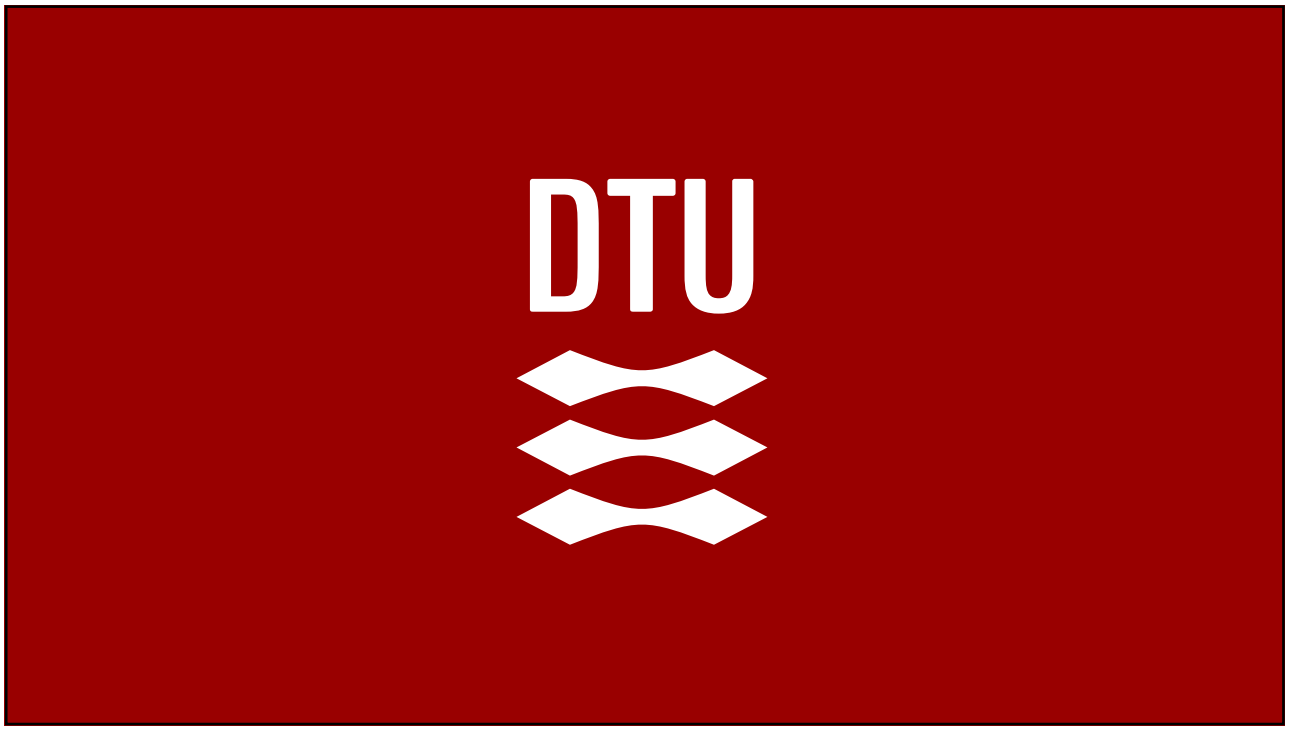


1

Paweł Wargocki (pawar@dtu.dk)
DTU SUSTAIN
Technical University of Denmark

ASHRAE 241: Nowy standard w celu ograniczania ryzyka infekcji

2

Preamble

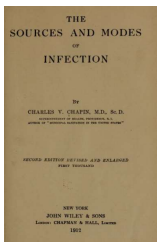
3

The point of disagreement, the mode of transmission

Source: https://munglobal.com.au/

4

Chapin doctrine vs. Wells-Riley study

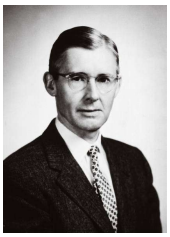

THE
SOURCES AND MODES
OF
INFECTION

By
CHARLES V. CHAPIN, M.D., Sc.D.

