AIVC April Workshop

Arnold Janssens – Chair of AIVC COVID-19 Working Group

- **Series of four webinars**
  - Organised in collaboration with IEA-EBC Annex 86 ‘Energy efficient IAQ management’
- April 1, Building ventilation: How does it affect SARS-CoV-2 transmission?
- April 8, IAQ and ventilation Metrics
- April 13, Big data, IAQ and ventilation -part 1
- April 21, Big data, IAQ and ventilation -part 2

Register at www.aivc.org

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Introduction: context of the webinar

- Scientific consensus that airborne transmission by aerosols plays important role in spreading COVID-19 in indoor spaces
- Many organisations are working on this topic and have produced guidelines: REHVA, ASHRAE, CIBSE, IEQ-GA, …
- AIVC-project ‘Ventilation, airtightness and COVID-19’: collect, discuss and disseminate information about COVID-19 in relation to ventilation and airtightness
  - Newsletters
  - Webinars
  - FAQ’s

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AIVC-newsletter, FAQ website

AIVC Newsletter Special Issue COVID-19

Editorial

We hope you are keeping safe and healthy during this challenging period. The COVID-19 pandemic has an unprecedented impact on all of us, both personally and professionally. As researchers and practitioners we also have a role to play in developing solutions to provide healthy indoor spaces to reduce disease transmission, and in informing the public. Based on developing scientific knowledge it has become clear that, although close contact transmission is the dominant transmission route, long-range airborne transmission through small size infected aerosols plays an important role in spreading COVID-19 in indoor spaces. As a consequence, increasing outdoor air change rates, or applying other technical measures to remove infected aerosols are necessary to avoid infection indoors.

The AIVC board decided in their last (online) meeting of September 2020 to start a project to collect, discuss and disseminate information about COVID-19 in relation to ventilation and airtightness. A working group was created to define the activities and outputs of the project with the title 'Ventilation, airtightness and COVID-19'. The working group members are listed at the last page of this newsletter.

This newsletter is a first outcome of the project. It presents a number of questions and answers developed and reviewed by working group members. The collection of relevant questions and the development of clear answers in line with most recent scientific understanding is a continuing process, to which we also invite you, as a reader, to participate. Let us know if you have a question that the working group should look into. This way we hope to expand the FAQ-section, also on the AIVC-website. Many other international organizations in the domain of HVAC, health care or prevention have developed information and guidance documents to support decision makers and public about the COVID-19 pandemic. This newsletter therefore contains an overview of frequently asked questions in relation to COVID-19 and building ventilation, developed by a number of those organizations. The ventilation related guidelines by REHVA and ASHRAE will receive specific attention during the upcoming AIVC webinar, to be held on November 20th, 2020. This webinar is a second outcome of the project, and is announced in more detail in this newsletter and on the AIVC website.
We wish you a pleasant reading and look forward to seeing you in our future events.

Arnold Janssens, chair of AIVC Working Group on COVID-19

@AIVCnews

Contents

November 2020

20 November 2020 (16:00-17:30 CET) – AIVC Webinar – COVID-19 Ventilation related guidance by ASHRAE and REHVA

Ventilation is recognized as a major element in strategies for minimizing the risk of COVID infection. REHVA and ASHRAE have developed guidelines, insisting on existing evidence of long-range aerosol-based transmission and emphasizing the importance of ventilation.

The Air Infiltration and Ventilation Centre with support from ASHRAE and REHVA are organizing the webinar "COVID-19 Ventilation related guidance by ASHRAE and REHVA" to be held on Friday November 20th, 2020 at 16:00-17:30 (CET).

The webinar will present the COVID-19 related guidelines by REHVA and ASHRAE and will also have a closer look to the similarities and differences in both guidelines.

Presentations and Speakers

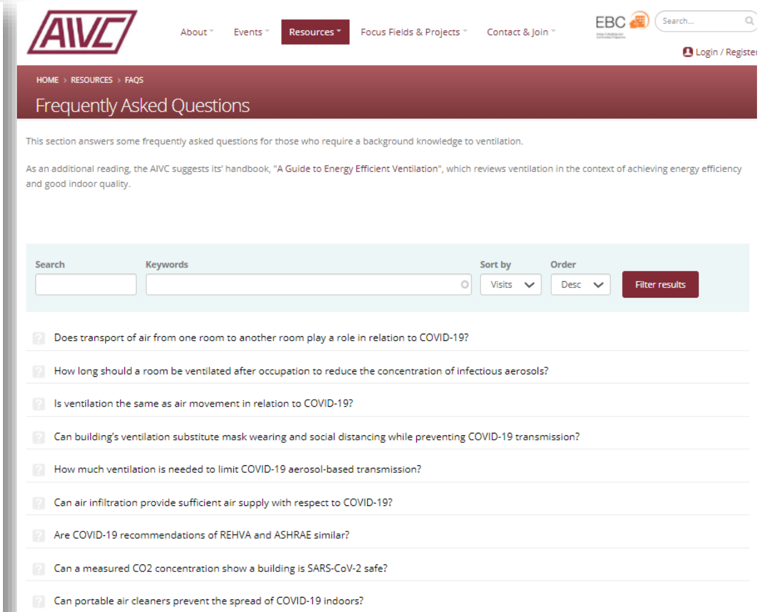
- Introduction, *Arnold Janssens, chair of AIVC WG COVID-19*
- REHVA guidance regarding ventilation, *Jarek. Kurnitski – chair of REHVA COVID-19 task force*
- ASHRAE guidance regarding ventilation, *William P. Bahnfleth, chair of ASHRAE's Epidemic task force*
- Similarities and differences between REHVA's & ASHRAE's guidance, *Valérie Leprince, member AIVC COVID-19 working group & ASHRAE's Epidemic task forces*

Participation to the webinar is **FREE** but requires you to **REGISTER** for the event. For further information please visit our website.

Call to readers

The AIVC's COVID-19 Working Group members researched and provided responses to the frequently asked questions (FAQ), in this special issue.

Have a question for the FAQ? Email us at info@aivc.org



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Building ventilation: How does it affect SARS-CoV-2 transmission?

webinar
2021.04.01

Objectives:

- To address mitigating role of building ventilation in spread of pandemic,
- To discuss how ventilation affects exposure to infectious aerosols, based on knowledge developed in modelling, experiments and system design.

17:00 | Introduction, ***Arnold Janssens – chair of AIVC WG COVID-19, Ghent University, Belgium***

17:10 | The Role of Building Ventilation in Indoor Infectious Aerosol Exposure, ***Andrew Persily – NIST, USA***

17:25 | Modelling uncertainty in the relative risk of exposure to the SARS-CoV-2 virus by airborne aerosol transmission, ***Cath Noakes – University of Leeds, UK***

17:40 | Questions and Answers

17:50 | Field measurements of aerosol exposure in indoor environments, ***Roberto Traversari – TNO, Netherlands***

18:05 | Ventilation system design and the risk areas for spreading airborne contaminants in office buildings, ***Alireza Afshari – Aalborg University, Denmark***

18:20 | Questions and Answers

18:30 | Closing & End of webinar

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Building ventilation: How does it affect SARS-CoV-2 transmission? speakers

webinar
2021.04.01

Andrew Persily
NIST, USA

Cath Noakes,
University of Leeds, UK

Roberto Traversari,
TNO, the Netherlands

Alireza Afshari,
Aalborg University, Denmark

Webinar management

Maria Kapsalaki
(INIVE, BE)

Valérie Leprince
(INIVE, BE)

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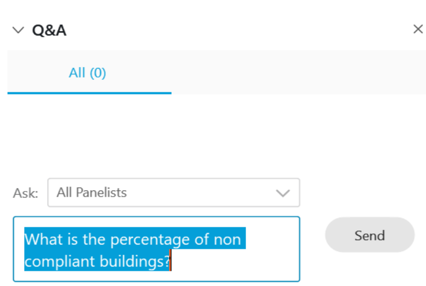
webinar
2020.04.01

How to ask questions during the webinar

Locate the **Q&A box**

Select **All Panelists** | Type your question | Click on Send



Note: Please DO NOT use the chat box to ask your questions!

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webinar
2020.04.01

NOTES:

- The webinar will be **recorded and published** at www.aivc.org within a couple of weeks, along with the presentation slides.
- After the end of the webinar you will be redirected to our **post event survey**. Your feedback is valuable so take some minutes of your time ti fill it in.

