United Nations COVID-19 Response

Covid-19 & Aerosol / Airborne

christophe@my-poppy.eu – 2021-01-21
version 0.2

The slides will be available in the chat & at blog.my-poppy.eu

About you

- Event & logistics managers
- Registered nurses
- Emergency medical technicians
- Health & safety advisors & consultants
- Emergency planners & risk managers
- Decision-makers (HCFRN, municipality, province, school, police, 112, entreprise network, …)

Let’s interact through the chat!
After 3 pm we can talk, or organize smaller groups later

About me

Christophe Cloquet, 40
Founder of Poppy since 2014

A sharp ***technical background***
backed by a solid ***field experience***

4 years with the Belgian Defence
20 years as a volunteer Emergency Medical Technician

MSc in Applied Physics (2002)
PhD in Applied Sciences (medical imaging, 2011)
Post-doc in Data Science

Certifications

- ISO 27001:2013 Foundations
- GDPR Foundations
- ITIL 4 Foundations
- HAREC

Customers: Brussels 112 & Fire Brigade, National Crisis Centre, Federal Agency for Nuclear Control, SPF Interior, SPF Public Health, Red-Cross, ...

⇒ No MD – virologist - epidemiologist
⇒ No psychologist
⇒ No lawyer
⇒ No decision-maker
⇒ No guru

⇒ Believe of a pluridisciplinary approach

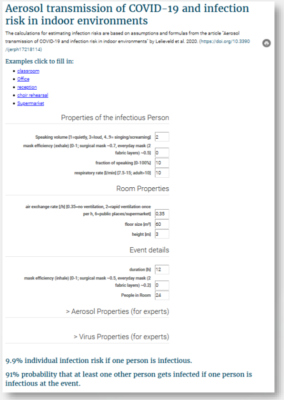
Goals

- Give each of you at least **one useful new piece of information**
- **Global overview & references** to go further by yourself
- Present myself should you want to **collaborate**

Your goals

- You want **your collaborators to air more**
  - Buy a CO_2 sensor (200 €)

- You want to **quickly assess the risk & airing in your facilities**
  - Use & understand the risk calculators
  - Buy a bunch of CO_2 sensors + fans & follow the Harvard guide



Aerosol transmission of COVID-19 and infection risk in indoor environments

The calculations for estimating infection risks are based on assumptions and formulas from the article "Aerosol transmission of COVID-19 and infection risk in indoor environments" by Lelieveld et al. 2020. (https://doi.org/10.3390/ijerph17218114)

Examples click to fill in:

- classroom
- Office
- reception
- choir rehearsal
- Supermarket

Properties of the infectious Person

Speaking volume [1=quietly, 3=loud, 4..9= singing/screaming]	2
mask efficiency (exhale) [0-1; surgical mask ~0.7, everyday mask (2 fabric layers) ~0.5]	0
fraction of speaking [0-100%]	10
respiratory rate [l/min] [7.5-15; adult=10]	10

Room Properties

air exchange rate [/h] [0.35=no ventilation, 2=rapid ventilation once per h, 6=public places/supermarket]	0,35
floor size [m²]	60
height [m]	3

Event details

duration [h]	12
mask efficiency (inhale) [0-1; surgical mask ~0.5, everyday mask (2 fabric layers) ~0.2]	0
People in Room	24

> Aerosol Properties (for experts)

> Virus Properties (for experts)

9.9% individual infection risk if one person is infectious.

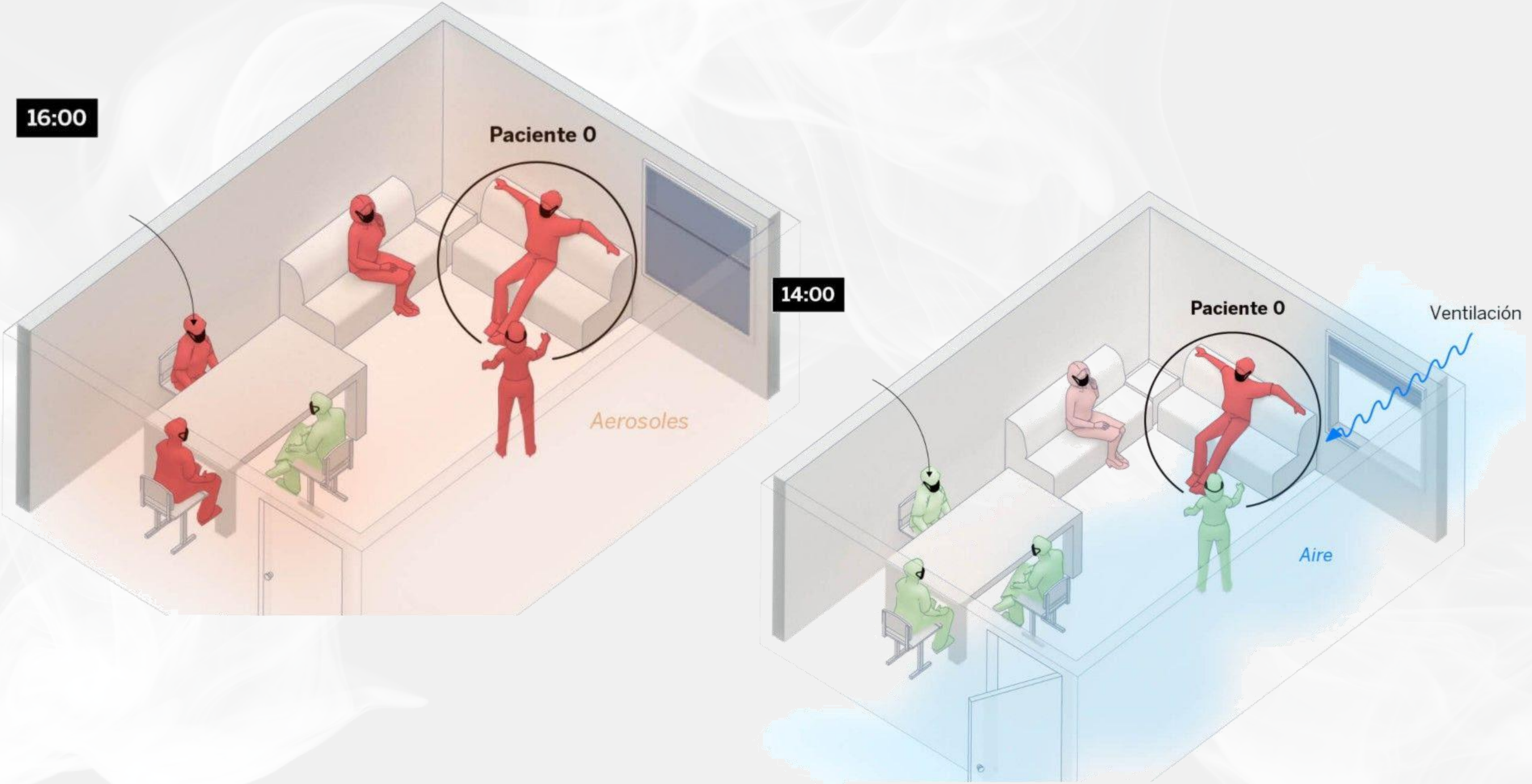
91% probability that at least one other person gets infected if one person is infectious at the event.

- You **cannot air more**
  - Properly install (true & well-dimensioned) HEPA-filters

- You have a **broader view**
  - Get inspiration about why/what/how can be done
- Your **issue is complex**
  - Hire me as a consultant!

2021-01-21

Why ?


16:00
Paciente 0
Aerosoles
14:00
Paciente 0
Ventilación
Aire

EL PAÍS

Why ?

Sciensano (24/12/2020)

"In the absence of any ventilation, according to a study, SARS-CoV-2 remains viable in aerosols for 3 hours, with median half-life 1.1-1.2 hours"

"The potential of long-range airborne transmission of SARS-CoV-2 is no longer disputed, although its relative importance remains unclear"

Some other references

Vuorinen et al (2020), *Modelling aerosol transport and virus exposure with numerical simulations in relation to SARS-CoV-2 transmission by inhalation indoors*, Safety Science

Tang et al (2020) *Aerosol transmission of SARS-CoV-2? Evidence, prevention and control*, Environ Int

Tang et al (2020), *Dismantling myths on the airborne transmission of severe acute respiratory syndrome coronavirus (SARS-CoV-2)*, Journal of Hospital Infection