SECOND EDITION REVISED AND ENLARGED

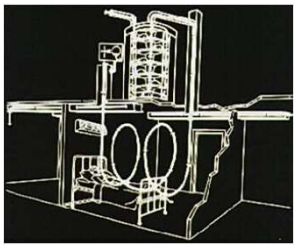
NEW YORK
JOHN WILEY & SONS
London: CHAPMAN & HALL, Limited
1912

Contact, including direct droplet spread, was considered the only route of contagion (Chapin, Providence)



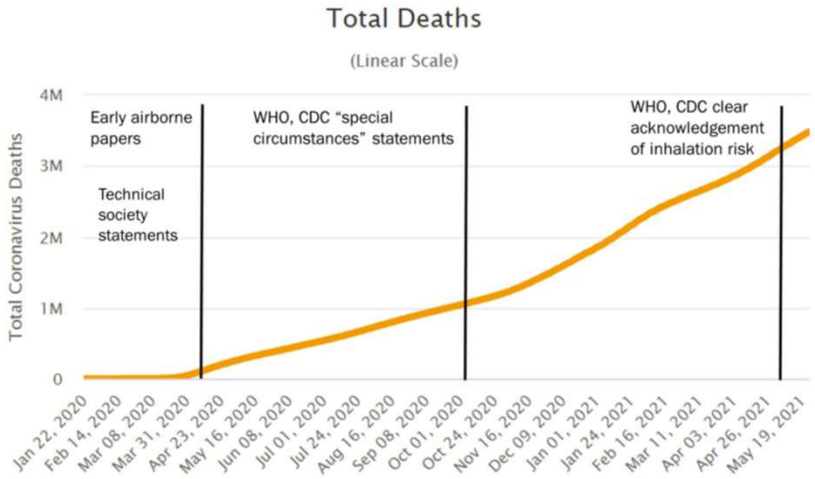

HISTORICAL PAPER

AERIAL DISSEMINATION OF PULMONARY TUBERCULOSIS
A TWO-YEAR STUDY OF CONTAGION IN A TUBERCULOUS GROUP



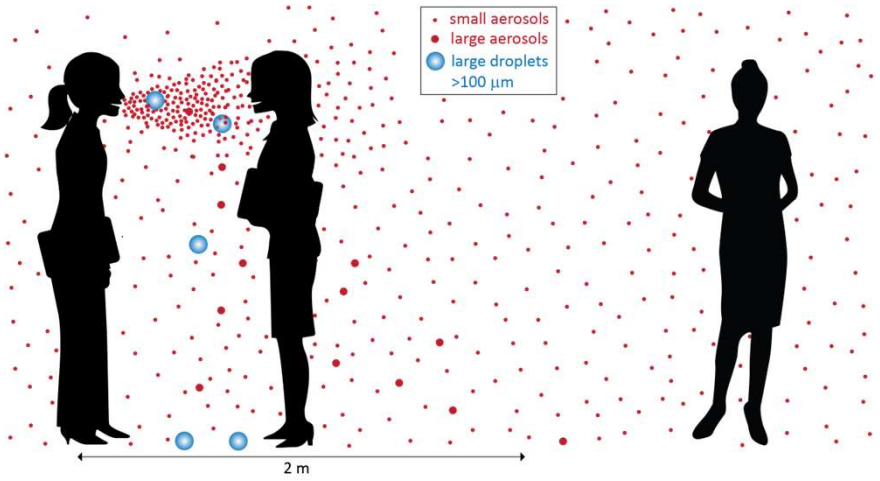
1958-62, Riley's experimental ward proved TB was airborne

What has happened between 3/2020 and 5/2021



Source: Bahnfleth (2021)

Droplets vs. aerosols

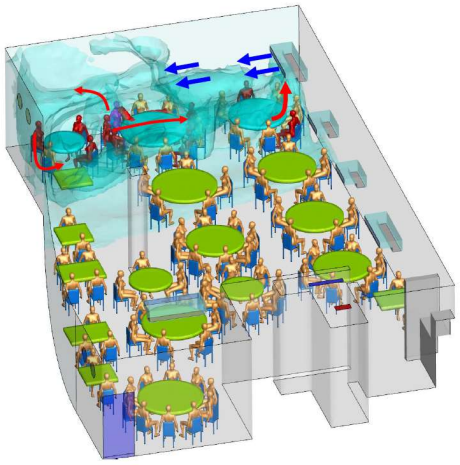


Source: Morawska et al. (2020)

7

Science behind (weak but consistent)

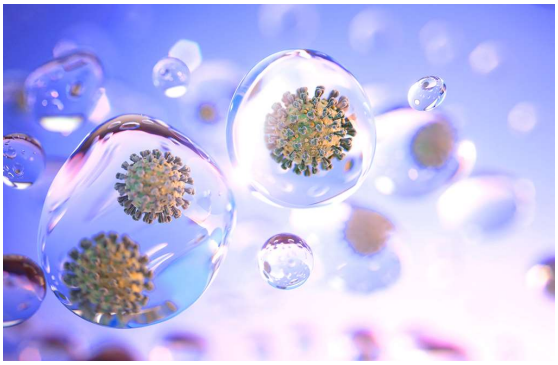
- Guangzhou restaurant outbreak
- 1 pre-symptomatic
- 9 infections at 3 tables
- Same recirculation zone
- Ventilation rate (estimated) 1 L/sp
- No close contact or fomite contact was identified
- None of the restaurant staff or the 68 patrons at the other 15 tables became infected.



