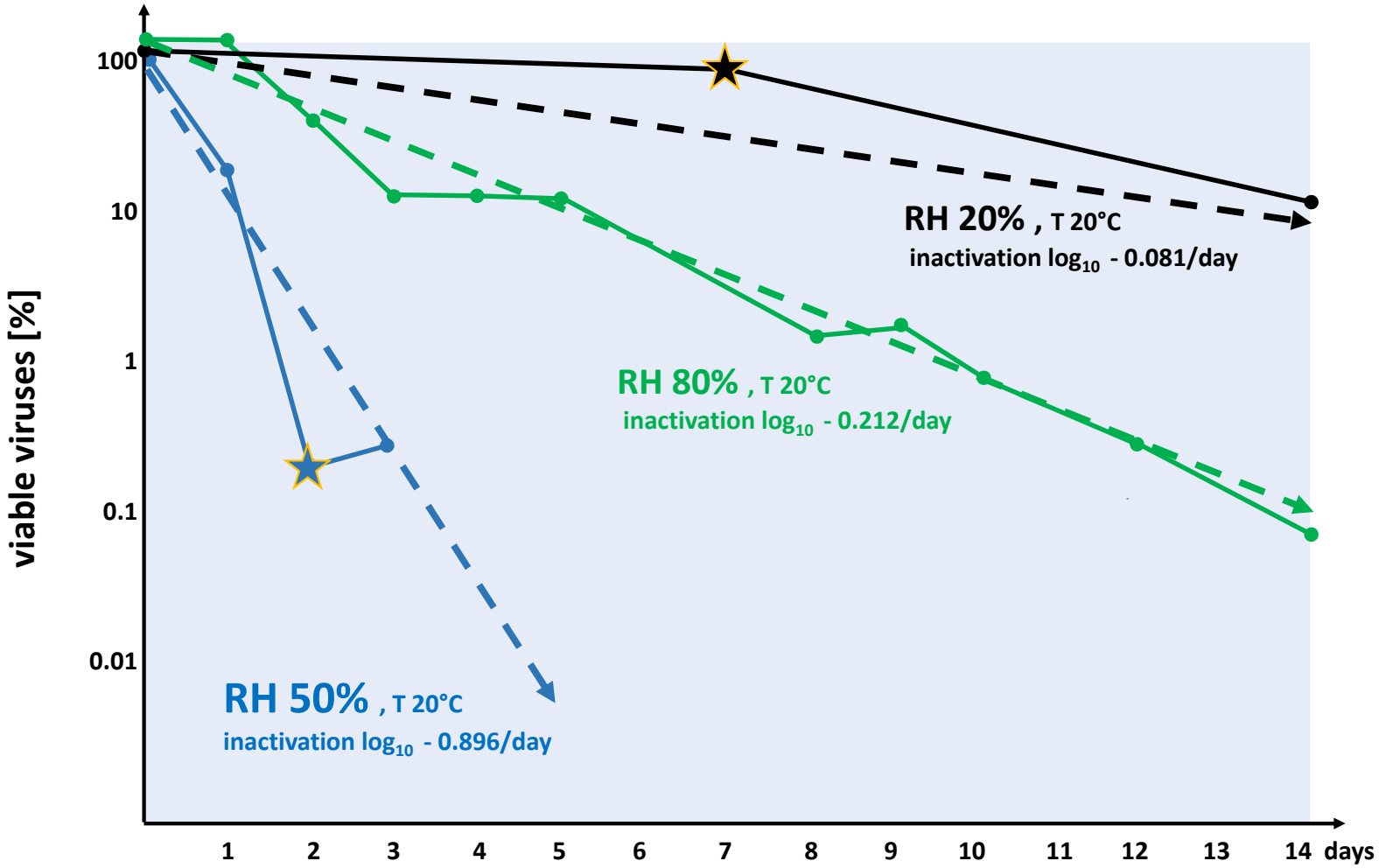
Coefficients[a]

Standardized Coefficients		
Beta	t	Sig.
	-2.348	.023
-9.060	-2.396	.020

Infection rates were lowest when indoor RH = 40-60%



Humidification to 50% RH reduces the viable Coronavirus to less than 1% in 2 days, significantly decreasing the infection risk (blue line).