Organized by: www.aivc.org

Facilitated by INIVE

The Role of Building Ventilation in Indoor Infectious Aerosol Transport

Andrew Persily
Engineering Laboratory
National Institute of Standards and Technology
Gaithersburg, Maryland USA
andyp@nist.gov

AIVC Webinar: Building ventilation
How does it affect SARS-CoV-2 transmission?
1 April 2021

National Institute of Standards and Technology
U.S. Department of Commerce

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Outline

Which airflows and their magnitudes

Reducing aerosol exposure with airflow

Ventilation suggestions to reduce viral exposure

Summary

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Some Key Concepts

Ventilation
(ASHRAE Standard 62.1) the process of supplying air to or removing air from a space for the purpose of controlling air contaminant levels, humidity, or temperature within the space

Every building is different

Buildings are not tight unless built that way

Air moves based on physics, not design intent

Airflow has been studied in very, very few buildings

Outdoor air isn't necessarily fresh air

1 air change per hour does not mean all the air in a building is replaced in 1 hour

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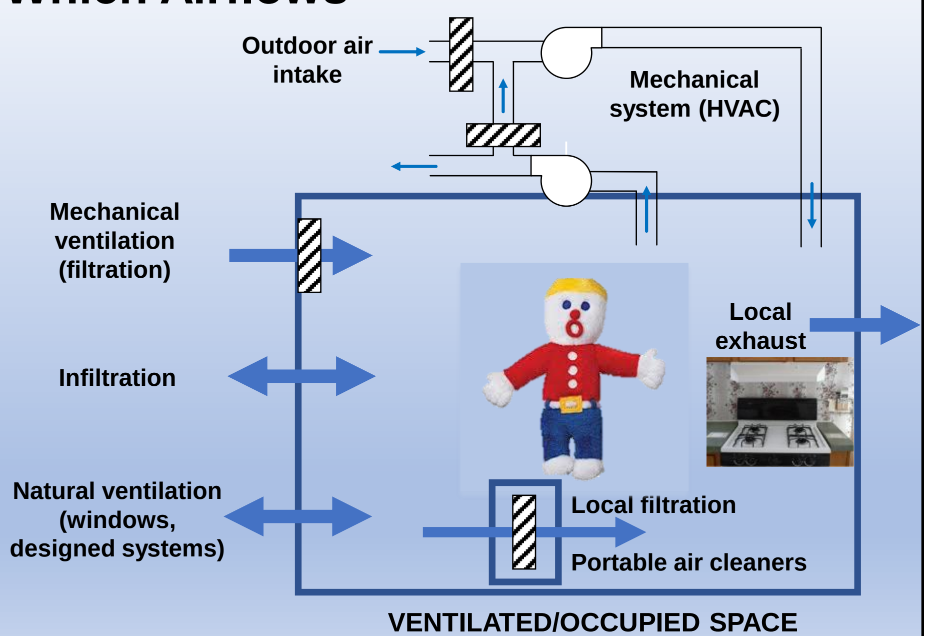
Which Airflows



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Magnitudes

Mechanical/Commercial
Outdoor air: ~1 h^{-1}, highly variable, up to ~5 h^{-1}
Supply air: ~ 3 to 5 h^{-1}, higher in healthcare

Mechanical/ Residential
OA: ~0.1 to 0.5 h^{-1}

Infiltration
~0.1 to 1.0 h^{-1}
~5 to 1 variation in individual building

Natural ventilation
>1 h^{-1}, hard to measure and predict

Local exhaust
(Residential, 25 L/s to 50 L/s, ~1/4 to 1/2 h^{-1})

Local filtration
CADR ratings
(~Local exhaust flows)

Interzone airflows

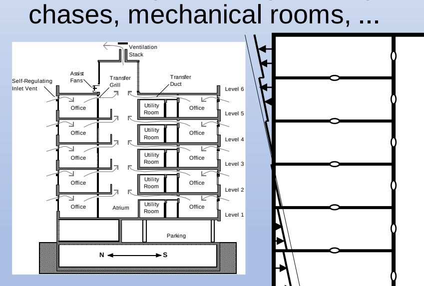
Magnitudes similar to airflows from outdoors

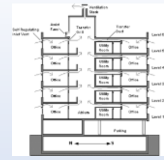
Residential

Crawl spaces, basements, attics, ...

Commercial

Return air plenums, plumbing chases, mechanical rooms, ...

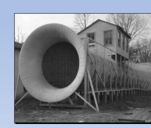


Buildings are diverse
USA: 100 million dwellings; 6 million commercial

Building systems vary and matter
Layout, design & controls, occupant activities, operation & maintenance (O&M), …

Ventilation has been studied in very few buildings
Impacts of HVAC & ventilation on aerosol transport in even less

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Reducing Exposure with Airflow

Build tight, ventilate (filter) right

Overpressure buildings (careful with moisture**)**

Airflow/pressure from clean spaces to dirty

Commissioning, Operations & Maintenance

Ventilation limited for strong, local sources

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Recommendations for Re-Opening Buildings

Ventilation

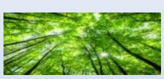
ASHRAE
REHVA Federation of European Heating, Ventilation and Air Conditioning Associations

Health & Safety

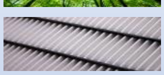
AIHA Protecting Worker Health
CDC Centers for Disease Control and Prevention
CDC 24/7: Saving Lives, Protecting People™
United States Department of Labor
Occupational Safety and Health Administration

Broad issues

National Institute of Building Sciences
U.S. Department of Energy
APPA Leadership in Educational Facilities
BOMA International



- Outdoor ventilation



- Filtration

- Relative humidity

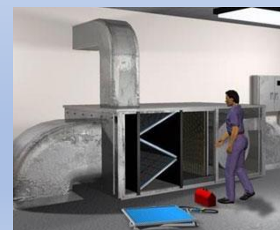
- Toilet areas

- UV-C and air cleaners

- Maintenance personnel

Increase outdoor air ventilation
System capacity
Outdoor air quality
Moisture management
Assuming good HVAC control

More efficient filtration
System capacity
Sealing
Maintenance



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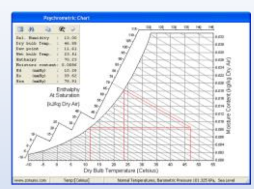
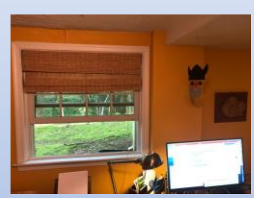
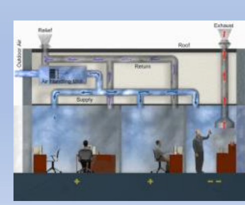
Change relative humidity
Do we know the right number?
System capacity
Condensation potential/microbial growth



Open windows
Outdoor air quality
Moisture, Noise, Security
Direction, magnitude, distribution



Change air distribution
System configuration
Options often limited



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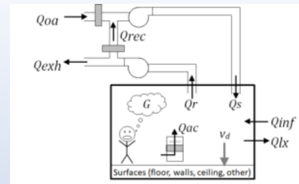
Summary



Do no harm

Good ventilation is good practice

Excellent time to check system, review O&M practice (Schoen 2020 and ASHRAE guidance)
https://www.ashrae.org/technical-resources/resources

NIST on-line tool for comparing impacts of ventilation, filtration, etc. on indoor aerosols
https://www.nist.gov/services-resources/software/fatima

Schoen, L.J. (2020) Guidance for Building Operations During COVID-19 Pandemic, *ASHRAE Journal*, 62 (5), 72-74.

Modelling uncertainty in airborne SARS-CoV-2 risks

Professor Cath Noakes, OBE, CEng, FIMechE, FIHEEM
School of Civil Engineering, University of Leeds
C.J.Noakes@leeds.ac.uk

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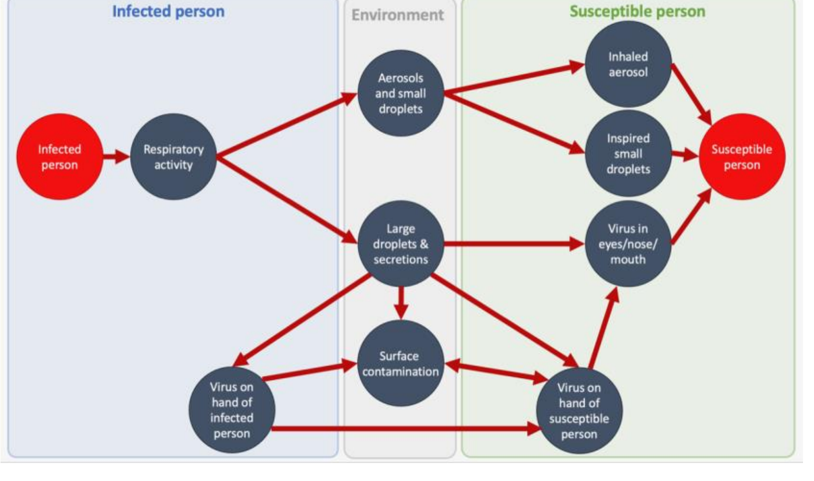
SARS-CoV-2 transmission routes



Airborne – via aerosols (>2m) in a shared room

Close range –via aerosols and droplets (<2m)

Surfaces - via contaminated hands

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Evidence for transmission

- Relative importance of different transmission routes unclear
  - Animal studies show air and surface both possible
  - Outbreaks and contact tracing data show close proximity risk
  - Fomite evidence hard to find, but some association with hand hygiene/cleaning
  - Super-spreading can happen and is associated with higher exhalations
  - Air and surface sampling data patchy, but evidence of virus in small aerosols
  - Airborne transmission associated with poorly ventilated spaces (1-3 l/s/person) – potential for room to room
  - Little evidence for outdoor transmission – crowded/close
  - Modelling (physics, risk models) gives insights into the likely exposure
- Transmission can happen in any setting
  - Risk factors make some settings more/less risky
  - Transmission associated with a setting is not always what it seems