Source: Li et al. (2021)

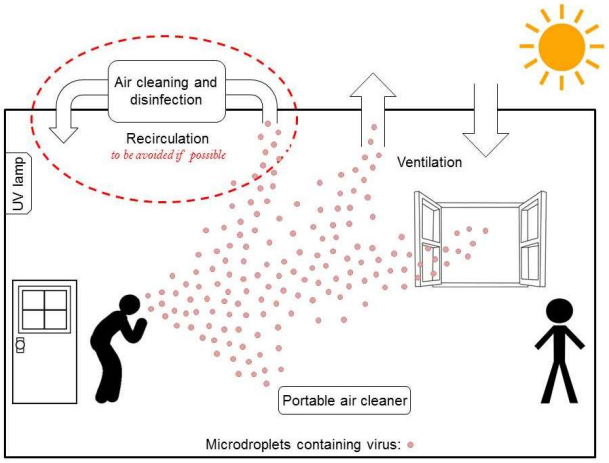
8

Background



9

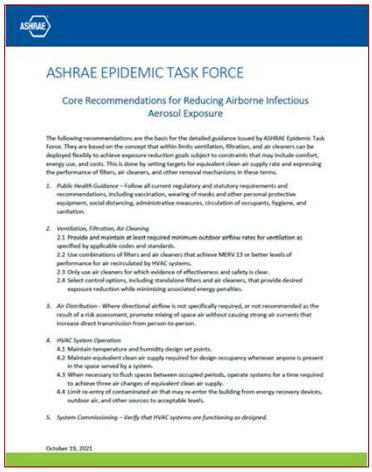
Ventilation
Filtration/air cleaning



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

10

PAST DEVELOPMENTS for infection control guidelines



ASHRAE EPIDEMIC TASK FORCE

Core Recommendations for Reducing Airborne Infectious Aerosol Exposure

The following recommendations are the basis for the detailed guidance issued by ASHRAE Epidemic Task Force. They are based on the concept that within limits ventilation, filtration, and air cleaners can be deployed flexibly to achieve exposure reduction goals subject to constraints that may include comfort, energy use, and costs. This is done by setting targets for equivalent clean air supply rate and expressing the performance of filters, air cleaners, and other removal mechanisms in these terms.

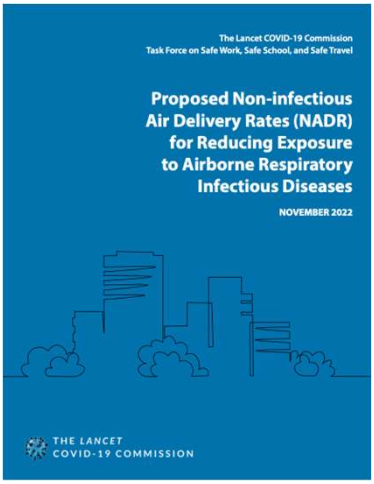
1. *Public Health Guidance* – Follow all current regulatory and statutory requirements and recommendations, including vaccination, wearing of masks and other personal protective equipment, social distancing, administrative measures, circulation of occupants, hygiene, and sanitation.
2. *Ventilation, Filtration, Air Cleaning*
   2.1 Provide and maintain at least required minimum outdoor airflow rates for ventilation as specified by applicable codes and standards.
   2.2 Use combinations of filters and air cleaners that achieve MERV 13 or better levels of performance for air recirculated by HVAC systems.
   2.3 Only use air cleaners for which evidence of effectiveness and safety is clear.
   2.4 Select control options, including standalone filters and air cleaners, that provide desired exposure reduction while minimizing associated energy penalties.
3. *Air Distribution* - Where directional airflow is not specifically required, or not recommended as the result of a risk assessment, promote mixing of space air without causing strong air currents that increase direct transmission from person-to-person.
4. *HVAC System Operation*
   4.1 Maintain temperature and humidity design set points.
   4.2 Maintain equivalent clean air supply required for design occupancy whenever anyone is present in the space served by a system.
   4.3 When necessary to flush spaces between occupied periods, operate systems for a time required to achieve three air changes of equivalent clean air supply.
   4.4 Limit re-entry of contaminated air that may re-enter the building from energy recovery devices, outdoor air, and other sources to acceptable levels.
5. *System Commissioning – Verify that HVAC systems are functioning as designed.*