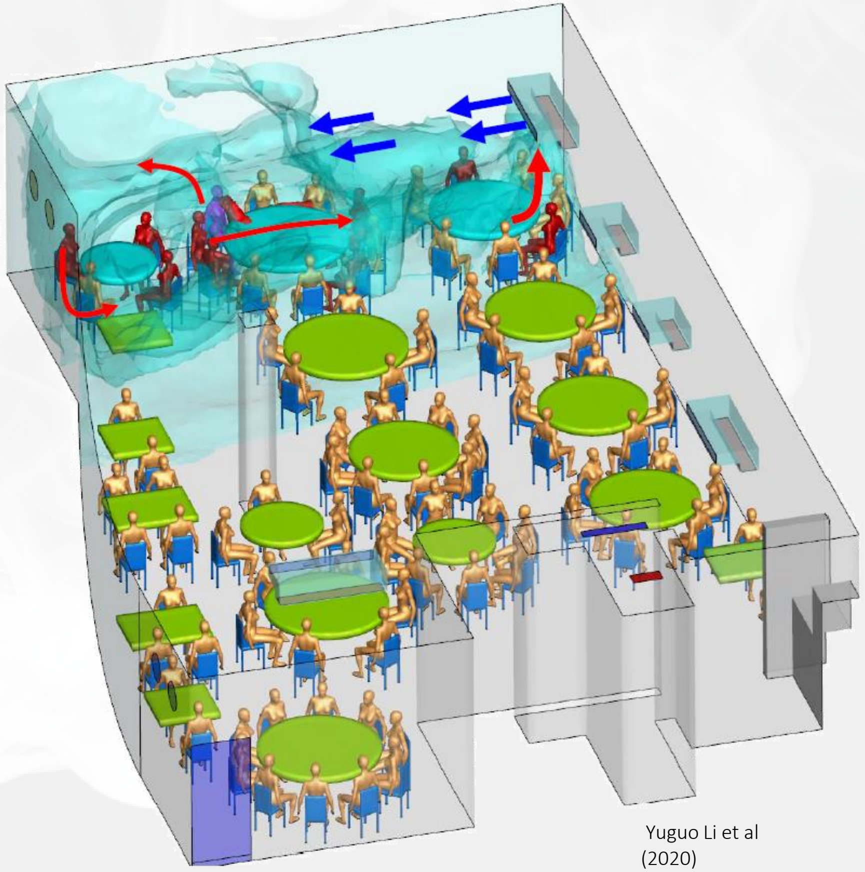
Examples

High SARS-CoV-2 Attack Rate Following Exposure at a Choir Practice — Skagit County, Washington, March 2020

Weekly / May 15, 2020 / 69(19);606–610

On May 12, 2020, this report was posted online as an MMWR *Early Release.*

Lea Hamner, MPH[1]; Polly Dubbel, MPH[1]; Ian Capron[1]; Andy Ross, MPH[1]; Amber Jordan, MPH[1]; Jaxon Lee, MPH[1]; Joanne Lynn[1]; Amelia Ball[1]; Simranjit Narwal, MSc[1]; Sam Russell[1]; Dale Patrick[1]; Howard Leibrand, MD[1] (View author affiliations)



Yuguo Li et al (2020)

Comments (1)

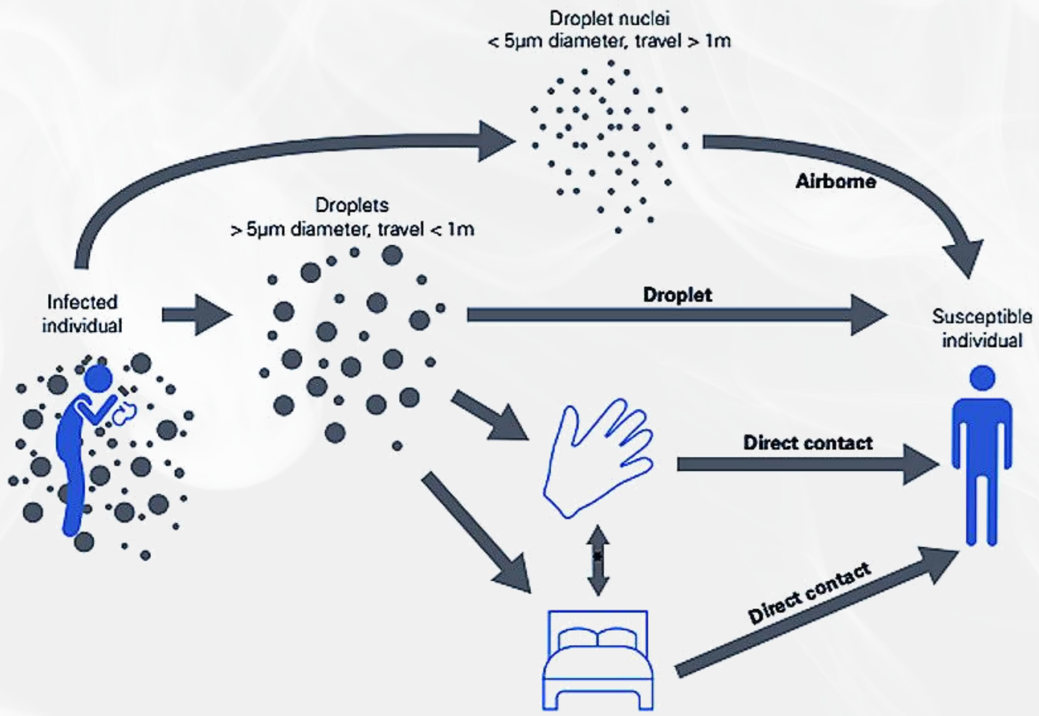
Evidence for probable aerosol transmission of SARS-CoV-2 in a poorly ventilated restaurant

Yuguo Li, Hua Qian, Jian Hang, Xuguang Chen, Ling Hong, Peng Liang, Jiansen Li, Shenglan Xiao, Jianjian Wei, Li Liu, Min Kang

doi: https://doi.org/10.1101/2020.04.16.20067728

Sars-Cov-2 Transmission routes

Figure 1 – Modélisation des voies de transmission « Air », « Gouttelettes » et « Contact », d'après Otter et al. 2016.



*Transmission routes involving a combination of hand & surface = indirect contact.

Droplets: ⚠ Wind, air flows, cough
Aerosols: ⚠ Bathrooms

Why (also) tackle this problem on the long term ?

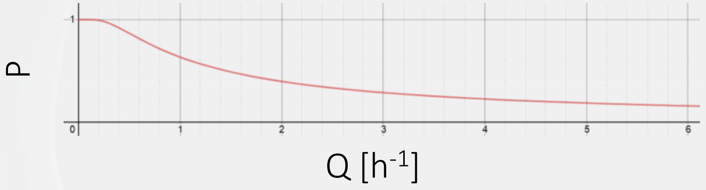
- ⇨ Respect the law (indoor air – max 900 ppm CO_2)
- ⇨ Variants / endemic Covid-19
- ⇨ Influenza (evitable ICU & deaths)
- ⇨ Increasing tuberculosis / measles
- ⇨ Prepare other pandemics

Risk calculators

Wells-Riley relates airing to infection probability:

(base for the Max Planck Institute, UColorado & REHVA models)

There is a limit to what Q can reasonably achieve



Probability of being infected =

$$\boxed{\frac{Iqp\Delta t}{Q}}$$

with

I = # of carriers
p = breathing rate
q = quantas rate
Δt = time
Q = airing rate [ACH]

1 quantum = dose of airborne particles to cause infection with 63 % of susceptible persons

Hypotheses

- « Perfect mixing », Volume < **300 m³**
- Uncertainty on quantas + cf variant (but scenarios)

Result

- Average, but **no information on the variability**
- Does not tell what is the **acceptable probability** (to be drawn from **epidemiological** models & other hypotheses - Buonanno et al suggest 1/1000 as a discussion base)

Refs eg, Issarow et al (2015), *Modelling the risk of airborne infectious disease using exhaled air*, Journal of Theoretical Biology
Noakes & Sleigh (2009), *Mathematical models for assessing the role of airflow on the risk of airborne infection in hospital wards*, J R Soc Interface

Practical

Calculator 1: Max Planck Institute

International Journal of *Environmental Research and Public Health*

MDPI

Article

Model Calculations of Aerosol Transmission and Infection Risk of COVID-19 in Indoor Environments

Jos Lelieveld [1,2,*], Frank Helleis [1], Stephan Borrmann [1], Yafang Cheng [1], Frank Drewnick [1], Gerald Haug [1], Thomas Klimach [1], Jean Sciare [2], Hang Su [1] and Ulrich Pöschl [1]

1 Max Planck Institute for Chemistry, 55128 Mainz, Germany; frank.helleis@mpic.de (F.H.); stephan.borrmann@mpic.de (S.B.); yafang.cheng@mpic.de (Y.C.); frank.drewnick@mpic.de (F.D.); gerald.haug@mpic.de (G.H.); t.klimach@mpic.de (T.K.); h.su@mpic.de (H.S.); u.poschl@mpic.de (U.P.)

2 The Cyprus Institute, Climate and Atmosphere Research Center, 2121 Nicosia, Cyprus; j.sciare@cyi.ac.cy

* Correspondence: jos.lelieveld@mpic.de

Received: 18 October 2020; Accepted: 31 October 2020; Published: 3 November 2020

check for updates

mpic.de/4747361/risk-calculator?en

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> Aerosol Properties (for experts)

> Virus Properties (for experts)

9.9% individual infection risk if one person is infectious.

91% probability that at least one other person gets infected if one person is infectious at the event.

