ATIC webinar 22-10-2022

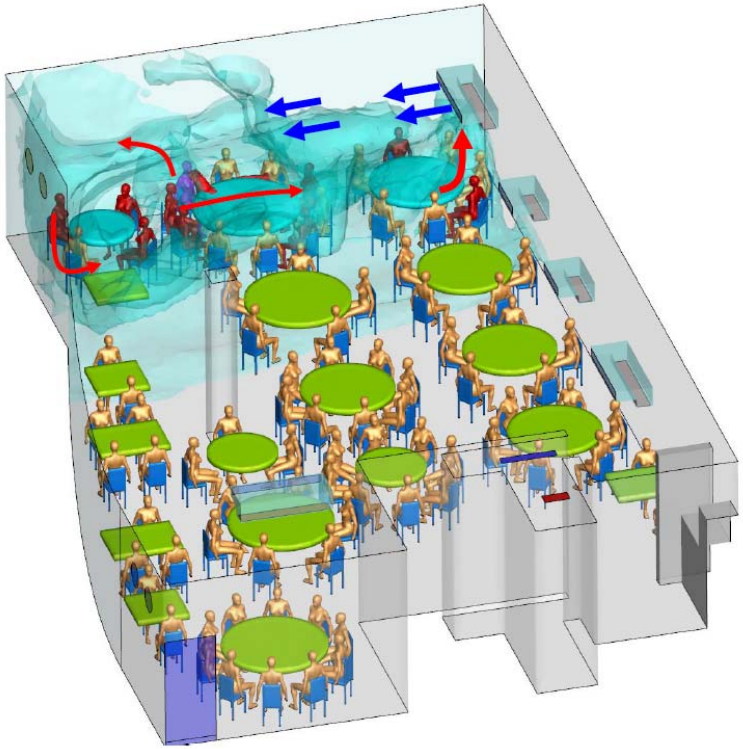
How to counteract COVID-19 transmission with / via HVAC systems

dr. ir. Atze Boerstra

REHVA vice-president / bba binnenmilieu managing director

HVAC > Friend or Foe?

CASE: Guangzhou Restaurant January 2020, study Yuguo Li et al:



- Air movement triggered by split-unit really a problem?
- Core problem here was POOR VENTILATION (fresh air supply of 1 L/s per person) (personal communication Yuguo Li)

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REHVA's mission:

- To develop and disseminate economical, energy efficient, safe and healthy technology for mechanical services of buildings; …..

REHVA's strategic objectives:

- Advocating health, comfort, safety, productivity and energy efficiency in all buildings and communities
- Promoting high quality HVAC engineering practice through technical guidance aiming at zero energy and adequate ventilation in European Buildings, as well as training, standardization, and certification

More backgrounds: www.rehva.eu

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GENERAL INTRODUCTION

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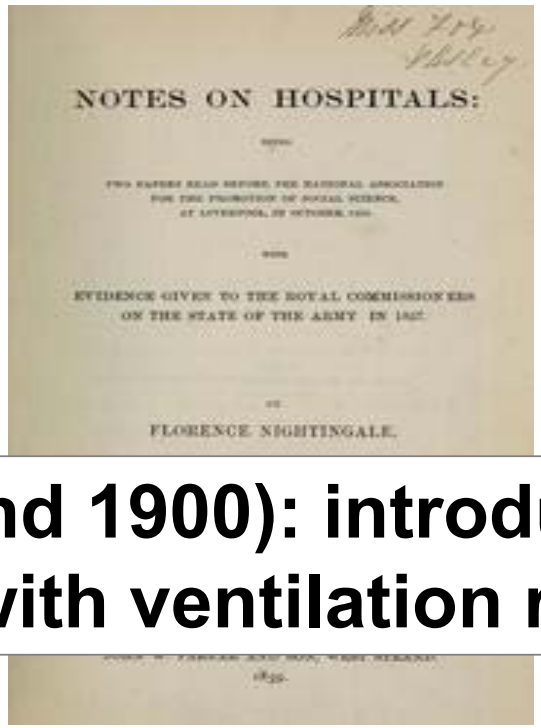
Historical context: Florence Nightingale


NOTES ON HOSPITALS:

EVIDENCE GIVEN TO THE ROYAL COMMISSIONERS ON THE STATE OF THE ARMY IN

FLORENCE NIGHTINGALE.

Environmental theory:

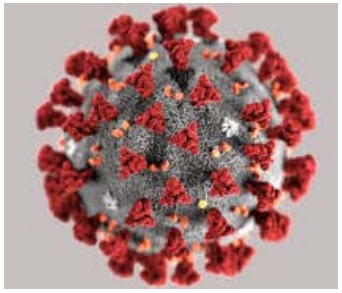
"Essential components of a healthy environment:

- ***fresh air***
- *pure water*
- *efficient drainage*

Effect (around 1900): introduction of building codes with ventilation requirements

source: Nightingale, 1859

Fast forward 2020: China buddhist bus case

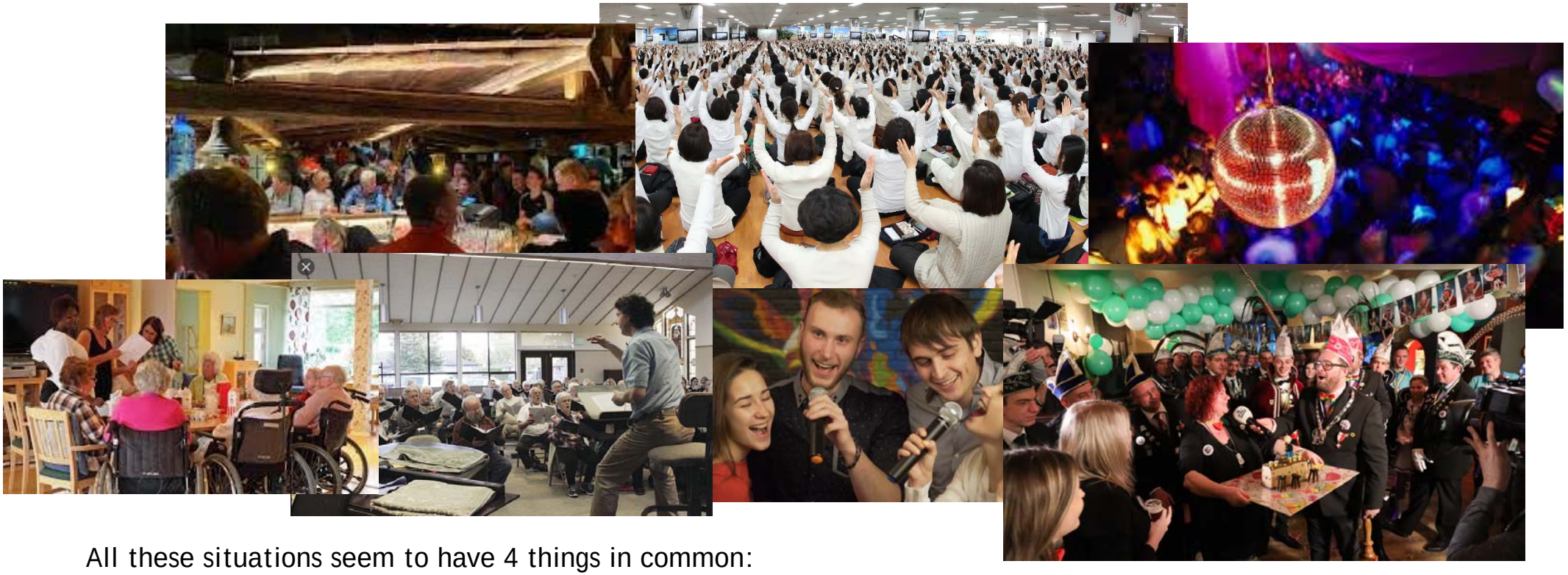


COVID-19

One person infects 18 others during a bus ride within 2 x 50 minutes (!);
probable cause: *insufficient ventilation / system in recirculation mode*

