



HSE

Occupational Health & Safety
and Environmental Protection unit

Airborne Transmission of COVID-19

Measures to be taken indoors

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HSE Seminar
<https://indico.cern.ch/event/968258/>

03/11/2020

Introduction

- Scientific community (mainly physicists / engineers) have defended the importance of airborne transmission
- Evidence continues to grow. Although it has been endorsed by the scientific community, advisory bodies and governmental agencies, is the general public aware?
- The HSE Unit has developed a quantitative assessment tool to address the infection probability via airborne transmission
- This seminar will cover:
 - the importance of a multidisciplinary approach in the fight against COVID (medical, engineering, fluid dynamics, physics in general)
 - the importance of airborne transmission indoors
 - how can we react and minimize the risk (on and off CERN sites)
 - how to prepare for the winter period

Medical aspects are based exclusively on scientific facts / literature review [1].. [56] and with a personal (non-expert) interpretation

The findings are mainly based on scientific publications on aerodynamic studies on the transmission modes of the virus.
Comments made reflect individual insights only.

Content

- Aerodynamics of airborne particles
- Airborne transmission of SARS-CoV-2
 - General concepts
 - Endorsement
 - Evidence
 - Mitigation measures
- COVID Airborne Risk Assessment (CARA) tool
- General recommendations / advice

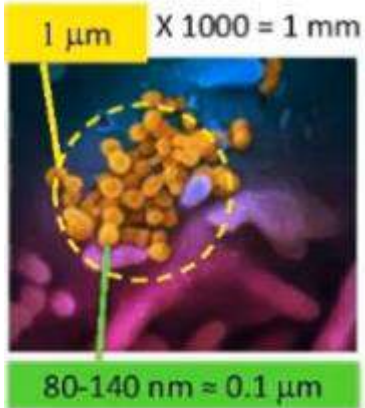
Aerodynamics of airborne particles



Airborne Particles - Size

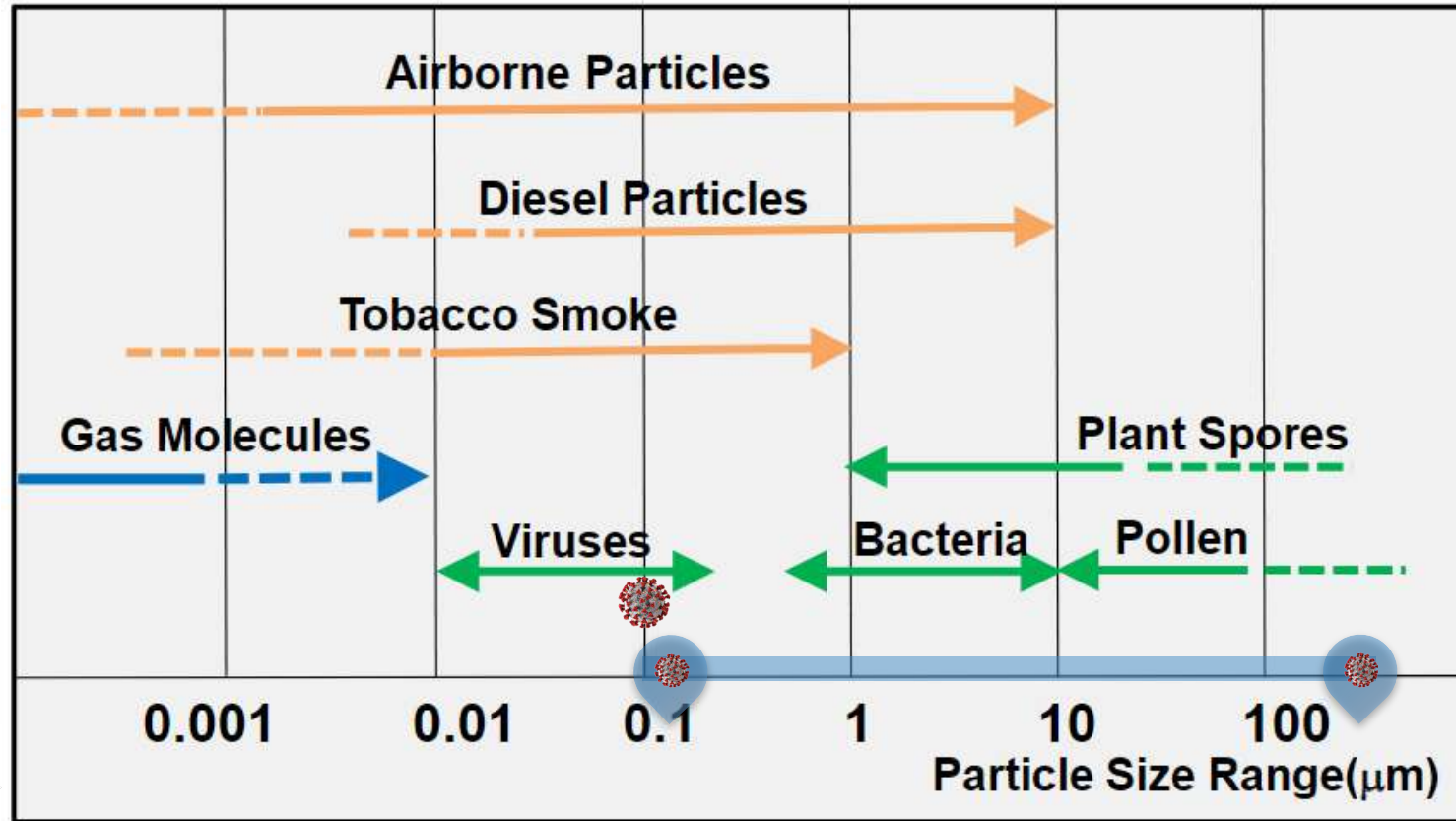


SARS-CoV-2



HEALTH

This Is What The COVID-19 Virus Looks Like Under The Microscope
 JACINTA BOWLER
 14 FEBRUARY 2020



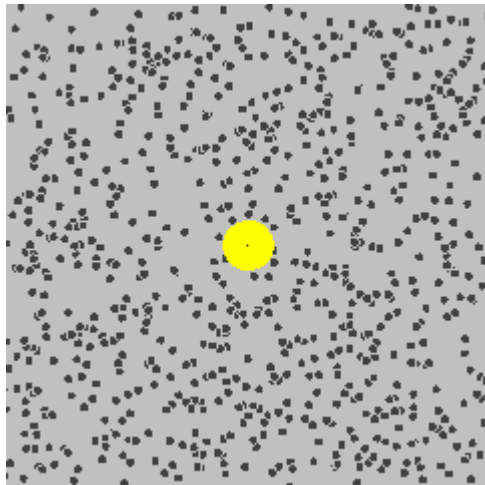
Respiratory particles (droplets, droplet nuclei, aerosols, etc..)

300 x bigger than nitrogen, oxygen or water vapour molecules

Typical range of airborne particles [4]

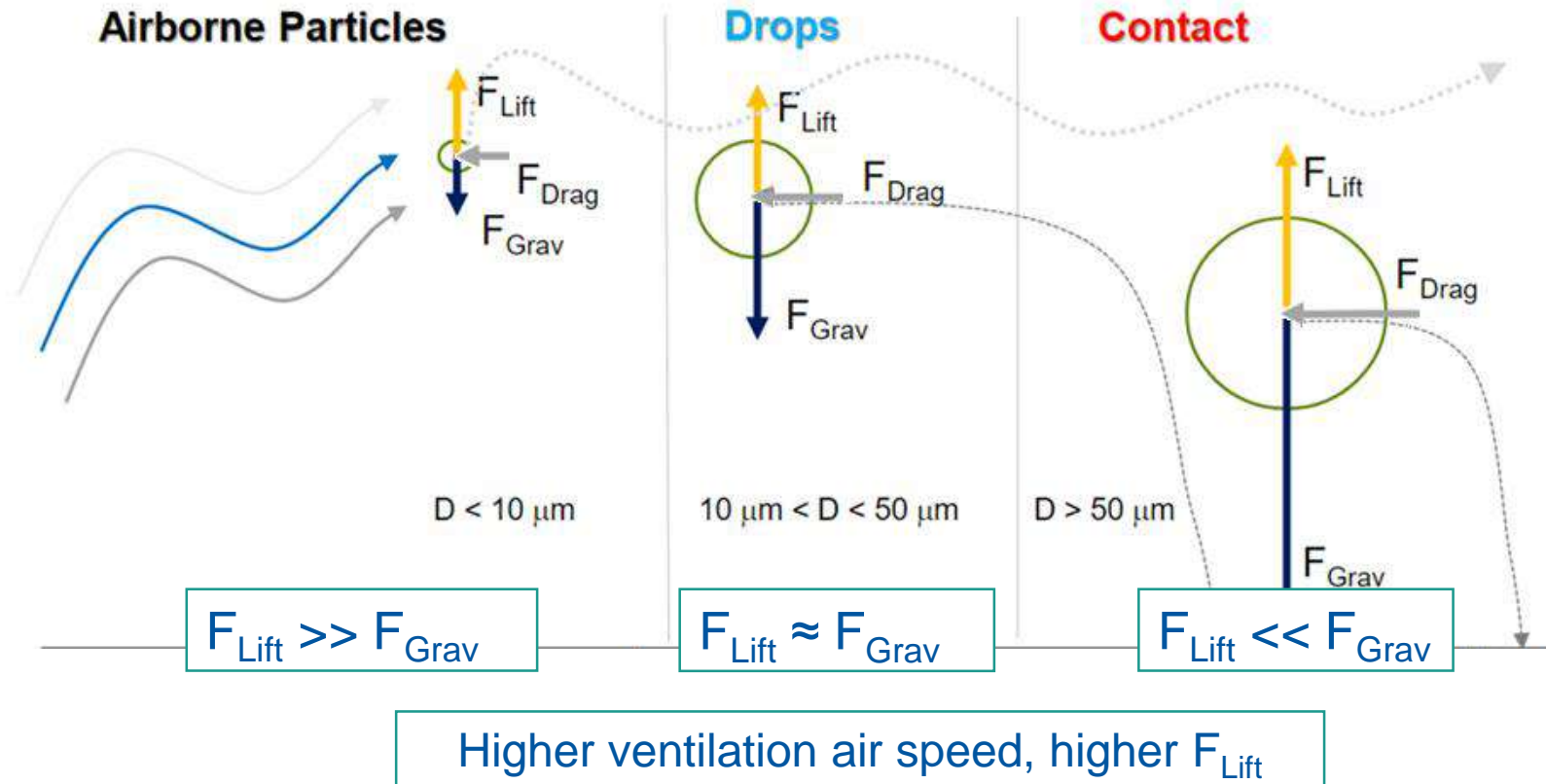
Airborne Particles – Aerodynamics

Typical trajectories of particles in the air, depending on their size [1]



$D < 0.3 \mu\text{m}$

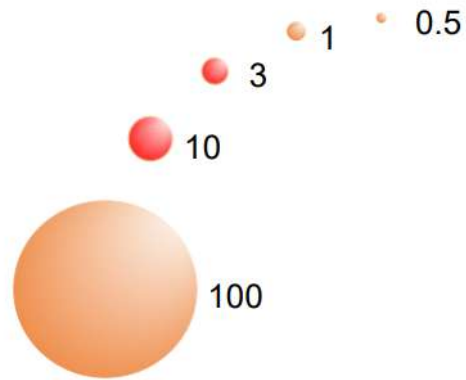
Other effects may apply e.g. Brownian motion



An analysis of the transmission modes of COVID-19 in light of the concepts of Indoor Air Quality [4]

Airborne Particles – Aerodynamics

Droplet diameter in microns (um)



Float time

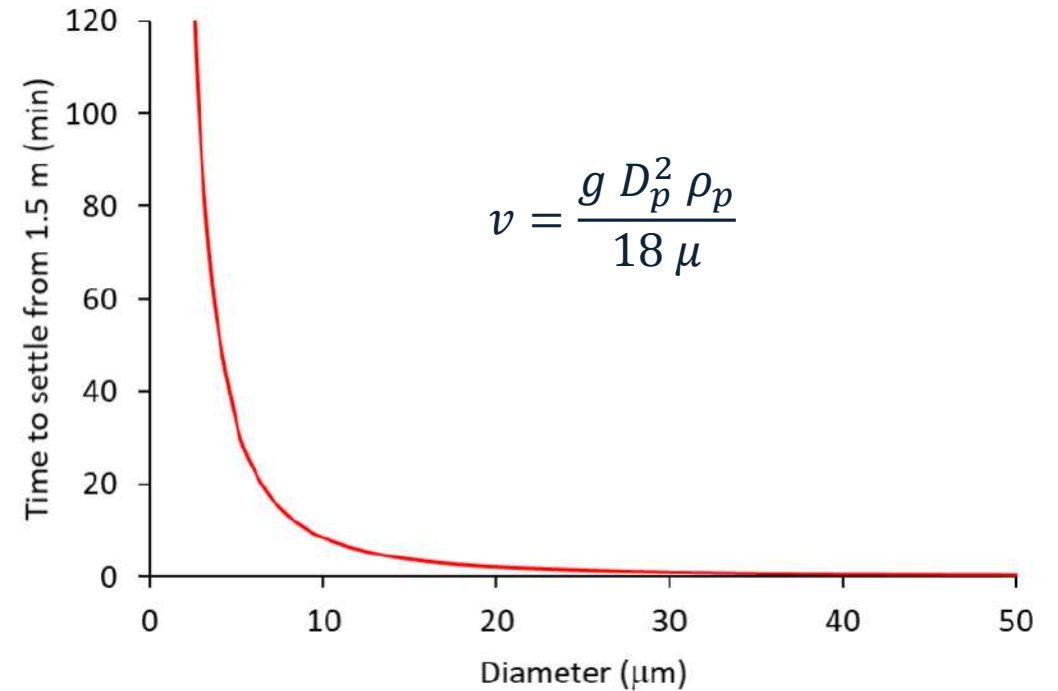
41 hours – 21 days

1.5 hours

6 seconds

Distance travelled: 1m 10m+

Float time and travel distance of different size aerosols, in normal indoor environments [5]