Outputs

- **Individual probability** of acquiring the virus **if** there is one person infected at the event
- **Probability at least one person** would become infected

⇨ Gives an **order of magnitude** (0,1 - 1 - 10 - 50 - 100 %)
⇨ Compares between scenarios

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Practical

Aerosol transmission of COVID-19 and infection risk in indoor environments

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Aerosol Properties (for experts)

effective Mean diameter [μm]	5
concentration breath [#/ccm]	0,06
concentration speak [#/ccm]	0,6
deposition efficiency lung	0,5

Virus Properties (for experts)

Dosis at 50% infection prob [100-1000]	316
RNA conc in liquid [copies/ml] [1e8-1e11]	5e+8

The reported viral RNA concentration of approximately 5×10^8/ml represents the category of highly infectious patients and represents approximately 20% of individuals tested positive for SARS-CoV-2

lifetime in air [h]	1,7

5e+9 for super-spreaders (5%)
8.5e+8 for variant

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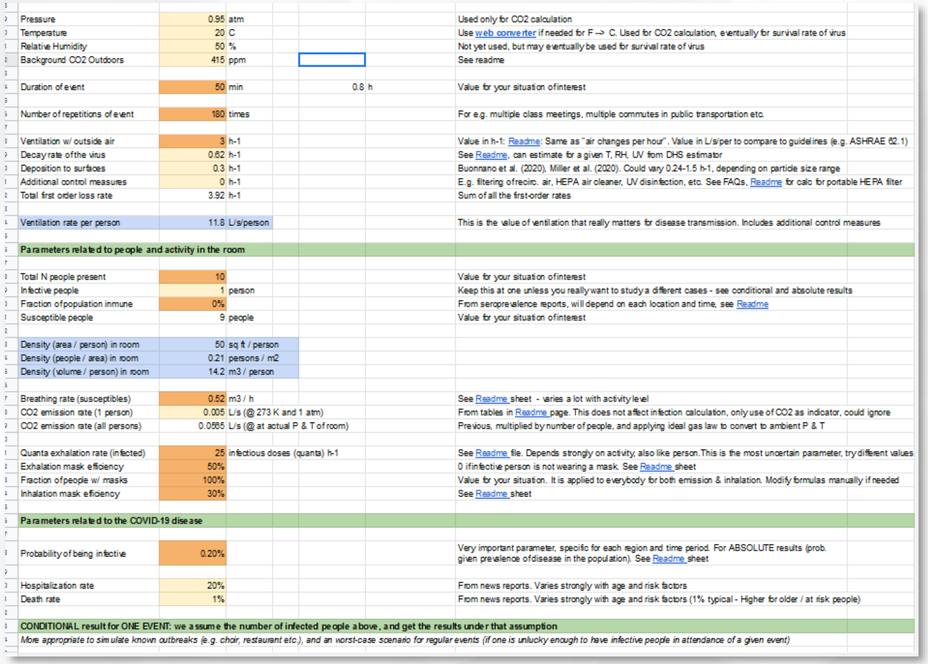
2021-01-21

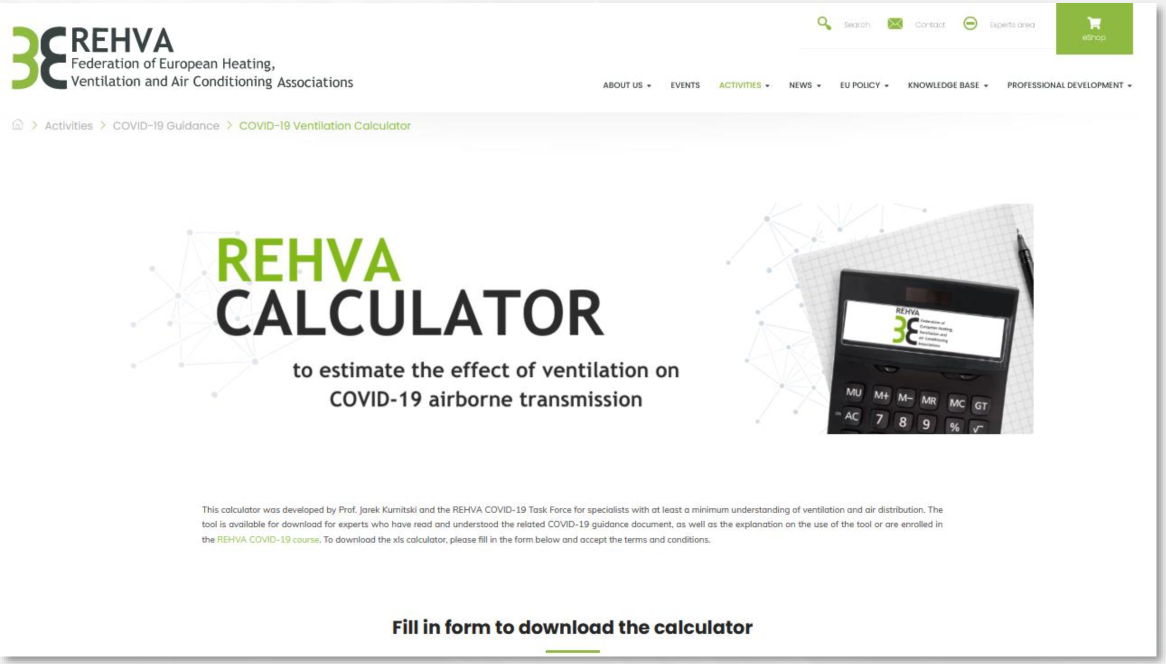
Calculator 2: University of Colorado



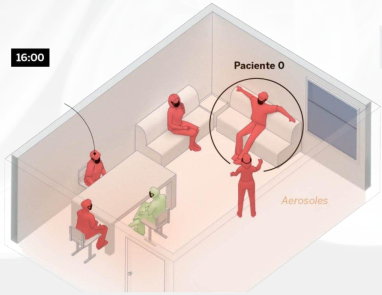
Pressure	0.95	atm		Used only for CO2 calculation
Temperature	20	C		Use web converter if needed for F --> C. Used for CO2 calculation, eventually for survival rate of virus
Relative Humidity	50	%		Not yet used, but may eventually be used for survival rate of virus
Background CO2 Outdoors	415	ppm		See readme
Duration of event	50	min	0.8 h	Value for your situation of interest
Number of repetitions of event	180	times		For e.g. multiple class meetings, multiple commutes in public transportation etc.
Ventilation w/ outside air	3	h-1		Value in h-1: Readme: Same as "air changes per hour". Value in L/s/per to compare to guidelines (e.g. ASHRAE 62.1)
Decay rate of the virus	0.62	h-1		See Readme, can estimate for a given T, RH, UV from DHS estimator
Deposition to surfaces	0.3	h-1		Buonnano et al. (2020), Miller et al. (2020). Could vary 0.24-1.5 h-1, depending on particle size range
Additional control measures	0	h-1		E.g. filtering of recirc. air, HEPA air cleaner, UV disinfection, etc. See FAQs, Readme for calc for portable HEPA filter
Total first order loss rate	3.92	h-1		Sum of all the first-order rates
Ventilation rate per person	11.8	L/s/person		This is the value of ventilation that really matters for disease transmission. Includes additional control measures
Parameters related to people and activity in the room				
Total N people present	10			Value for your situation of interest
Infective people	1	person		Keep this at one unless you really want to study a different cases - see conditional and absolute results
Fraction of population inmune	0%			From seroprevalence reports, will depend on each location and time, see Readme
Susceptible people	9	people		Value for your situation of interest
Density (area / person) in room	50	sq ft / person		
Density (people / area) in room	0.21	persons / m2		
Density (volume / person) in room	14.2	m3 / person		
Breathing rate (susceptibles)	0.52	m3 / h		See Readme sheet - varies a lot with activity level
CO2 emission rate (1 person)	0.005	L/s (@ 273 K and 1 atm)		From tables in Readme page. This does not affect infection calculation, only use of CO2 as indicator, could ignore
CO2 emission rate (all persons)	0.0565	L/s (@ at actual P & T of room)		Previous, multiplied by number of people, and applying ideal gas law to convert to ambient P & T
Quanta exhalation rate (infected)	25	infectious doses (quanta) h-1		See Readme file. Depends strongly on activity, also like person. This is the most uncertain parameter, try different values
Exhalation mask efficiency	50%			0 if infective person is not wearing a mask. See Readme sheet
Fraction of people w/ masks	100%			Value for your situation. It is applied to everybody for both emission & inhalation. Modify formulas manually if needed
Inhalation mask efficiency	30%			See Readme sheet
Parameters related to the COVID-19 disease				
Probability of being infective	0.20%			Very important parameter, specific for each region and time period. For ABSOLUTE results (prob. given prevalence of disease in the population). See Readme sheet
Hospitalization rate	20%			From news reports. Varies strongly with age and risk factors
Death rate	1%			From news reports. Varies strongly with age and risk factors (1% typical - Higher for older / at risk people)
CONDITIONAL result for ONE EVENT: we assume the number of infected people above, and get the results under that assumption				
More appropriate to simulate known outbreaks (e.g. choir, restaurant etc.), and an worst-case scenario for regular events (if one is unlucky enough to have infective people in attendance of a given event)				

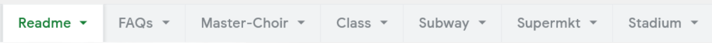
tinyurl.com/covid-estimator

Calculator 3: REHVA



rehva.eu/covid19-ventilation-calculator





Extensive & interesting explanations

J. L Jimenez, Dept. of Chem. and CIRES, Univ. of Colorado-Boulder

Theory

Environment International 145 (2020) 106112

Contents lists available at ScienceDirect

Environment International

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

Quantitative assessment of the risk of airborne transmission of SARS-CoV-2 infection: Prospective and retrospective applications