Source: Shen et al, 2020

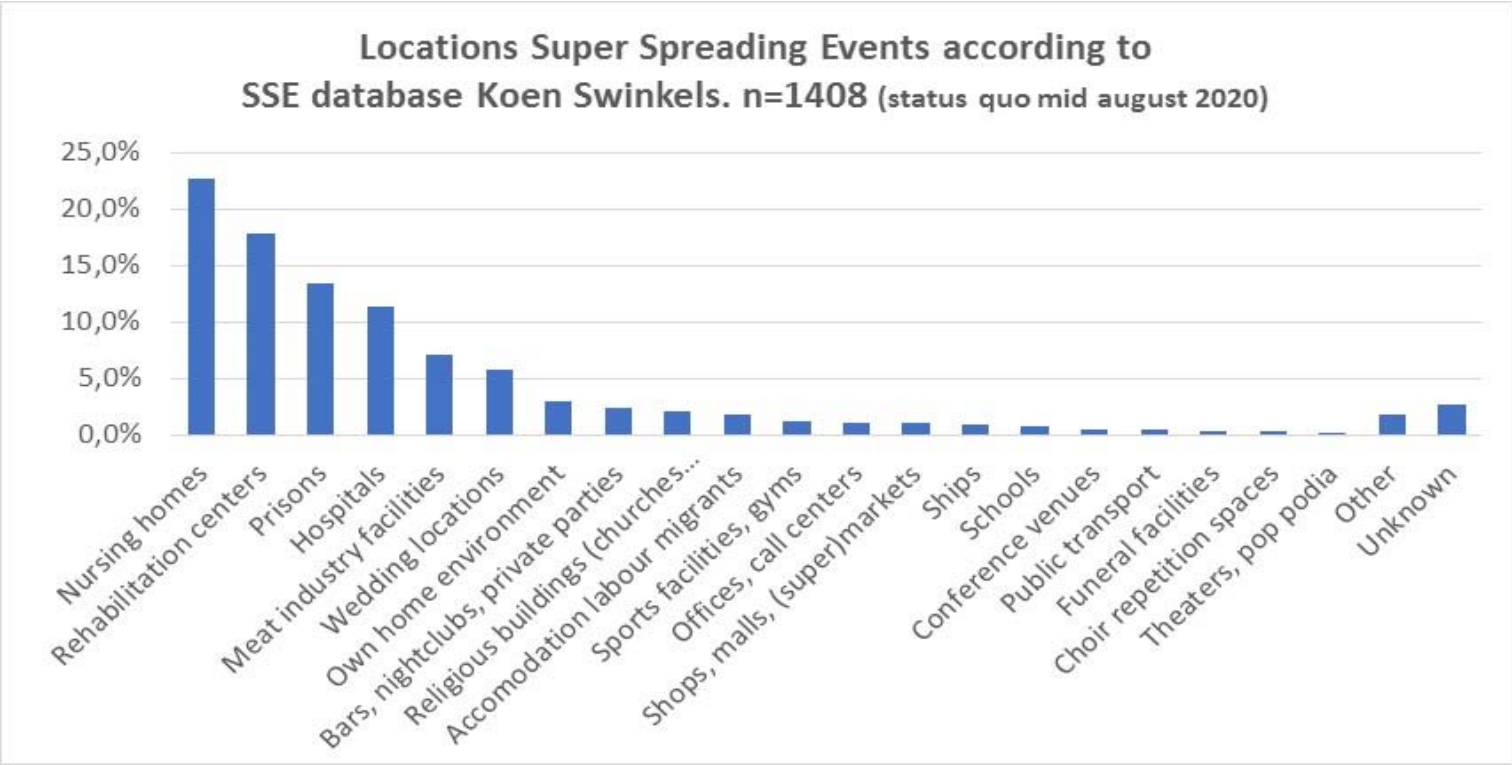
Other examples COVID-19 Super Spreading Events



All these situations seem to have 4 things in common:

1. crowding 2. small/medium sized spaces 3. <u>mediocre fresh air supply</u> 4. lots of talking, shouting, singing

Outcomes recent SSE database analysis



(Boerstra et al., unpublished results)

Aerosols / airborne route really important?

Microscopic respiratory droplets generated by talking and breathing can hover in the air for minutes or hours and drift many metres horizontally before infecting people, argue 239 experts from 32 countries, in a commentary published in *Clinical Infectious Diseases*.[1]

"We appeal to the medical community and to the relevant national and international bodies to recognise the potential for airborne spread of covid-19," wrote the scientists, who include physicians, epidemiologists, and experts in environmental health and building design.

"Studies by the signatories and other scientists have demonstrated beyond any reasonable doubt" that airborne droplets can pose a risk beyond 2 m from an infected person, the authors argued. They cited the

Covid-19: Airborne transmission is being underestimated, warn experts

Owen Dyer

Feature

Mounting evidence suggests that coronavirus can travel in airborne aerosols – but health advice has been slow to catch up. **By Dyani Lewis**

"Hand washing is always a good measure," says the aerosol scientist, who works at the Queensland University of Technology. But the sign might be outdated.

that waft through the air and accumulate over time. After months of debate about whether people can transmit the virus through exhaled air, there is growing concern among scientists

transmission. It maintains that more research is needed "given the possible implications of such [a] route of transmission", but acknowledges that short-range aerosol transmission

510 | Nature | Vol 583 | 23 July 2020

Sources: NY Times, Nature, British Medical Journal (original source: Morawska & Milton, 2020)

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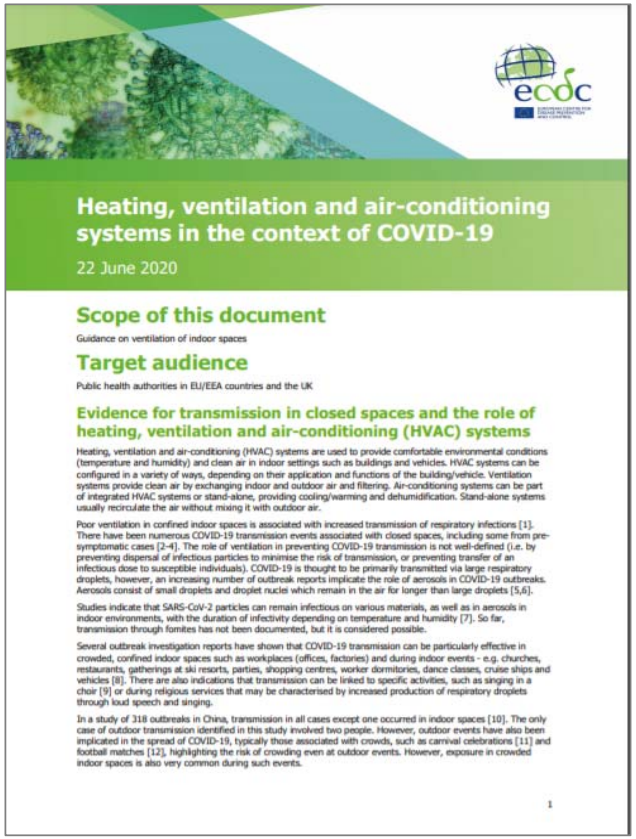
Position European Centre for Disease Control

‘*HVAC systems may have a complementary role in decreasing transmission in indoor spaces by increasing the rate of air change, decreasing recirculation of air and increasing the use of outdoor air.’*



ecdc

Heating, ventilation and air-conditioning systems in the context of COVID-19

22 June 2020

Scope of this document

Guidance on ventilation of indoor spaces

Target audience

Public health authorities in EU/EEA countries and the UK

Evidence for transmission in closed spaces and the role of heating, ventilation and air-conditioning (HVAC) systems

Heating, ventilation and air-conditioning (HVAC) systems are used to provide comfortable environmental conditions (temperature and humidity) and clean air in indoor settings such as buildings and vehicles. HVAC systems can be configured in a variety of ways, depending on their application and functions of the building/vehicle. Ventilation systems provide clean air by exchanging indoor and outdoor air and filtering. Air-conditioning systems can be part of integrated HVAC systems or stand-alone, providing cooling/warming and dehumidification. Stand-alone systems usually recirculate the air without mixing it with outdoor air.