Gravitational settlement velocity and suspension time [47]

Airborne transmission of SARS-CoV-2

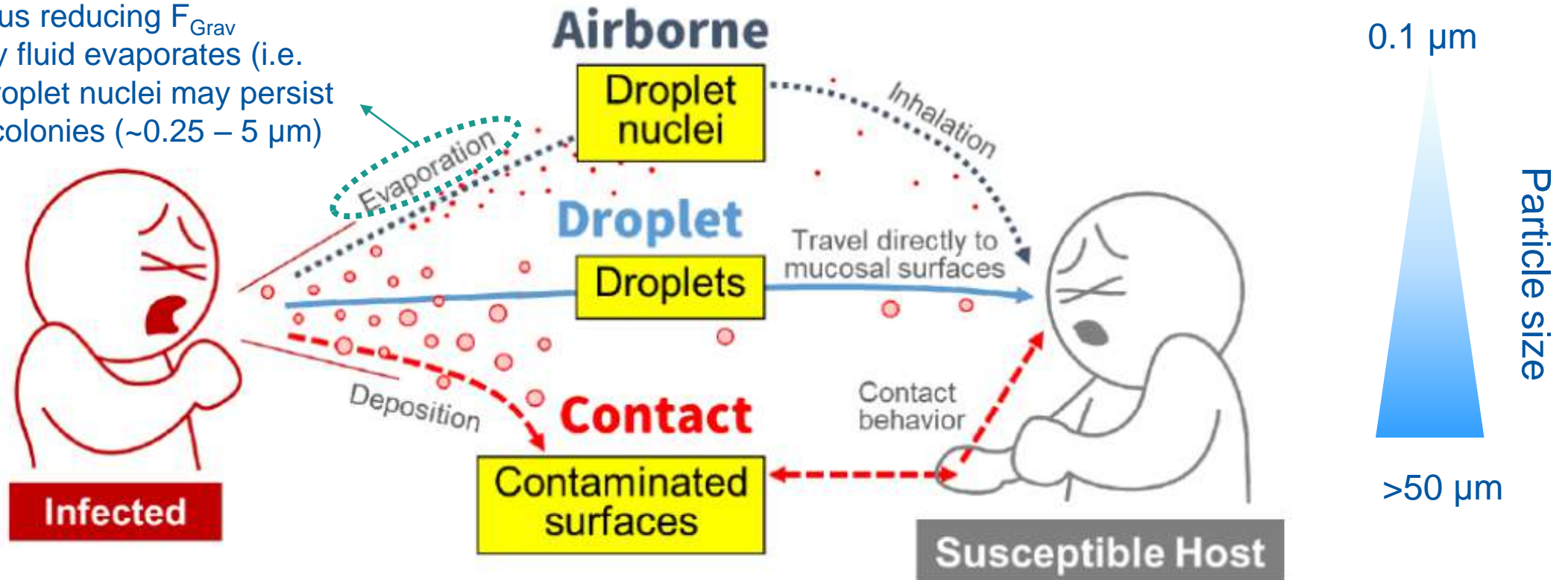
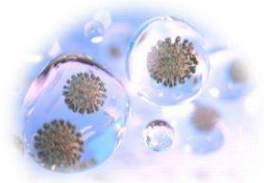
General concepts



Transmission mechanisms

Small droplets (5-10 μm) may evaporate quickly (<1s)^[6], thus reducing F_{Grav}

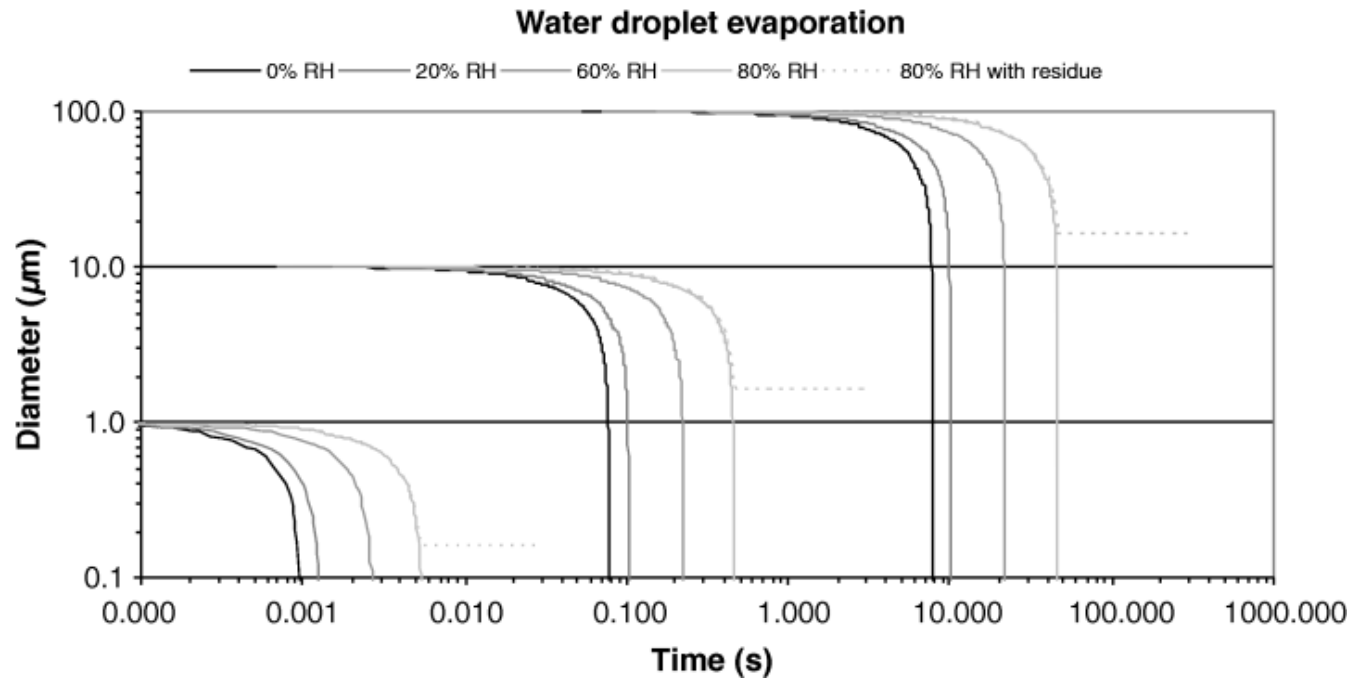
- When the body fluid evaporates (i.e. desiccates), droplet nuclei may persist with the virus colonies (~0.25 – 5 μm)



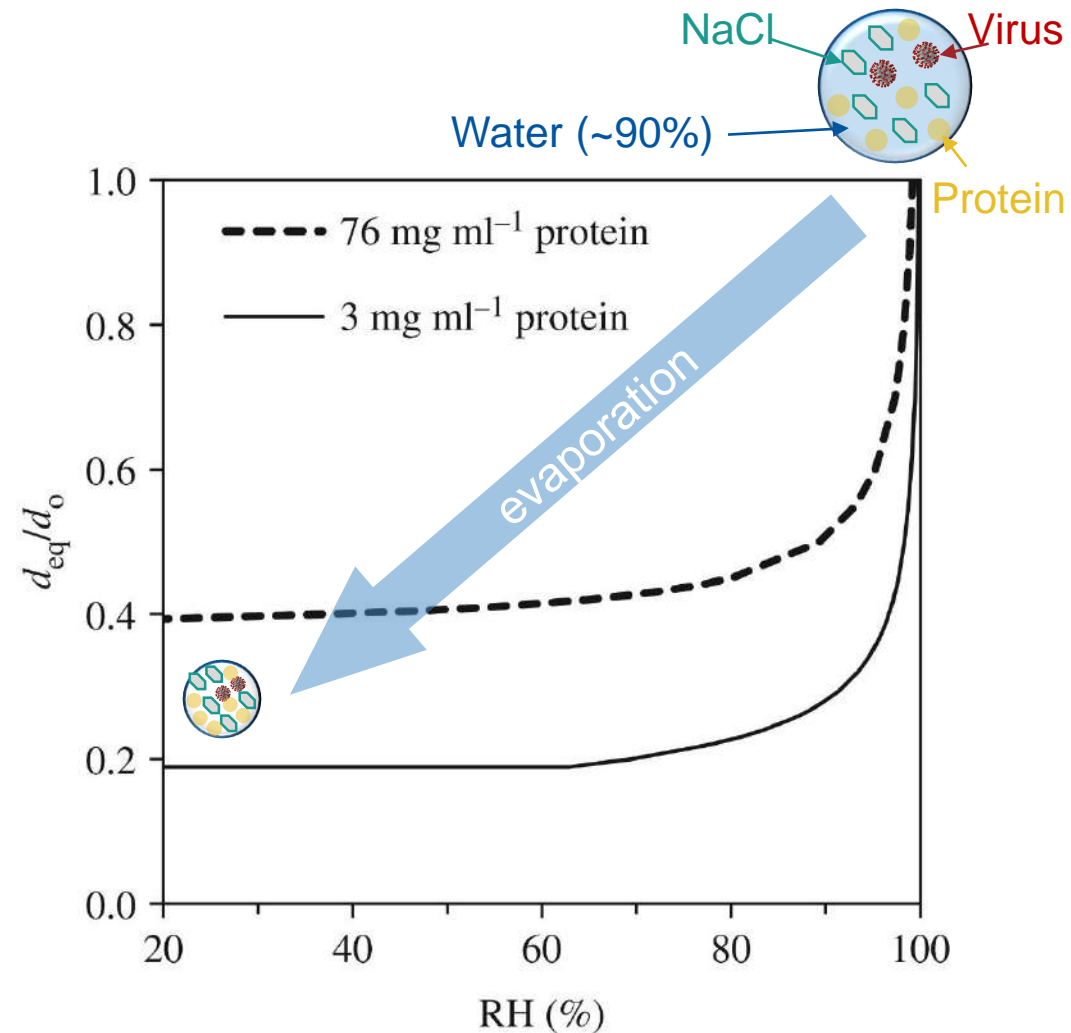
Modes of Transmission from Exhaled Pathogens

(Source: Office of the Prime Minister and the Ministry of Health, Labor and Welfare of Japan, 2020^[13] – adapted by [4])

Droplet evaporation



Droplet evaporation time as a function of initial size [48]

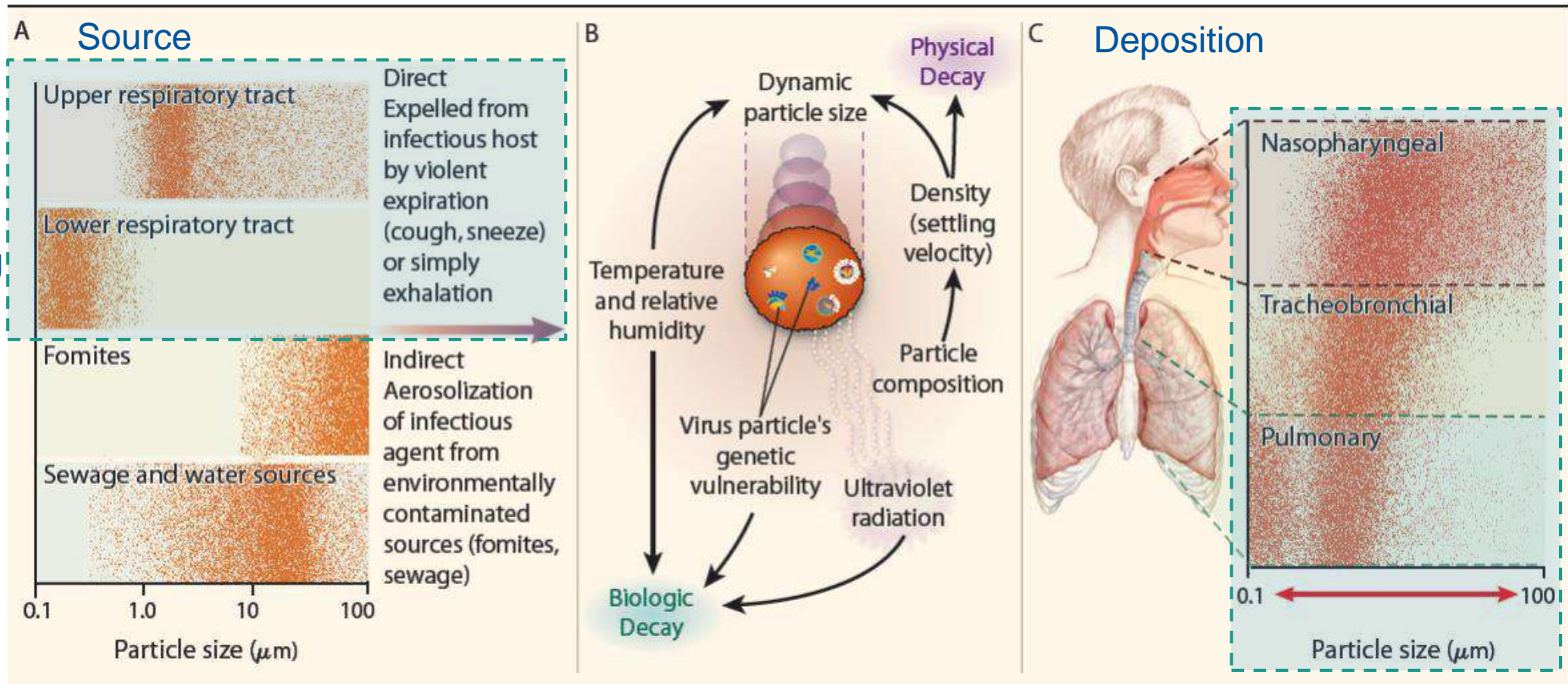


Size reduction factor due to evaporation, based on Kohler equation [49]