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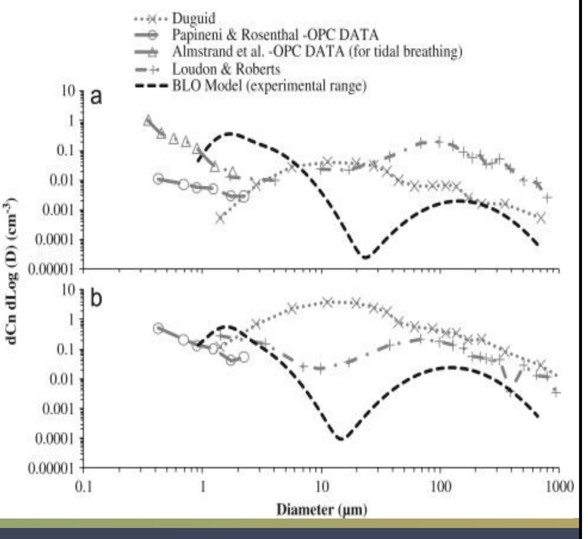
Respiratory aerosols

Johnson et al (2011) J Aero Sci: 12: 839

- Virus around 100nm but contained within respiratory fluids
- Johnson et al suggest 3 modes:
  - Bronchiolar fluid film burst – breathing
  - Laryngeal – voice and coughing
  - Oral – speech and coughing
- Evaporation depends on composition of fluids – salts, surfactants, proteins.
  - final diameter ~0.2-0.5 original
  - happens rapidly



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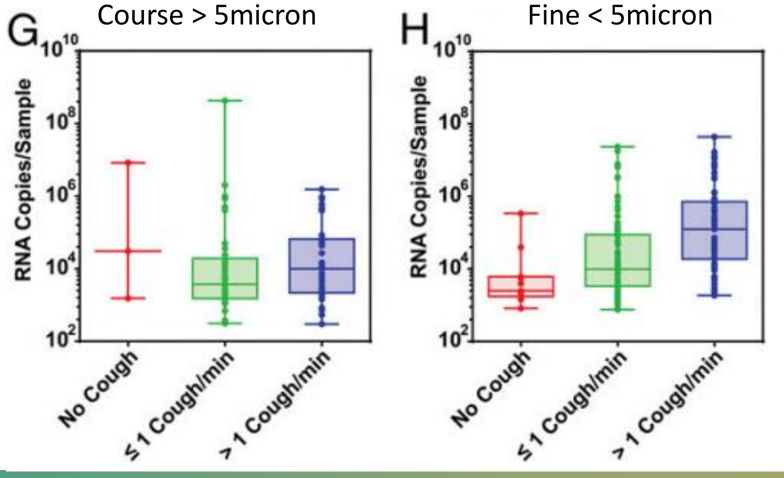
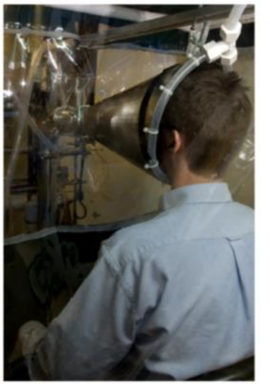
Respiratory pathogens



Influenza in aerosol



Yan et al, PNAS 2018

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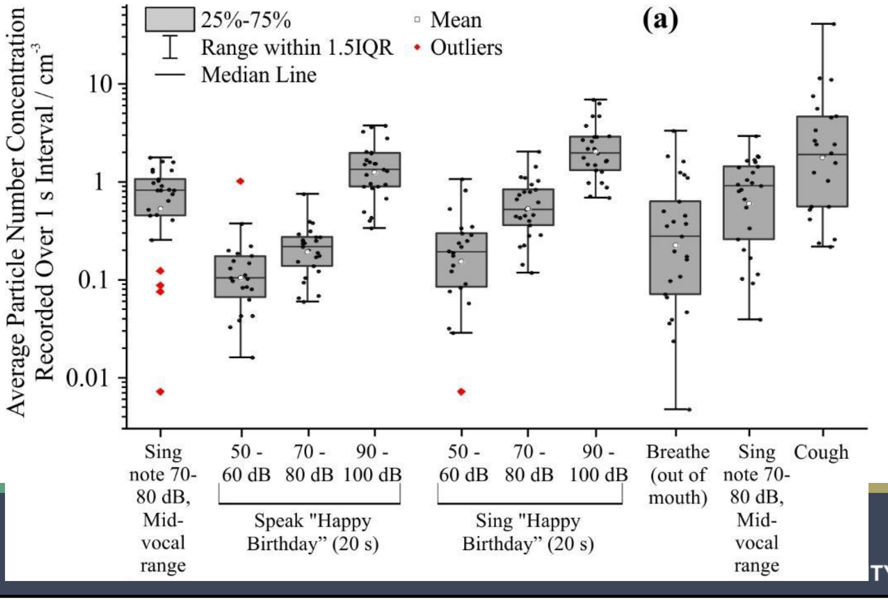
Variation with activity

Gregson et al, 2020



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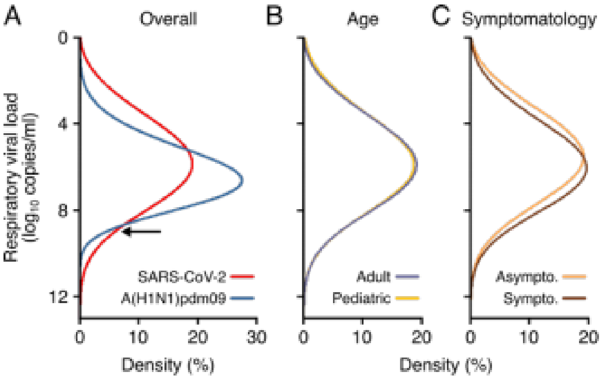
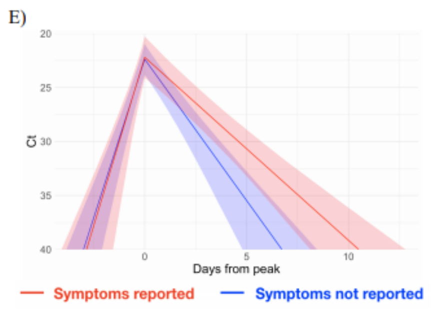
Viral load



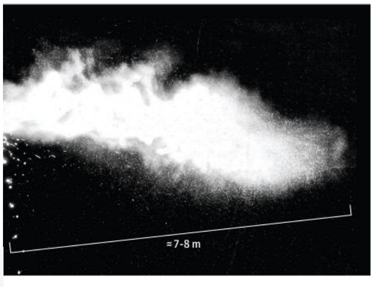
Chen P.Z. et al, 2020, pre-print



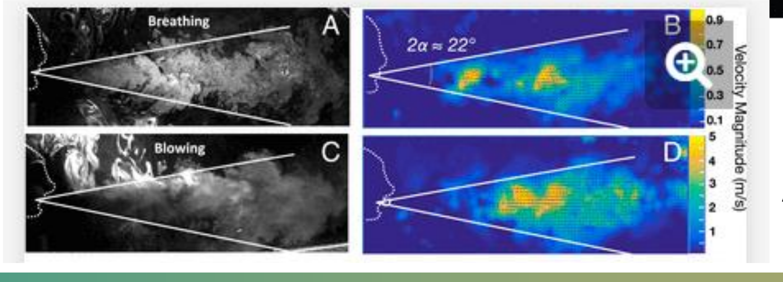
Kissler et al, 2020, pre-print

Exhalation physics

- Exhaled breath similar to Gaussian plume
- Particles influenced by thermal plume
- Interaction between droplets for violent ejections – turbulent puff

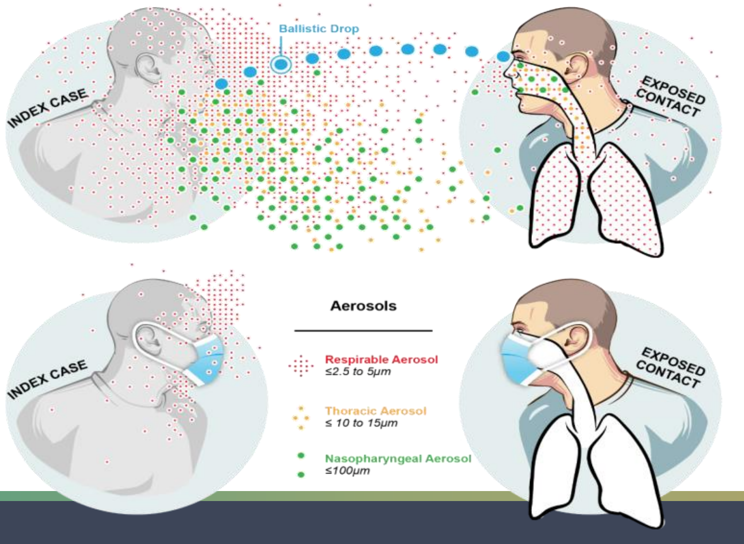


Bourouiba L, JAMA Insights, 2020



Abkarian M et al, PNAS, 2020

Complexity of aerosols and droplets



Milton, 2020

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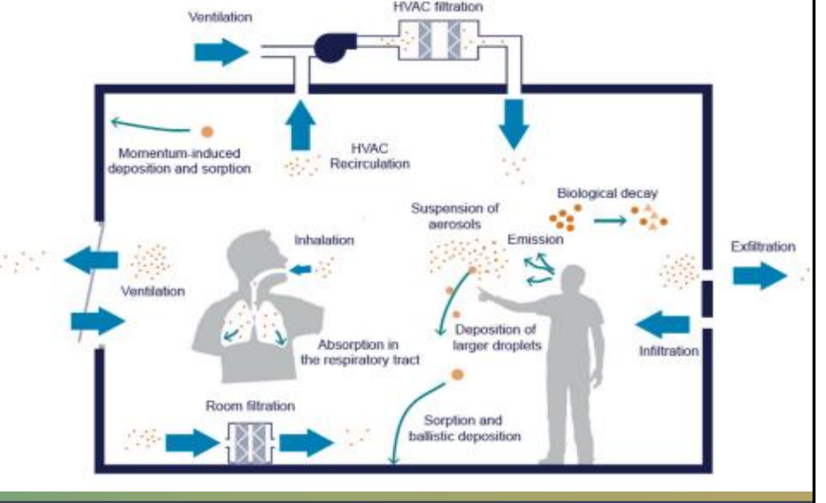
Modelling aerosol exposure