Poor ventilation in confined indoor spaces is associated with increased transmission of respiratory infections [1]. There have been numerous COVID-19 transmission events associated with closed spaces, including some from pre-symptomatic cases [2-4]. The role of ventilation in preventing COVID-19 transmission is not well-defined (i.e. by preventing dispersal of infectious particles to minimise the risk of transmission, or preventing transfer of an infectious dose to susceptible individuals). COVID-19 is thought to be primarily transmitted via large respiratory droplets, however, an increasing number of outbreak reports implicate the role of aerosols in COVID-19 outbreaks. Aerosols consist of small droplets and droplet nuclei which remain in the air for longer than large droplets [5,6].

Studies indicate that SARS-CoV-2 particles can remain infectious on various materials, as well as in aerosols in indoor environments, with the duration of infectivity depending on temperature and humidity [7]. So far, transmission through fomites has not been documented, but it is considered possible.

Several outbreak investigation reports have shown that COVID-19 transmission can be particularly effective in crowded, confined indoor spaces such as workplaces (offices, factories) and during indoor events - e.g. churches, restaurants, gatherings at ski resorts, parties, shopping centres, worker dormitories, dance classes, cruise ships and vehicles [8]. There are also indications that transmission can be linked to specific activities, such as singing in a choir [9] or during religious services that may be characterised by increased production of respiratory droplets through loud speech and singing.

In a study of 318 outbreaks in China, transmission in all cases except one occurred in indoor spaces [10]. The only case of outdoor transmission identified in this study involved two people. However, outdoor events have also been implicated in the spread of COVID-19, typically those associated with crowds, such as carnival celebrations [11] and football matches [12], highlighting the risk of crowding even at outdoor events. However, exposure in crowded indoor spaces is also very common during such events.

1

see: www.ecdc.europa.eu

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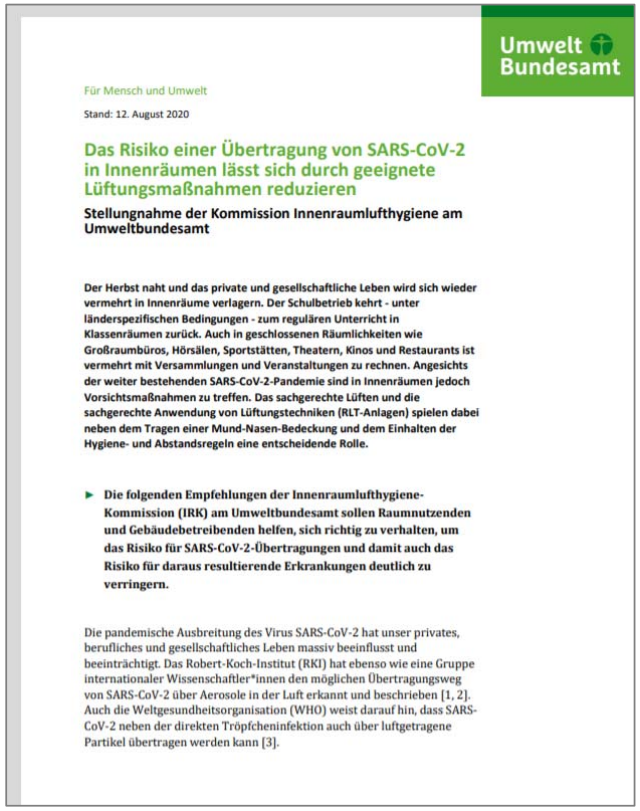
In the meantime, in Germany

Angela Merkel:

Wir werden auch ein Schwerpunkt auf das thema Luftung setzen, denn wir wissen dass die aerosole bei Corona eine grosse Rolle spielen'

Umwelt Bundesamt

source: www.umweltbundesamt.de



Umwelt Bundesamt

Für Mensch und Umwelt

Stand: 12. August 2020

Das Risiko einer Übertragung von SARS-CoV-2 in Innenräumen lässt sich durch geeignete Lüftungsmaßnahmen reduzieren

Stellungnahme der Kommission Innenraumlufthygiene am Umweltbundesamt

Der Herbst naht und das private und gesellschaftliche Leben wird sich wieder vermehrt in Innenräume verlagern. Der Schulbetrieb kehrt - unter länderspezifischen Bedingungen - zum regulären Unterricht in Klassenräumen zurück. Auch in geschlossenen Räumlichkeiten wie Großraumbüros, Hörsälen, Sportstätten, Theatern, Kinos und Restaurants ist vermehrt mit Versammlungen und Veranstaltungen zu rechnen. Angesichts der weiter bestehenden SARS-CoV-2-Pandemie sind in Innenräumen jedoch Vorsichtsmaßnahmen zu treffen. Das sachgerechte Lüften und die sachgerechte Anwendung von Lüftungstechniken (RLT-Anlagen) spielen dabei neben dem Tragen einer Mund-Nasen-Bedeckung und dem Einhalten der Hygiene- und Abstandsregeln eine entscheidende Rolle.

- **Die folgenden Empfehlungen der Innenraumlufthygiene-Kommission (IRK) am Umweltbundesamt sollen Raumnutzenden und Gebäudebetreibenden helfen, sich richtig zu verhalten, um das Risiko für SARS-CoV-2-Übertragungen und damit auch das Risiko für daraus resultierende Erkrankungen deutlich zu verringern.**

Die pandemische Ausbreitung des Virus SARS-CoV-2 hat unser privates, berufliches und gesellschaftliches Leben massiv beeinflusst und beeinträchtigt. Das Robert-Koch-Institut (RKI) hat ebenso wie eine Gruppe internationaler Wissenschaftler*innen den möglichen Übertragungsweg von SARS-CoV-2 über Aerosole in der Luft erkannt und beschrieben [1, 2]. Auch die Weltgesundheitsorganisation (WHO) weist darauf hin, dass SARS-CoV-2 neben der direkten Tröpfcheninfektion auch über luftgetragene Partikel übertragen werden kann [3].