Indoor climate and health outcomes in residents in a long-term care facility (over 4 yrs)

Patient infections

Infections
- respiratory (viral & bacterial)
- GI (Noro. & Notovirus, C. diff)
- urinary tract
- conjunctivitis
- cellulitis

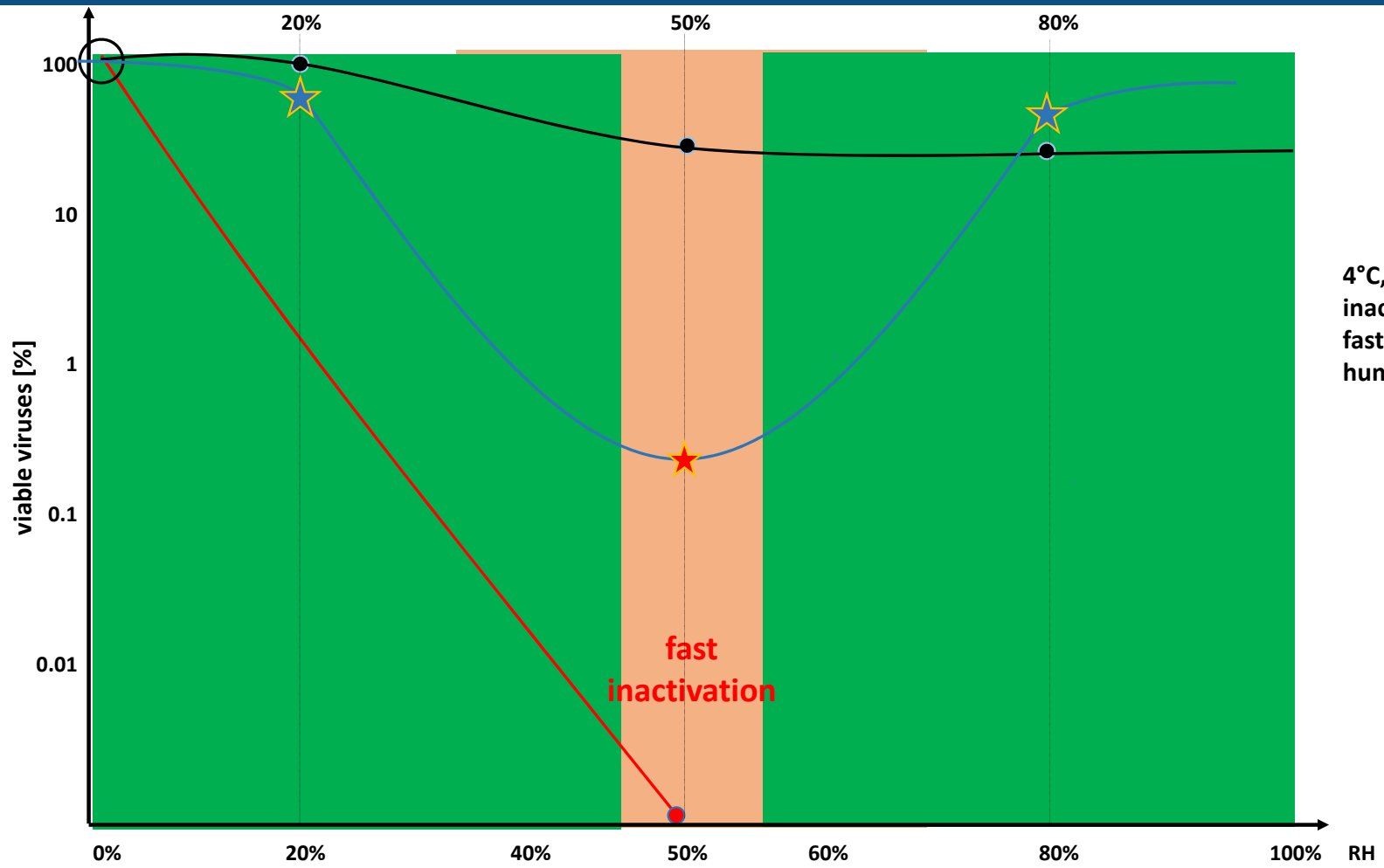
VS

Environmental data