- Mass balance models to estimate concentration in air with ventilation rate for given emission
- Exposure from inhalation rate and time
- Simple spaces assume fully mixed flow
- Reasonable estimate >2m from source
- Can include filtration, deposition, air cleaners



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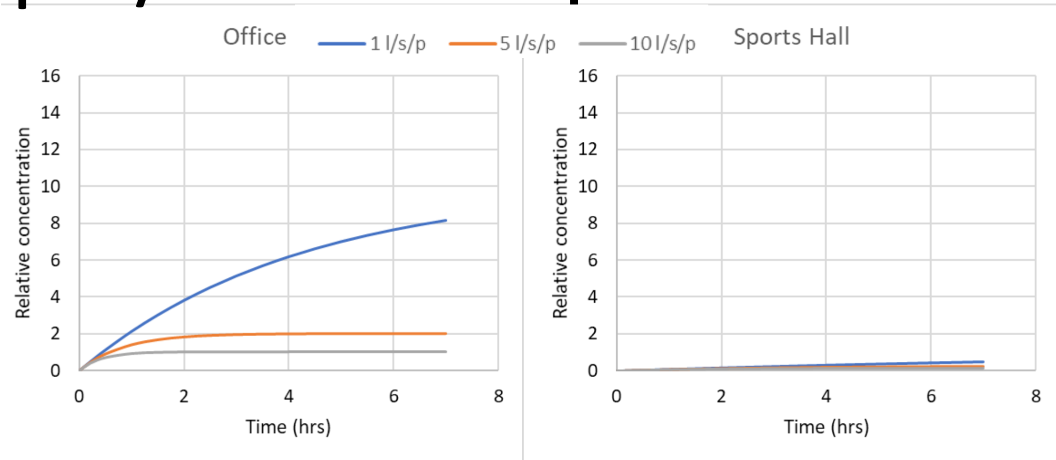
Space/flow relationships



20 people, 300 m3 (0.24-2.4 ACH)

160 people, 8750 m3 (0.06-0.65 ACH)

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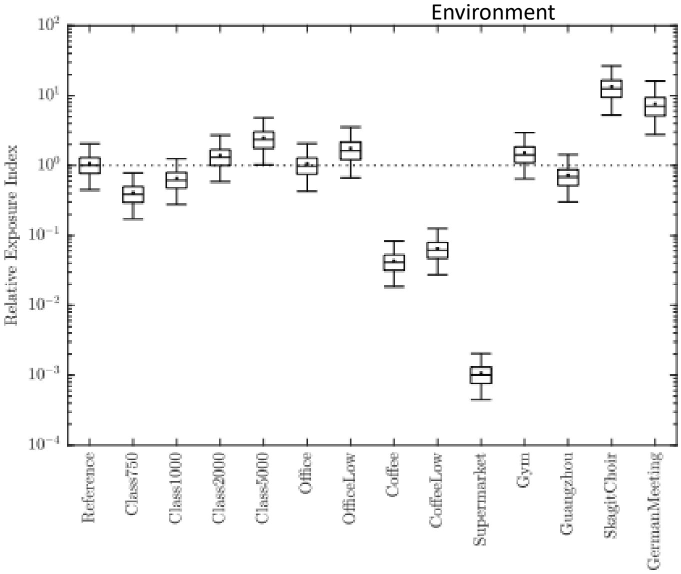
Estimating Relative Exposure

Jones et al (2021) Building and Environment

Relative to classroom designed to 1500 ppm CO2 standard

Depends on:

- Duration of exposure
- Ventilation
- Size of space
- Aerosol emission/ vocalisation



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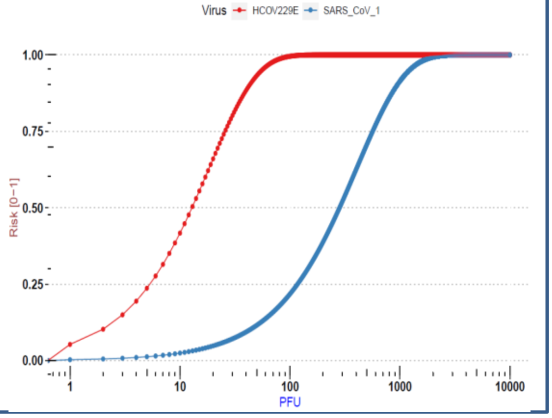
Linking exposure to risk of infection

Wells-Riley Approach

$$N_c = S\left[1 - e^{\left(\frac{Iqpt}{Q}\right)}\right]$$

New infections (N_C) with time (t):
- *S* = number of susceptibles,
- I = number of infectors
- *Q* = room ventilation rate
- *P* = occupant breathing rate
- *q* = Quanta, number of infectious doses generated per unit time

Dose-response Approach



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Quanta values

Disease	Case	Quanta/h	Reported by
TB	Average TB patient	1.25	Nardell et al (1991)
	Outbreak in office building	12.7	Nardell et al (1991)
	Human to guinea pig transmission	0.3-44	Escombe et al (2007)
	Human to guinea pig transmission (MDR-TB)	40,52,226	Escombe et al (2008)
Measles	Outbreak in a school	570	Rudnick &Milton(2003)
Influenza	School cases in Taiwan	66.91 (LN*)	Liao et al (2005)
	Aircraft outbreak	79-128	Rudnick &Milton(2003)
	Human challenge studies	0.11	Bueno de Mesquita et al (2020)
	Data from exhaled breath studies	0.17-630	Bueno de Mesquita et al (2020)
SARs	Taipei Hospital outbreak	28.77 (LN*)	Liao et al (2005)
Rhinovirus	Experimental data of Dick et al 1987	1-10	Rudnick &Milton(2003)

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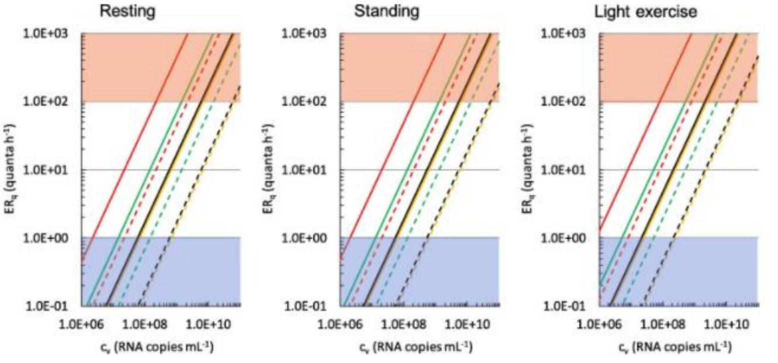
Quanta for SARS-CoV-2

- Buonnano et al (2020) estimated quanta from respiratory viral load (RNA copies) and aerosol generation rate
- Range from 0.1 to 1000 quanta/hr
- Miller et al estimated ~950 quanta/hr for Skagit choir outbreak



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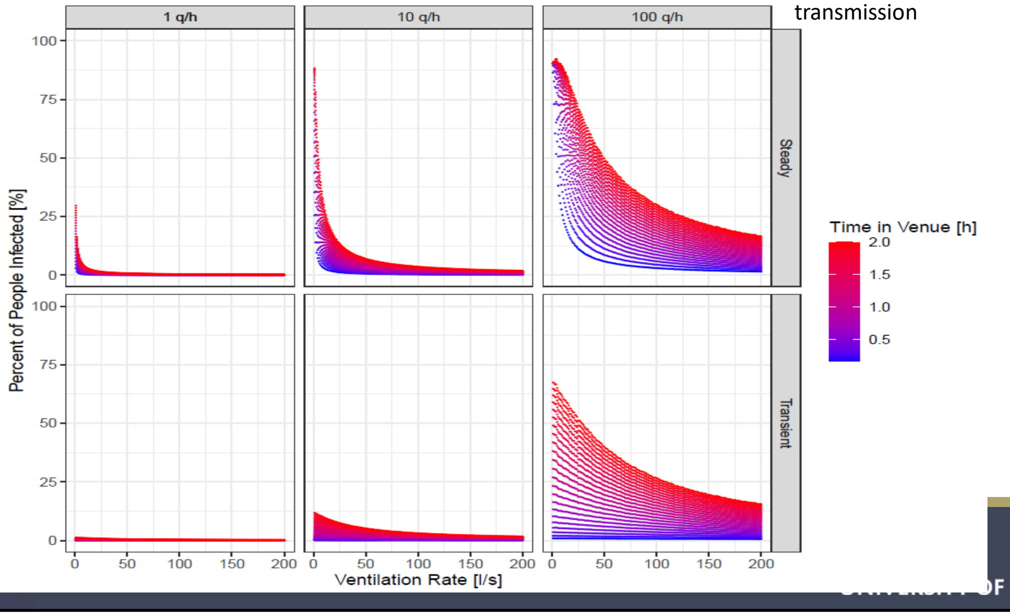
Ventilation-risk relationships

