Buildings and Us: what we learned from COVID-19 and what will change

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World Health Organization

Collaborating Centre for Air Pollution and Health

In this presentation

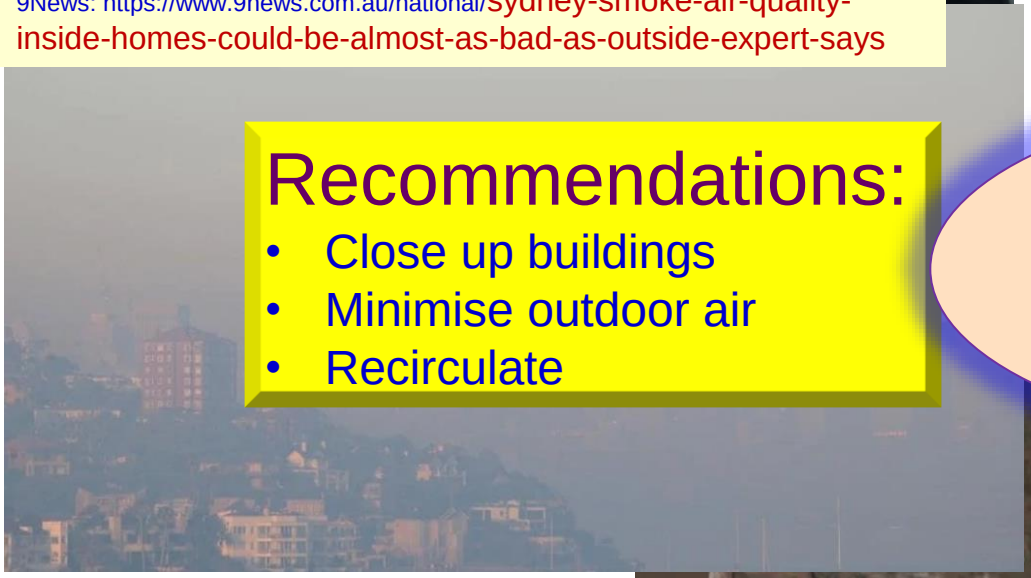
- Buildings: contradicting requirements
- What we knew ***before*** COVID-19
- Lessons from the pandemic
- Future: change in thinking and actions

BUILDINGS: contradicting requirements

(of these complex systems)

Bushfires in Australia: Sydney 2019 -2020

9News: https://www.9news.com.au/national/sydney-smoke-air-quality-inside-homes-could-be-almost-as-bad-as-outside-expert-says



Recommendations:

- Close up buildings
- Minimise outdoor air
- Recirculate

Apply to any situations of outdoor air pollution

https://www.sbs.com.au/news/the-feed/parents-worried-that-schools-aren-t-equipped-for-hazardous-bushfire-air-quality

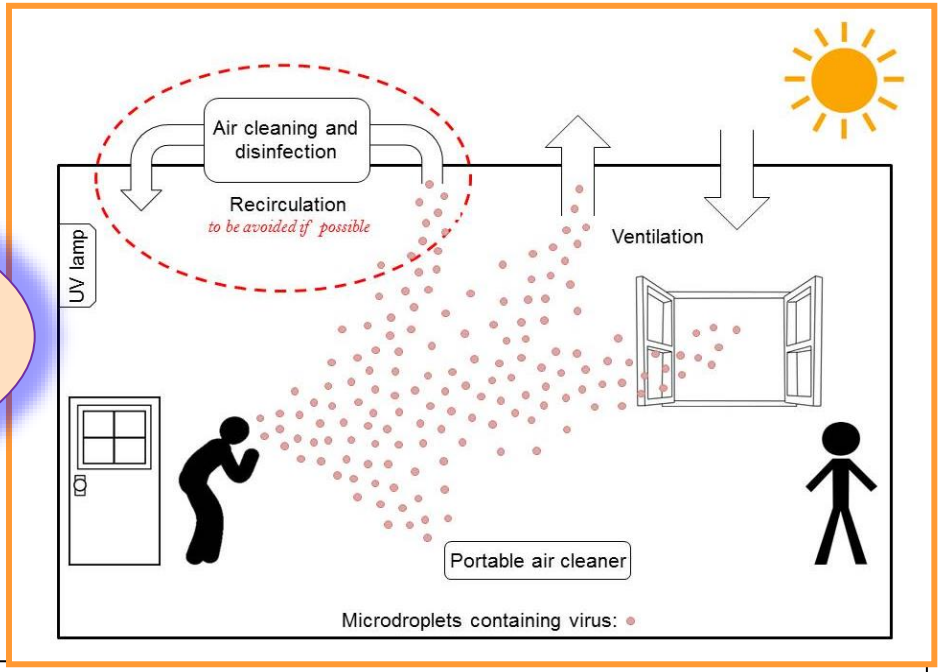
https://www.theguardian.com/australia-news/gallery/2019/nov/12/catastrophic-fire-conditions-along-australias-east-coast-in-pictures

COVID-19 around the world

Recommendations:

- Open up buildings
- Maximise outdoor air
- Do not recirculate

Apply to any situations of respiratory infections

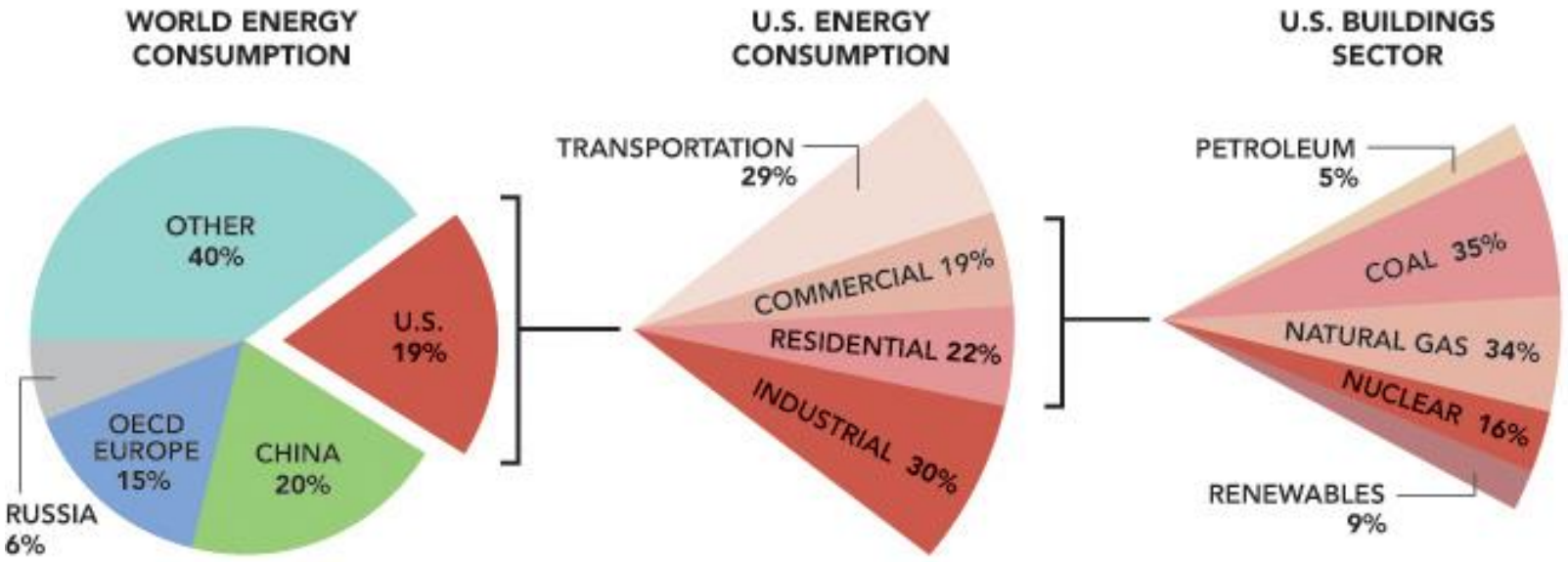


Morawska, et al., "How can airborne transmission of COVID-19 indoors be minimised?", Environment International, 142: 105832, 2020

Buildings and energy

Recommendation:

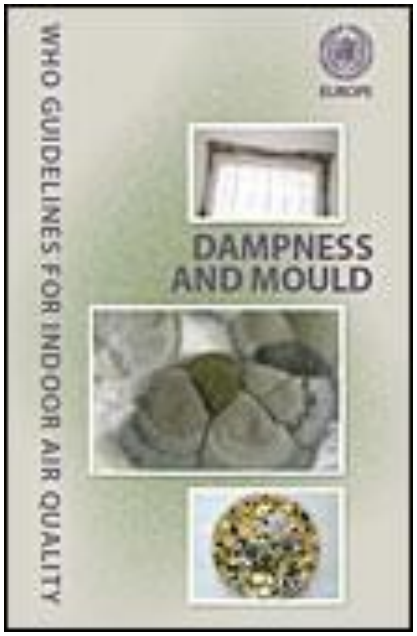
- Tighten up buildings

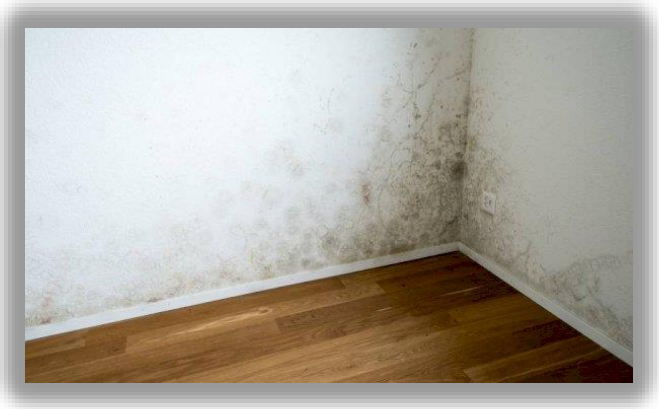


U.S. Energy Info Admin., AEO2014

Buildings and mould

We don’t generate biological agents but often create conditions under which they can propagate





Recommendation:

- Open up buildings

What we knew ***before*** COVID-19

(about respiratory infection transmission)

Indoor Air 2005 conference

Title of my plenary presentation:
Droplet fate in indoor environment: can we prevent the spread of infection?

IA 2005

Morawska, L. 2006. Droplet Fate in Indoor Environments, Or Can We Prevent the Spread of Infection. *Indoor Air* 16(5): 335-347.

IA 2005

How common are respiratory infections?

Some examples from UK estimates:

Colds per year :

- infants and preschool children 4 to 8
- adults 2 to 5

For every case reported, the number of unreported in the community:

- 35 rotavirus
- 1562 cases of Norvalk-like virus

Sperber 1994

Wheeler et al. 1999

Economics of infection spread

IA 2005

Communicable respiratory infections in USA indoor work environment (annual):

- Health care costs: $10 billion;
- Costs from absence due to illness: $19 billion
- Other performance loss: $3 billion

Influenza and common cold: 52 million cases

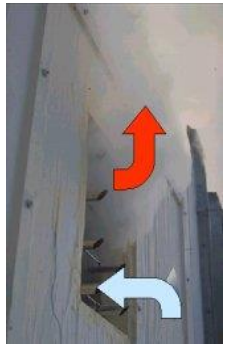
- Possible reduction: 10 to14%
- Possible economic benefits: $3 to 4 billion