Indoor factors
- temperature
- relative humidity
- visitors
- staff absenteeism

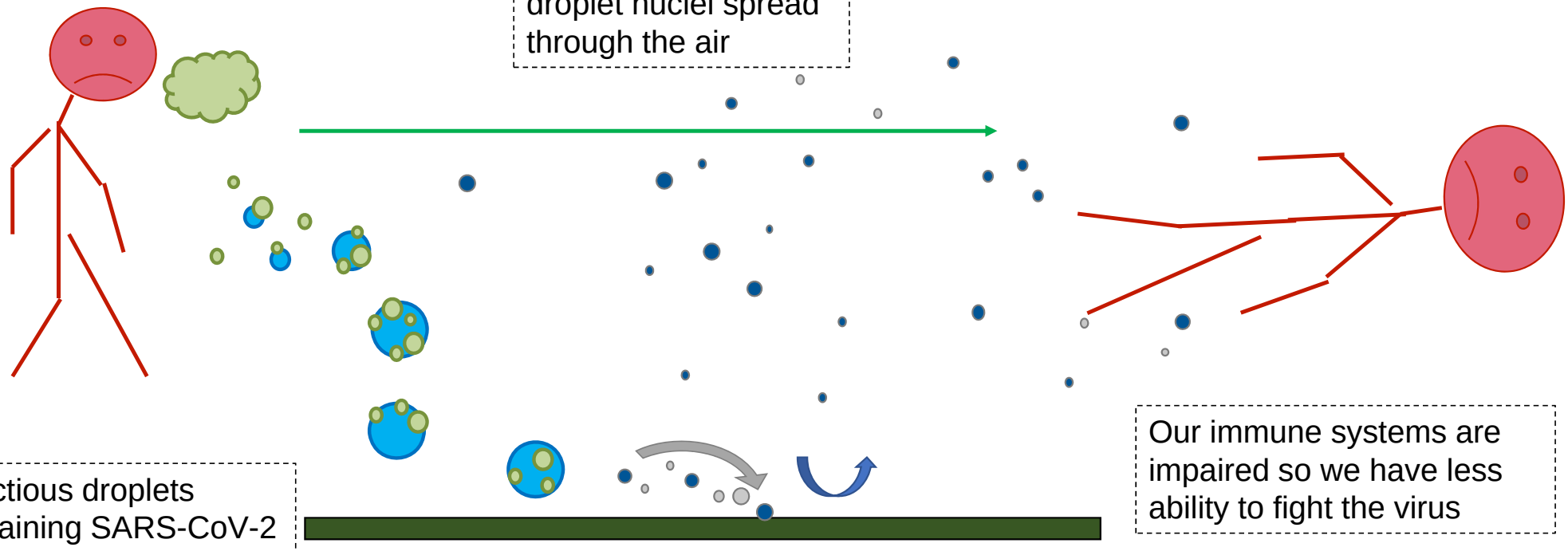
Outdoor factors
- temperature
- relative humidity
- flu outbreaks

This was true in all temperature settings tested - 50% RH inactivated Coronavirus particles in air and on surfaces