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VENTILATION & COVID-19 TRANSMISSION

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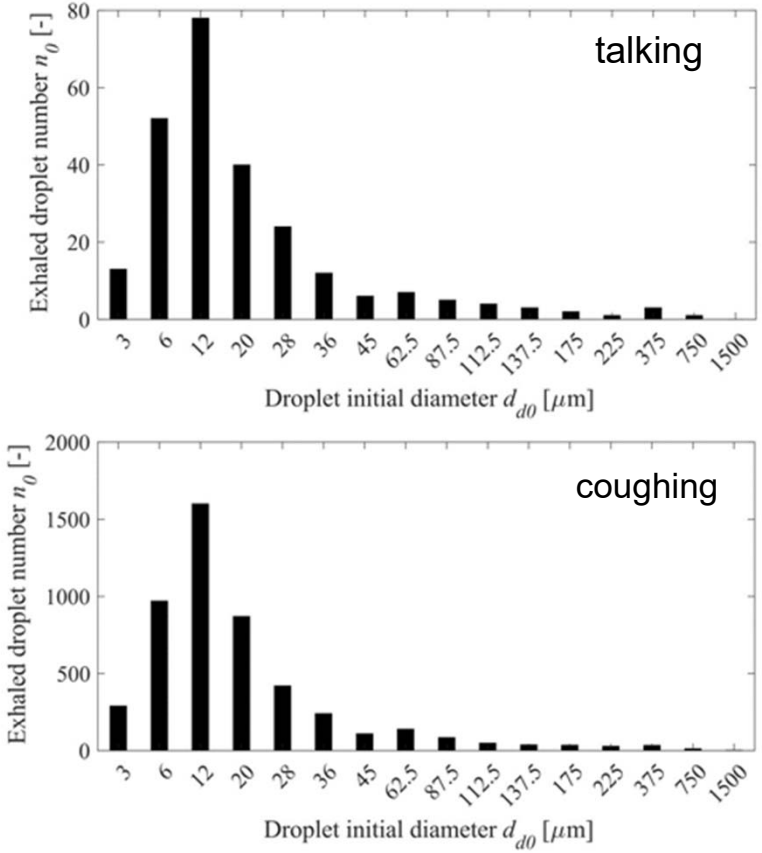
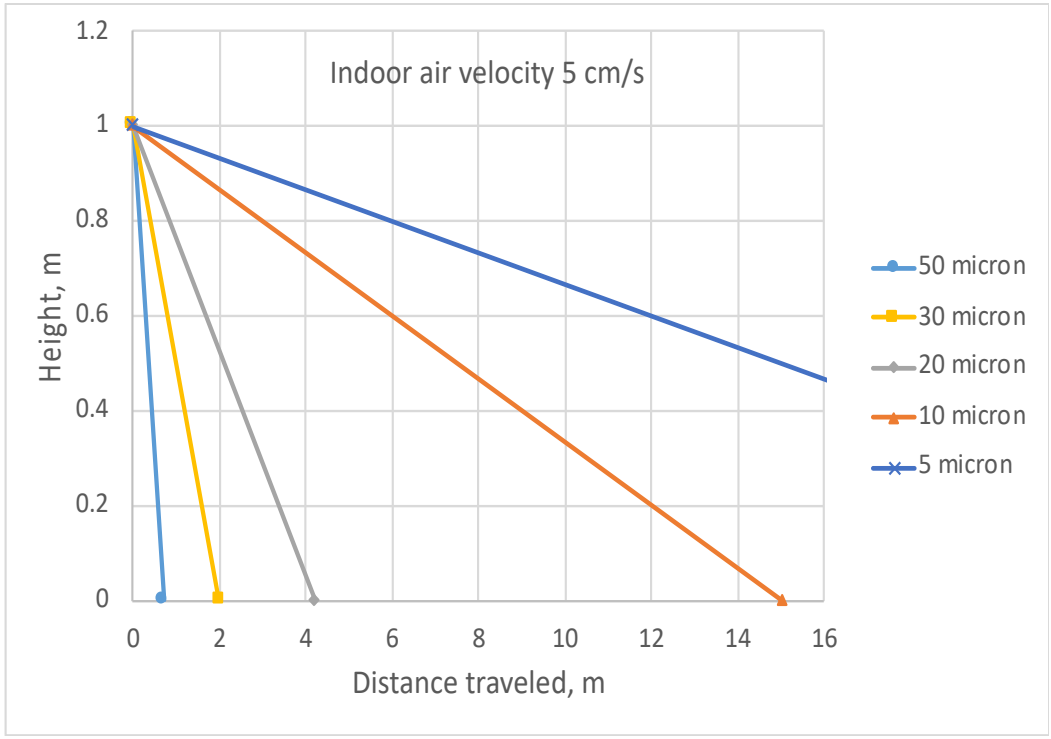
Keeping 1,5 m distance = 100% safe?





Chen et al, 2020; Kurnitski / Morawska, 2006

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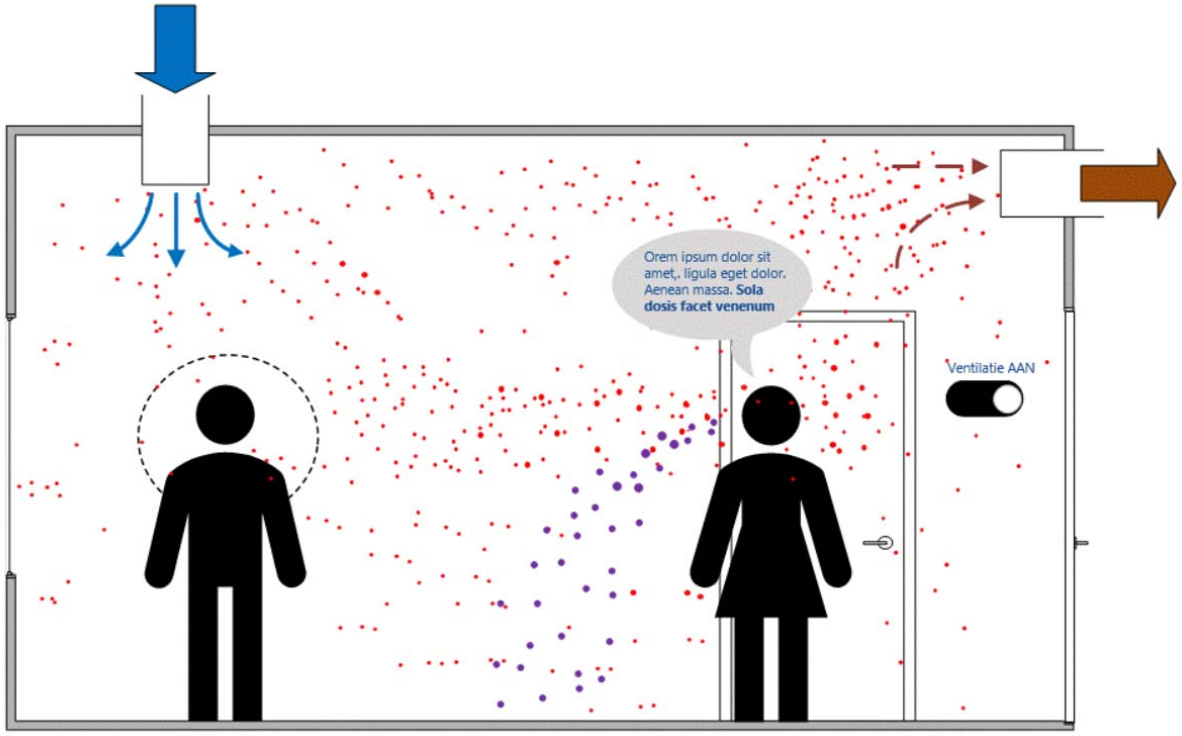
To ventilate = to dilute = to decrease infection risk