Droplets evaporate very quickly
In the process, they reduce from 20 – 40 % of their initial size

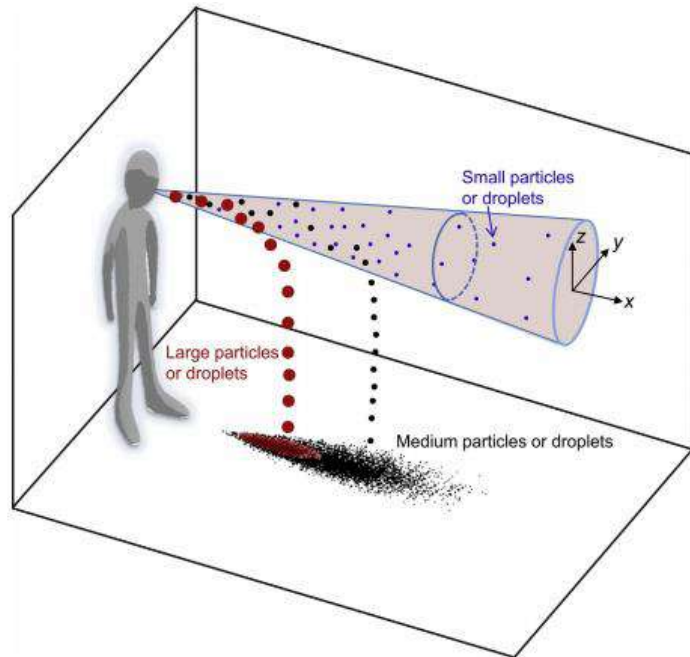
Viral behavior in respiratory tract (1/2)

Coughing
Breathing



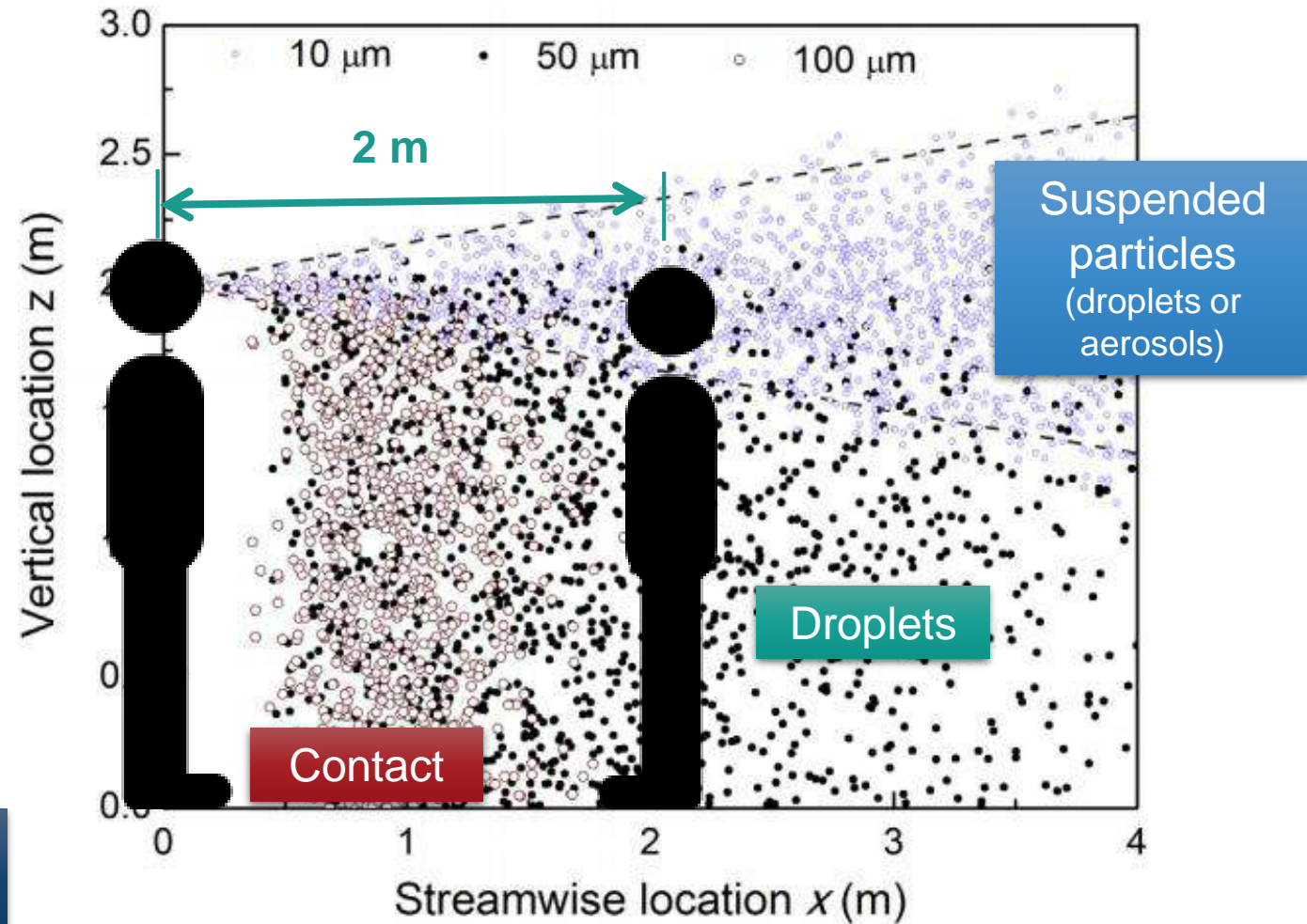
Total & Regional Respiratory Tract Deposition of Aerosols [50]

Airborne transmission



Simulation of spread of expiratory droplets by turbulence in a cough jet [8]

The 2m rule is still very important to protect against larger droplets



Instantaneous dispersion pattern of particles ($t = 100$ s) in the buoyancy neutral jet (mouth opening diameter $D = 2$ cm, initial velocity $= 10$ m/s, $T_{\text{amb}} = 25$ C). Particles are continuously released from $t = 0$. The top-hat width of the jet is indicated by the dashed line, which collapses with the visible boundary of the jet.

Airborne Transmission

NHK World Japan Documentary:
Fighting a Pandemic – Micro-droplets
<https://www.youtube.com/watch?v=H2azcn7MqOU>

Full:
<https://www3.nhk.or.jp/nhkworld/en/ondemand/video/5001289/>

- 2 people talking – micro-droplet projection

**Breathing, talking and singing
produce ~100-1000x more airborne
particles than ‘large falling droplets’**



Video

Airborne Transmission

NHK World Japan Documentary:
Fighting a Pandemic – Micro-droplets
<https://www.youtube.com/watch?v=H2azcn7MqOU>

Full:
<https://www3.nhk.or.jp/nhkworld/en/ondemand/video/5001289/>

- Natural ventilation effect on the dilution of micro-droplets



Video



Airborne transmission of SARS-CoV-2

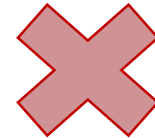
Endorsement



Why Airborne was not endorsed ?

- Definition of 'airborne' is not only a function of size

Pre-COVID infection control strategy: dichotomous classification between large vs small droplets: Cut-off criteria at 5 μm ^[10]



Human body can be airborne and a leaf could fall...

<https://www.iflyworld.com/>

<https://pin.it/18ugH3Q>

SARS-CoV-2 Transmission

- Transmission between people in close contact
- Transmission via particles that remain in the air over time and distance
- Infected surfaces
- Virus found in stool, blood, semen and ocular secretions; role in transmission unknown
- Animals (including domesticated) not major source of human infection

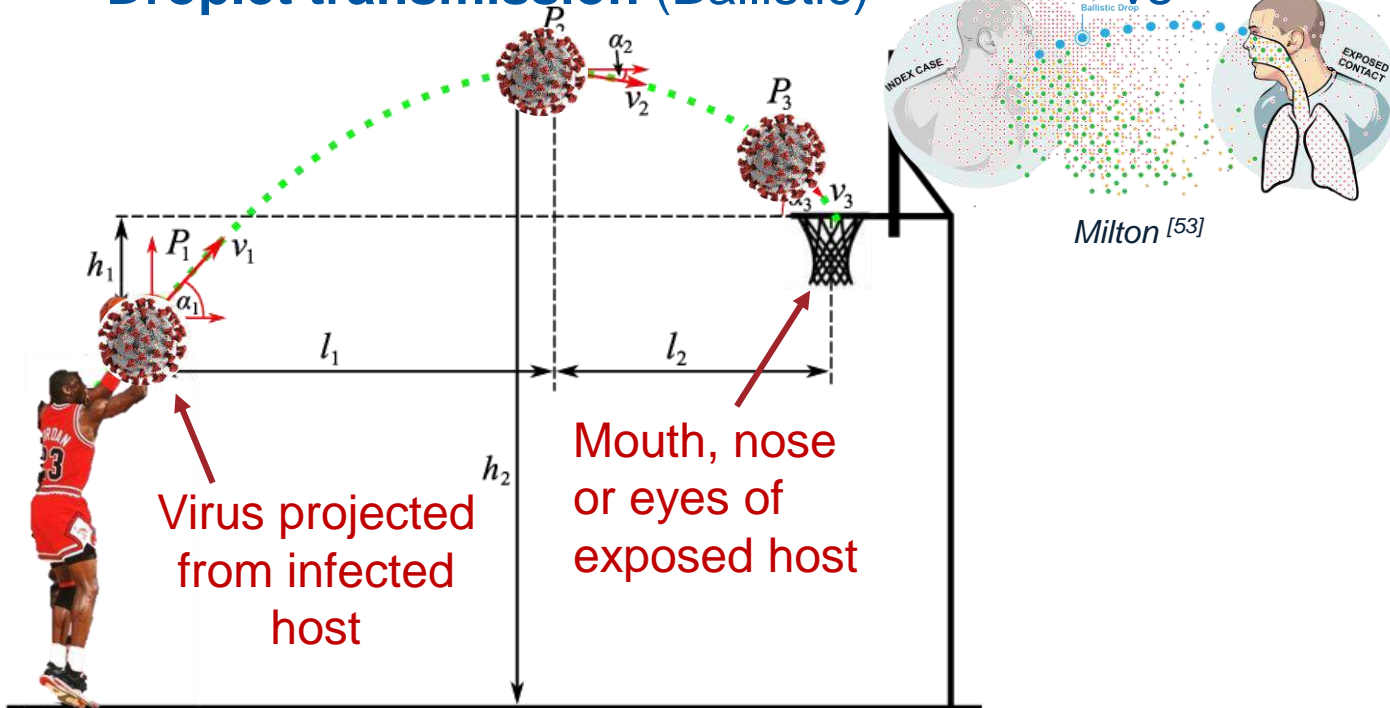


Dr. Anthony Fauci – September 2020 ^[11]

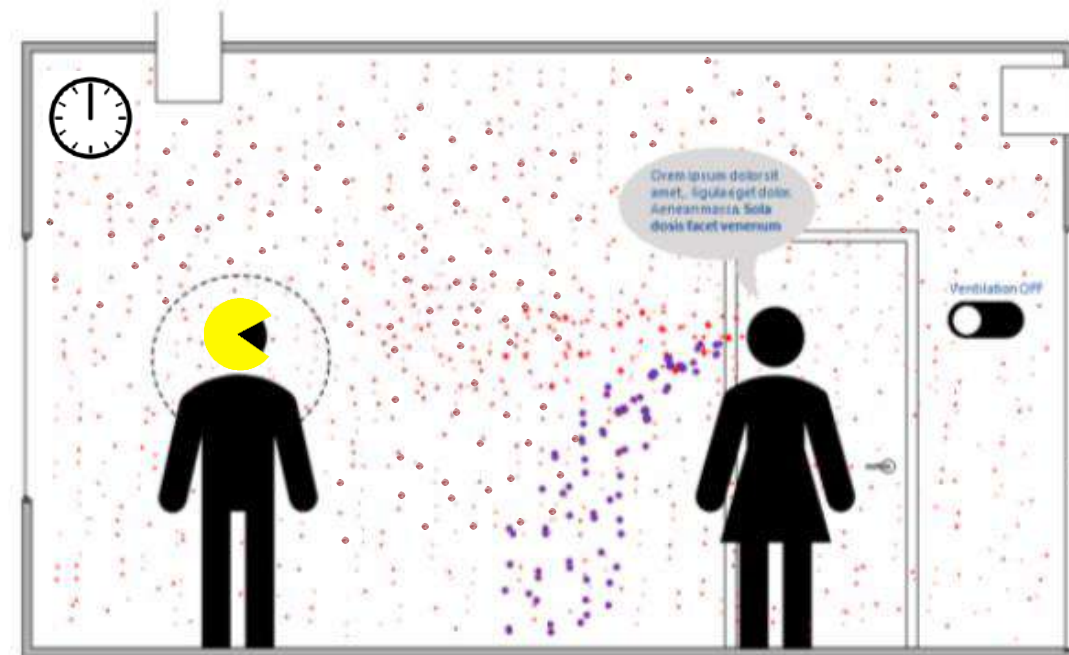
Why Airborne was not endorsed ?