[Mendell et al 2002]

CONCLUSIONS: role of building design in infection prevention

IA 2005

1. Setting the key building parameters according to the current understanding of their optimal ranges, would also result in lowering of the potential for infection spread



2. Whether this is the limit of what can practically be achieved in minimization of infection spread, is not known

3. Need for application of the science of infection spread towards developing quantitative knowledge guiding building design and operation

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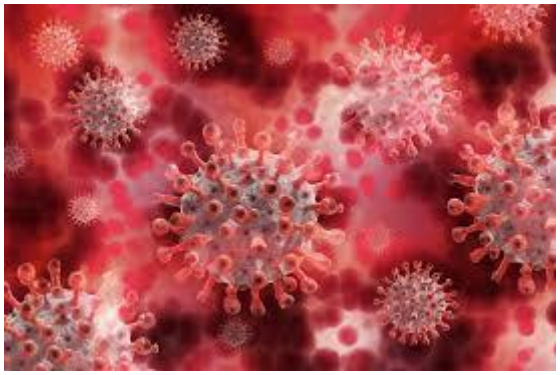
2020 COVID-19



The science of infection transmission wasn't used to prepare us for COVID-19!

LESSONS FROM THE PANDEMIC

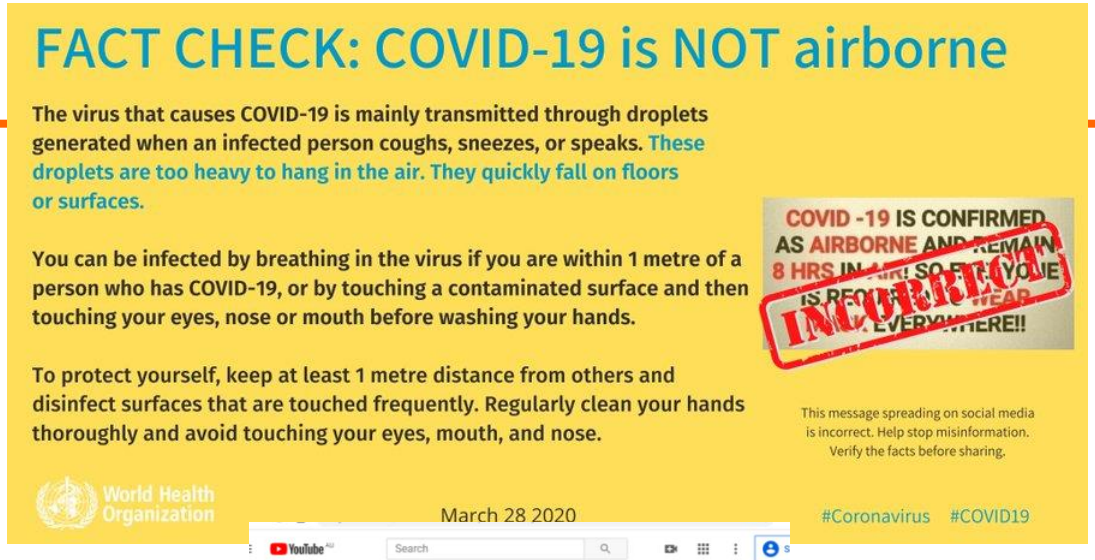
The risk

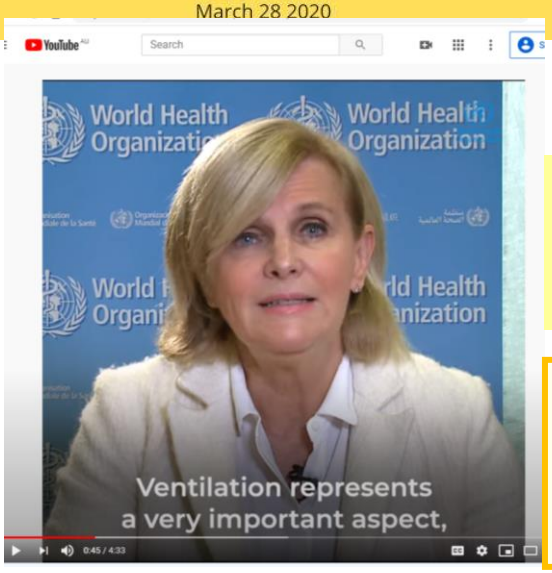
Outbreaks: how to quantify the risk

Is *IT* airborne?

"It goes through air, Bob. That's always tougher than the touch.“

President Trump, interview with Bob Woodward February 2020





Dr Maria Neira
October 2020

... to prevent the virus from spreading indoors”.

https://www.youtube.com/watch?v=XJC1f7F4qtc&feature=youtu.be

Not a controversy anymore?

Dr. Anthony S. Fauci: “There was some real misunderstanding about respiratory droplets and so-called aerosolised particles. The aerosol and particles physicists that have approached us now have told us that we really have got it wrong over many years… ”

“Bottom line is this: there is much more aerosol than we thought."

https://masscpr.hms.harvard.edu/event/harvard-medical-school-grand-rounds-featuring-dr-anthony-s-fauci

US CDC 5 Oct:

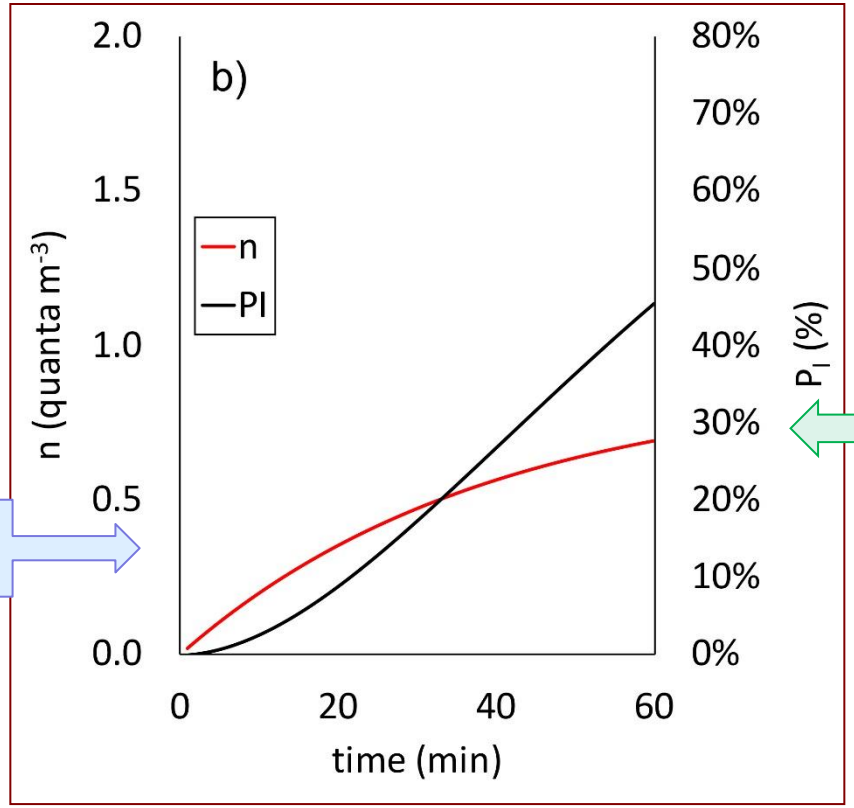
“COVID-19 **most commonly** spreads during close contact ”
“COVID-19 **can sometimes** be spread by airborne transmission”

Outbreaks and airborne tranmission

While all three modes of transmission occur, airborne emerges as the most significant in typical public settings

Skagit Valley choir

The Mount Vernon Presbyterian Church in Mount Vernon, Wash. (Karen Ducey / For The Times)



Quanta concentration

Probability of infection

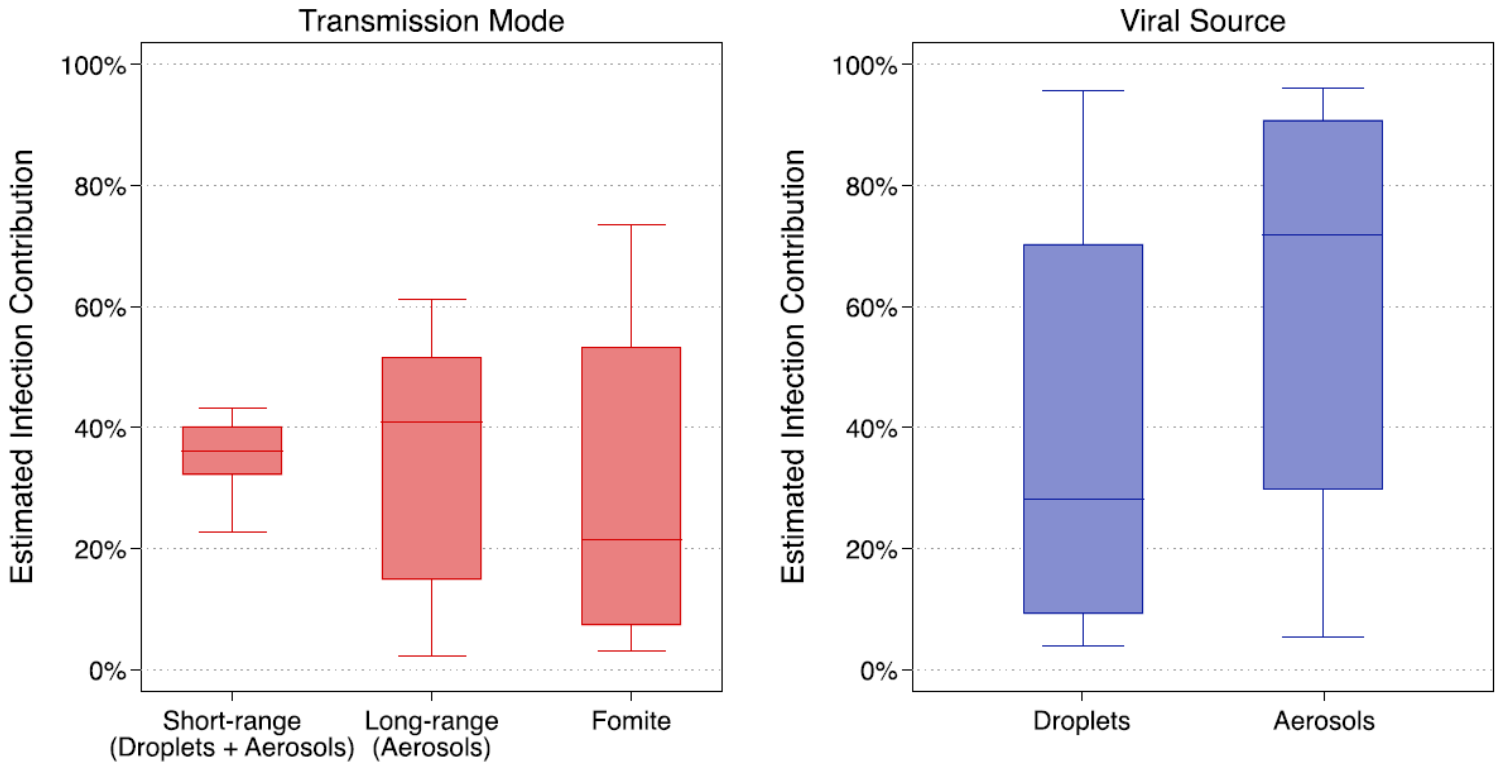
ER_q=341 quanta h^{-1}

Stable, L., Buonanno, G. and Morawska, L. Quantitative assessment of the risk of airborne transmission of SARS-CoV-2 infection: prospective and retrospective applications. *Environment International,* **Accepted 31 August 2020, In Press.**