Simulation: Stijn van der Horst, bba binnenmilieu

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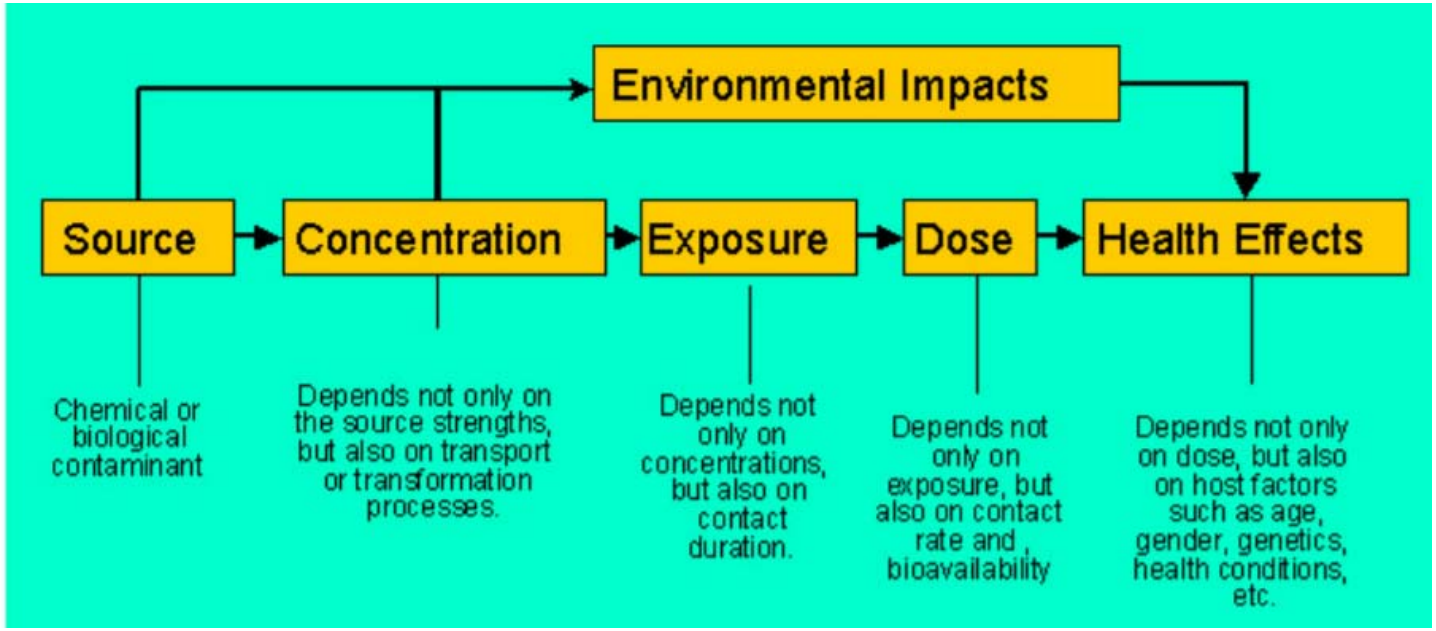
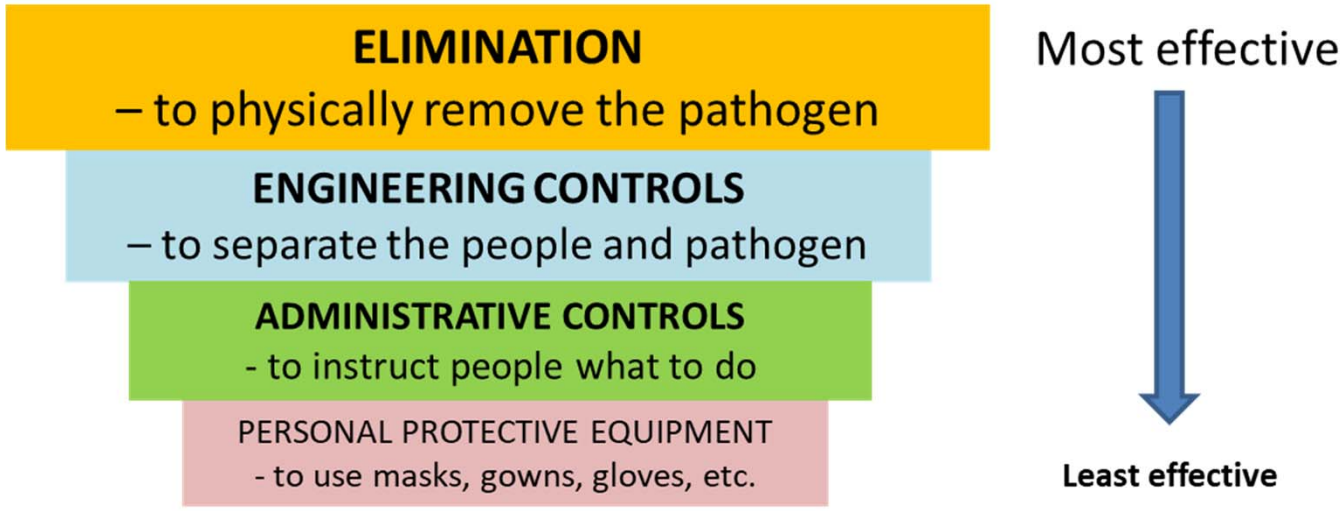
Standard theory (occupational health)



Air pollution system as defined by Zhang & Lioy, 2002

Prefered infection control strategy



- Infection control pyramid adapted from US CDC (CDC, 2015)
- Elimination is tricky with COVID-19 (large amount of transmission is via pre/a-symptomatic persons)
- Ventilation solutions & filtration should be main engineering controls (in combi with masks where interpersonal distance of 1,5 meter is not possible)

How much ventilation is enough?

- Shelly Miller: *'minimum 5 l/s per person'*
- Yuguo Li: *'minimum 10 l/s per person'*
- Me (NOT OFFICIAL REHVA STANDPOINT!): *'depends very much from on the situation; in smaller spaces where one stays 4 hours or so 15+ l/s might not even be enough; in larger spaces where one stays an hour 5 l/s might be more than enough'*

Table B2.1.2-1 Design ventilation rates for non-adapted persons for diluting emissions (bioeffluents) from people for different categories

Category	Expected Percentage Dissatisfied	Airflow per non-adapted person l/(s per person)
I	15	10
II	20	7
III	**30**	**4**
IV	40	2,5*

Fresh air supply requirements EN 16798-1: 2019

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Ideal ventilation rates can be estimated with Wells Riley method

Wells Riley formula:

$$P(inf) = 1 - e^{\wedge} ((-I \times q \times P \times t) / Q)$$

P(inf) = infection risk (%)

I = amount of infected persons in the room (sources)

q = virusload / source strength of 1 infected person (quanta/h)

P = pulmonary ventilation / lung air intake (m^3/h)

t = exposure time (h)

Q = hourly room ventilation (m^3/h) (= AER x room volume)

First presented in:
Wells, 1955

Example Wells Riley evaluation outcome (classrooms)

Scenario	Total Fresh Air Supply (m3/h)	Air Exhange Rate (AER)	Steady state CO2 conc. (ppm)	Total class time: 1,5 hours		Total class time: 3,0 hours		Total class time: 8,0 hours	
				P(inf) when quiet	P(inf) when talking	P(inf) when quiet	P(inf) when talking	P(inf) when quiet	P(inf) when talking
Excellent fresh air supply (8,5 l/s per person)	765	4,9	1000	**1,0%**	**2,5%**	**2,0%**	**4,9%**	**5,3%**	**12,6%**
Basic fresh air supply (6 l/s per person)	550	3,7	1200	**1,5%**	**3,5%**	**2,7%**	**6,5%**	**7,0%**	**16,5%**
Mediocre fresh air supply (3,5 l/s per person)	310	2,1	1800	**2,3%**	**5,7%**	**4,6%**	**11,1%**	**11,8%**	**27,0%**
Very low fresh air supply (1,7 l/s per person)	150	1,0	3200	**4,6%**	**11,1%**	**9,0%**	**21,0%**	**22,3%**	**46,8%**