- Misconception / Misinterpretation

Droplet transmission (Ballistic)



Aerosol transmission (inhalation)

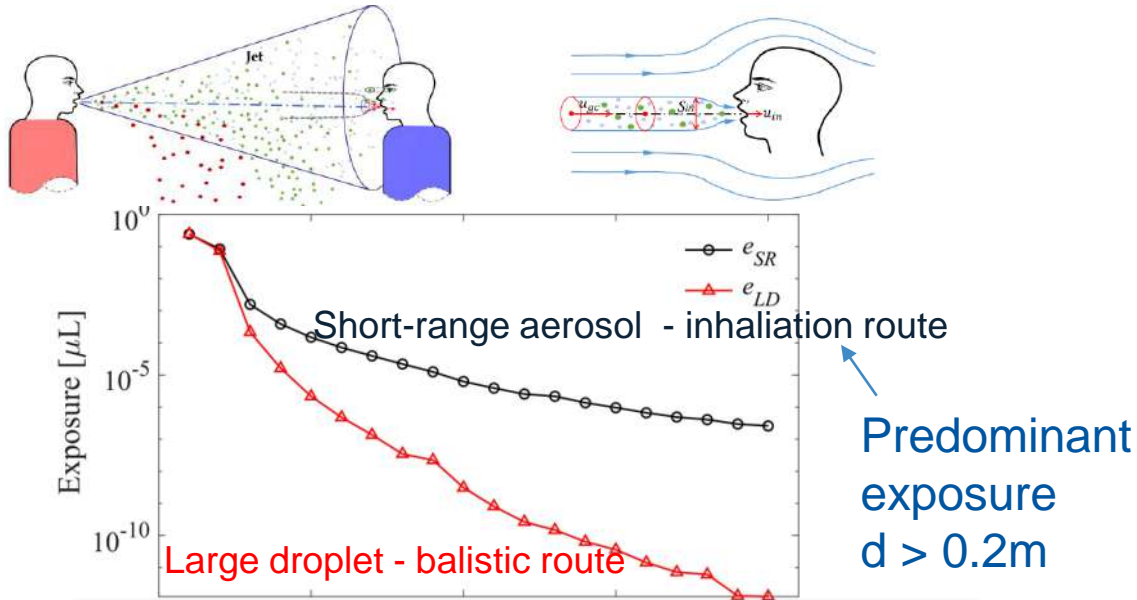


What is more probable $1 * 100 \mu\text{m}$ droplet or $100 * 1 \mu\text{m}$ aerosol inhalation ??
Let's talk about **AIRBORNE transmission** (independently if it is a 'droplet' or 'aerosol')

Why Airborne was not endorsed ?

- Misconception / Misinterpretation

Claim that transmission risk in close proximity is higher, thus demonstrates the predominance of large droplet transmission and disproves aerosols transmission? [1] Hence the importance of physical distance.



The 2m rule is still very important to protect against ~~larger droplets~~

Short-range aerosols

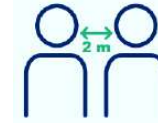
Physical distance is **important** but **not enough...**
Cigarette smoke analogy



<https://asmall1863.wordpress.com/2015/11/03/the-smoke-filled-room-is-dead-long-live-the-smoke-filled-room/>

Why Airborne was not endorsed ?

- Miscommunication



??

FACT CHECK: COVID-19 is NOT airborne

The virus that causes COVID-19 is mainly transmitted through droplets generated when an infected person coughs, sneezes, or speaks. These droplets are too heavy to hang in the air. They quickly fall on floors or surfaces.

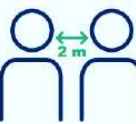
You can be infected by breathing in the virus if you are within 1 metre of a person who has COVID-19, or by touching a contaminated surface and then touching your eyes, nose or mouth before washing your hands.

To protect yourself, keep at least 1 metre distance from others and disinfect surfaces that are touched frequently. Regularly clean your hands thoroughly and avoid touching your eyes, mouth, and nose.

COVID-19 IS CONFIRMED AS AIRBORNE AND REMAIN 8 HRS IN THE AIR! SO PLEASE IS REQUIRED TO WEAR MASKS EVERYWHERE!!

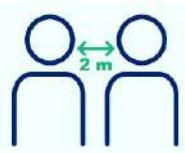
This message spreading on social media is incorrect. Help stop misinformation. Verify the facts before sharing.

World Health Organization March 28 2020 #Coronavirus #COVID19



Director General on press conference in February 2020:

'Corona is airborne'
WHO DG, 11.02.2020 [14]



Transmission of SARS-CoV-2: implications for infection prevention precautions

Scientific brief
9 July 2020 → Updated version (previous: 29 March) World Health Organization

“...some outbreak reports (...) have suggested the possibility of aerosol transmission, (...)” [15]



Why Airborne was not endorsed ?

- Historical

All aerosol transmittable diseases must be extremely contagious e.g.
Tuberculosis, Measles, chickenpox...

Paradigm of Chapin (1910) [16]

If one declares COVID-19 as airborne we will need to follow the TB protocol (?)



Ebola

Not Airborne

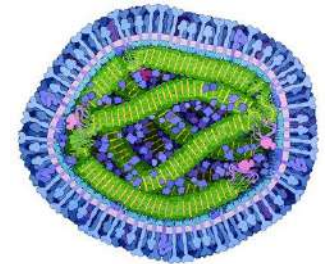


**SARS-CoV-2, SARS,
Influenza, MERS ???**

Contagiousness



Tuberculosis



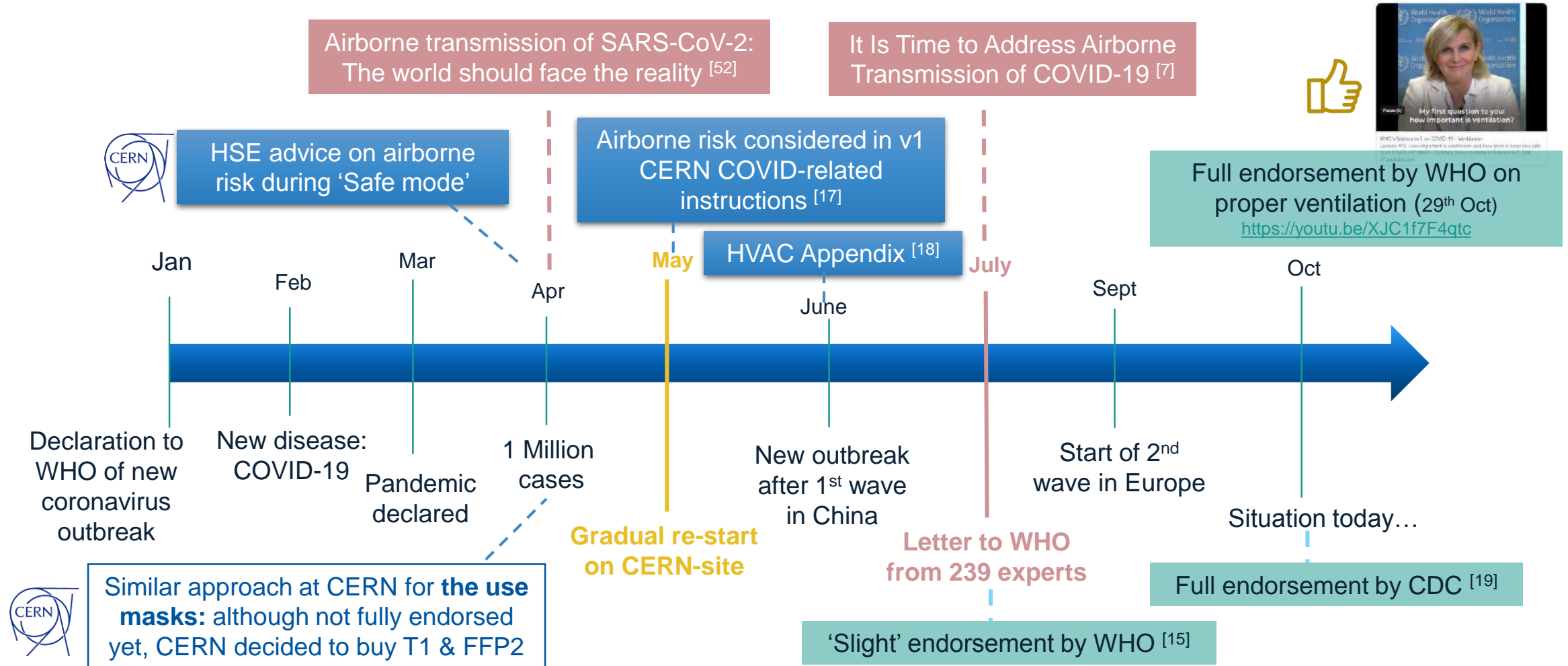
Measles

Airborne



Mode of transmission should not be determined by contagiousness of a given disease

'Endorsement' of airborne transmission



Airborne transmission of SARS-CoV-2

Evidence

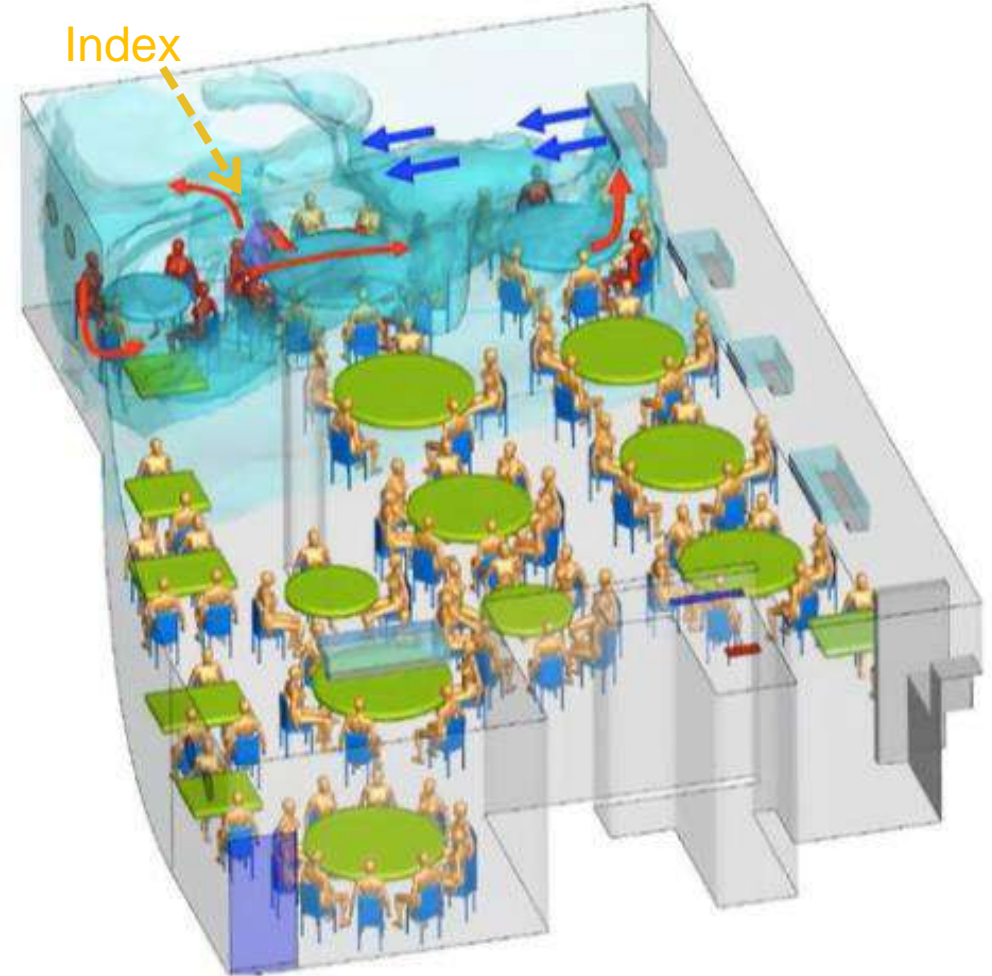


Airborne transmission in Restaurants

Evidence of possible SARS-CoV-2 spread in a Chinese restaurant ^[20] ^[21]

- 1 index patient infected 9 others
- Main reasons:
 - Poorly ventilated (1 L/s/occ. & 0.7-0.5 ACH)
 - A/C recirculation units helped spread the virus via airborne transmission

Aerosol transmission of SARS-CoV-2 due to poor ventilation may explain the community spread of COVID-19 ^[21]



Airborne transmission in choirs

Evidence of possible airborne SARS-CoV-2 spread in a choir in WA, USA ^[3]

- 1 index patient infected 52 others (1 to 13 m distance behind) – 2.5 h rehearsal
- Main reasons:
 - Poorly ventilated (~ 0.5 ACH)
 - No masks
 - Strong vocal activity – singing (10 times more airborne emission than talking)
 - Small volume (10 m³/occ)