October 19, 2021

> 2. *Ventilation, Filtration, Air Cleaning*
> 2.1 Provide and maintain at least required minimum outdoor airflow rates for ventilation as specified by applicable codes and standards.
> 2.2 Use combinations of filters and air cleaners that achieve MERV 13 or better levels of performance for air recirculated by HVAC systems.
> 2.3 Only use air cleaners for which evidence of effectiveness and safety is clear.
> 2.4 Select control options, including standalone filters and air cleaners, that provide desired exposure reduction while minimizing associated energy penalties.

ASHRAE Epidemic Task Force

How much ventilation is needed?



	Volumetric flow rate per volume	Volumetric flow rate per person		Volumetric flow rate per floor area	
	ACHe	cfm/person	L/s/person	cfm/ft²	L/s/m²
Good	4	21	10	0.75 + ASHRAE minimum outdoor air ventilation	3.8 + ASHRAE minimum outdoor air ventilation
Better	6	30	14	1.0 + ASHRAE minimum outdoor air ventilation	5.1 + ASHRAE minimum outdoor air ventilation
Best	>6	>30	>14	>1.0 + ASHRAE minimum outdoor air ventilation	>5.1 + ASHRAE minimum outdoor air ventilation

The Lancet COVID-19 Commission

It is time to advance IAQ standards

- In the 19th century Chadwick's Sanitary Report (1842) led to the introduction of clean water supplies and centralized sewage.
- In the 21st century **there is a need to establish the foundations to ensure that the air in our buildings is clean with a substantially reduced pathogen count**, contributing to the building occupant's health such as we expect for the water coming of our taps.

POLICY FORUM

INFECTIOUS DISEASE

A paradigm shift to combat indoor respiratory infection

Building ventilation systems must get much better

By **Lidia Morawska, Joseph Allen, William Bahnfleth, Philomena M. Bluyssen, Atze Boerstra, Giorgio Buonanno, Junji Cao, Stephanie J. Dancer, Andres Floto, Francesco Franchimon, Trisha Greenhalgh, Charles Haworth, Jaap Hogeling, Christina Isaxon, Jose L. Jimenez, Jarek Kurnitski, Yuguo Li, Marcel Loomans, Guy Marks, Linsey C. Marr, Livio Mazzarella, Arsen Krikor Melikov, Shelly Miller, Donald K. Milton, William Nazaroff, Peter V. Nielsen, Catherine Noakes, Jordan Peccia, Kim Prather, Xavier Querol, Chandra Sekhar, Olli Seppänen, Shin-ichi Tanabe, Julian W. Tang, Raymond Tellier, Kwok Wai Tham, Pawel Wargocki, Aneta Wierzbicka, Maosheng Yao**

Science (2021)

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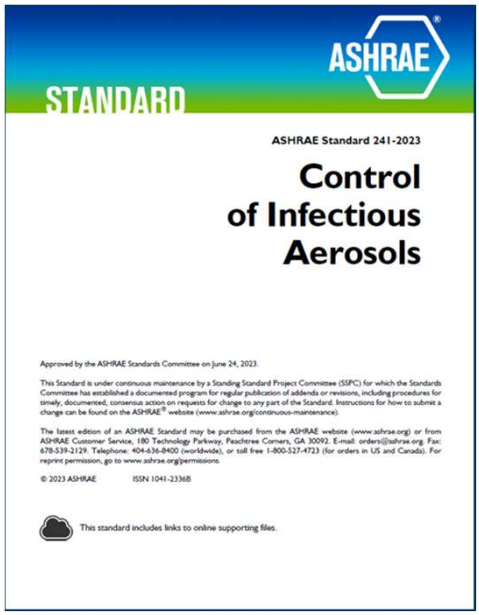
ASHRAE Standard 241



ASHRAE

STANDARD

ASHRAE Standard 241-2023

Control of Infectious Aerosols

Approved by the ASHRAE Standards Committee on June 24, 2023.

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. Instructions for how to submit a change can be found on the ASHRAE® website (www.ashrae.org/continuous-maintenance).