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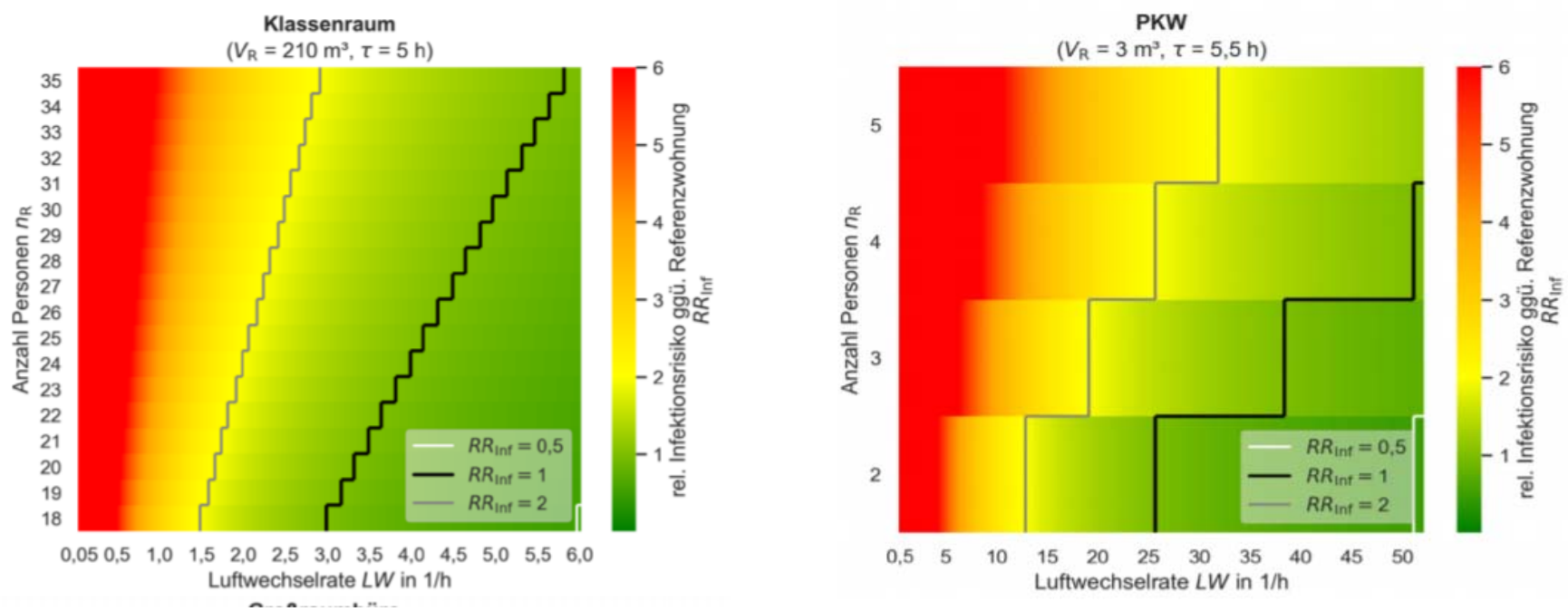
Example results Wells Riley analysis Muller et al, 2020



(source: Muller et al, 2020; https://publications.rwth-aachen.de/record/795437)

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REHVA COVID-19 guidance

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REHVA COVID-19 guidance

- Documents available via: https://www.rehva.eu/activities/covid-19-guidance
- First version March 17, updates April 3 & August 3
- New version ‘on the horizon’
- Targeted to: HVAC professionals and facility managers but may be useful too e.g. for HVAV component manufacturers, occupational health & safety specialist, public health officials etc.
- Present scope is limited to commercial and public buildings
- Practical guidance on temporary, easy-to-organize measures for existing buildings
- Several parts can be used when designing new buildings too

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REHVA COVID-19 guidance document, August 3, 2020

(this document updates previous April 3 and March 17 versions. Further updates will follow as necessary)

How to operate HVAC and other building service systems to prevent the spread of the coronavirus (SARS-CoV-2) disease (COVID-19) in workplaces

1 Introduction

In this document, REHVA summarizes advice on the operation and use of building service systems during an epidemic of a coronavirus disease (COVID-19), to prevent the spread of COVID-19 depending on HVAC (Heating, Ventilation, and Air Conditioning) or plumbing systems related factors. The advice below should be treated as interim guidance; the document will be complemented with new evidence and information when it becomes available.

The suggestions below are meant as an addition to the general guidance for employers and building owners that are presented in the WHO document 'Getting workplaces ready for COVID-19'. The text below is intended primarily for HVAC professionals and facility managers. It may be useful for occupational and public health specialists and others involved in decisions on how to use buildings.

In this document, building services related precautions are covered. The scope is limited to commercial and public buildings (e.g., offices, schools, shopping areas, sports premises, etc.) where only occasional occupancy of infected persons is expected. Residential buildings are out of the scope of this document.

The guidance is focused on temporary, easy-to-organise measures that can be implemented in existing buildings that are in use during or after epidemic with normal or reduced occupancy rates.

Disclaimer:
This document expresses REHVA expert advice and views based on the available scientific knowledge of COVID-19 available at the time of publication. In many aspects, SARS-CoV-2 information is not complete, so evidence[1] from previous SARS-CoV-1 experience has been used for best practice recommendations. REHVA, the contributors and all those involved in the publication exclude all and any liability for any direct, indirect, incidental damages or any other damages that could result from, or be connected with, the use of the information presented in this document.

[1] In the last two decades we have been confronted with three coronavirus disease outbreaks: (i) SARS in 2002-2003 (SARS-CoV-1), (ii) MERS in 2012 (MERS-CoV) and COVID-19 in 2019-2020 (SARS-CoV-2). In the present document our focus is on the current instance of SARS-CoV-2 transmission. When referring to the SARS outbreak in 2002-2003 we use the name SARS-CoV-1.