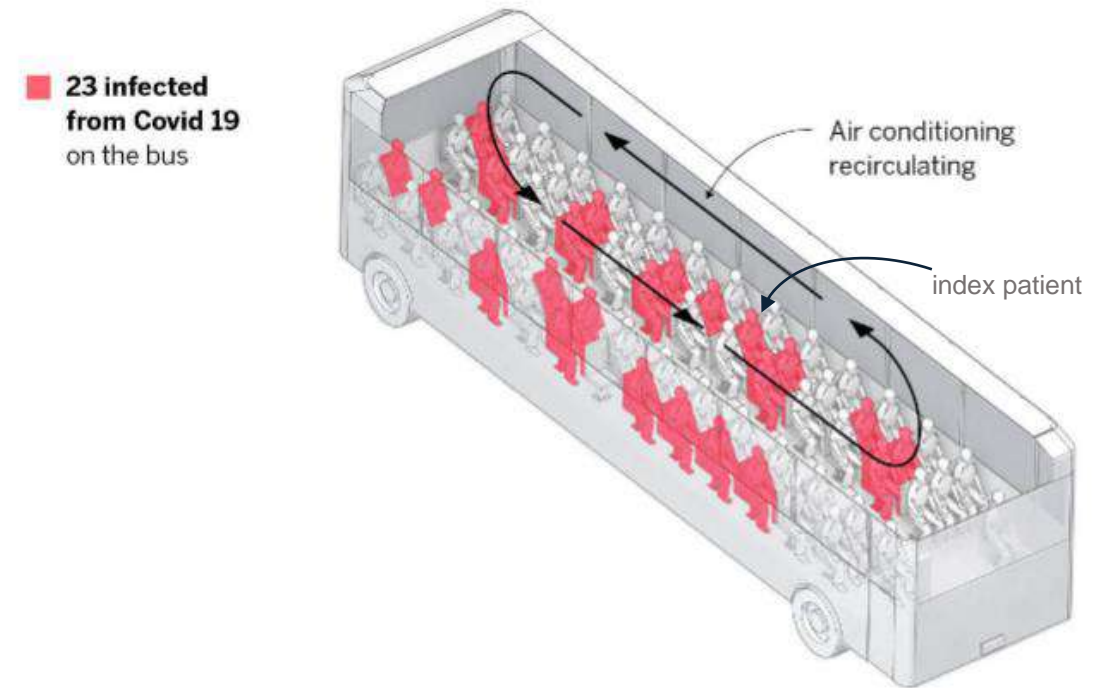
Superspreading event

Airborne transmission in Buses

Evidence of possible airborne SARS-CoV-2 spread in a bus in China ^[22]

- 1 index patient infected 23 out of 68 passengers – 1.5 h journey
- Main reasons:
 - Poorly ventilated, just recirculation of air
 - No masks

Superspreading event

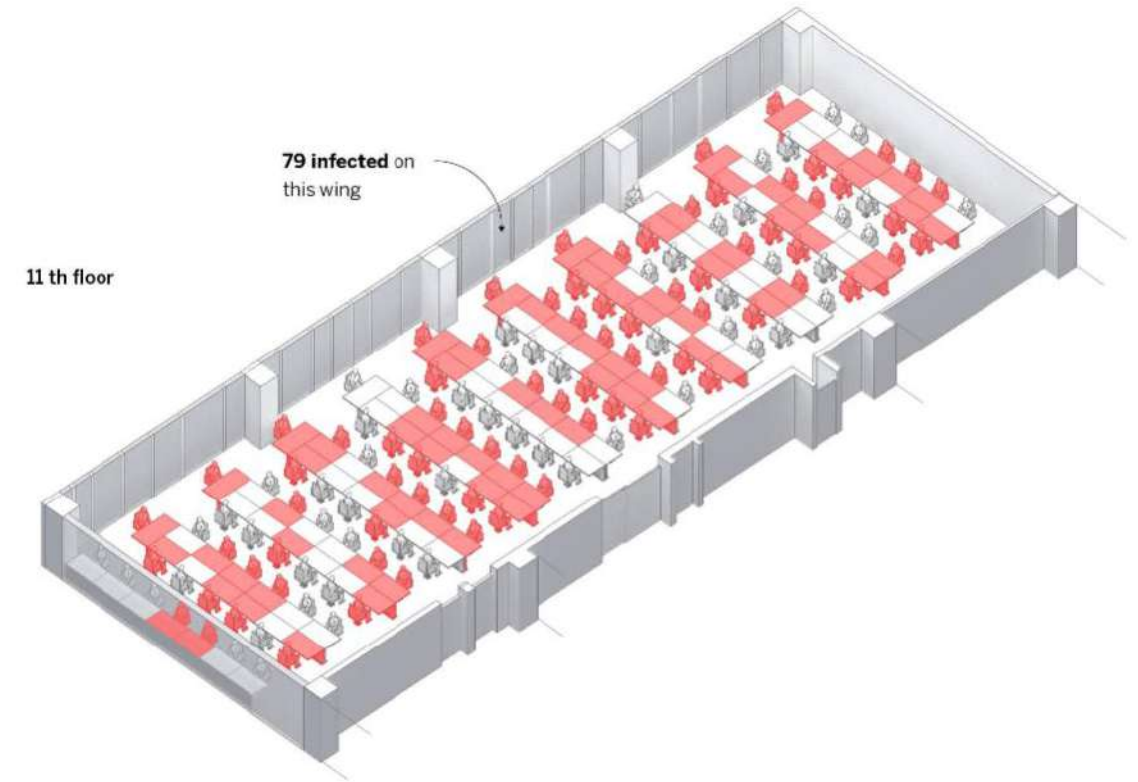


https://english.elpais.com/spanish_news/2020-06-17/an-analysis-of-three-covid-19-outbreaks-how-they-happened-and-how-they-can-be-avoided.html?rel=listapoyo

Airborne transmission in call centers

Evidence of possible airborne SARS-CoV-2 spread in a call centre in Seoul [23]

- 79 out of 137 workers (~60%) infected
- Main reasons:
 - Call center company have workers on many floors but large scale infection only happened in this open office
 - Continuous vocal activity
 - No masks
 - For the rest of the workforce (927 employees) only 0.3 % tested positive, despite the fact they shared lobbies, elevators and other communal areas



https://english.elpais.com/spanish_news/2020-06-17/an-analysis-of-three-covid-19-outbreaks-how-they-happened-and-how-they-can-be-avoided.html?rel=listapoyo

Superspreading event

Airborne transmission of SARS-CoV-2

Mitigation measures



Mitigation measures

- Physical distancing
- Use of masks
- Hand hygiene (incl. barrier gestures)
- Collective mitigation measures (e.g. teleworking, flexible work schedule...)

Still very important

- **Proper ventilation (ACH, filtration,...)**

Also very important



Mitigation measures

→ Les gestes-barrières doivent être renforcés : ^[25] - adapted



France has included “venting” in their list of barrier gestures

Mitigation measures

- Fresh air supply (i.e. bring in outdoor air) and Air Changes per Hour (ACH)

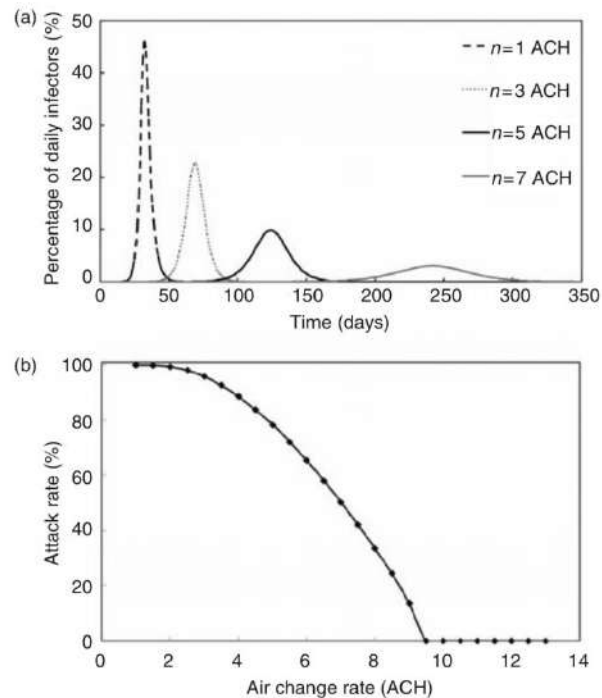
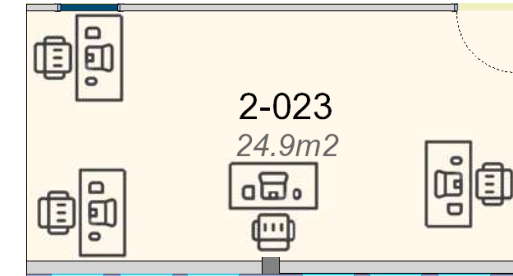


Fig. 2. The effect of increasing ventilation rate: (a) change of daily incidents, (b) change of overall attack rate.

@ CERN (based on FR and CH): **30-36 m³/h/occ.**

- 6 m²/occ.
- Height 2.5 m
- 4 occupants
Volume = 60 m³



- 36 m³/h/occ.
Fresh air supply: 144 m³/h

$$\text{ACH} = 144 / 60 = 2.5$$

1 volume exchange in 24 min

- Open window in winter
Fresh air supply: 660 m³/h

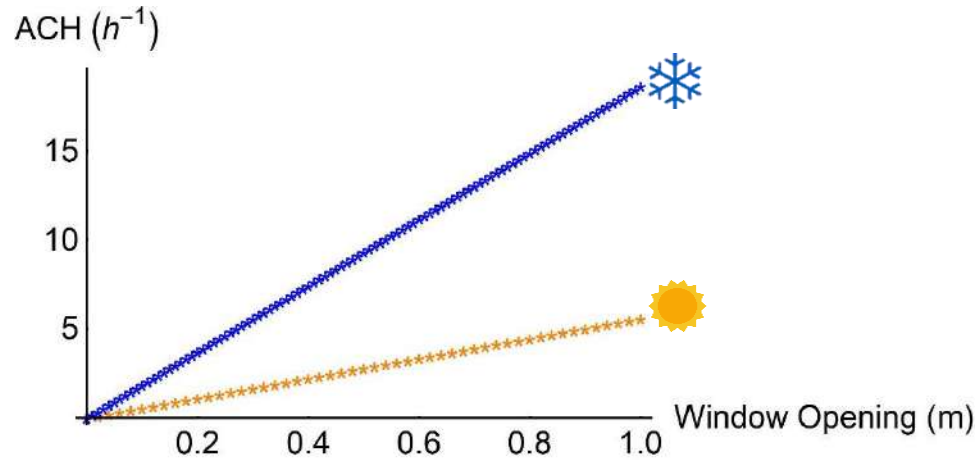
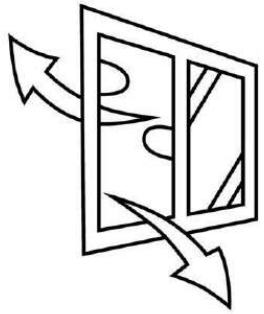
$$\text{ACH} = 660 / 60 = 10$$

Ventilation rates of < 18 m³/h per person may impact on acute respiratory infections [27]

Ventilation control of indoor transmission of airborne diseases [26]

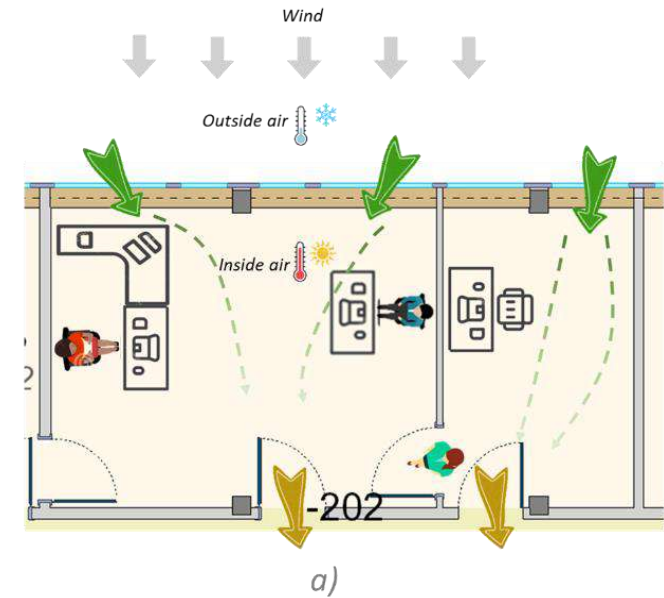
Mitigation measures

- Natural supply of fresh air (e.g. open windows)



Single-sided natural ventilation via open window – CARA

Despite uncomfortableness due to cold air,
natural ventilation in winter is much more efficient



HVAC Annex to CERN COVID-related
Health & Safety Instructions ^[18]

Mitigation measures

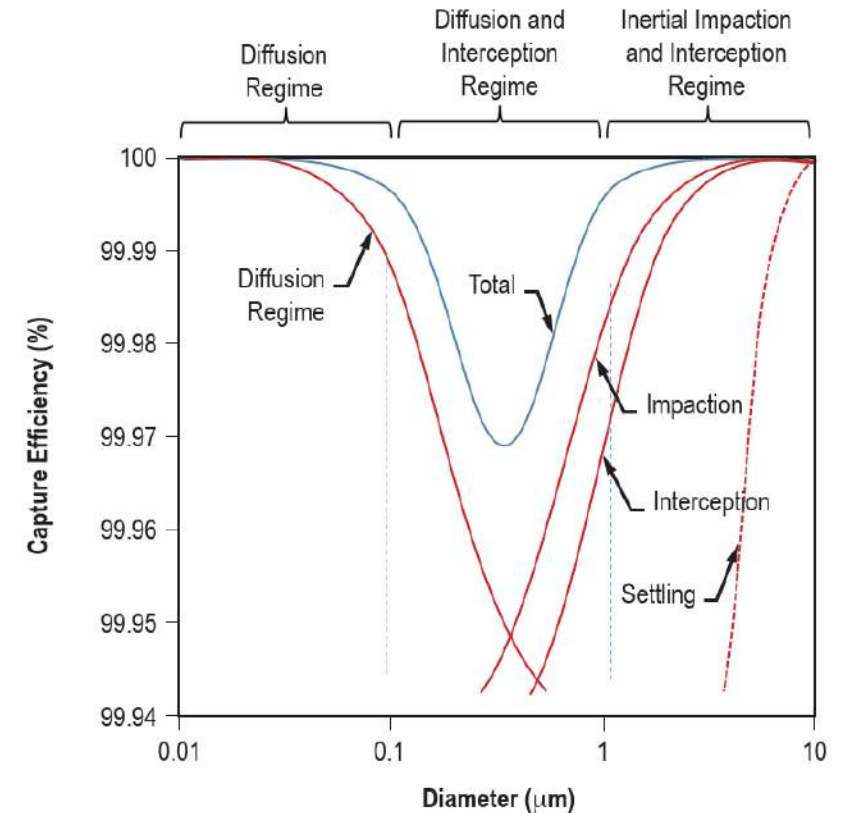
- HEPA filtration

Particles of $\sim 0.3 \mu\text{m}$ are the hardest to catch

- The critical particle diameter is $\sim 0.3 \mu\text{m}$
- Reason why $0.3 \mu\text{m}$ is the Most Penetrating Particle Size (MPPS) in standards for HEPA filters