Airborne Infection Risk Tool

https://research.qut.edu.au/ilaqh/wp-content/uploads/sites/174/2020/09/AIRC-Tool-v2.0.xlsx

Estimates of contributions: transmission modes + viral sources

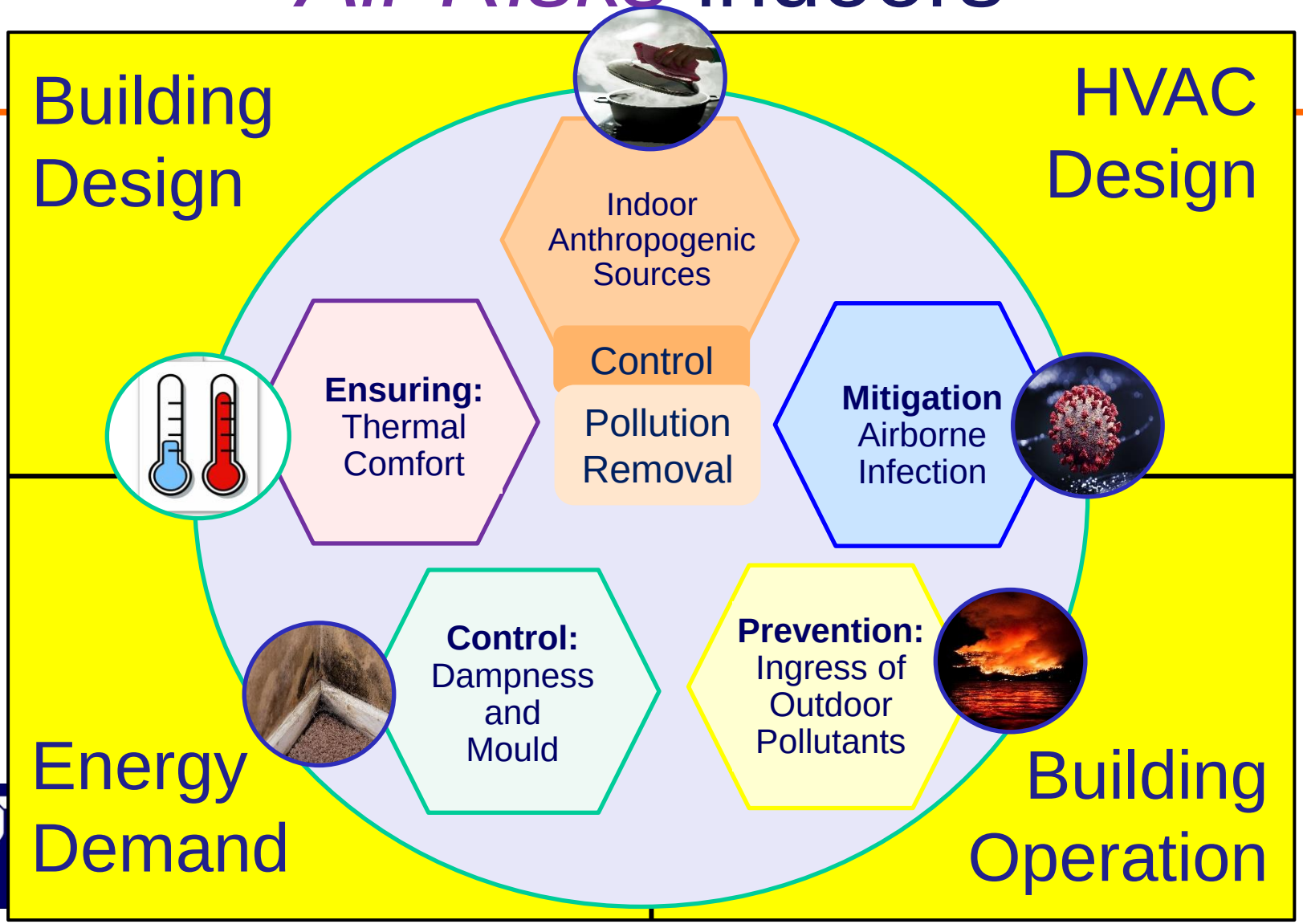


Azimi et al. preprint: *Mechanistic transmission modelling of COVID-19 on the Diamond Princess Cruise ship demonstrates the importance of aerosol transmission*.

FUTURE:
CHANGE IN ACTIONS

Mitigation of all *Air Risks*
Airborne infection: focus on ventilation
Guidelines for engineering controls
Empowering individuals

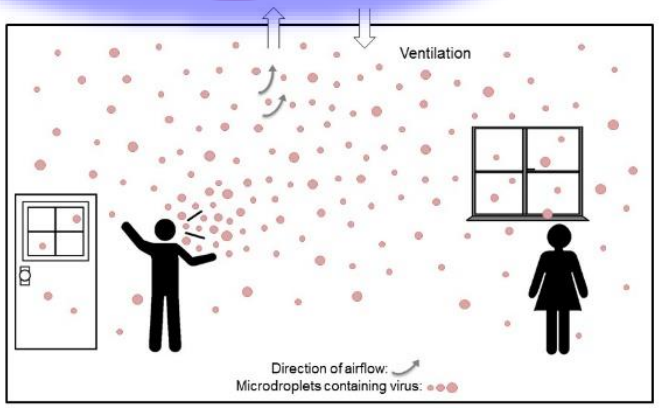
Change in actions: mitigation of all *Air Risks* indoors