The latest edition of an ASHRAE Standard may be purchased from the ASHRAE website (www.ashrae.org) or from ASHRAE Customer Service, 180 Technology Parkway, Peachtree Corners, GA 30092. E-mail: orders@ashrae.org. Fax: 678-539-2129. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

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This standard includes links to online supporting files.

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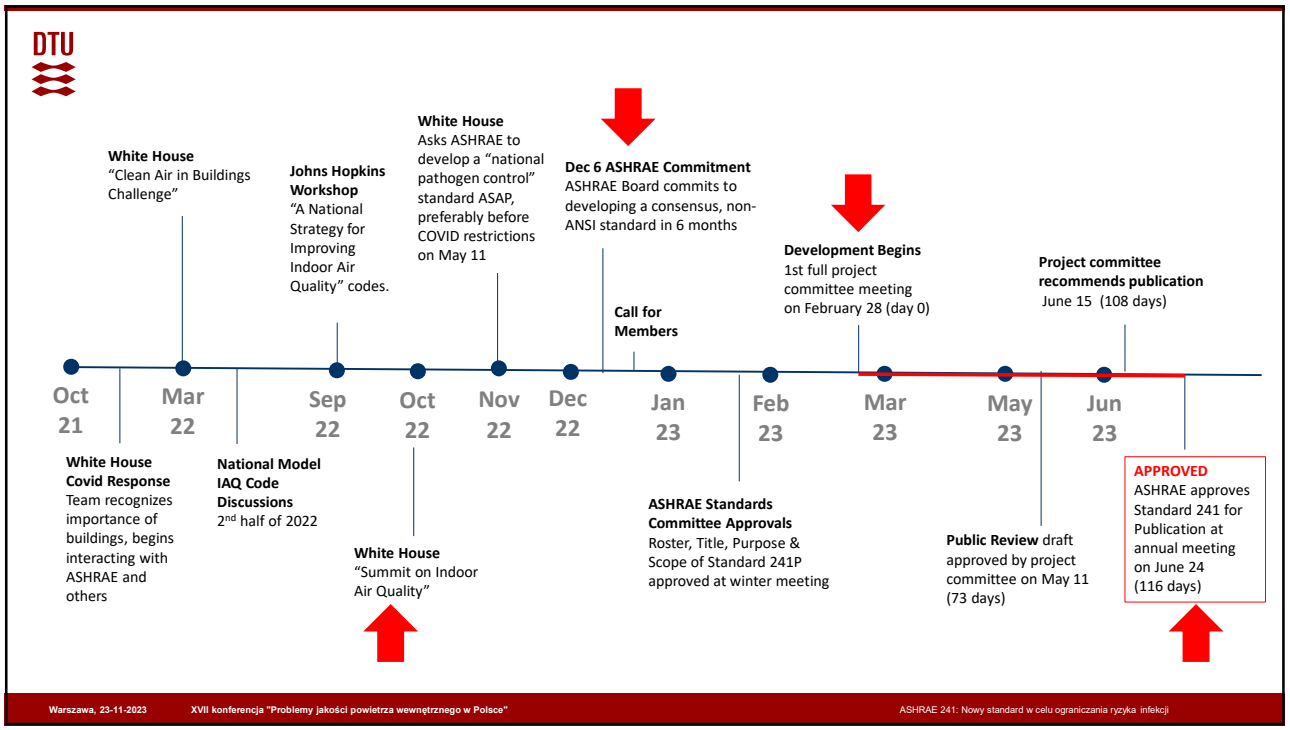

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Objective – Define Equivalent Clean Airflow (ECA)

- The flow rate of pathogen-free air that, if distributed uniformly within the breathing zone, would have the same effect on infectious aerosol concentration as the sum of actual outdoor airflow, filtered airflow, and inactivation of infectious aerosols
- Concept on which the entire standard depends
  - Determine ECA for infection risk mitigation (ECAi)
  - Determine total ECA for spaces, systems (V_{ECAi})
  - Determine how best to achieve it during infection risk management mode
- Prerequisites:
  - Standard 241 only addresses infection risk
  - A facility must comply with the applicable version of IAQ standard based on occupancy date and date of construction or major renovation (ASHRAE 62.1, ASHRAE 62.2, ASHRAE/ASHE 170 or other approved by Authority Having Jurisdiction
  - Prerequisite sets minimum outdoor air and filtration requirements for normal operation

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The key assumptions

- Equal risk in all buildings*
- Risk level <0.1% (per hour)
- 95th-percentile total ECAi
- Long-range only
- No minimum infector – one infected person usually assumed