Smaller particles are easier to catch due to the effect of the 'Brownian motion' – *Diffusion mechanism*

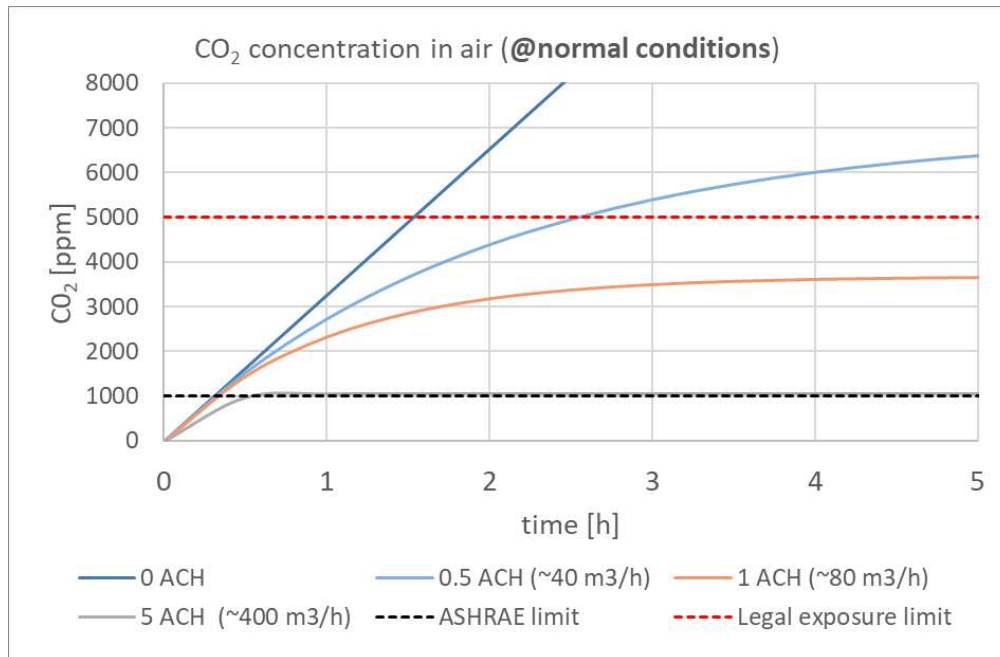
Filtration reduces the particle load in the air and thus viral concentration, whereas ventilation dilutes the viral concentration and displaces the viruses with outdoor air



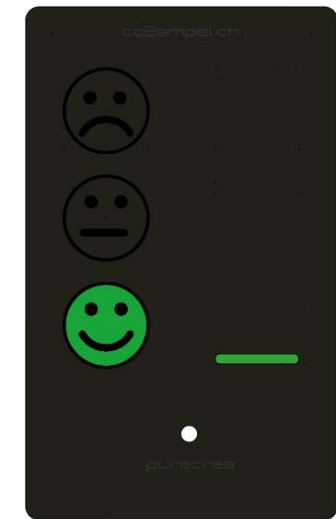
Filter efficiency as a function of particle diameter [28]

Mitigation measures

- CO₂ as surrogate to exhaled viruses
 - High CO₂ concentration in offices is a good indication of poor ventilation



CO₂ concentration in meeting room of Bldg. 24



Courtesy of V. Baggiolini BE-CO

<https://www.mobistyle-project.eu/en/mobistyle>

Mitigation measures – use of masks

Schlieren imaging to study the human cough with and without wearing masks for aerosol infection [29]



No
mask



3pl type
mask

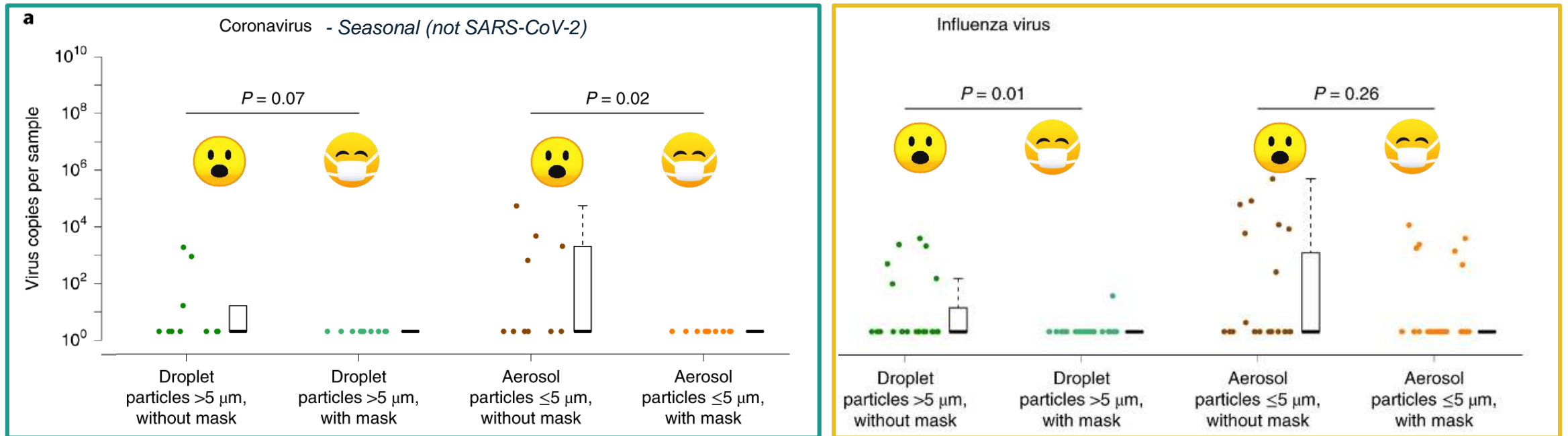


N95
(FFP2)

Videos: Schlieren images of two volunteers facing one another [29]

Mitigation measures – use of masks

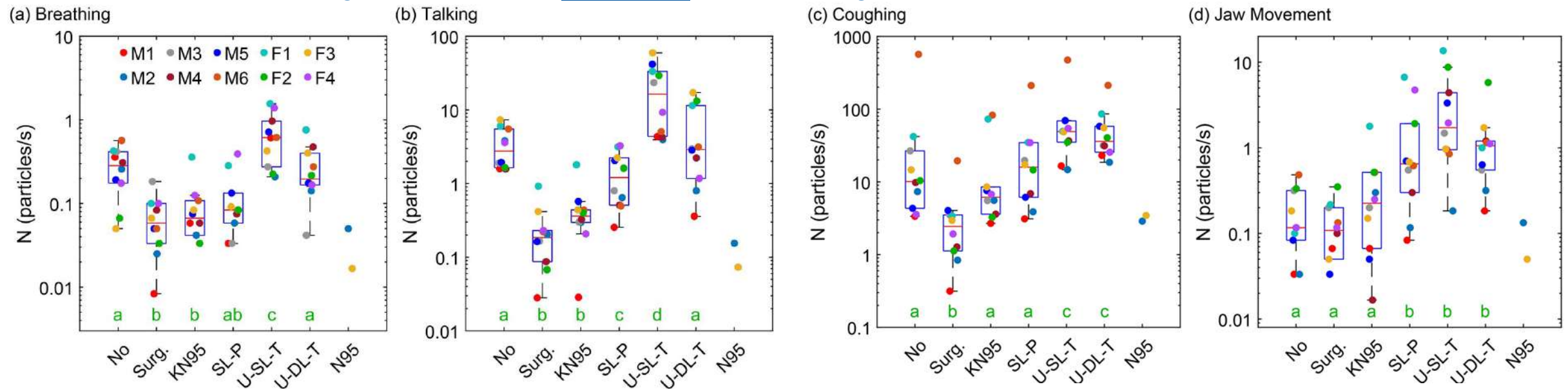
- CoVs were more commonly emitted in aerosols than in droplets through normal tidal breathing [54]
- The use of surgical face masks could be used to control the transmission of COVID-19 through exhaled breath [54]



Efficacy of surgical face masks in reducing respiratory virus shedding in respiratory droplets and aerosols during exhaled breath [54]

Mitigation measures – use of masks

- Surgical masks and KN95 masks reduce the outward emission of particles (0.3 – 20 μm) by a **factor 6** when breathing and a median **factor 10** when talking [55]



Surg.: surgical; KN95: unvented KN95; SL-P: single-layer paper towel; U-SL-T: unwashed single-layer cotton t-shirt; U-DL-T: unwashed double-layer cotton t-shirt; N95: vented N95.

Efficacy of masks and face coverings in controlling outward aerosol particle emission from expiratory activities [55]

CARA

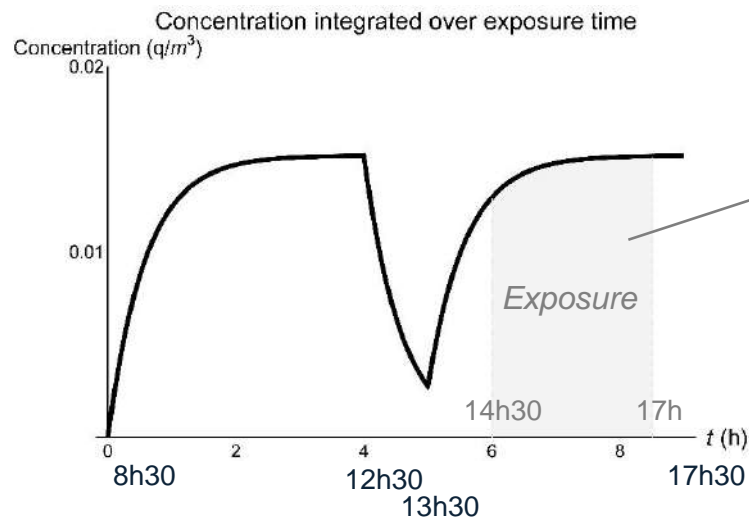
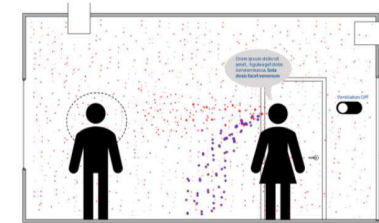
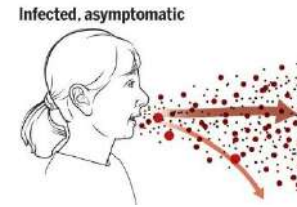
C*COVID* A*Airborne* R*Risk* A*Assessment*

Quantitative approach



Methodology

1. Estimate the emission rate of viruses (ER)
2. Estimate the concentration of infectious quanta in a room ($c(t)$)
Effect of: *ACH + Bio decay + deposition + HEPA*
3. Estimate the infection probability of an exposed individual (P_i) and the estimated number of possible new cases (R_0)

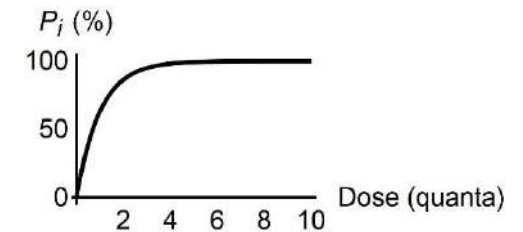


$$D = \int_{t_i}^{t_f} c(t) dt * \text{Inhalation flow rate}$$

= **Dose** (# of infectious quanta in the system)

$$P_i = 1 - e^{-D}$$

$$1 - e^{-1} = 63\%$$



$$R_0 = P_i * \text{number of exposed subjects}$$

Boundary conditions

- Only airborne risk (*long range*) estimated in closed spaces!

- Other transmission modes: droplet contact (direct), fomite (indirect), fecal-oral, bloodborne, mother-to-child, outdoor settings, effect of physical distancing etc. are not considered

- **Homogeneous mixture of viruses in the room** (simplification)

- Used broadly in epidemic modeling (*Sze To and Chao, 2010* [36]).