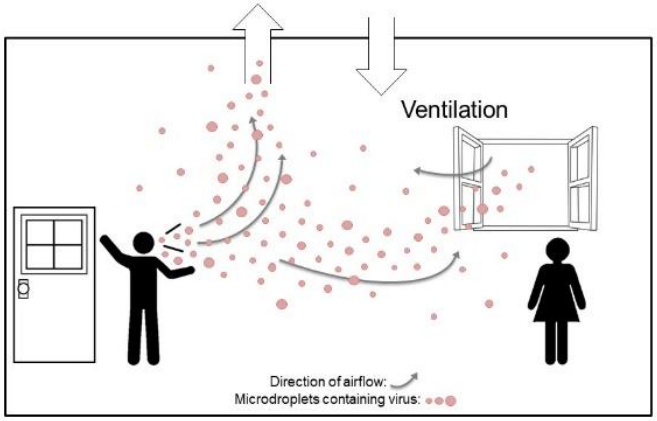


Mitigating airborne infections: sufficient and effective ventilation

Enough of it

Everywhere





Can we use the existing ventilation guidelines for controlling infection transmission?

For example guidelines for removing CO_2 exhaled by the occupants?

Morawska, L. and Milton, D. "It is Time to Address Airborne Transmission of COVID-19". *Clinical Infectious Diseases*, 6: ciaa939, 2020

Unlike exhalation of CO_2 by the occupants…

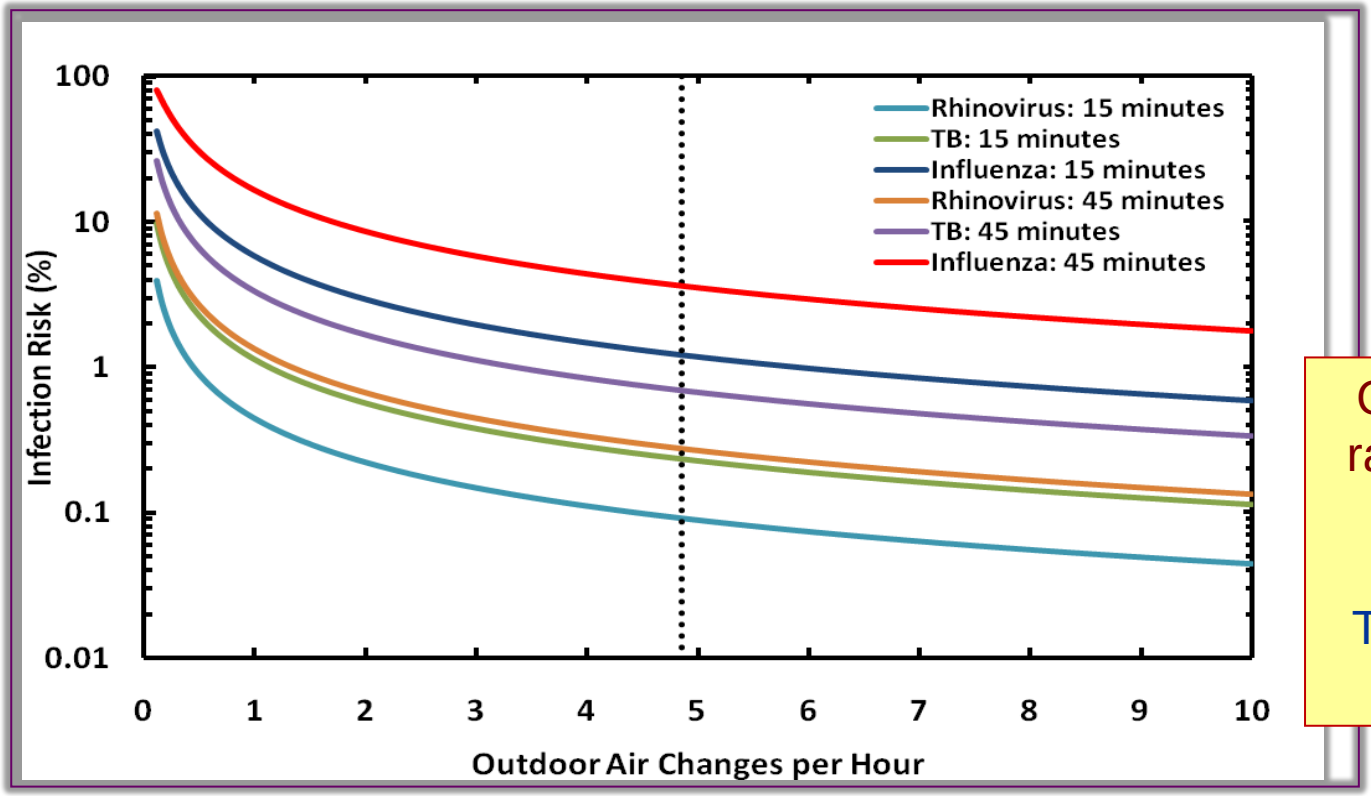
Infection transmission: infectious quanta

A quantum is the dose of infectious airborne droplets required to cause infection in 63% of susceptible persons

Emitted quanta depend on:

- Location of the pathogen in the respiratory tract
- Physiology of the respiratory tract
- Stage of the disease
- Type of respiratory activity
- THE VIRUS