G. Buonanno [a,b], L. Morawska [b], L. Stabile [a,*]

[a] Department of Civil and Mechanical Engineering, University of Cassino and Southern Lazio, Cassino, FR, Italy
[b] International Laboratory for Air Quality and Health, Queensland University of Technology, Brisbane, Qld, Australia

	Scenario B
Type of indoor environment	Gym
Emitting subject	Exercising person (heavy exercise, oral breathing; IR = 3.30 $m^3\ h^{-1}$)
Exposed subject	Exercising person (heavy exercise; IR = 3.30 $m^3\ h^{-1}$)
Volume (m^3)	300
Ventilation, AER (h⁻	
Deposition rate, *k* (h	
Inactivation rate, λ (h^{-1})	

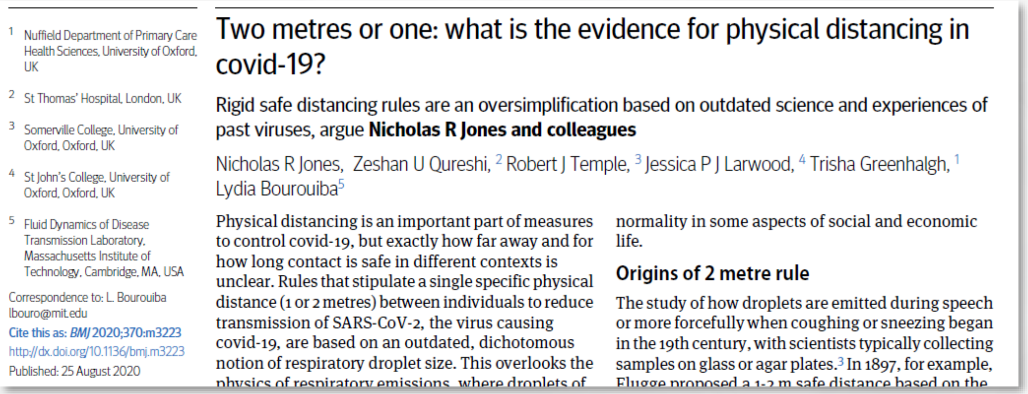
Exposure scenarios	AER (h^{-1})	Accepted maximum individual infection risk (R_{max})				
		1×10^{-1}	1×10^{-2}	1×10^{-3}	1×10^{-4}	1×10^{-5}
Scenario B – Gym	0.5	225	43	12	4	1
Emitting subject:	3.0	528	59	13	4	1
Exercising person	10.0	1440	132	17	4	1
Exposed subject:						
Exercising person						

(ER_q)). In these two cases, an individual risk of < 10^{-3} would be not actually achievable by varying and optimizing the room ventilation (e.g. AER > 1000 h^{-1} would be required), and is maybe achievable only by reducing the exposure time of the susceptible subjects and the quanta emission rates, and through advanced ventilation able to remove air exhaled by the infected subject before it is mixed with the room air.

decrease to 2.0 and 0.7 for auditorium and conference room, respectively, in the case of mechanical ventilation at 10 h^{-1}. The maximum number of subjects that could attend simultaneously the event in order to guarantee $R_0 \leq 1$ is 26 and 135 for AERs equal to 0.5 h^{-1} and 10 h^{-1}, respectively. Thus, in the management of the epidemic, reducing the crowding index and exposure time could be essential. Accepting higher

Practical

BMJ qualitative score sheet



1 Nuffield Department of Primary Care Health Sciences, University of Oxford, UK
2 St Thomas' Hospital, London, UK
3 Somerville College, University of Oxford, Oxford, UK
4 St John's College, University of Oxford, Oxford, UK
5 Fluid Dynamics of Disease Transmission Laboratory, Massachusetts Institute of Technology, Cambridge, MA, USA
Correspondence to: L. Bourouiba lbouro@mit.edu

Cite this as: *BMJ* 2020;370:m3223
http://dx.doi.org/10.1136/bmj.m3223
Published: 25 August 2020

Two metres or one: what is the evidence for physical distancing in covid-19?

Rigid safe distancing rules are an oversimplification based on outdated science and experiences of past viruses, argue **Nicholas R Jones and colleagues**

Nicholas R Jones, Zeshan U Qureshi,[2] Robert J Temple,[3] Jessica P J Larwood,[4] Trisha Greenhalgh,[1] Lydia Bourouiba[5]

Physical distancing is an important part of measures to control covid-19, but exactly how far away and for how long contact is safe in different contexts is unclear. Rules that stipulate a single specific physical distance (1 or 2 metres) between individuals to reduce transmission of SARS-CoV-2, the virus causing covid-19, are based on an outdated, dichotomous notion of respiratory droplet size. This overlooks the physics of respiratory emissions, where droplets of

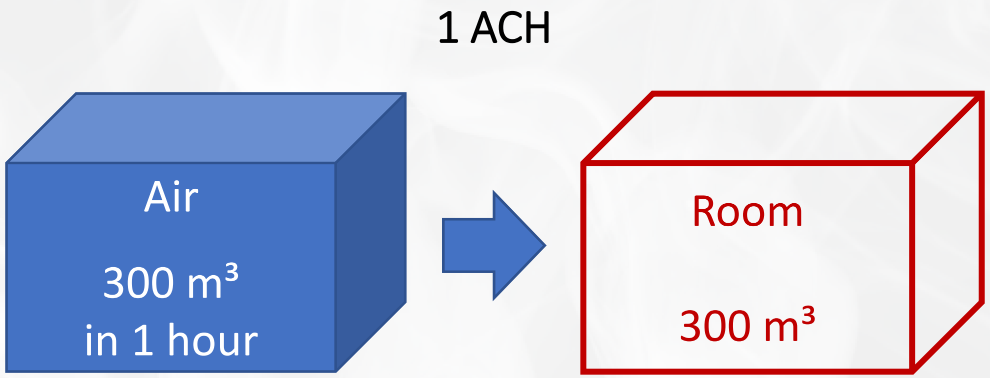
normality in some aspects of social and economic life.

Origins of 2 metre rule

The study of how droplets are emitted during speech or more forcefully when coughing or sneezing began in the 19th century, with scientists typically collecting samples on glass or agar plates.[3] In 1897, for example, Flugge proposed a 1-2 m safe distance based on the

bmj.com/content/370/bmj.m3223

"Air Changes per Hour" (ACH)



- Mixing
  - 1 ACH = 63 % renewed in 1 hour
  - 6 ACH = 99 % renewed in 1 hour

- Examples
  - House windows closed : ~ **0,5 ACH**
  - Hospital : **6-12 ACH**

  - Birnir (2020) / Buonanno : in Ghinzou restaurant **60-1000 ACH** would have be required

Practical

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fraction of speaking [0-100%] 25

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Room Properties

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floor size [m²] 60

height [m] 3

Event details

duration [h] 8

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People in Room 24

> Aerosol Properties (for experts)

Virus Properties (for experts)

Dosis at 50% infection prob [100-1000] 316

RNA conc in liquid [copies/ml] [1e8-1e11] 5e+8

The reported viral RNA concentration of approximately 5×10^8/ml represents the category of highly infectious patients and represents approximately 20% of individuals tested positive for SARS-CoV-2

lifetime in air [h] 1,7

9.1% individual infection risk if one person is infectio

89% probability that at least one other person gets in infectious at the event.

Properties of the infectious Person

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Room Properties

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36% probability that at least one other person gets infe infectious at the event.

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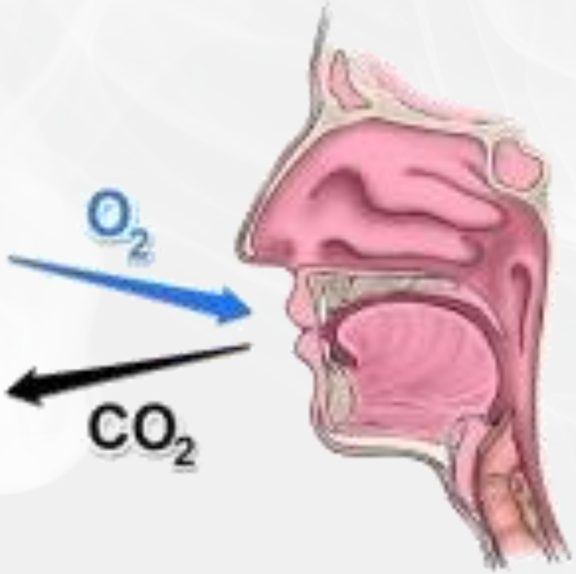
lifetime in air [h] 1,7

3.3% individual infection risk if one person is infectiou

53% probability that at least one other person gets infe infectious at the event.

How to obtain the ACH ?



Too much CO_2 = not enough airing

Practical

CO_2 : how much is too much ?