SAGE EMG: Role of ventilation in controlling SARS-CoV-2 transmission



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Skagit Choir

Outbreak

- 61 attendees (~half normal)
- 2.5 hour rehearsal
- 1 infector – mild symptom
- 53 cases, 33 with testing
- Use of sanitzer, no contact
- Distance 0.75-1.4m
- Cases dispersed throughout the room

Model assumptions

- Transient Wells-Riley model
- Monte-Carlo approach to estimate quanta
- 810 m3 room
- Breathing rate 10.8-23 l/min
- Ventilation rate 0.3-1.0 ACH
- Deposition 0.3-1.5, inactivation 0-0.63

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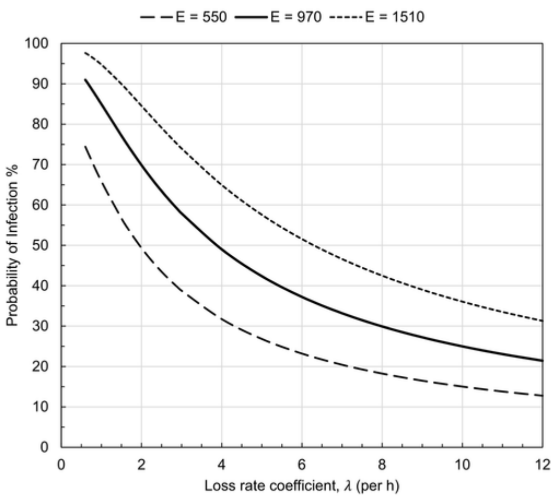
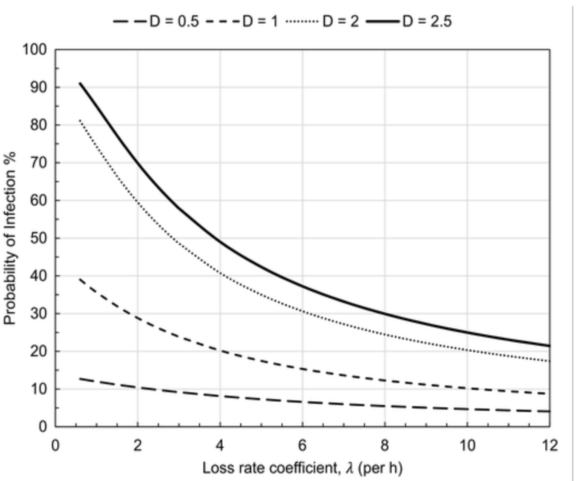
Skagit Choir





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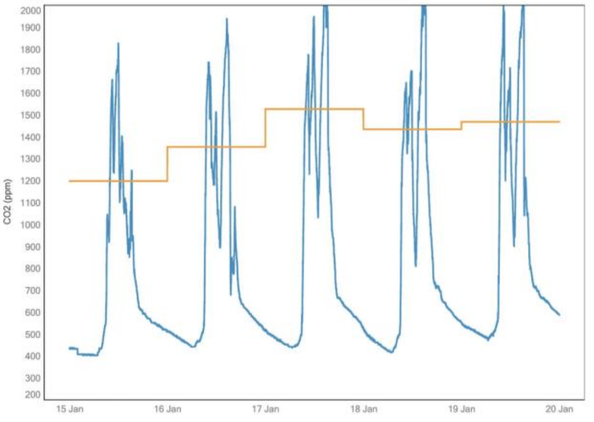
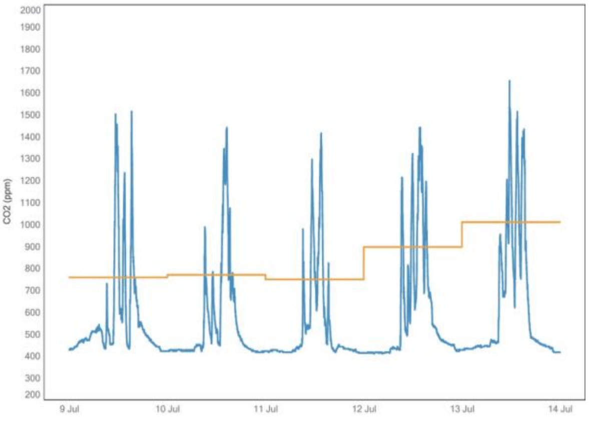
Rebreathed air model

Vouriot et al, Indoor Air, March 2021



CO_2 levels in January



CO_2 levels in July

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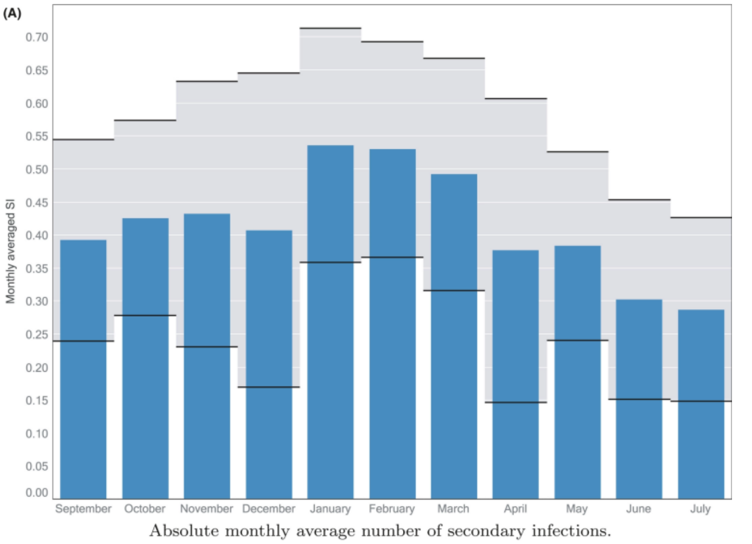
Relative risk

- CO2 data from 45 classrooms, 11 schools
- Hybrid ventilation with control based on temperature and CO2
- Risk modelled for 1 quanta/hr
- Airborne contribution within classroom only



Absolute monthly average number of secondary infections.

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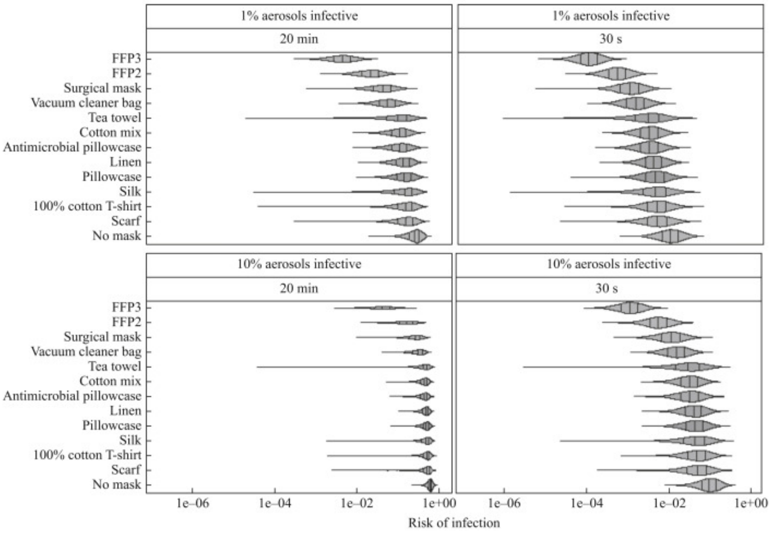
21

Modelling masks

- Measured RNA copies in room air
- Inhaled dose for different fraction of infectious virus
- Infection risk from SARS-CoV1 & HCoV-229E dose-response



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What about hands?

Depends on multiple parameters:

- Number of microorganisms on surfaces touched
- Frequency of surface touch
- Transfer efficiency from surface
- Area of contact

- Frequency of touching face
- Transfer efficiency to mucous membranes
- Area of contact

- Hand and surface cleaning frequency and efficiency
- Decay rate on surfaces and hands

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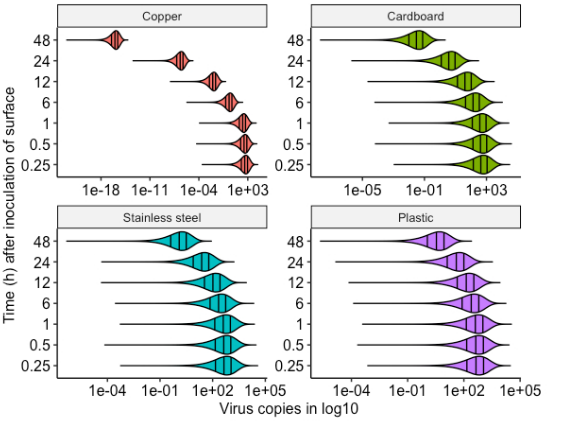
Modelling contact risks

- Uncertainty in viral copies to nose over one hour following surface touch
- Depends on surface decay rate, amount on surface, transfer efficiency, face touch frequency, area of contact
- Lacking data on viral transfers for SARS-CoV-2



M-F King, M Lopez Garcia

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What can we conclude?