Ventilation and infection risk



Using Wells-Riley model

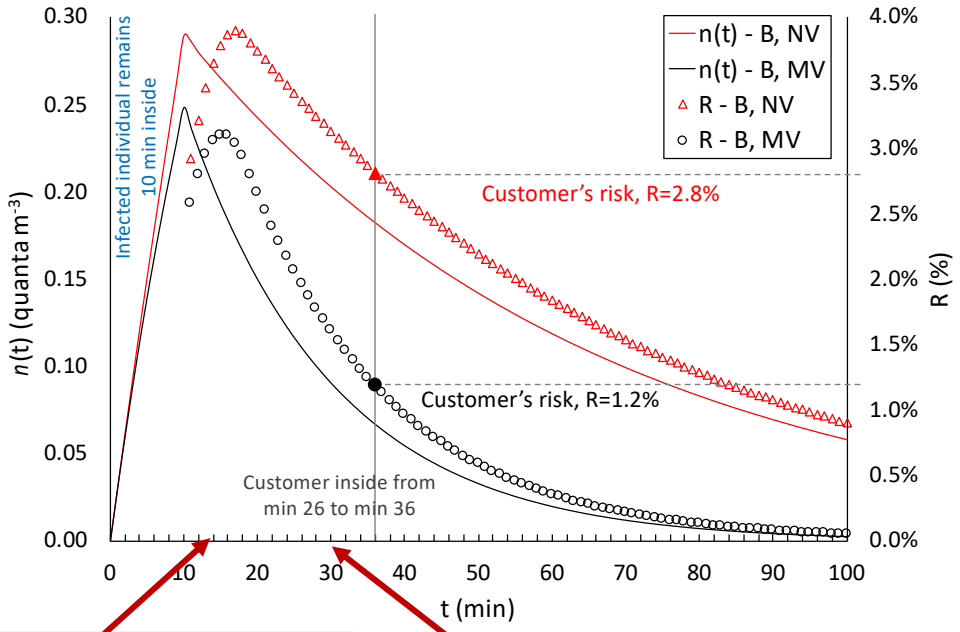
Quanta generation rates from literature (quanta/hour):
Influenza - 67
Tuberculosis - 12.7
Rhinovirus – 5

The Prince Charles Hospital, Brisbane, Lung Function Laboratory: infection risk for 15 and 45 min occupancy

Laboratory for Air Quality and Health
WHO Collaborating Centre

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

Quanta concentrations and infection risks in a pharmacy for exposure scenarios before lockdown (B) in Italy



NV- natural ventilation
MV -mechanical ventilation

An infected individual enters

The risk for a customer entering at min 26 and remaining for 10 min

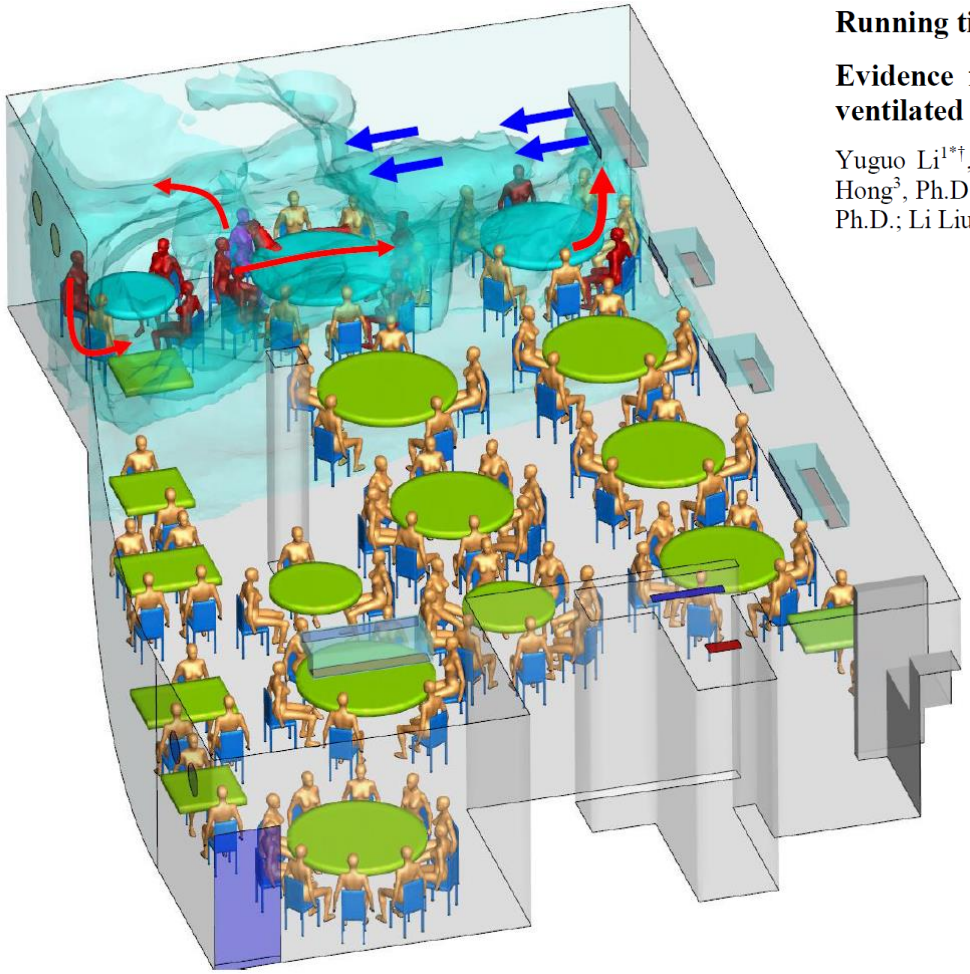
Buonanno et al. *Environment International,* 141: 105794, 2020

Stabile et al. Quantitative assessment of the risk of airborne transmission of SARS-CoV-2 infection: prospective and retrospective applications. *Environment International,* **Accepted 31 August 2020, In Press.**

Airborne Infection Risk Tool

https://research.qut.edu.au/ilaqh/wp-content/uploads/sites/174/2020/09/AIRC-Tool-v2.0.xlsx

Air flow distribution/direction and infection risk



Running title: Aerosol transmission of SARS-CoV-2

Evidence for probable aerosol transmission of SARS-CoV-2 in a poorly ventilated restaurant

Yuguo Li[1*†], Ph.D.; Hua Qian[2†], Ph.D.; Jian Hang[3†], Ph.D.; Xuguang Chen[4], M.Sc.; Ling Hong[3], Ph.D.; Peng Liang[5], M.Sc.; Jiansen Li[4], M.Sc.; Shenglan Xiao[1], Ph.D.; Jianjian Wei[6], Ph.D.; Li Liu[7], Ph.D.; and Min Kang[4†], M.Sc.