** The infection risk independent of the spaces a person one might visit during a day, so that an office worker who spends time at home and in an office might have the same daily risk as their child who spends time at home and school*

Equivalent Clean Airflow for infection control (ECAi) depends on space type, number of people, activity

$$V_{ECAi} = ECAi \times P_{Z,IRMM}$$

or

Design occupancy

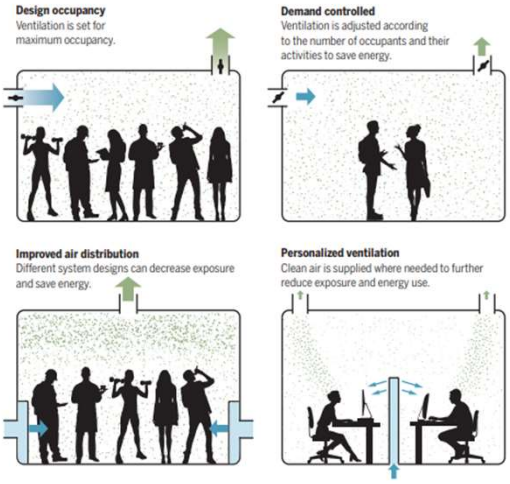
IRMM occupancy

Occupancy Category	ECAi cfm/person	ECAi L/s/person
Correctional Facilities		
Cell	30	15
Dayroom	40	20
Commercial/Retail		
Food and beverage facilities	60	30
Gym	80	40
Office	30	15
Retail	40	20
Transportation waiting	60	30
Educational Facilities		
Classroom	40	20
Lecture hall	50	25
Industrial		
Manufacturing	50	25
Sorting, packing, light assembly	20	10
Warehouse	20	10
Health Care		
Exam room	40	20
Group treatment area	70	35
Patient room	70	35
Resident room	50	25
Waiting room	90	45
Public Assembly/Sports and Entertainment		
Auditorium	50	25
Place of religious worship	50	25
Museum	60	30
Convention	60	30
Spectator area	50	25
Lobbies	50	25
Residential		
Common space	50	25
Dwelling unit	30	15

Various ventilation solutions/air distribution

- Natural ventilation
- Mechanical ventilation
- Personal ventilation
- Others

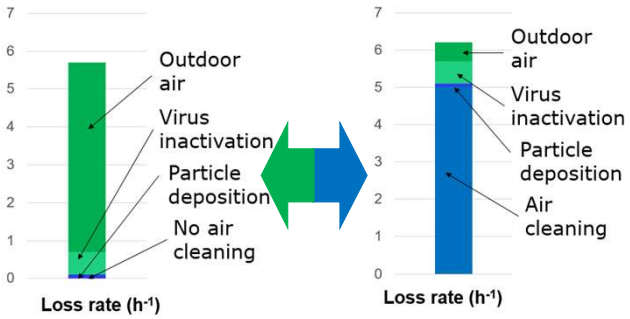
- ECAi=Ventilation+extra ventilation
- Extra ventilation=outdoor air, air distribution, filtration/air cleaning



Morawska, Lidia, et al. "A paradigm shift to combat indoor respiratory infection." Science 372.6543 (2021): 689-691.

Filtration/Air Cleaning

- Reducing infectious aerosol concentration through capture and removal or inactivation
- Air cleaning technologies
  - Mechanical filters (including electret media)
  - Germicidal ultraviolet light
  - Reactive species – ionizers, photocatalytic oxidation, other oxidants
- Mention of specific technologies in the standard is not endorsement!



- Standard 241 establishes minimum requirements for effectiveness and safety testing in Normative Appendix A - *Determining air cleaning system effectiveness and safety* (does not apply to mechanical filters tested by ASHRAE 52.2 or comparable standard)