- Close-range carries the most virus
- Far-field aerosol is likely to matter for longer duration exposure – may be more frequent?
- Surfaces may matter when sharing a space with an infector
- Significant uncertainty - need more evidence to understand importance
  - Variation in viral load
  - Size of aerosols that contain virus and their emission rates
  - Dose-response and how it changes with route
  - Impact of different mitigation measures

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Thank you

Leeds:

Louise Fletcher

Marco-Felipe King

Amir Khan

Martin Lopez-Garcia

Andy Sleigh

Richard Wood

Lee Benson

Jess Procter

Collaborators:

Ben Jones, Patrick Sharpe, Chris Iddon, Abigail Hathway, Shaun Fitzgerald, Carolanne Vouriot, Henry Burridge, Paul Linden, Amanda Wilson, Mark Weir, Kelly Reynolds, Stephanie Dancer, Shelly Miller + Skagit Choir group, All of SAGE EMG, aerosol and ventilation colleagues worldwide

UKRI Engineering and Physical Sciences Research Council

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Any Questions?

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DETERMINING THE EFFECT OF SCREENS IN EXPOSURE TO AEROLS IN RESTAURANTS

DR. ROBERTO TRAVERSARI

INDEX

EVALUATION OF SPREADING AEROSOLS IN RESTAURANTS

DISCLOSURE

Dr. Roberto Traversari

- I have the following potential conflicts of interest to report:

- [ ] Consulting
- [ ] Employment in industry
- [ ] Stockholder of a healthcare company
- [ ] Owner of a healthcare company
- [ ] Other(s)
- ✓ I do not have any potential conflict of interest

BACKGROUND

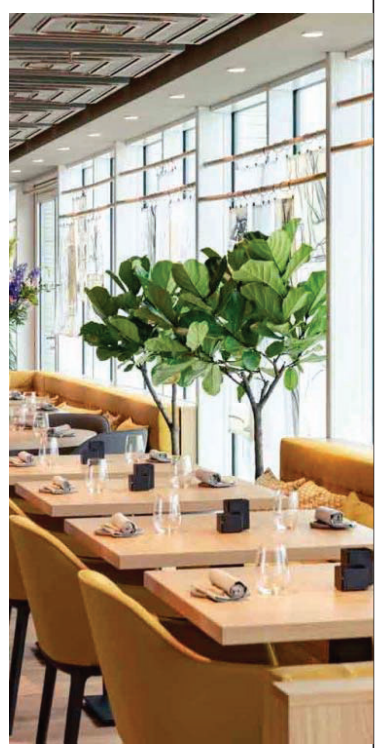
PROBLEM

- Reference setting is social distancing at > 1,5 meter (between different households)
- Limiting the capacity of a restaurant
- Can screens help to reduce the 1.5 distance in a safe way?
- Is there a relation with the ventilation system and ventilation rate?

Main research question:

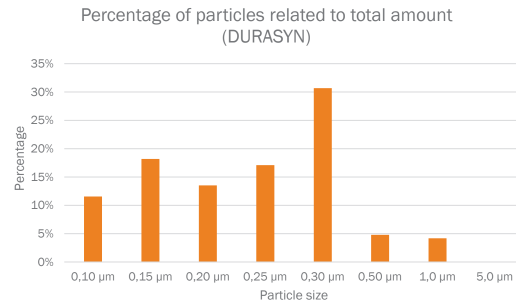
How to determine the effect of (protective) screens in a restaurant setting?

Project funded by the Dutch Ministry of Economic Affairs and Climate Policy



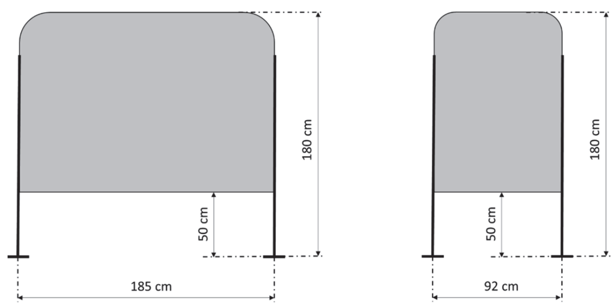
01 April 2021 | Determining the effect of screens in exposure to aerols in restaurants

METHOD



- Method was based on the guidelines for operating rooms (e.g. ISO 14644-3, HTM-03, DIN 1946-4, VCCN guideline 7)
- Emission of aerosols (particles) and measure particle levels
- Measuring the concentration of particles with particle counters
- Using ≥ 0.5 µm as guiding particles (airborne appr. < 5 µm)
- Concentration at 1,5 meter was the reference
- With and without screens

- Mock up (9 x 7 x 3 meters)

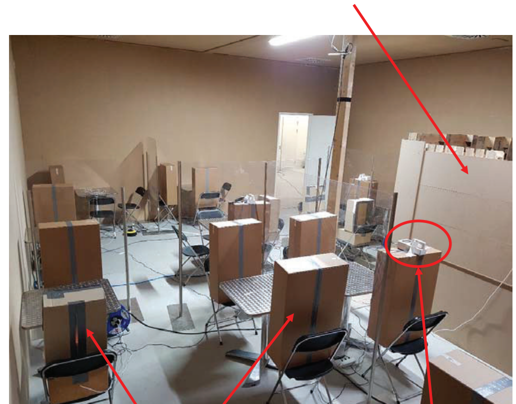


EXPERIMENTS
MOCK UP

- Two ventilation systems
  - linear diffusers
  - swirl diffusers

- Three “ventilation” rates (air with relative low particle level)
  - Low (900 $m^3 h^{-1}$, Dutch building act)
  - Medium (1.700 $m^3 h^{-1}$)
  - High (2.500 $m^3 h^{-1}$)

- Three different setups (excluding the reference setup)



PROCEDURE

Walking (according to protocol)

Time (minutes)	5	10	15	20	25	30	35	40	45
Baseline	■	■							
Emission			■	■	■				
Recovery						■	■	■	■

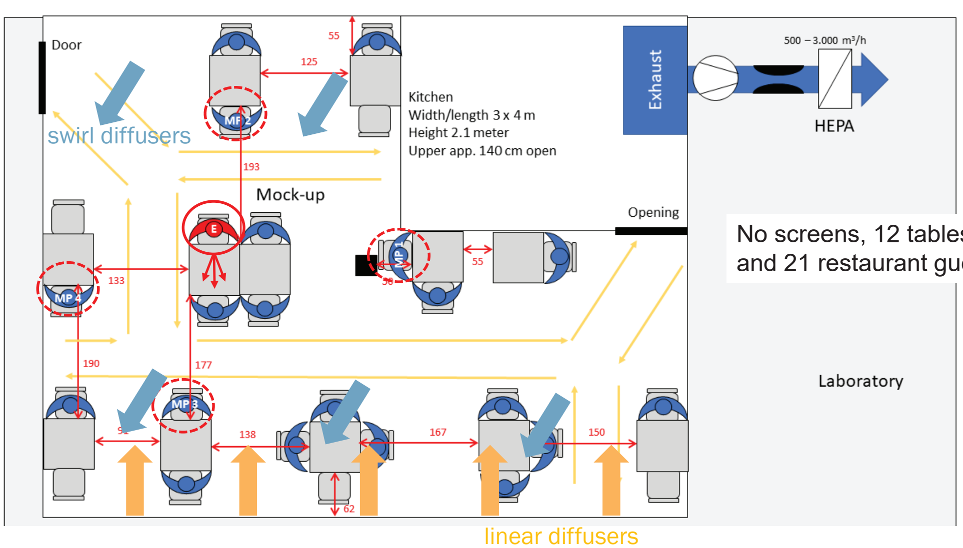
Start
Determine baseline concentration

Start
Emission

End
Emission
Start
Recovery

End

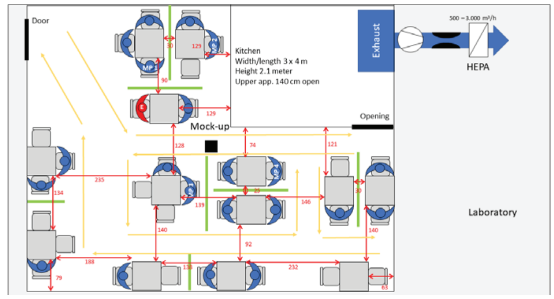
REFERENCE SETUP

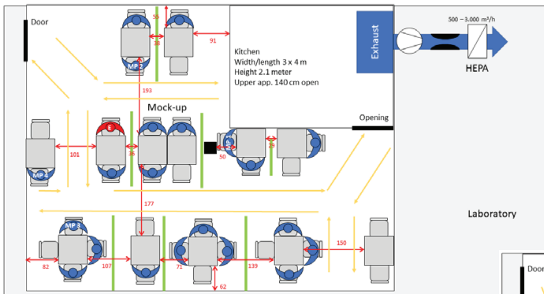


No screens, 12 tables, 26 chairs and 21 restaurant guests,

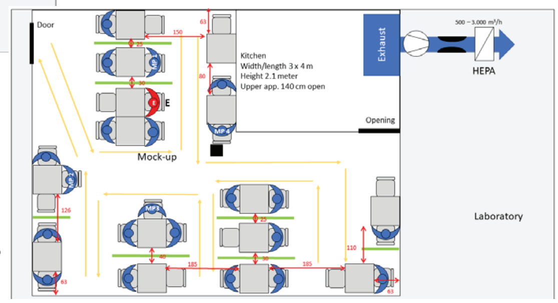
SETUPS WITH SCREENS

Setup B, 5 full screens, two half screens, 13 tables, 32 chairs and 22 restaurant guests