1 ppm
= 1 particle per million
= 1 μL/L

max. **900 ppm CO_2** during 95 % of the time
or min. **40 m^3 / hour / pers** during 95 % of the time

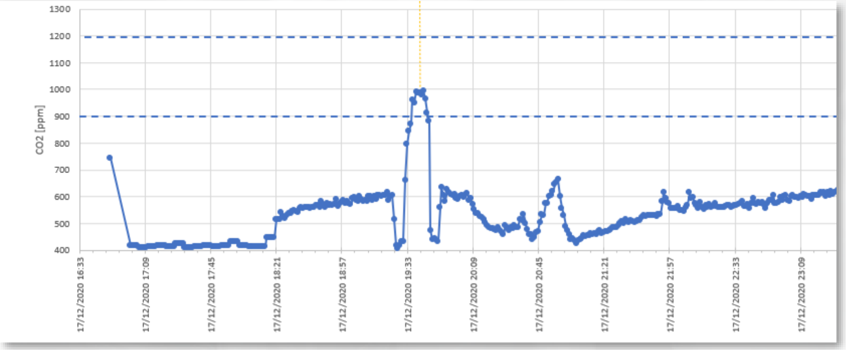
AR-KB 2/5/2019

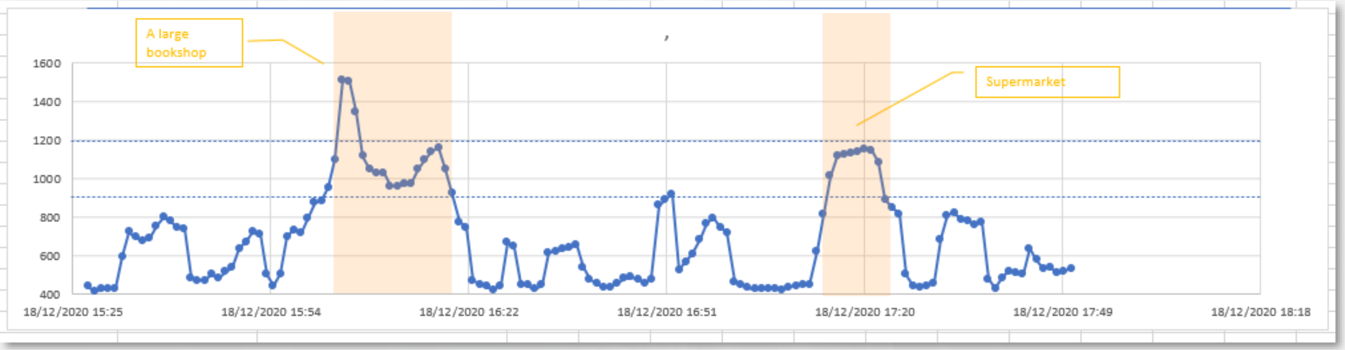
Poppy

Practical

CO_2 - Some results

a supermarket
in Jette

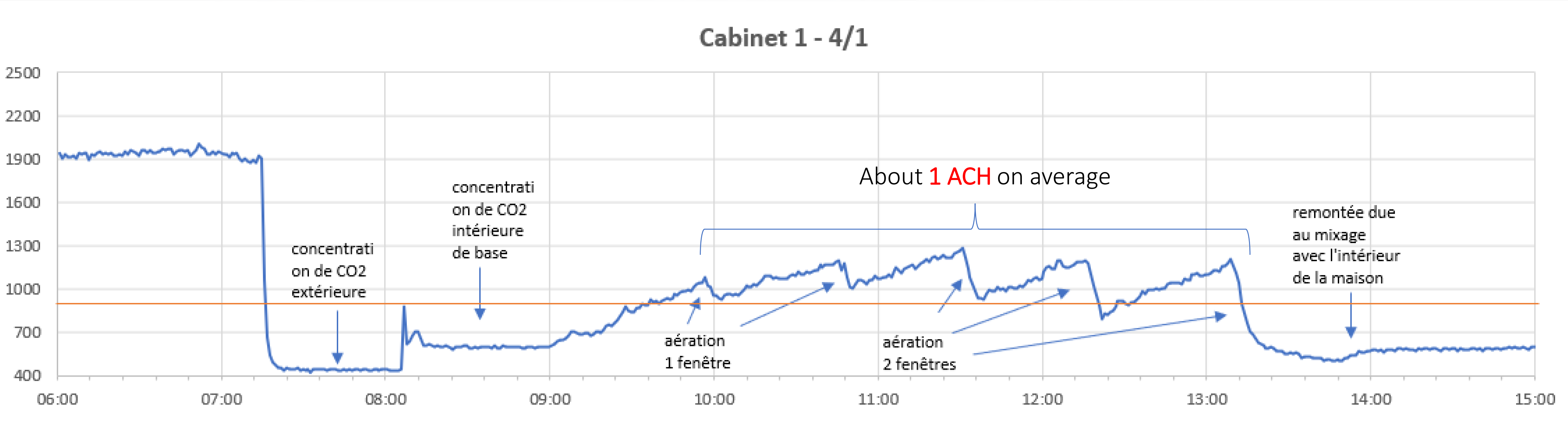




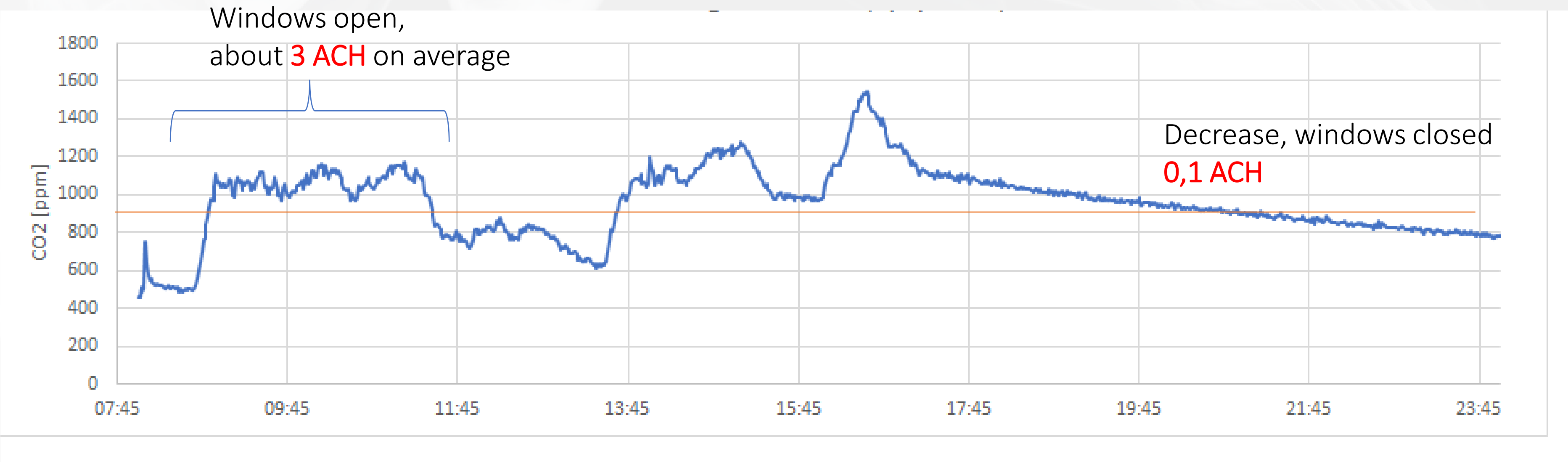
	ppm	Air changes per hour	m³/pers/h
Supermarket (Jette)	1150	0,7	31,5
Bookshop (Brussels)	1200	0,9	27

Poppy

Practical



Classroom



Theory

Quick airing assessement in steady state

"What risk is associated with this CO_2 value?"

1. Measure CO_2

2. $\mathbf{ACH} = \dfrac{N_{pers} \cdot S_0}{V \cdot (CO_2 - Cout)} \cdot 1000$

3. Determine the risk level

"What CO_2 value is allowed for this risk level?"

1. Set the risk level

2. Determine the ACH

3. $CO_2 = C_{out} + \dfrac{N_{pers} \cdot S_0}{ACH \cdot V} \cdot 1000$

V = volume of the room in m³ (max ~300)
S_0 ~ 20 l/h (breathing rate, for adults)
C_{out} ~ 430 ppm

Practical

REHVA rule of thumb (offices, when people are present, at equilibrium)