- At least 1 person is infected and emission rate is constant over time

- Viral load & Infectivity from literature (*G. Buonanno, et al., 2020* [31])

- Respiratory droplet nuclei according to *Morawska et al. (2009)* [34] – values without mask ($0.8 < d < 5.5 \mu m$)

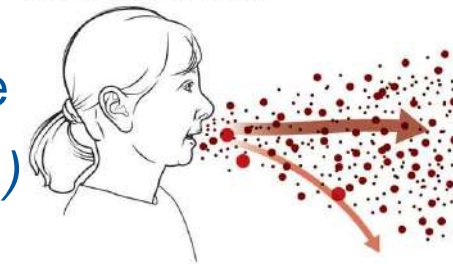
- With masks: contribution of filtering and leakages: *Gammaitoni et al (1997)* [32]

$$\eta_{\text{Mask}} = \eta_{\text{filter}} - (\eta_{\text{filter}} * \eta_{\text{leaks}})$$

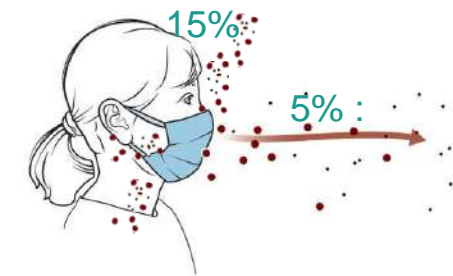
$$3 \leq d < 5.5 \mu m : \eta_{\text{Mask}} = 0.95 - (0.95 * 0.15)$$

$$\eta_{\text{Mask}} = 80.75 (\%)$$

Infected, asymptomatic



100%
 $0.8 < d < 5.5 \mu m$



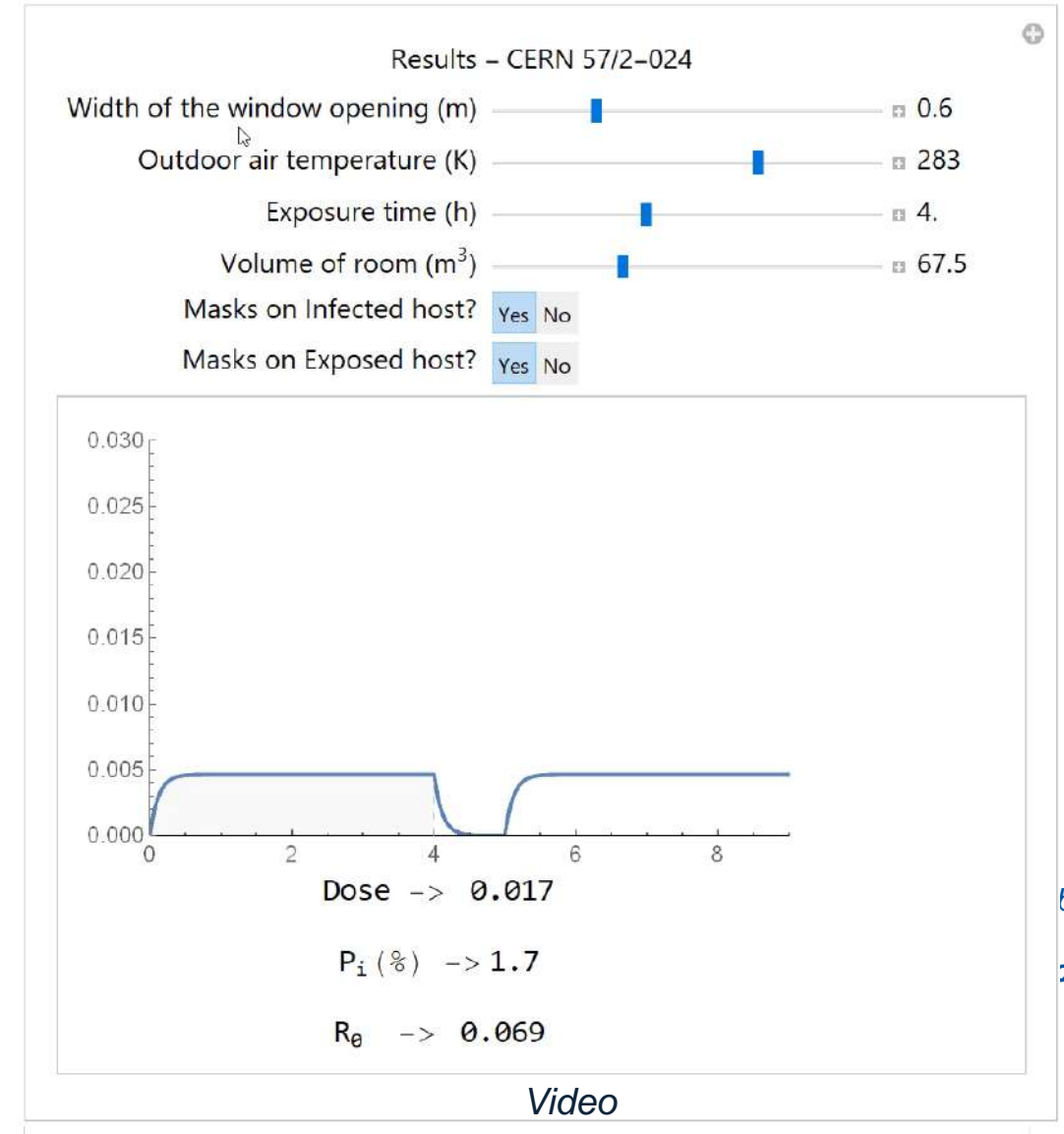
100%
 $0.8 < d < 3 \mu m$
95% :
 $3 \leq d < 5.5 \mu m$
&
15% leakage [33] :
 $3 \leq d < 5.5 \mu m$

GRAPHIC: V. ALTOUNIAN/SCIENCE (adapted)

Example - Office

Inputs:

- Office: 57/2-024
- Max occupants: 4
- Surface area: **6 m² / occ.**
- Volume: 68 m³
- Ventilation: Via an open window
 - ΔT (outdoor – indoor) = 10 K
- Physical activity: "Light exercise" , "Breathing"
- Masks: **Yes (Type I)**
- Infected subject: 8h workday in the office
- Exposed subject: in the office only in the morning

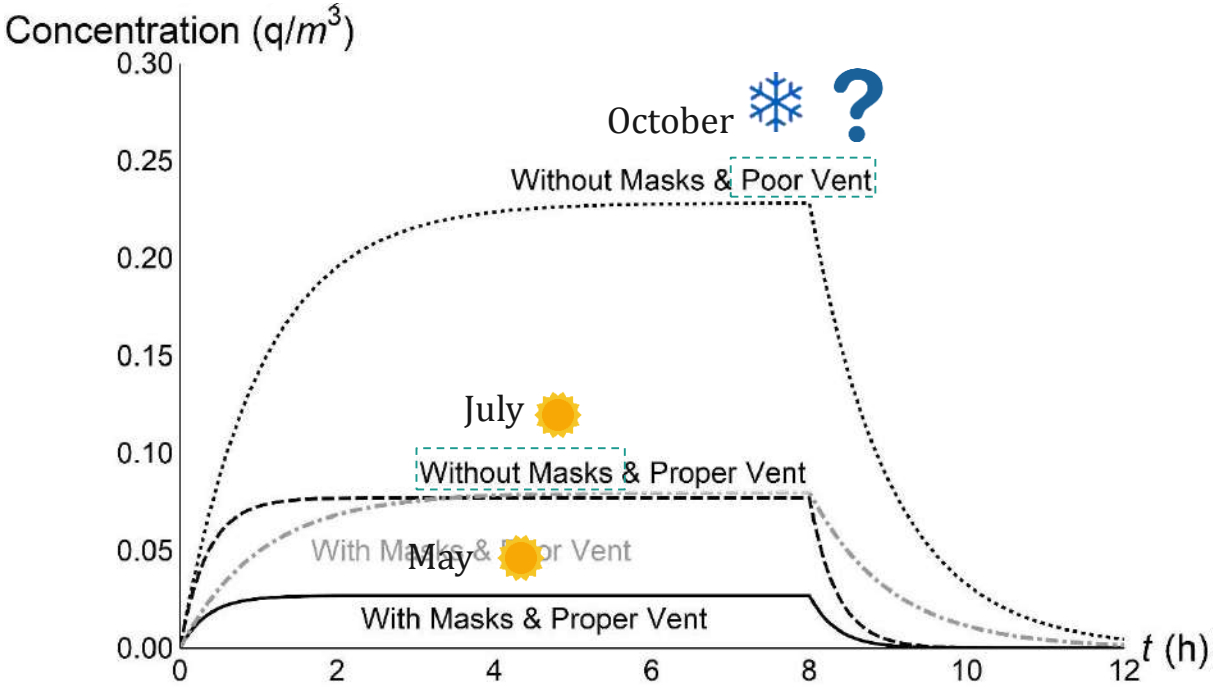


bject
ction

Values are representative for a certain room layout

Comparison

Office – 24 m² ; 4 occupants ; 6 m²/occ.



Proper venting: 2 – 6 ACH (e.g. 0.6m window opening)
 Poor venting: 0.1 – 0.5 ACH

Example:

4 occupants;
8h exposure

0.6 m permanent opening
 $\Delta T = 2 K$



R₀

Occupancy (m ² / occ.)				
4	3.0	1.0	1.1	0.27
5	2.6	0.97	0.93	0.26
6	2.4	0.92	0.79	0.25
7	2.1	0.89	0.69	0.24
9	1.8	0.83	0.55	0.22

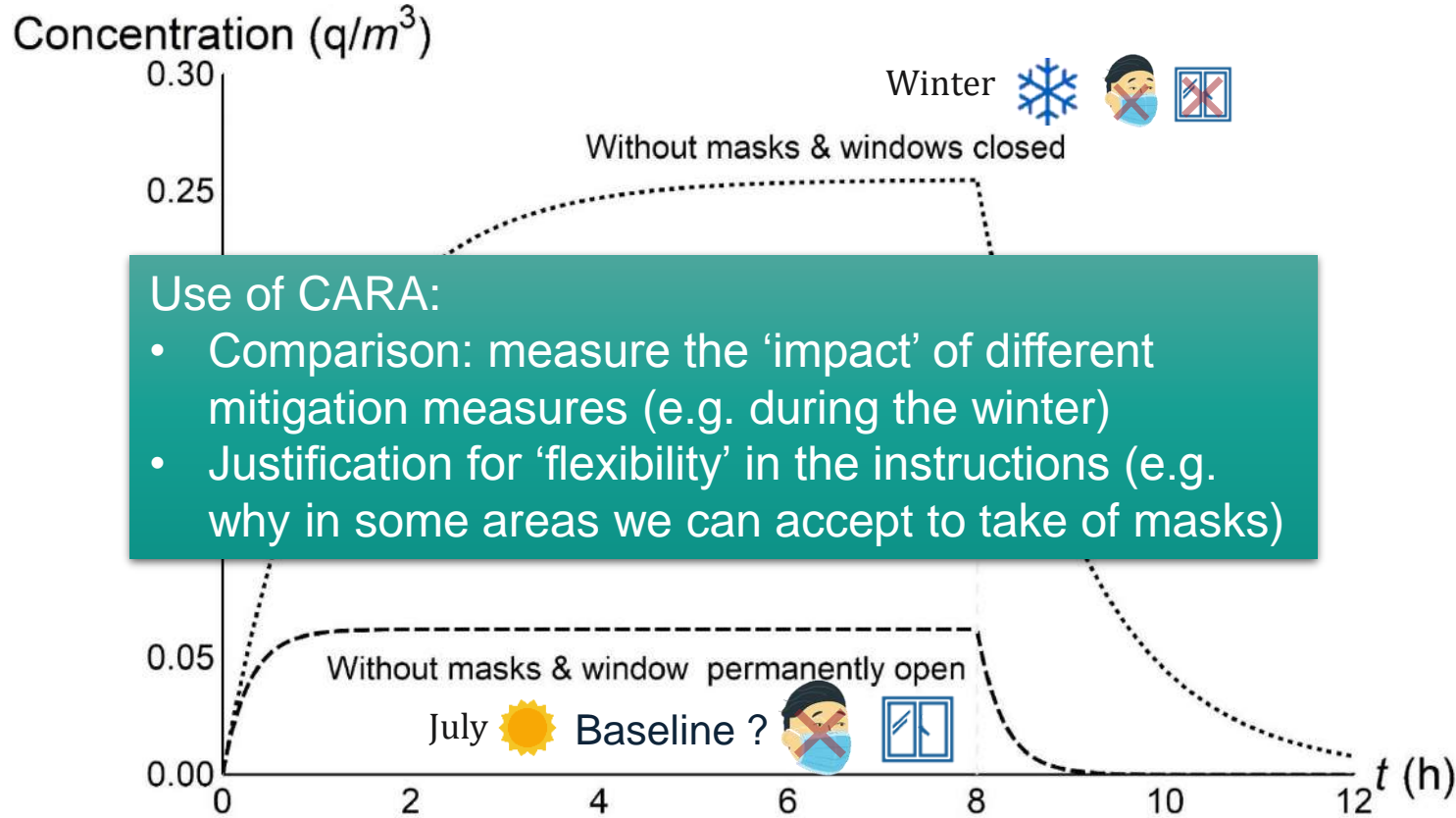
Today

Reduced venting during the winter will lead to increased infection rates, if no further measures are applied

Comparison – Summer vs Winter

Example: 8h office exposure

Values are representative for a certain office layout

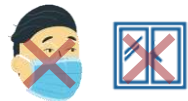


Use of CARA:

- Comparison: measure the 'impact' of different mitigation measures (e.g. during the winter)
- Justification for 'flexibility' in the instructions (e.g. why in some areas we can accept to take of masks)