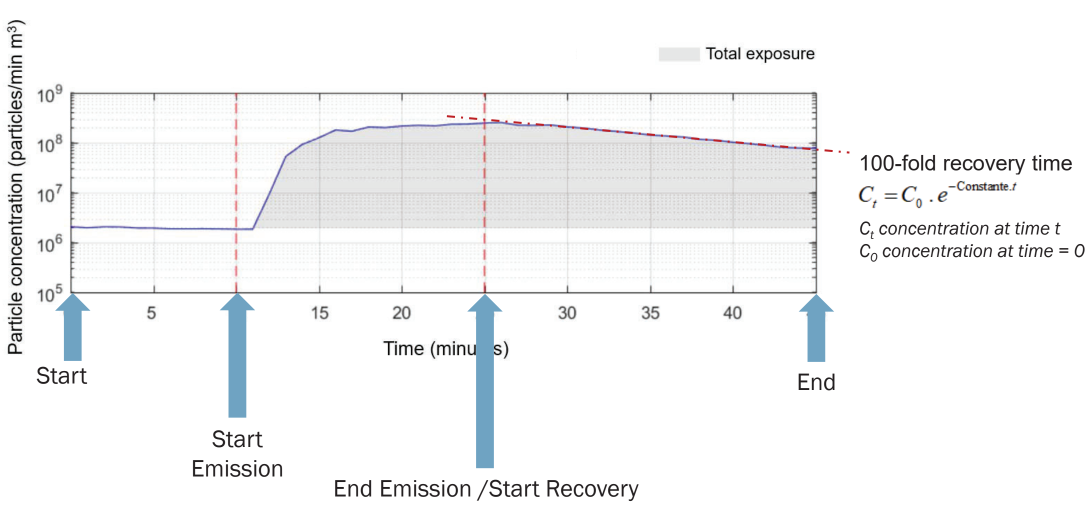


Setup A, 6 full screens, one half screen, 13 tables, 32 chairs and 22 restaurant guests

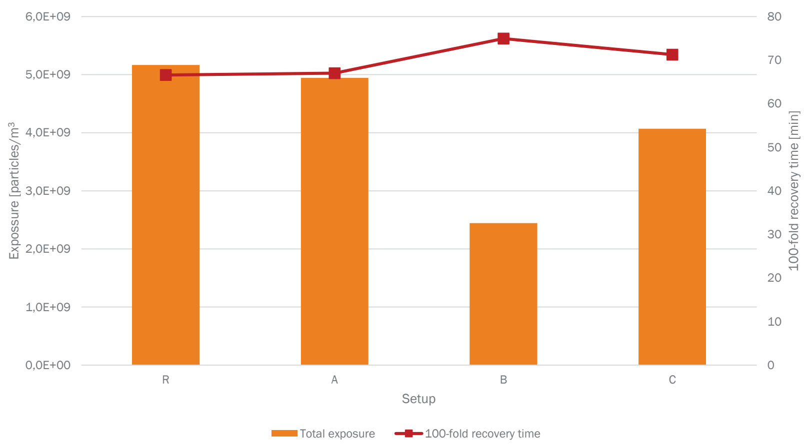


Setup C, 5 full screens, two half screens, 15 tables, 31 chairs and 23 restaurant guests

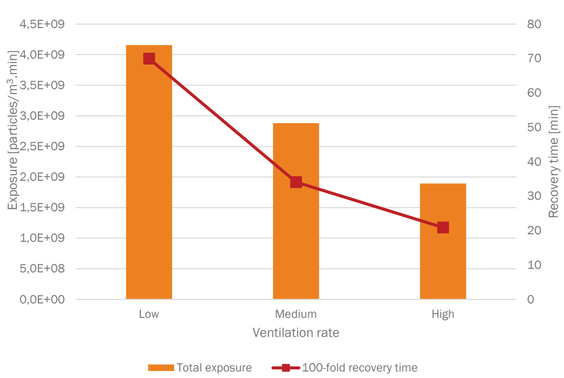
EXAMPLE OF THE MEASURED CONCENTRATION

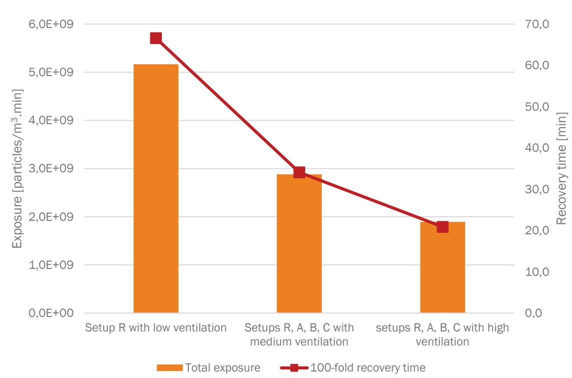


RESULTS
LOW VENTILATION RATE



RESULTS





CONCLUSIONS

- The amount of ventilation is the most determining factor for the total exposure and for the 100-fold recovery time. The higher the ventilation, the lower the total exposure and the faster the 100-fold recovery.
- The medium and high ventilation quantities result in a lower total exposure than the setup with the 1.5 meter protocol with a low ventilation quantity; the total exposure is on average 44% and 63% lower for the medium and high ventilation volume respectively. In addition, the 100-fold recovery is faster with a higher amount of ventilation.
- The diffuser type (line diffusers or swirl diffusers) has no significant influence.
- With the low ventilation amount, the total exposure for the three setups with screens is lower than for the reference situation. However, this difference is not significant for setup A.

THANK YOU FOR YOUR TIME

ROBERTO.TRAVERSARI@TNO.NL

TNO innovation for life

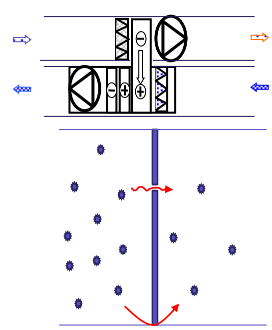
VENTILATION SYSTEM DESIGN AND THE RISK AREAS FOR SPREADING AIRBORNE CONTAMINANTS IN OFFICE BUILDINGS

PROFESSOR ALIREZA AFSHARI

DEPARTMENT OF THE BUILT ENVIRONMENT
AALBORG UNIVERSITY

1

Ventilation system design and the risk areas for spreading airborne contaminants in office buildings



Airborne transmission from room to room

Even if buildings have well-functioning ventilation systems, which is the case in most Nordic countries, it does not mean that airborne infectious disease transmission from room to room could be avoided.

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2

Ventilation system design and the risk areas for spreading airborne contaminants in office buildings

The **spread of airborne pollutants** depends on **air movement or airflow**.

Two prerequisites must be fulfilled for airflow from one room to another: **a pressure difference** and **a leakage path**.

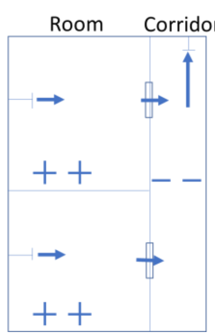
Pressure differences in buildings can be created through **wind forces, temperature differences and mechanical ventilation.**

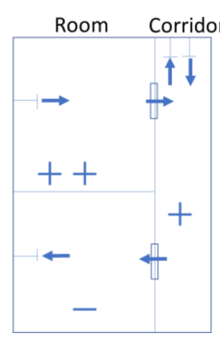
There must be **a careful design of a mechanical ventilation system** to accomplish directed airflows in a building, whereas **the pressure differences** created by **wind and temperature** are **considered disturbances**.

Ventilation system design and the risk areas for spreading airborne contaminants in office buildings

Depending on the balance between the supplied and exhausted airflows, **a mechanical ventilation system can create a pressure difference between the room and adjoining spaces**, both outside and between adjacent rooms.

The pressure difference depends on **the airtightness of the building envelope** and the **interior walls** and **airflow balance**.





Ventilation system design and the risk areas for spreading airborne contaminants in office buildings

Most of the new office buildings in **Nordic countries** are equipped with balanced mechanical ventilation systems.

The most common solutions in the office buildings are variable-air-volume (VAV) systems.

The ventilation systems should be able to **precisely control the indoor climate** or otherwise the target values of indoor temperature or CO_2 concentration may not be fulfilled.