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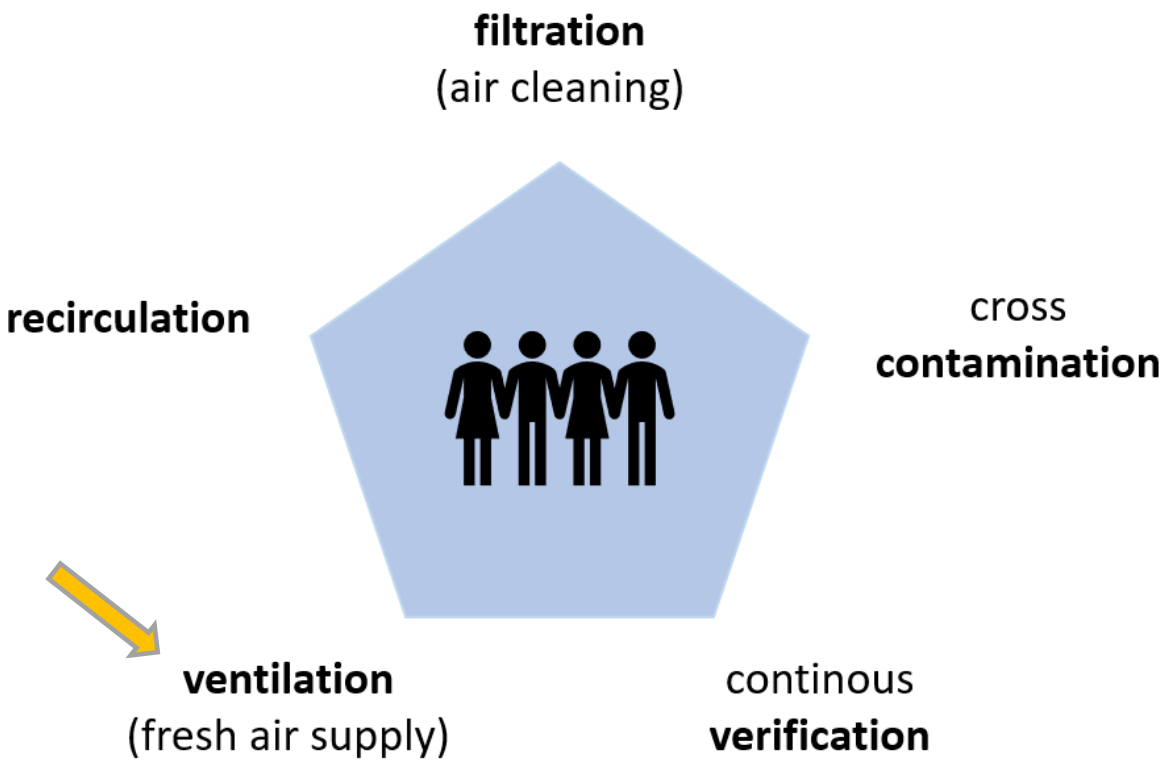
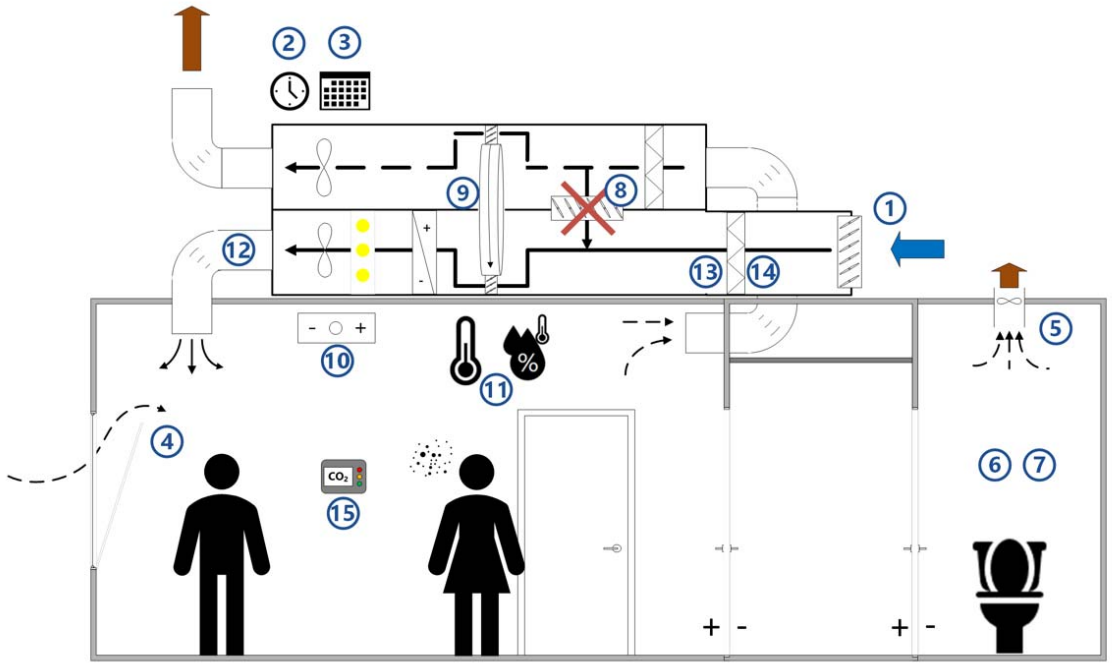
CORE MEASURES



15 recommendations for existing buildings

1. Ventilation rates
2. Ventilation operation times
3. Continuous operation of ventilation
4. Window opening
5. Toilet ventilation
6. Windows in toilets
7. Flushing toilets
8. Recirculation
9. Heat recovery equipment
10. Fan coils and induction units
11. Heating, cooling and possible humidificatic setpoints
12. Duct cleaning
13. Outdoor air and extract air filters
14. Maintenance works
15. IAQ monitoring

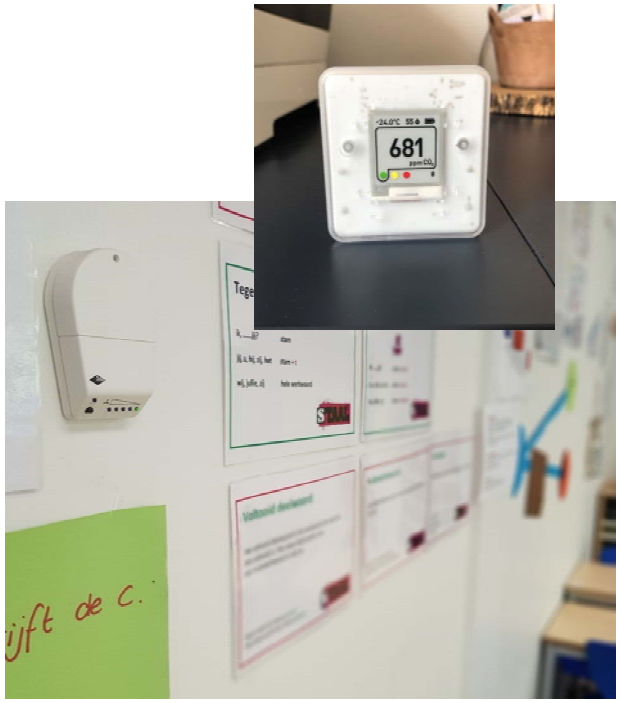


Longer and continuous ventilation operation

- Supply as much outside air as reasonably achievable. **The key aspect is the amount of fresh air supplied per person**
- Extended operation times are recommended: Change the clock times of system timers to start ventilation at nominal speed at least 2 hours before the building usage time and switch to lower speed 2 hours after the building usage time
- Do not switch off ventilation at nights and weekends, but operate at lowered speed
- Exhaust ventilation systems of e.g. toilets, elevators and other real small spaces should be kept on (ideally 24/7); make sure that under-pressure is created here (especially to avoid the faecal-oral transmission)
- **Double check demand control systems (lower CO2 setpoint to '450 ppm')!**
- Idea 'COVID setting' central system

What if there is no mechanical ventilation?

- In buildings without mechanical ventilation systems, it is recommended to **actively use openable windows and/or window ventilation grilles (dauerluftung)**
- Windows should be opened a few minutes every half hour or so (depends on occupancy); especially in between meetings make sure windows are opened
- Also, in buildings with mechanical ventilation, window opening can be used to boost ventilation further
- Install CO_2 sensors at the occupied zone that warn against underventilation (e.g. in naturally ventilated classrooms)
- Setpoints: yellow/orange at max. 800 ppm and red at 1000 ppm

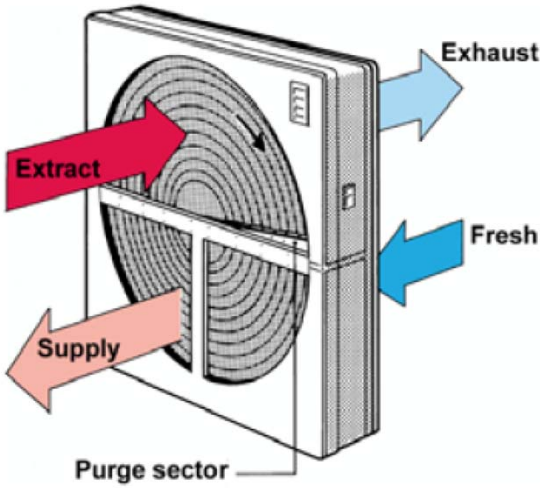


Effect of changes in humidification settings

- Extra humidification is NOT an effective method to block COVID-19 transmission
- No hard scientific evidence that radical changes in humidity levels is beneficial (van Doremalen et al., 2020)
- In case a humification system is in place: keep settings (e.g. 30% setpoint in winter) as they were before start of pandemic
- In theory elevating air temperature does help: SARS-CoV-2 has been found highly stable for 14 days at 4 ℃; at 37 ℃ this one has to wait one day and at 56 ℃ 30 minutes before virus is inactivated (Chin et al, 2020); but this is not achievable in practice (keeping building temperature at e.g. 40 C).