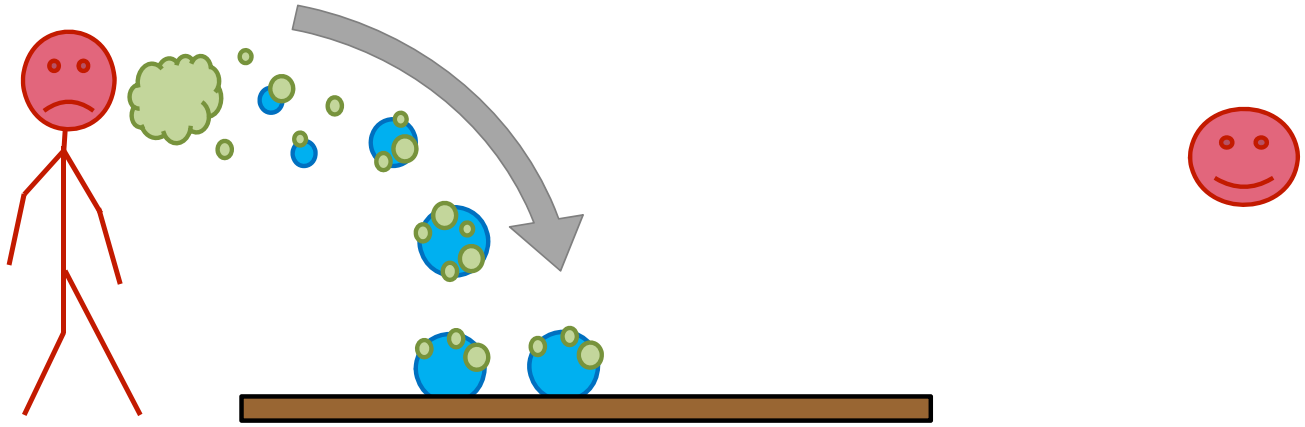


4°C, 20°C, 40°C the inactivation rate is fastest in intermediate humidity of 50% RH.

Dry Indoor Air Increases COVID-19 Droplet Spread



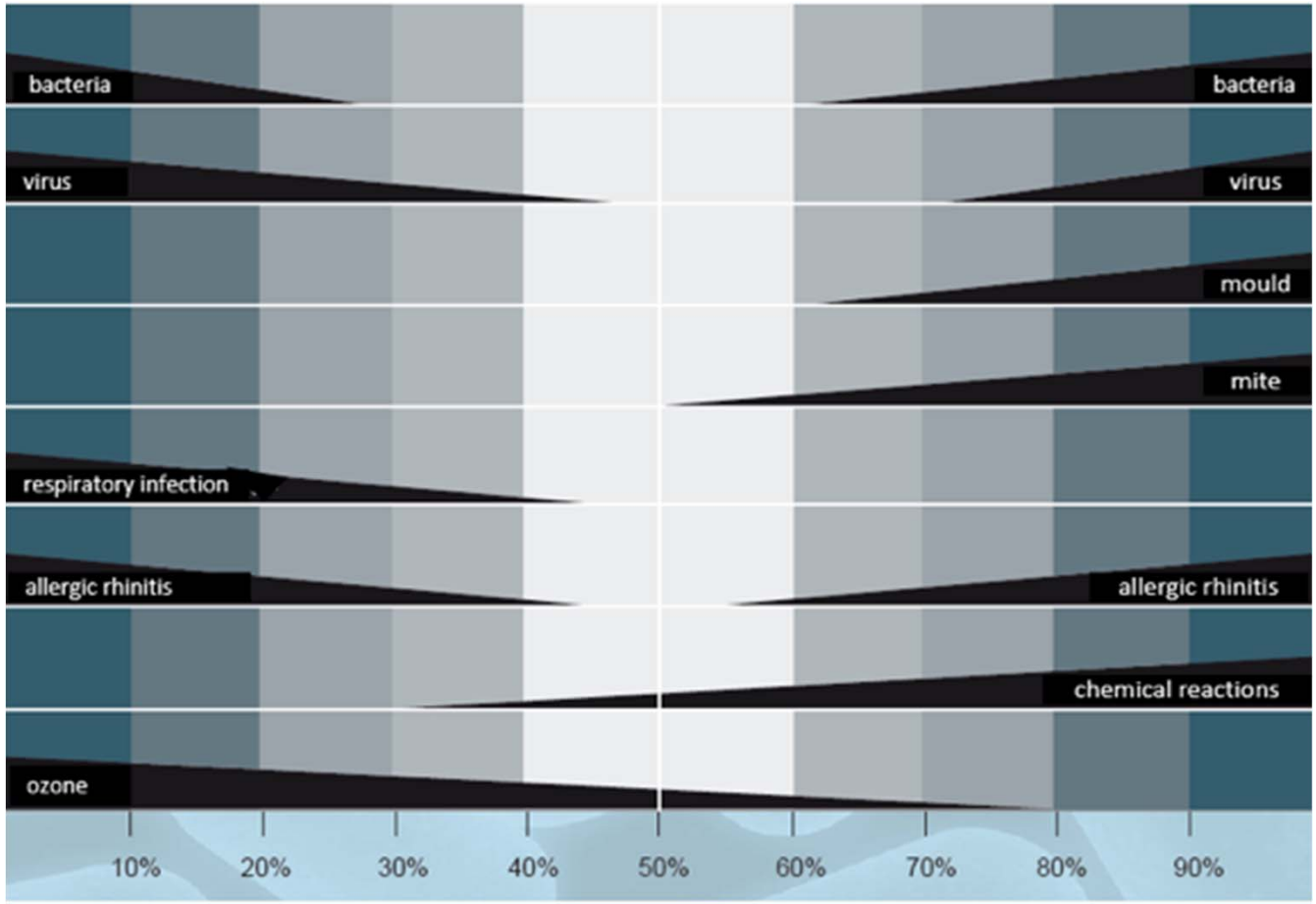
With healthy RH of 40%–60%, infectious droplets settle out of the airborne environment