Posted April 22, 2020 doi: https://doi.org/10.1101/2020.04.16.20067728. medRxiv preprint

The flow direction was a problem in this case

Contradicting requirement: misconceptions

"The university [in Spain] advices **to avoid cross ventilation** during any lectures."

"More precisely, the recommendation is **to avoid opening opposing windows and doors** during class in order to avoid air currents."

"The alleged rationale is that such **currents can transport aerosols from one person to another**."

But this will potentially lead to reduced venation, hence a higher risk.

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Guidelines for engineering controls

For mechanical systems REHVA, ASHRAE and others have already:

- recommended control measures based on the existing evidence on airborne transmission
- provided guidelines on their implementation

https://www.ashrae.org/technical-resources/resources
https://www.rehva.eu/fileadmin/user_upload/REHVA_COVID-19_guidance_document_V3_03082020.pdf

More advanced guidelines should be developed taking into account knowledge about airborne infection transmission

ISIAQ Webinar

Airborne Infection Risk Tool

https://research.qut.edu.au/ilaqh/wp-content/uploads/sites/174/2020/09/AIRC-Tool-v2.0.xlsx

Empowering individuals

…so they understand the system and can control it.

Do you know:

What is the temperature in your home or office?	YES (if I want to)
How good is the ventilation in your home or office?	MAYBE
How good is the ventilation in the cinema or restaurant?	NO
Where is the air coming from?	
How good is the indoor air quality?	NO

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journal homepage: www.elsevier.com/locate/scitotenv

Review

Real-time sensors for indoor air monitoring and challenges ahead in deploying them to urban buildings

Prashant Kumar [a,b,*], Andreas N. Skouloudis [c], Margaret Bell [d], Mar Viana [e], M. Cristina Carotta [f], George Biskos [g,h], Lidia Morawska [i]

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[b] Environmental Flow Research Centre, FEPS, University of Surrey, Guildford GU2 7XH, Surrey, United Kingdom
[c] Joint Research Centre, European Commission, Institute for Environment and Sustainability TP263, via E Fermi 2749, Ispra, VA I-20127, Italy
[d] Transport Operations Research Group, School of Civil Engineering and Geosciences, Newcastle University, Claremont Road, Newcastle upon Tyne, NE17RU, United Kingdom
[e] Institute of Environmental Assessment and Water Research, IDAEA-CSIC, Jordi Girona 18, 08034 Barcelona, Spain
[f] IMAMOTER - C.N.R. Sensors and Nanomaterials Laboratory, via Canal Bianco 28, 44124 Ferrara, Italy
[g] Faculty of Civil Engineering and Geosciences, Delft University of Technology, Delft 2628 CN, The Netherlands
[h] Energy Environment and Water Research Center, The Cyprus Institute
[i] International Laboratory for Air Quality and Health, Queensland Unive

HIGHLIGHTS

- State of the art on air pollution sensing in indoor environments is reviewed.
- Technology for indoor air sensing has notably progressed, albeit challenges remain.
- Awareness of, and regulation for, IAQ are lagging behind the technology.
- Therefore, the emerging IAQ sensing technologies appear ahead of their time.

GRAP

"…firstly, **much better awareness of IAQ** issues would need to be developed, and secondly, **tools to interpret the sensor data** to enable appropriate action on the information gathered…."

"Neither of these exists as yet, and therefore it is argued that currently **available sensors are ahead of their time**."

Paradigm change in using data from indoor sensors

Not for the purpose of data collection or network building, but for displaying the state of the indoor environment

Display:

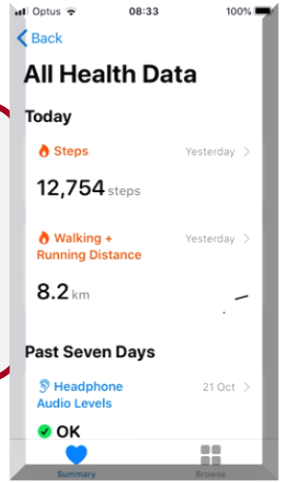
- in a meaningful way for the user to interpret
- a parameter or its proxy so an action can be taken

Time to have sensors around and be guided by them

Displaying the state of the indoor environment is very important

For this we don't need scientific grade instruments

Our mobile phones guide as to the amount of walking we should (*and they are not scientific grade instruments*)



FUTURE:
CHANGE IN THINKING

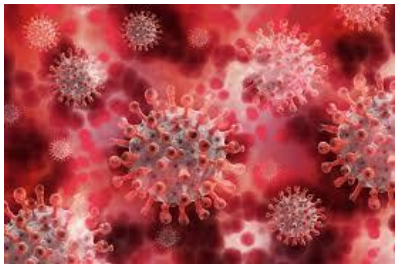
Change in thinking

- How buildings are designed
- How they are equipped in adequate engineering controls
- How all the requirements are linked including low energy consumption
  - How we think about indoor air quality
  - How we teach about it and train medical students
  - The perception that we cannot afford this: **the economic costs of the impacts of indoor air pollution by far exceed all other costs**

Buildings and us: what will change?

Every pandemic in history transformed humanity

Will COVID-19 transform our buildings?



Thank you!

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