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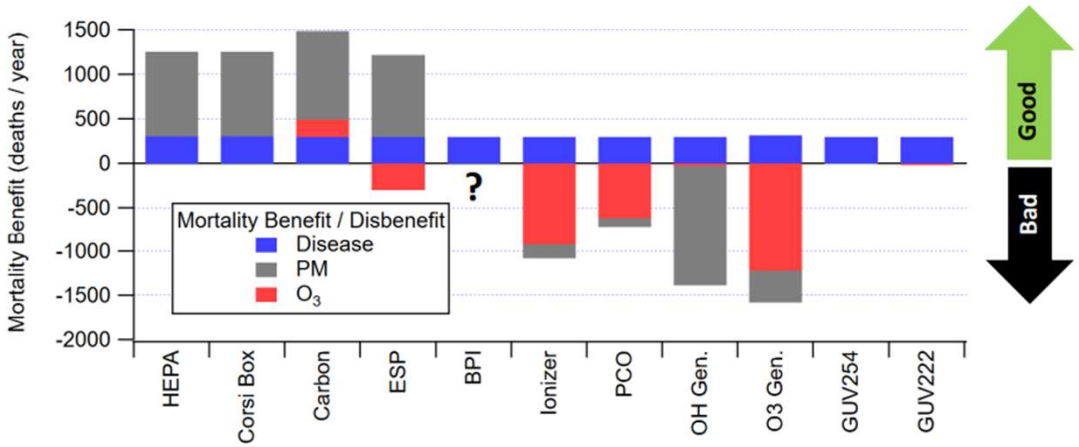
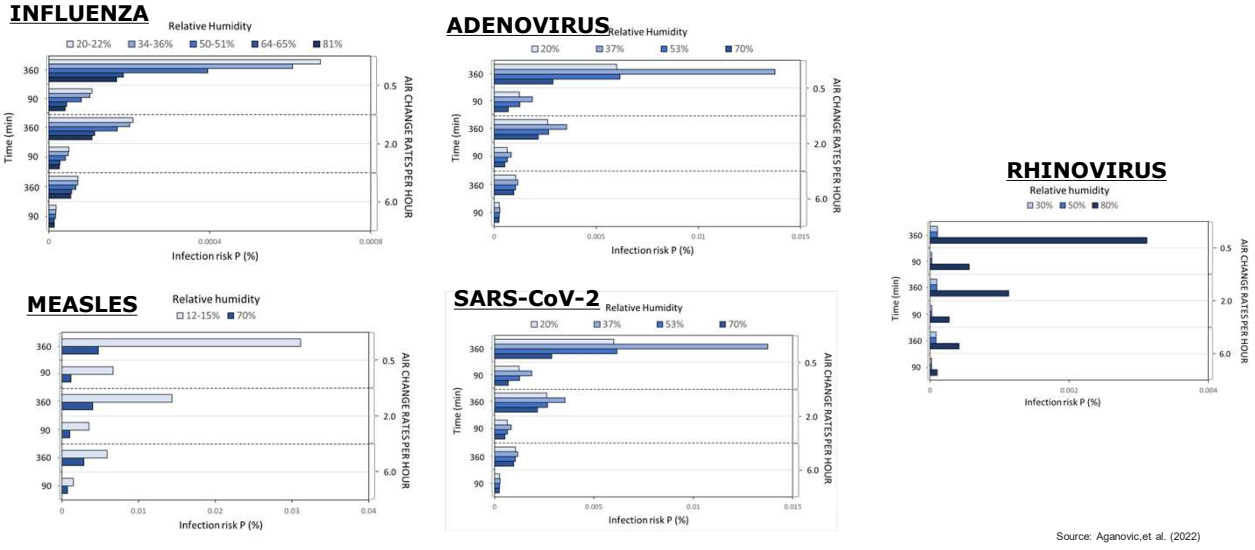
A recent analysis by Jimenez et al.



https://www.youtube.com/watch?v=TGyL7FtvpNw

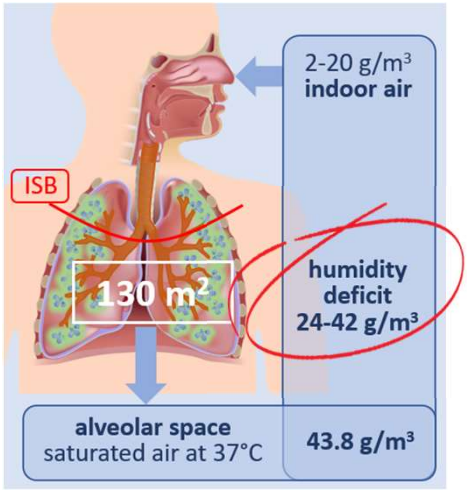
22

Low RH and effects on viruses released into the air: modelling (speaking person)



Source: Aganovic,et al. (2022)