Photo: Lindab, Denmark

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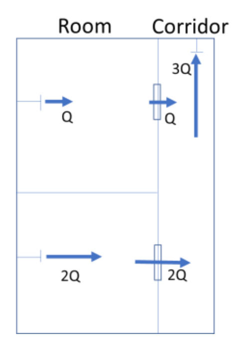
Ventilation system design and the risk areas for spreading airborne contaminants in office buildings

Typical Design of **Swedish** Office Buildings

Transferred air is often used in Swedish offices.

The air **is supplied to the office rooms** and **transferred into the adjoining corridor** where it is exhausted.

Special air terminal devices are used to accomplish this, allowing air to pass from the room to the corridor. These devices constitute a known opening, a controlled leakage path for the air.



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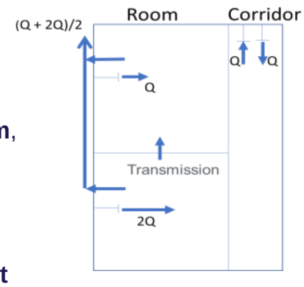
Ventilation system design and the risk areas for spreading airborne contaminants in office buildings

Typical Design of **Danish** Office Buildings

Supply and exhaust air is installed in every room.

Equal volumes of air are brought into and exhausted out of **the building**. However, in **a room**, the supplied air volume **is not equal** to the exhausted air volume when the supply air volume varies in a variable air volume system.

Thus, a common exhaust is used, and the **exhaust airflow rate from each room is an average airflow** rate from several given rooms.

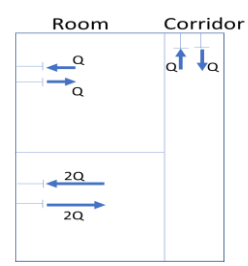


Ventilation system design and the risk areas for spreading airborne contaminants in office buildings

Typical Design of **Norwegian** Office Buildings

In Norway, the most common ventilation system in new office buildings is the balanced-room ventilation system.

In such systems, **the supply and exhaust sections usually depend on each other**; thus, the variation is often equal for the supply and exhaust air. This dependence **cannot cause over or under pressure in the rooms.**



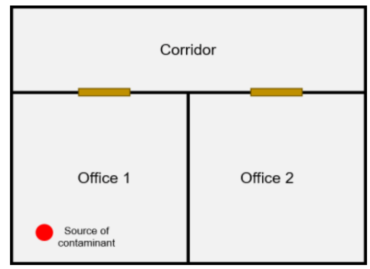
Ventilation system design and the risk areas for spreading airborne contaminants in office buildings

Simulation study

All three zones have the same volume (27 m^3), but different supply ventilation rates.

The zones were modelled assuming complete mixing of air.

Bi-directional airflow between offices and the corridor was modelled using a door model with a **leakage area of 0.02 m^2** when **the door is closed**.



Ventilation system design and the risk areas for spreading airborne contaminants in office buildings

Source of contaminant

Typical increase of PM10 in relation to CO_2, comparing **breathing and talking**, is shown in the figure , **strong correlation.**

Respiratory Aerosols in Correlation with Metabolic CO_2

N. Kappelt[1], M.S. Johnson[1], H. Russell[1], S. Kwiatkowski[1], A. Afshari[2]

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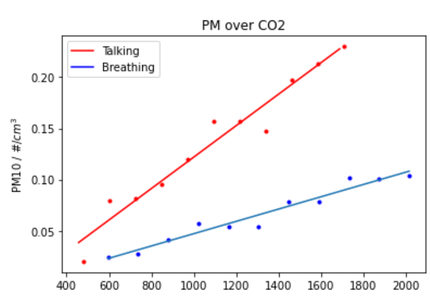
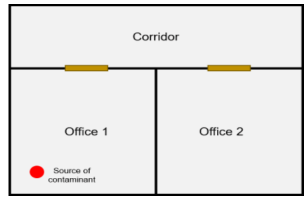
[2]Department of the Built Environment, Division of Sustainability, Energy and Indoor Environment, Aalborg University, 2450 Copenhagen SV, Denmark
Keywords: CO_2, Infection Risk, Airborne Transmission, Indoor Air
Presenting author email: niklas.kappelt@gmail.com



Ventilation system design and the risk areas for spreading airborne contaminants in office buildings

Simulation study

Table shows supply and exhaust ventilation rates for each ventilation system, together with the airflow passing through the doors.



	Supply ventilation rate [l/s]			Exhaust ventilation rate [l/s]			Airflow through doors [l/s]	
	Office 1	Office 2	Corridor	Office 1	Office 2	Corridor	Door 1	Door 2
Denmark	60	30	17	45	45	17	15	-15
Sweden	60	30	17	0	0	107	60	30
Norway	60	30	17	60	30	17	0	0

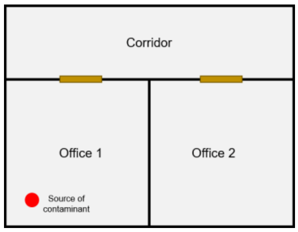
Ventilation system design and the risk areas for spreading airborne contaminants in office buildings

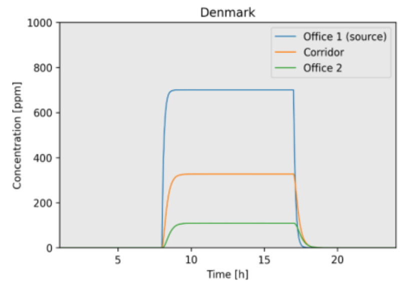
Tabel Pressure differences **[Pa]** across doors

	Doors open		Doors closed	
	Office 1 – Corridor	Office 2- Corridor	Office 1– Corridor	Office 2- Corridor
Denmark	0.001	-0.001	0.4	-0.4
Sweden	0.003	0.001	10	3.5
Norway	0	0	0	0

Ventilation system design and the risk areas for spreading airborne contaminants in office buildings

Denmark

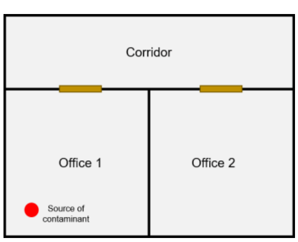


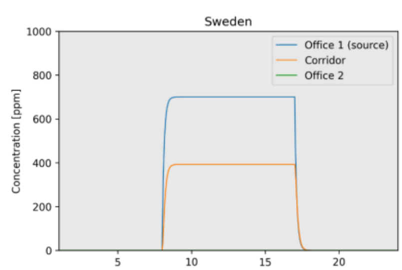


	Supply ventilation rate [l/s]			Exhaust ventilation rate [l/s]			Airflow through doors	
	Office 1	Office 2	Corridor	Office 1	Office 2	Corridor	Door 1	Door 2
Denmark	60	30	17	45	45	17	15	-15

Ventilation system design and the risk areas for spreading airborne contaminants in office buildings

Sweden

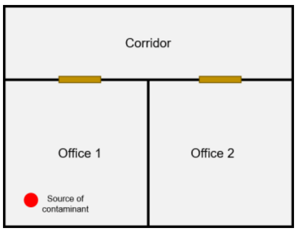


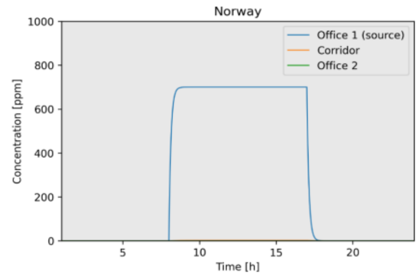


	Supply ventilation rate [l/s]			Exhaust ventilation rate [l/s]			Airflow through doors [l/s]	
	Office 1	Office 2	Corridor	Office 1	Office 2	Corridor	Door 1	Door 2
Sweden	60	30	17	0	0	107	60	30

Ventilation system design and the risk areas for spreading airborne contaminants in office buildings

Norway





	Supply ventilation rate [l/s]			Exhaust ventilation rate [l/s]			Airflow through doors [l/s]	
	Office 1	Office 2	Corridor	Office 1	Office 2	Corridor	Door 1	Door 2
Norway	60	30	17	60	30	17	0	0

Ventilation system design and the risk areas for spreading airborne contaminants in office buildings

Conclusions

The existing ventilation systems of **Swedish office rooms** can contribute to spreading airborne contaminants from office rooms to corridors but not to adjacent rooms.

Airflows should be supplied and exhausted from each room and from each corridor to avoid spreading airborne contamination to corridors.

Ventilation system design and the risk areas for spreading airborne contaminants in office buildings

Conclusions

The existing ventilation systems of **Danish office rooms** can contribute to spreading airborne contaminants from room to room when the room demands are different.

The extracted airflows must be equal to the supplied airflows of each room to achieve the correct pressurization.

Ventilation system design and the risk areas for spreading airborne contaminants in office buildings

Conclusions

The existing ventilation systems of **Norwegian office rooms** do not spread airborne contaminants from room to room or from room to corridor, even if the room demands are different.

Ventilation system design and the risk areas for spreading airborne contaminants in office buildings

HYPOTHESIS AND THEORY ARTICLE

Front. Built Environ. | doi: 10.3389/fbuil.2021.662489

Ventilation System Design and the Coronavirus (COVID-19)

Provisionally accepted The final, formatted version of the article will be published soon. Notify me

Alireza Afshari[1*], Göran Hultmark[1] and Peter V. Nielsen[1]

[1]Aalborg University, Denmark

Thank you

for your attention