$$Q_e = N_{pers} \cdot S_0 / (C_{in} - C_{out})$$

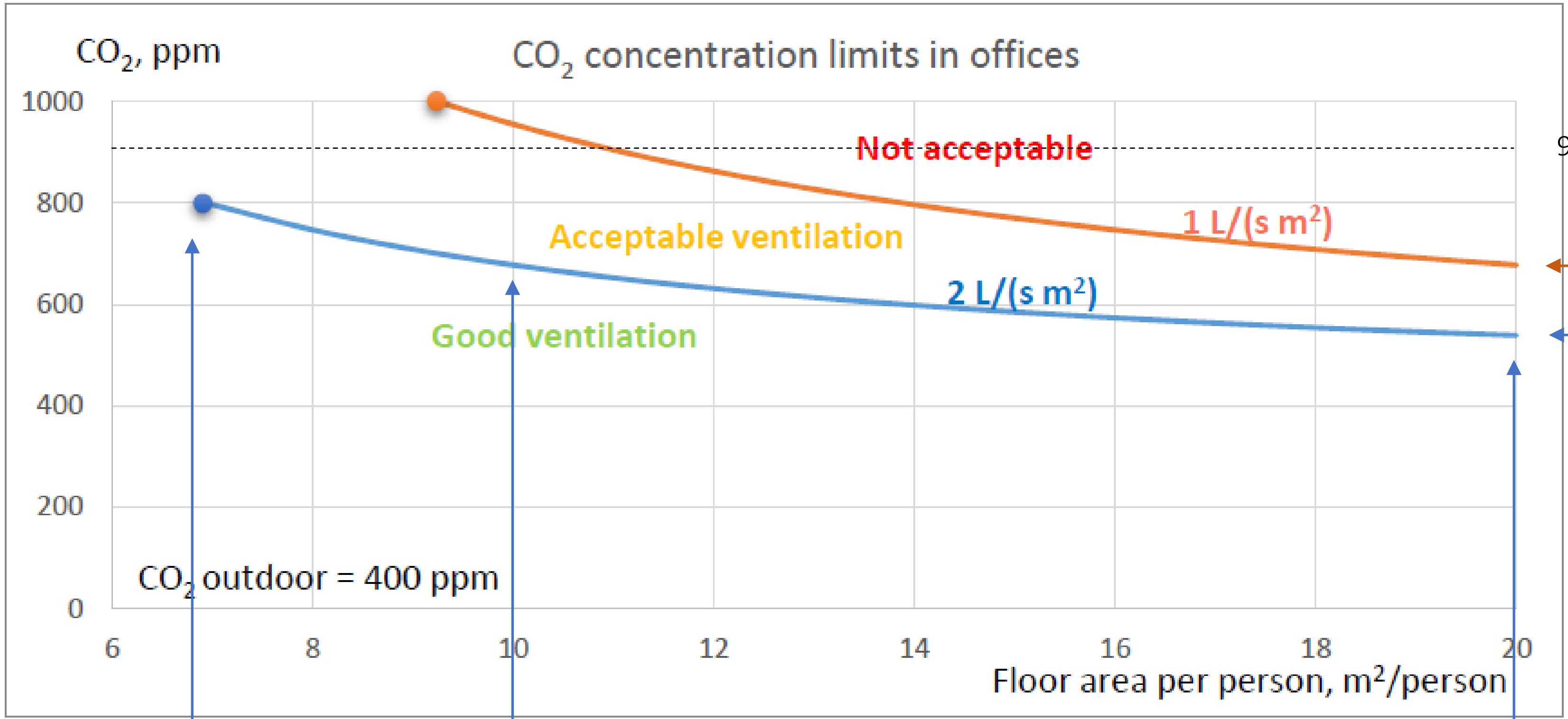


Figure 8. CO_2 concentration (absolute values that include outdoor concentration) dependency on ventilation rate and occupancy in offices.

900 ppm A.R. 2019

1,2 ACH

2,4 ACH

14 L / (s pers)
51 m³ / (h pers)

20 L / (s pers)
72 m³ / (h pers)

40 L / (s pers)
144 m³ / (h pers)

Hospital : 6-12 ACH
TGV : 6 ACH
Superspreading (eg choir/restaurant : vent. rate < 1-2 L/s/pers)

Assess airing – more precise method

SCHOOLS FOR HEALTH

How School Buildings Influence Student Health, Thinking and Performance

HARVARD T.H. CHAN
SCHOOL OF PUBLIC HEALTH

5-step guide to checking ventilation rates in classrooms

Joseph Allen, Jack Spengler, Emily Jones, Jose Cedeno-Laurent

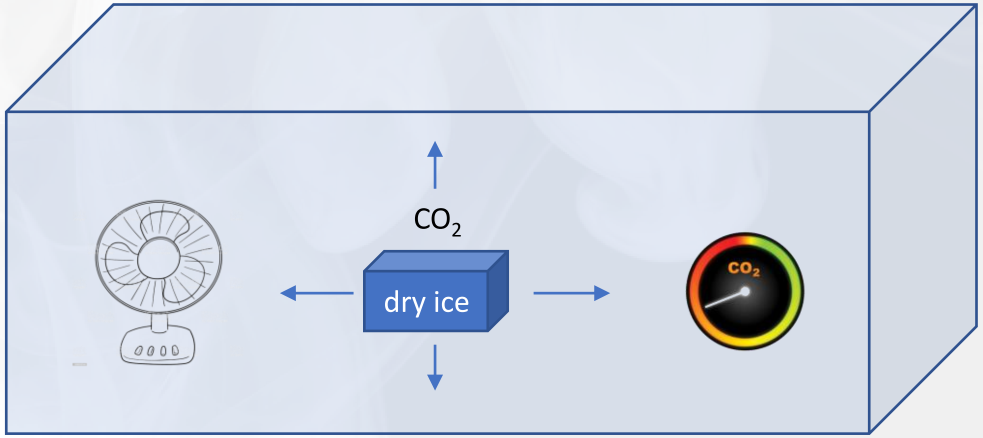
Harvard Healthy Buildings program | www.ForHealth.org

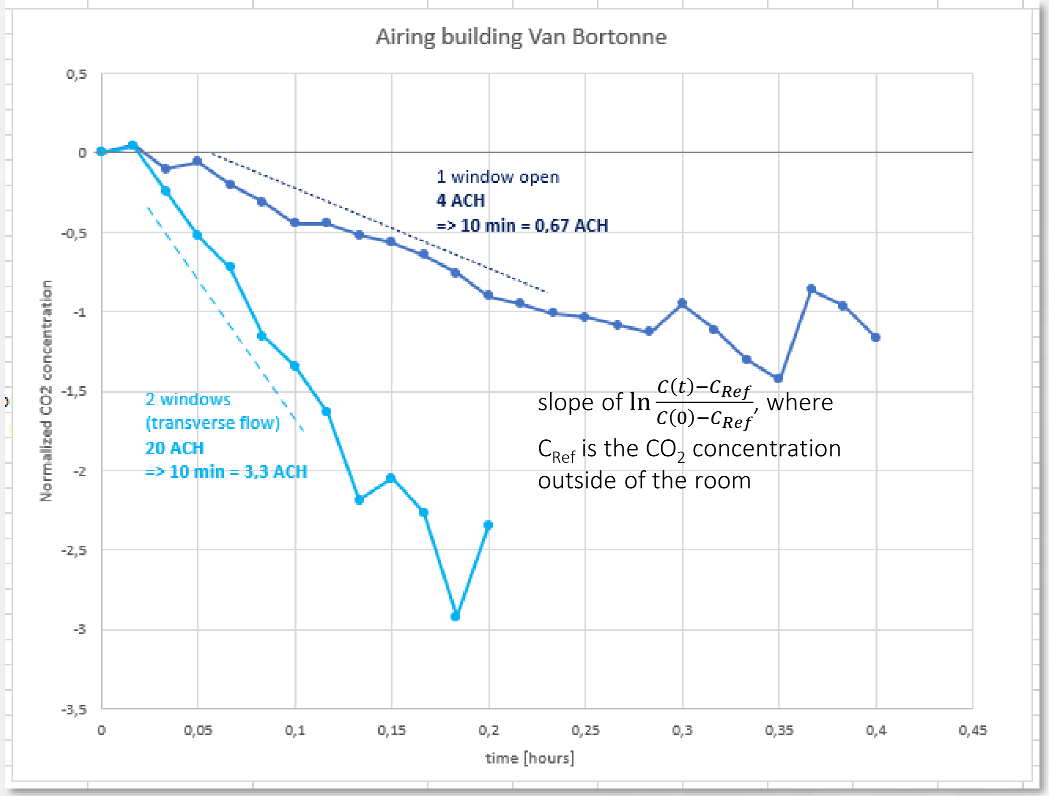
August, 2020

Measuring the ACH

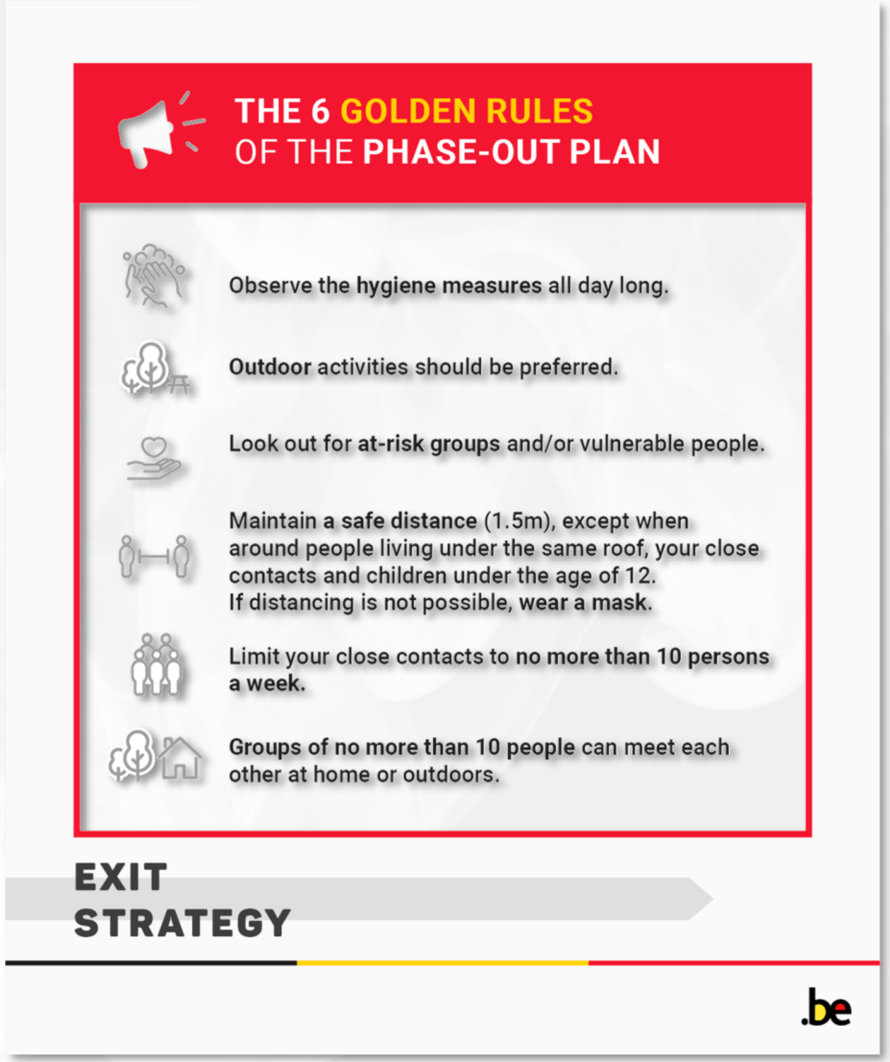
« dry ice »
or **after the occupation** of the building

- using CO_2
- measure baseline + scenarios (eg : 1 window open, transversal flow, …)
- ⚠ outside wind conditions





Practically…

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

Correspondence

How can airborne transmission of COVID-19 indoors be minimised?