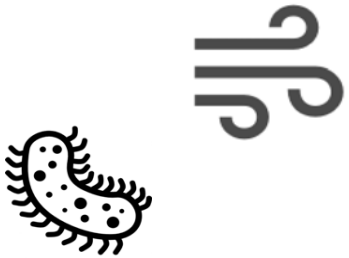
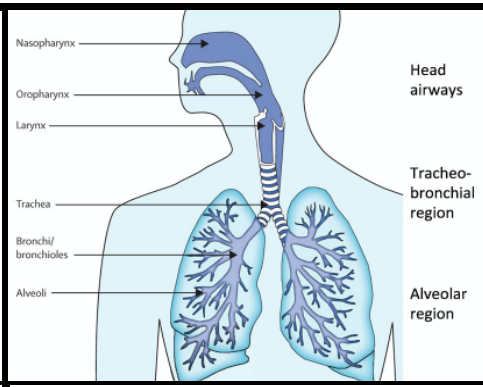
<u>Disinfection benefits of RH 40–60%:</u>

- The air carries fewer tiny infectious droplet nuclei
- Hands and frequently touched surfaces are more effectively cleaned
- Our immune system is able to protect us

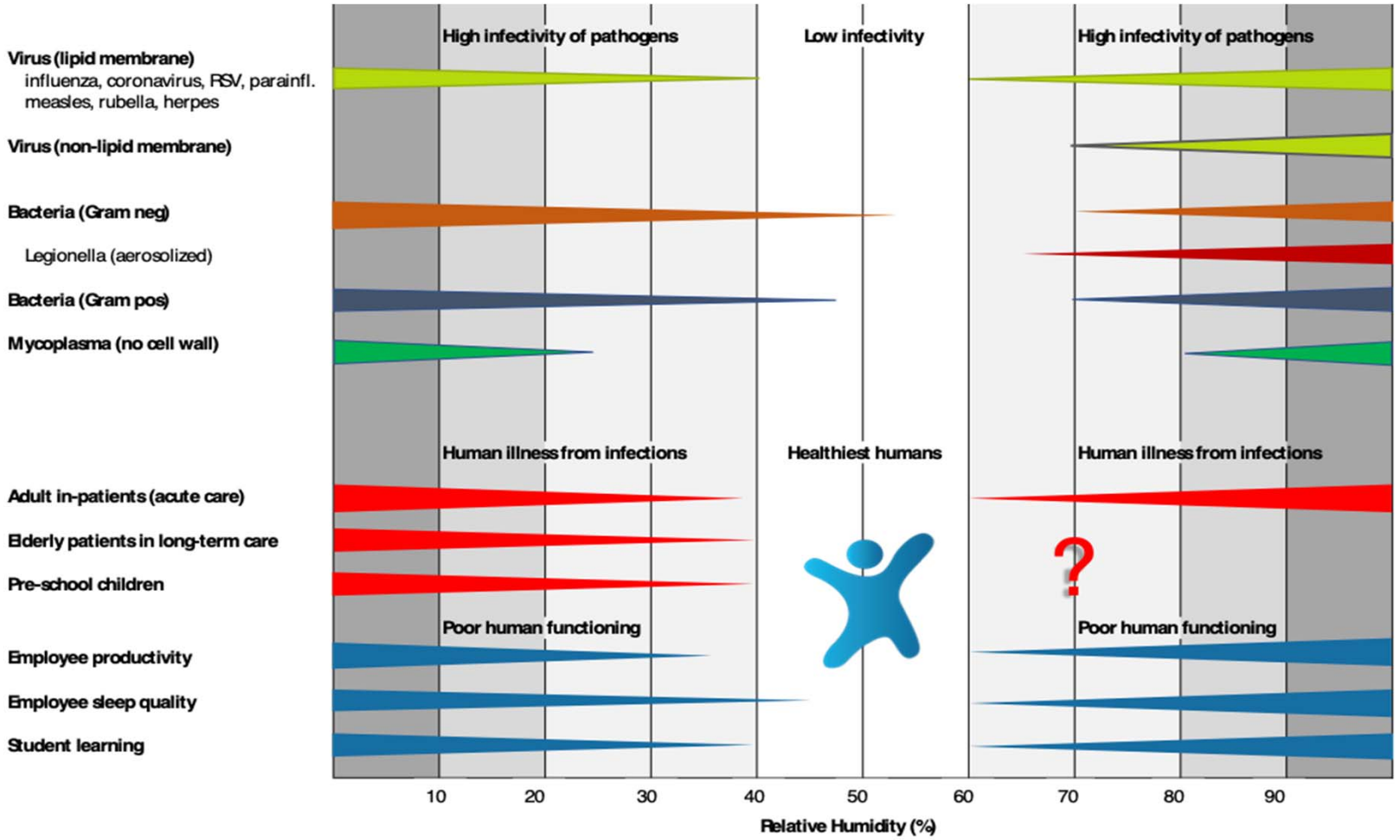
ASHRAE 1985:“Optimal RH Level For Health”



Three steps in spread of COVID-19 disease

Interventions to decrease spread of infections			
Step in infection cycle	Viral load from infected person	Virus transmission	Vulnerability of secondary person
Mask (common type)	***		N-95 or above
Quarantine			
Social distancing	***		
Hand hygiene	***		
Surface cleaning		***	***
Ventilation rates		***	
Humidification (RH40-60)		***	***
Temperature control			

Taylor Chart 2019 – which claims that infections are lowest if RH is kept between 40% and 60% RH



Conclusions:
COVID-19 requires engineered infection control

Humidity
- Indoor RH 40–60% is beneficial
- ASHRAE 'Schools re-opening' document advises engineers consider appropriate RH based on climate conditions, type and age of building, recommends 40% RH if appropriate for building. Install humidifier if necessary.
- Dry indoor environments are harmful to people and can spread diseases such as COVID-19

Air cleaning/disinfection
- Install UVGI or HEPA filtration to kill or capture corona virus

Fresh air
- Ventilation essential using clean fresh air.

Airflow strategies
- Clean air toward occupants then toward dirty areas

COVID-19 and Buildings:

Re-Occupation After Lockdown

Send questions concerning COVID-19 to:

COVID-19@ashrae.org

Engineer's lead infection control

Living with Covid

- PPE – masks
- Ventilate
- Kill virus using UVGI
- Control RH 40 to 60%
- Clean fresh air

Medical professionals

- Heal patients
- Follow clinical protocols
- Provide care

Building operators

- Follow building usage
- Reduce resource and energy use
- Stay within budget

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- *Note: Emerging Issue Reports are developed and approved by the ASHRAE Environmental Health Committee (EHC).* Pandemic SARS-CoV-2 and Airborne Transmission *Emerging Issue Brief was approved by EHC 04/17/20.*

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