Humidity deficit and mucocilliary clearance –effect on immune response



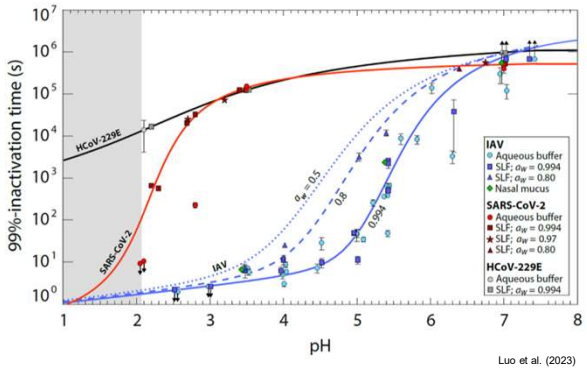
"Humidity Deficit" is the difference of absolute humidity in room air at room temperature and the absolute humidity

in the alveolar space, saturated at 37° C

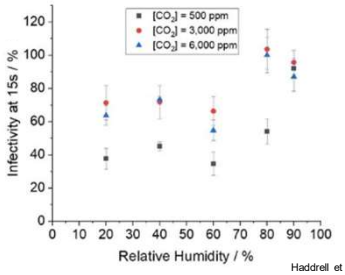
43.8 g/m³

ISB = **I**sothermic **S**aturation **B**oundary

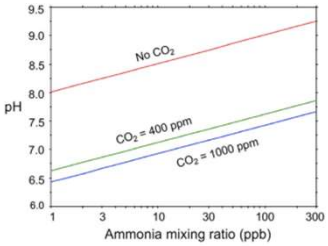
pH, CO_2 and virus inactivation



Luo et al. (2023)



Haddrell et al. (202x)



Nazaroff and Weschler (2020)

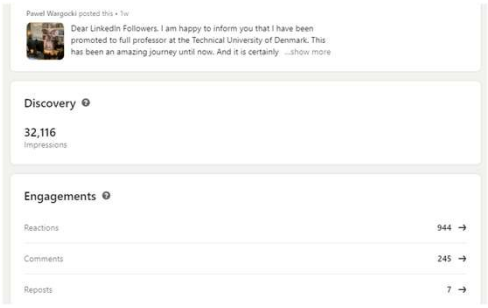
Epilogue

Take-home messages

- Airborne transmission is a dominant mode of infection risk.
- Masking and vaccination are not the sole methods for reducing the risk for infection. They must be supported by the technical solutions related to ventilation, air distribution and filtration/air cleaning.
- ASHRAE 241 defines the necessary equivalent clean airflow for reducing the risk of infection. The equivalent clean air can be obtained by increasing outdoor air rate, improving air distribution (ventilation efficiency), or by effective air cleaning/filtration. It can also be obtained by reducing the density of occupation. It is prerequisite that the minimum ventilation rates according to the standards (62.1, 62.2 and 170) are met with minimum filtration corresponding to MERV13 (EU7/8). The protection is for the long-range.
- ASHRAE 241 equivalent clean air should be used when there is epidemic/pandemic.
- Low relative humidity may reduce body defence mechanisms but further data are needed.
- UV-C may produce particles and increase their concentration in the air but further data are needed to understand the consequences.
- Many undocumented air cleaning solutions claiming the positive effect on virus inactivation should not be used before examined by authorized labs.
- pH of the air may result in virus deactiavtion and connected to the CO2 level in the air but further data are needed to provide evidence.

pawar@dtu.dk

Thank you



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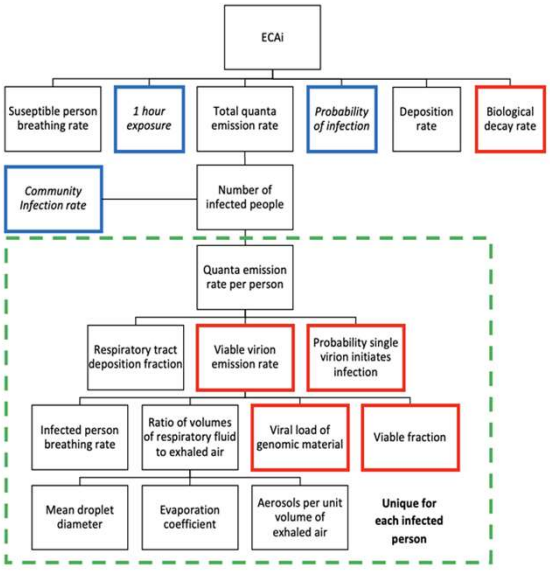
RISK ASSUMPTIONS IN STANDARD 241

- Wells-Riley model
  - Some variables are deterministic. Others are probabilistic, distributed variables.
  - Some variables are based on SARS-COV-2.
  - Variables inside the green box are unique for each infected person.
- Low personal risk per hour, equal for all space types



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