« Masks, ventilation, … »

How much ? -> Use the calculators & sensors

Practical

(Demo)

Monitor airing using CO_2 sensors

- **Low-cost OK** (NDIR technology - **~200 €**) – cf litterature
- Eg: **ARANET 4** (cited by REHVA), Yoctopuce, Renson, Laagom, ...
- Belgium: Airsain

- Characteristics
  - **Depend on your goal**
    - Measure for yourself/to motivate your small team
    - Monitor your company, your city
    - Control & enforcement

  - Connectivity : none, GSM, LORA, ...
  - Calibration
  - Maintenance

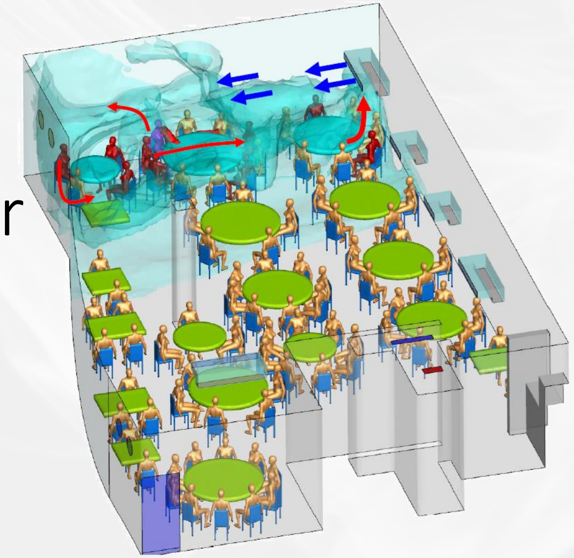
  - Traffic lights, beeps – configurable or not

Practical

“Specific airflow patterns, and not just average ventilation and air changes, within buildings are also important in determining risk of exposure and transmission.” BMJ

Increase airing

- 2 windows better than 1
- Mechanical ventilation with outside air
- Transverse flow but ! flows from person to person
- Low velocity
- May need an architect in complex situations
- ! Comfort, otherwise people close the window forever
- A sensor may help to motivate



Poppy

Practical

Supplement airing

(Portable) **HEPA** filters work above & below 300 nm

Mechanical filtration only

A HEPA filter adds **air changes per hour** (ACH)

Extensively used in hospitals

Min **H13** (norm EN 1822-1)

Must be **properly dimensioned, operated & maintained**

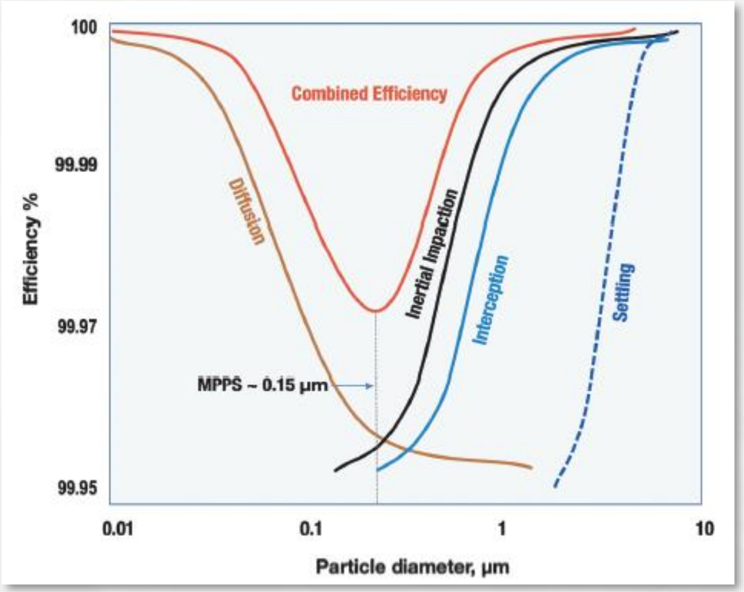
UVC inside the machine cannot hurt

! **Noise**, otherwise people will shut it down forever

Does not remove CO_2

Calculator: trox.be/fr/le-purificateur-dair-trox-603b7b4c4b6c1659

Harvard calculator: https://docs.google.com/spreadsheets/d/1zirxflfaDyiyXn9teMkt0kZfDAeu1dwC24bOWg6yl_M/edit#gid=1882881703



Cf, eg, Christopherson & al (2020), *High-Efficiency Particulate Air Filters in the Era of COVID-19* Otolaryngology–Head and Neck Surgery

Practical

Do not use fancy air-purifiers

« **catalysis, photocatalysis, plasma, ozonation, active coal**… »

« sometimes **incomplete degradation of the pollutants** […] forming potentially dangerous chemical compounds »

inrs.fr/header/presse/cp-dispositifs-anti-covid.html

Theory

Countermeasures for an event?

REHVA & ATIC.be, adapted from CDC

- 1. Reduce the probability an infected person is present at the event
  - Communication
  - Rapid testing ? Cf Barcelona
  - …
- 2. Prevent contacts between bubbles
  - End2end traffic & crowd management
- 3. Aerosol risk analysis =>
  - Outdoor if possible
  - Adequate density, masks, timing, …
  - Airing / HEPA well dimensioned
  - Air extraction from singer/speaker/… => <u>no mixing with the room</u>
  - …
- Administrative
  - Certification à la Vincotte (like for the electricity, …)
- 5. Be ready
  - Monitor airing in real time
  - Mandatory testing after the event, included in the ticket price?
    - Could even be pooled
  - Lightning fast contact tracing

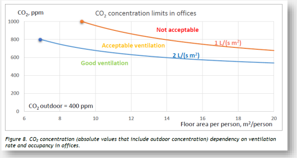
see also opsman.eu/fr/services/support-evenementiel/rapport-covid-19-0

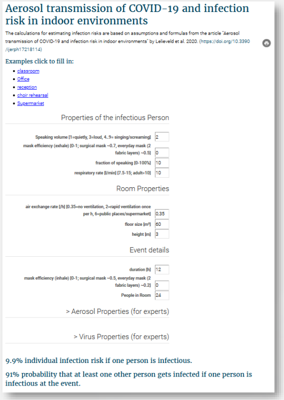
Practical

Next steps

- You want your employees to **air more**
  - Buy a CO_2 sensor (200 €)
  - Participatory / Beep / Control
- You want to quickly **assess the risk & airing** in your facilities
  - Use & understand the risk calculators
  - Buy a bunch of CO_2 sensors + fans & follow the Harvard guide
  - Try to strive for min 4 ACH
- You **cannot air more**
  - Properly install (true) HEPA-filters

+ max 900 ppm





More broadly

Do research

- **Ask epidemiologists for a probability threshold** so that the R stays below 1
- For each practical setting, relate it to the amount of airing
- Prospective research to relate infection & bad airing in practical settings
- Assess the efficiency-curves of portable HEPA filters using lab experiments & in practical settings

Involve the community

- Effective sensibilisation campaign
- Go preventively with CO_2 sensors in risky spaces (eg: prayer-rooms, chicha-bars, ...), **even clandestine ones** (**risk reduction approach, as for drugs**)
- Build momentum, diffuse the knowledge, have citizens measure at home & report ("citizen science")

Norms & certifications

- Inform & train the professionals associations (event industry, HORECA, ...) + audits
- Certification (Vinçotte, OCB, ...)