Safe use of heat recovery sections

- Under certain conditions virus particles in extract air can re-enter the building. Heat recovery devices may carry over virus attached to particles from the exhaust air side to the supply air side via leaks.
- In the case of regenerative heat exchangers (rotors) the minimal leakage (seals + carry over) and correct pressure difference between exhaust and supply side are important
- The leakage, carrying over also particles, may increase from the 2% to 20% if fans create higher pressure on the exhaust air side



- Evidence suggest that rotors with adequate purge sector practically do not transfer particles, but the transfer is limited to gaseous pollutants (e.g. smells, tobacco smoke)
- Because the leakage does not depend on the rotation speed, it is not needed to switch rotors off. If needed, the pressure differences can be corrected by dampers or by other arrangements.

Use of central recirculation

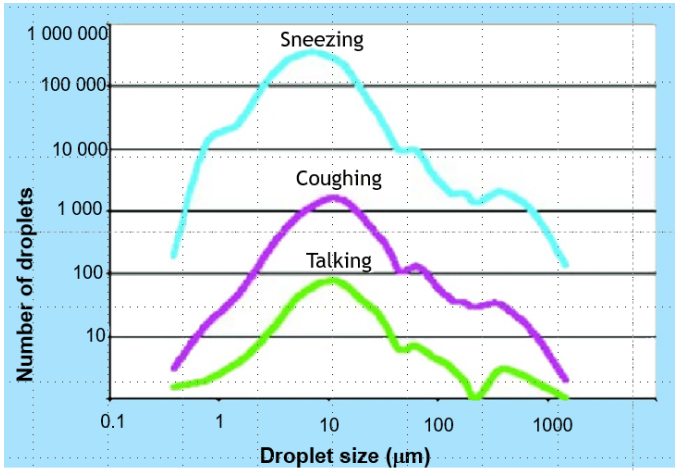
- Virus particles in return ducts can also re-enter a building when centralized air handling units are equipped with recirculation sectors (may be in use at least in older all-air heating and cooling systems)
- Especially risky in e.g. hospitals and nursing homes (offices, schools less of an issue)
- Recirculation dampers should be closed (via the Building Management System or manually)
- In air systems and air-and-water systems where central recirculation cannot be avoided because of limited cooling or heating capacity, the outdoor air fraction has to be increased as much as possible and additional measures might be needed for return air filtering

Room level circulation: fan coil, split and induction units

- In rooms with fan coils only or split units (all-water or direct expansion systems), the first priority is to achieve adequate outdoor air ventilation. In such systems, mechanical ventilation is usually independent of the fan coils or split units and two options are possible to achieve ventilation:
  1. Active operation of window opening together with the installation of CO2 monitors as indicators of outdoor air ventilation;
  2. Operation/installation of a standalone mechanical ventilation system (either local or centralized, according to its technical feasibility)

Outdoor air filtration

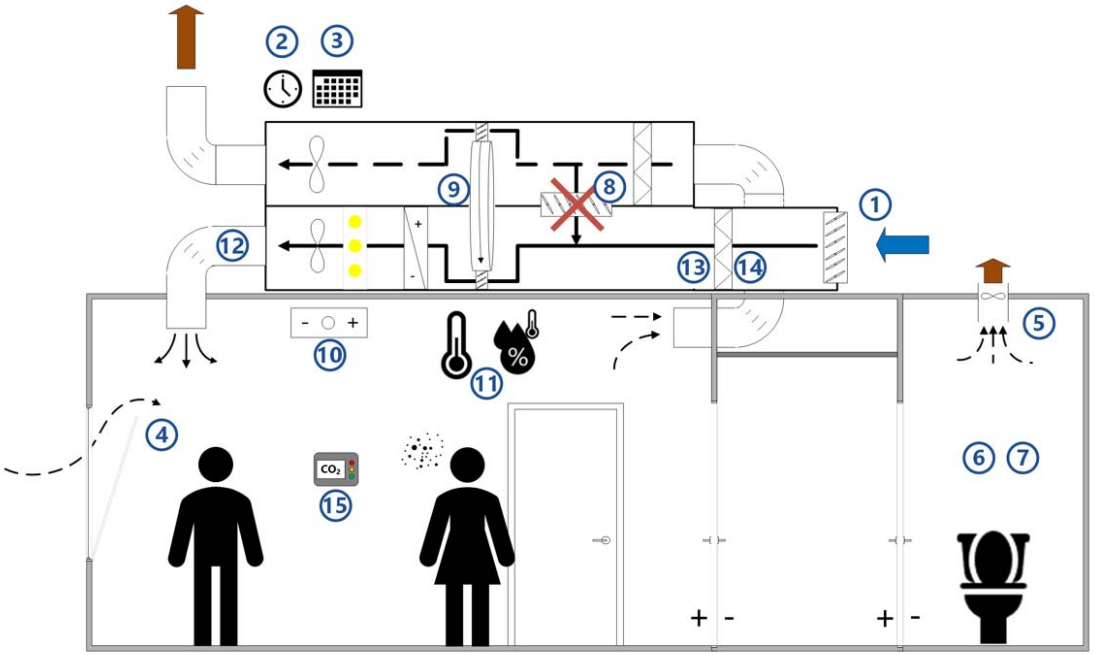
- Outdoor air is not a source of viruses, thus no need to replace filters (despite of regular maintenance)
- Outdoor air filters (filter class F7 or F8 or ISO ePM1) are not designed to capture viruses – the size of the smallest viral droplets in respiratory aerosols of about 0.2 mm (PM0.2) is smaller than the capture area of ePM1 / F8 filters (capture efficiency 65-90% for PM1)
- No need to clean ventilation ductworks as well (despite of scheduled maintenance)
- Maintenance personnel needs to apply common protective measures when replacing filters including respirators, because filters may have active microbiological material on them



Room air cleaners

- Room air cleaners remove particles from the air, which provides a similar effect compared to the outdoor air ventilation
- To be effective, air cleaners need to have HEPA filter efficiency
- Air cleaners with electrostatic filtration principles (not the same as room ionizers!) often work well too
- To select the right size air cleaner, the airflow capacity of the unit (at an acceptable noise level) has to be at least 2 ACH and will have positive effect until 5 ACH (calculate the airflow rate through the air cleaner in m^3/h by multiplying the room volume by 2 or 5)
- In large spaces, air cleaners need to be placed close to people in a space and should not be placed in the corner and out of sight
- Filtration systems that use ultraviolet light (UVGI disinfection equipment): still under debate, might be usefull to inactivate viruses e.g. in health care settings
- Use it in always in combination with SOME fresh air supply (e.g. to keep CO2 levels ok)

Summary



1. Provide adequate ventilation of spaces with outdoor air
2. Extended ventilation operation times: 2 hours before and after the building usage time
3. Not switching ventilation off at nights and weekends, but keeping at a lower speed
4. Open windows regularly (even in mechanically ventilated buildings)
5. Keep toilet ventilation in operation 24/7
6. Avoid open windows in toilets to maintain the right direction of ventilation
7. Instruct building occupants to flush toilets with closed lid
8. Switch air handling units with recirculation to 100% outdoor air
9. Inspect heat recovery equipment to be sure that leakages are under control
10. Adjust fan coil settings to operate so that fans are continuously on
11. Do not change heating, cooling and possible humidification setpoints
12. Carry out scheduled duct cleaning as normal (additional cleaning is not required)
13. Normal maintenance schedule for the replacement of central outdoor air and extract air filters
14. Use of protective measures including respiratory protection for maintenance personnel
15. Introduce an IAQ sensor network that allows occupants and facility managers to monitor that ventilation is operating adequately

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QUESTIONS?

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https://www.rehva.eu/pre-registration-safe-building-operation-during-covid-19