Monitor

- Assess the airing in real time (voluntarily / displayed / remote-monitored)

Audits

- Results of the measurements for several airing scenarios per room + a 24 hours measurement
- ACH estimations
- Simulations for several risk scenarios per room
- Recommendations

Risk Scenarios

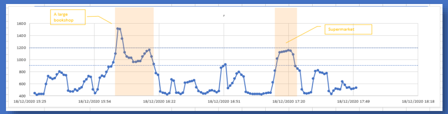
Using the risk-models, for different scenarios

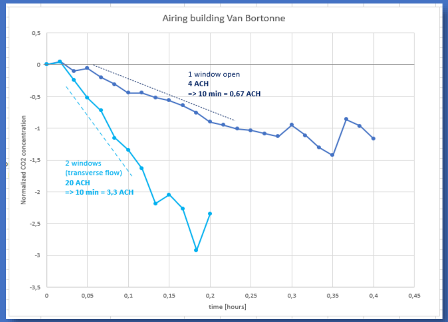
- Considering the speaker/singer/… is infected
- Considering someone in the audience is infected
- Normal-spreader (20%)
- Super-spreader (5 %)
- Several residence time
- Several airing scenarios
- Use a safety coefficient
- If volume > 300 m³, consider several the worst case of several independant 300 m³ volumes

Compare against risk & different norms

- Eg : conditional indiv risk threshold < 1 % on the whole period
- Eg : HARVARD classroom > 5 ACH
- Ventilation Cat II
- < 900 ppm during > 95 % time

Report





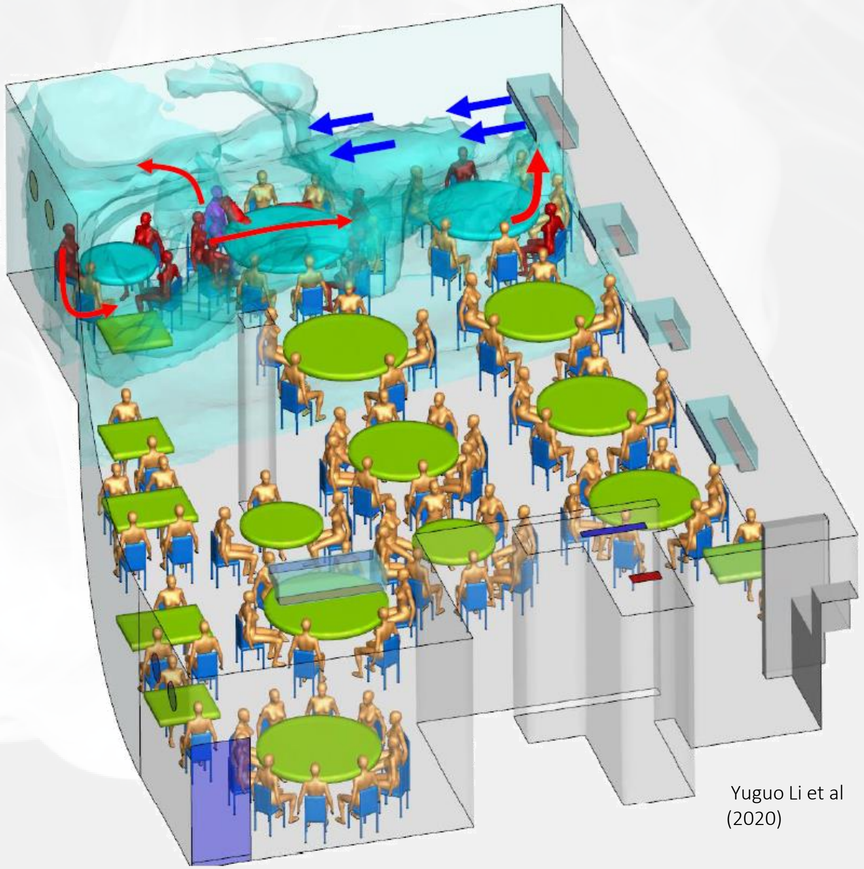
Scen.	Ppm	ACH	m³/pers/h
A	980	3	20
B	730	6	50

Recommendations

- Amount of airing needed: …
- Achieved by:
  - Windows/doors opening constant/… times per hour
  - Opposite flow
  - Indirect flow / velocity limit
  - External ventilation
  - AC with outside air
- HEPA Filtration
  - Of the whole volume
  - Targeted on the high risk emission/reception zone
  - No other physico-chemical !
- Correct wearing of masks
- Limiting exposure time
- Potentially
  - Max CO_2 before airing
  - One apparatus to motivate to open windows

More complex situations:

Computational Fluid Dynamics **simulations** and/or **tracer smoke**

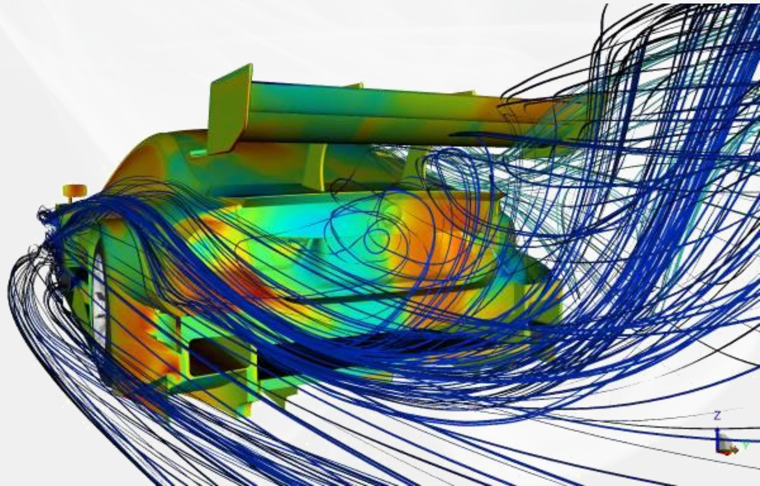


Yuguo Li et al (2020)

To ensure:

- no stationary flows
- no direct flows on people
- low velocity

press.bmwgroup.com/belux/photo/detail/P90252892/30-03-2017-bmw-motorsport-computational-fluid-dynamics-cfd-simulation-bmw-m4-dtm



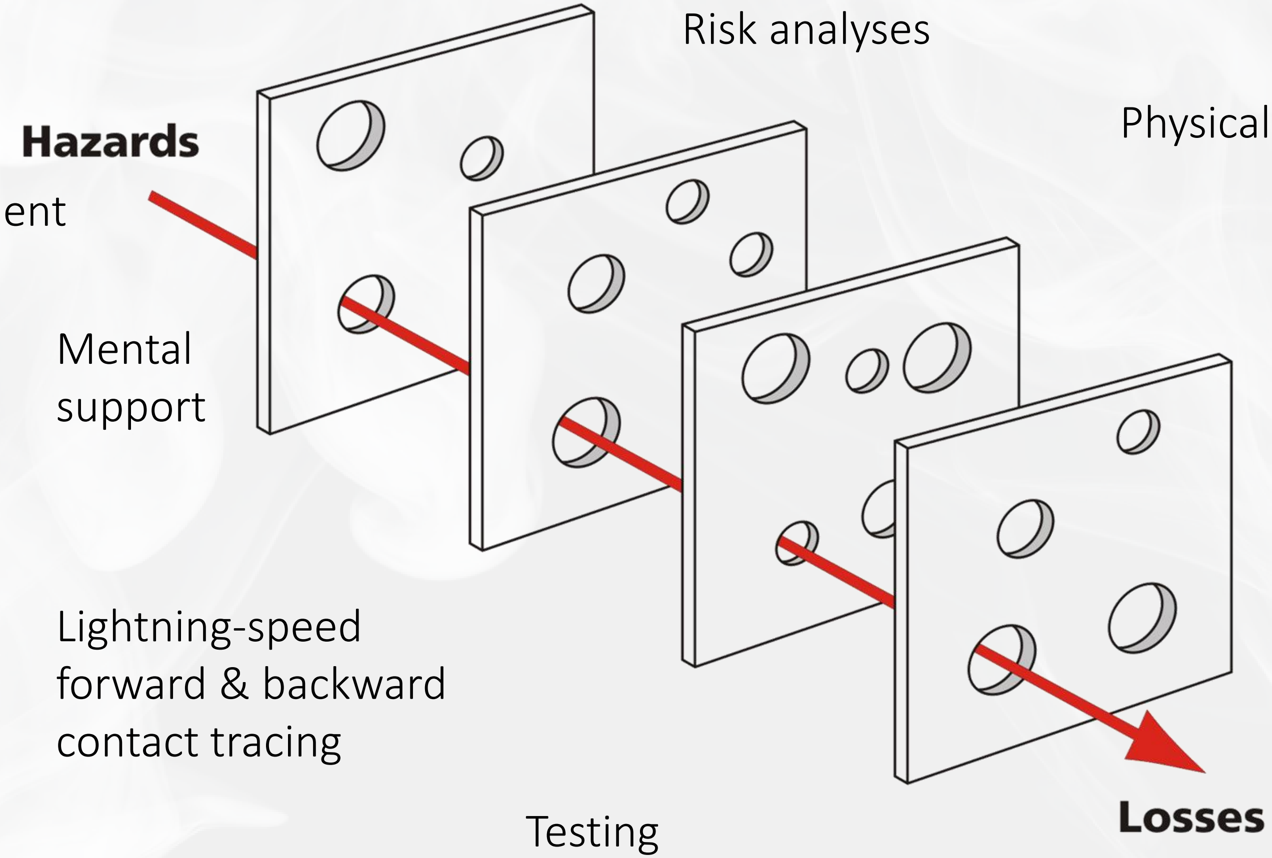
Theory

Aerosol countermeasures are only one tool

To control
To contain
To prioritize
To reopen
…

Crowd management

Risk analyses



Physical exercise

Side-effects management (eg: gathering after the concert)

Mental support

Vaccines

6 golden rules

Healthy lifestyle, eating & dietary supplements

Lightning-speed forward & backward contact tracing

Stress reduction

Testing strategies

Never reach the point in your head where you are feeling too safe

Community involvement

…

Some references

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REHVA
Federation of European Heating, Ventilation and Air Conditioning Associations

Atic
for HVAC professionals

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