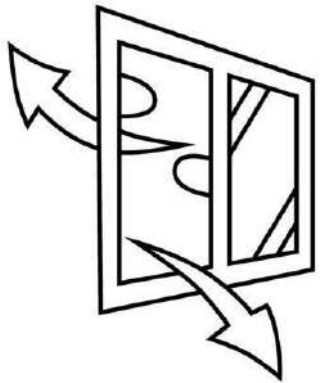
R_0



2.4





0.9 = Baseline



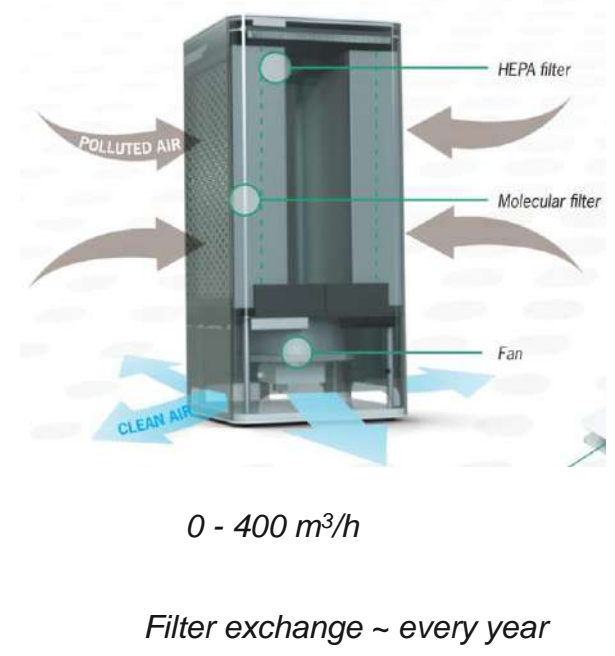
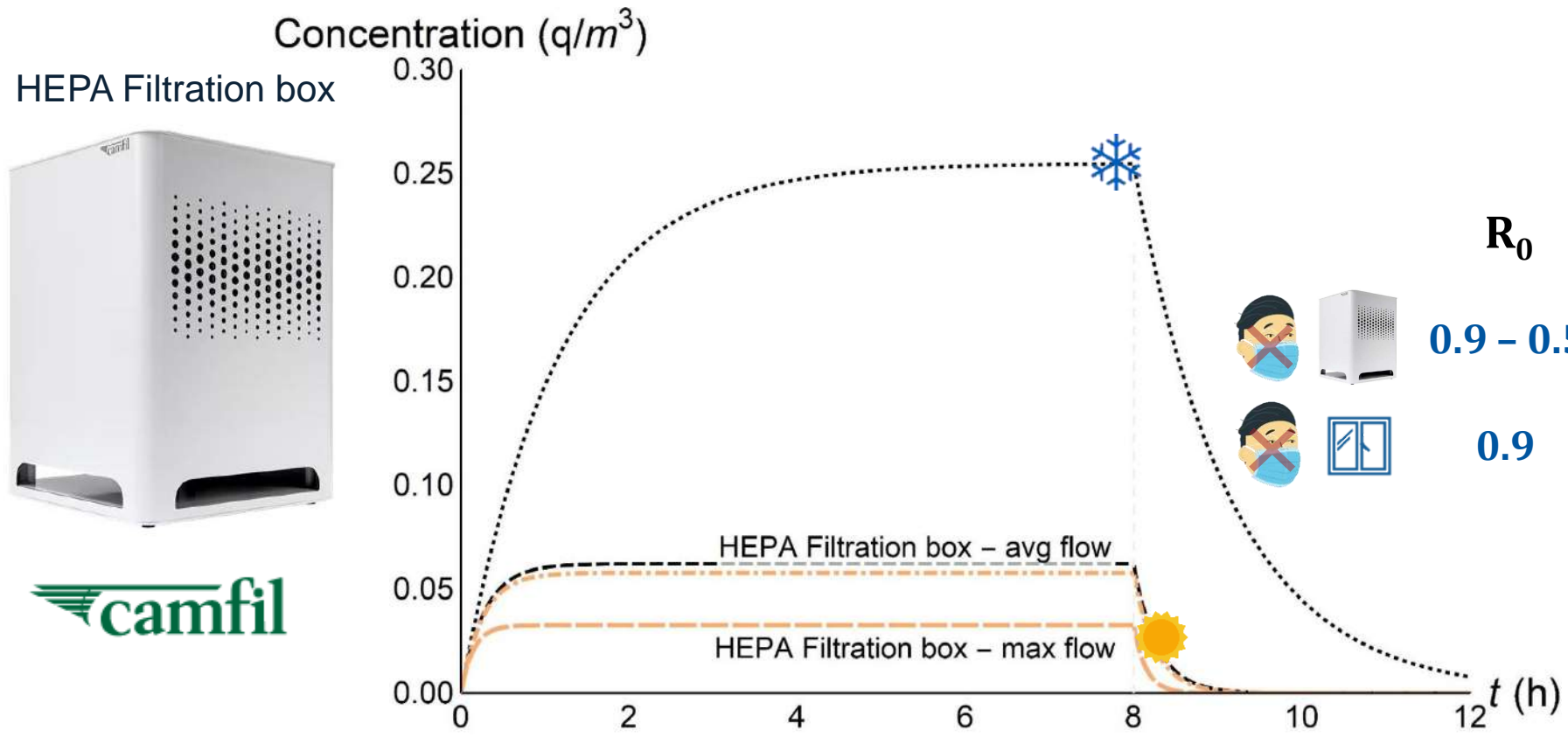
☀️ 0.6 m opening
 $\Delta T = 2 K$

Alternative measures to the use of masks during winter

Values are representative for a certain office layout

-  Without masks & windows closed
-  Without masks & windows permanently open

8h office exposure



Courtesy of C. Martel, T. Duverger - SMB

Usability – CARA to python

Wolfram Mathematica

'CARA' (COVID Airborne Risk Assessment)

Airborne Transmission of SARS-CoV-2

by Andre Henriques HSE-OHS
Main model

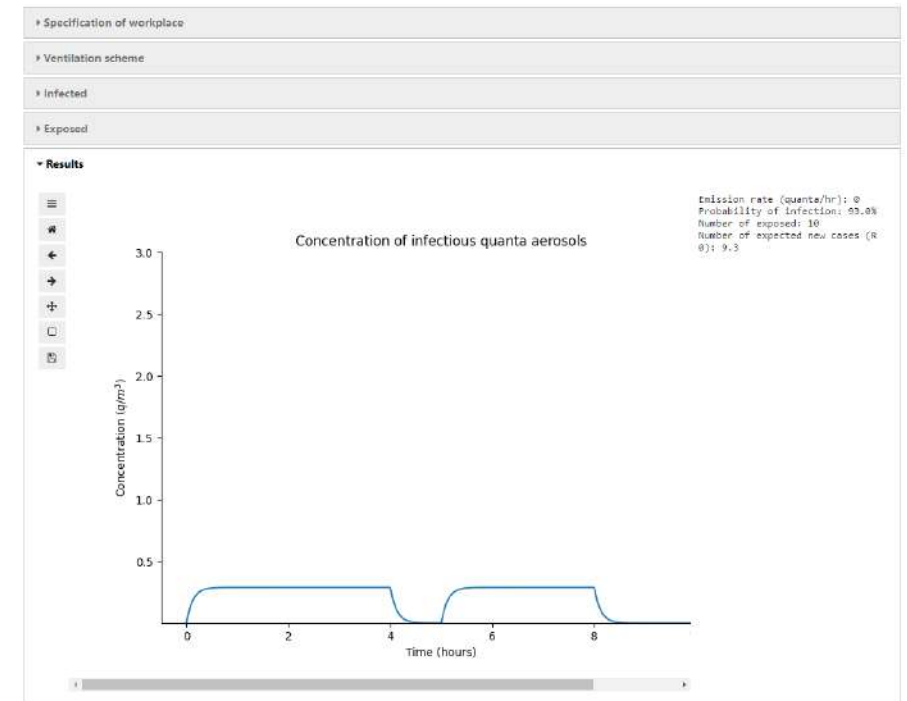
- Inputs »
- Model »
- Results and Plots »
- Comparison of measures »



Web app
Under development

'CARA' (COVID Airborne Risk Assessment)

Airborne Transmission of SARS-CoV-2



Many thanks to:

- P. Elson; N. Mounet; M. Rognlien, G. Azzopardi (BE)
- J. Devine (EP)

General recommendations / advice



General Recommendations

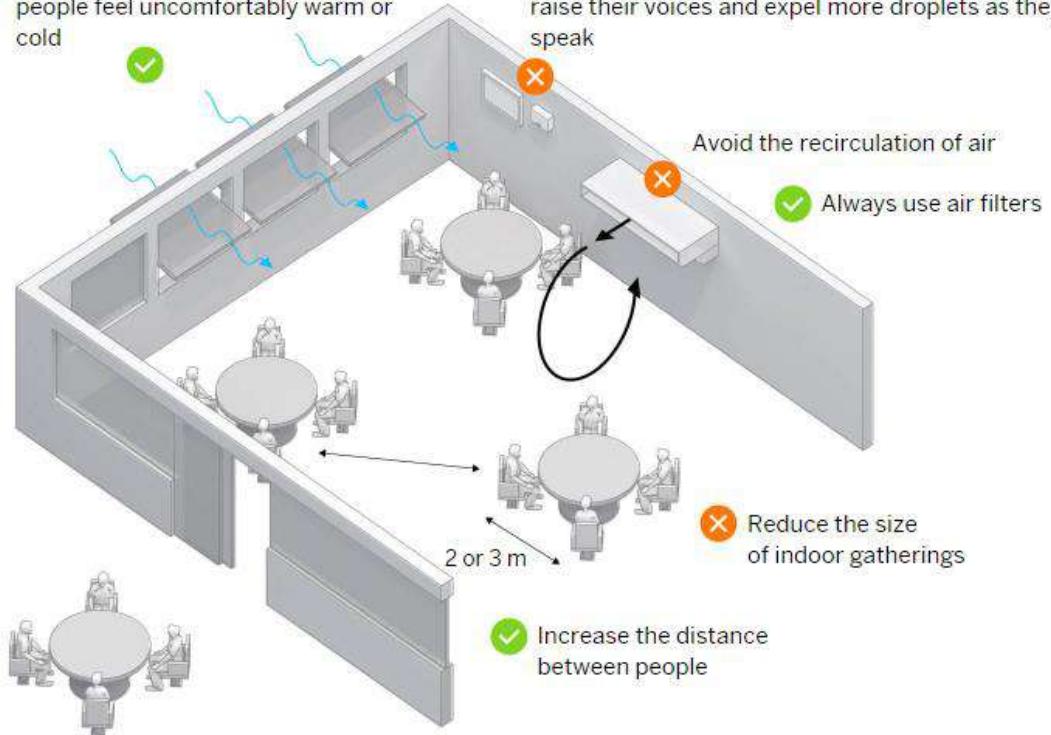
An analysis of three Covid-19 outbreaks: how they happened and how they can be avoided ^[39]

EL PAÍS

How it can be avoided

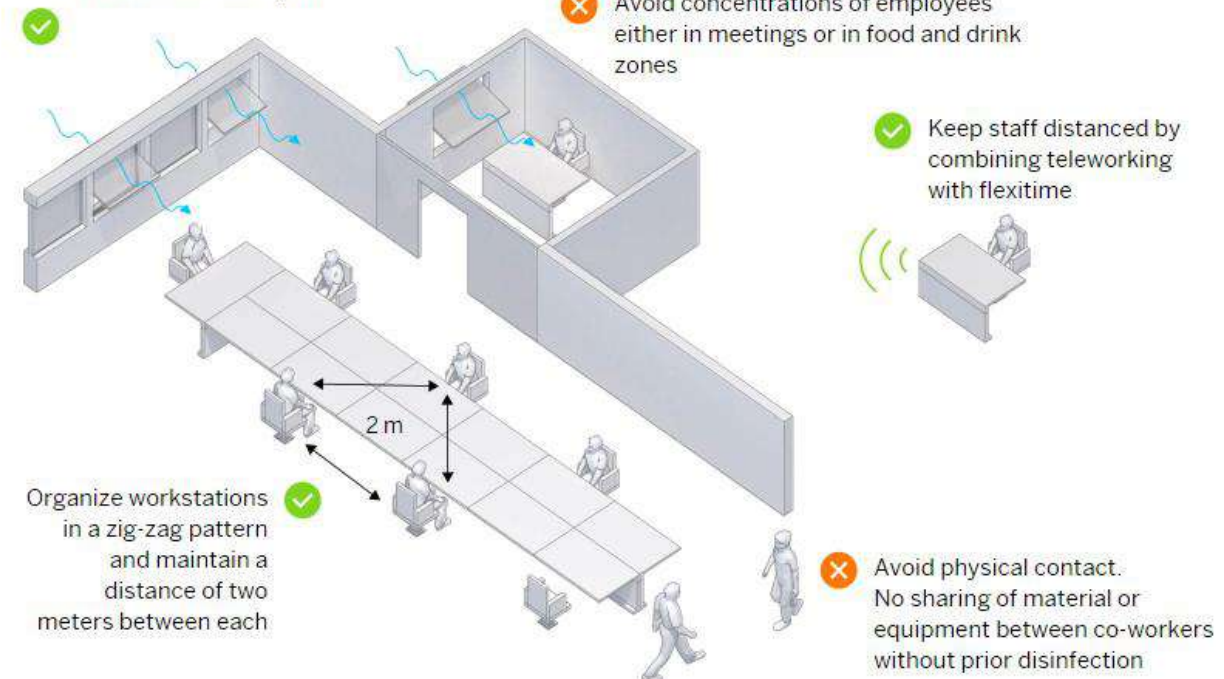
Open windows even if it makes people feel uncomfortably warm or cold

Avoid background music so people don't have to raise their voices and expel more droplets as they speak



Natural ventilation to avoid the recirculation of infected particles

Avoid concentrations of employees either in meetings or in food and drink zones




https://english.elpais.com/spanish_news/2020-06-17/an-analysis-of-three-covid-19-outbreaks-how-they-happened-and-how-they-can-be-avoided.html?rel=listapoyo

General Recommendations

Avoid the 3 C's: [40]

- Crowds
- Close-contact
- **Confined areas with poor ventilation**






Avoid the Three C's 
Be aware of different levels of risk in different settings.

There are certain places where COVID-19 spreads more easily:

- 1 Crowded places**
with many people nearby
- 2 Close-contact settings**
Especially where people have close-range conversations
- 3 Confined and enclosed spaces**
with poor ventilation

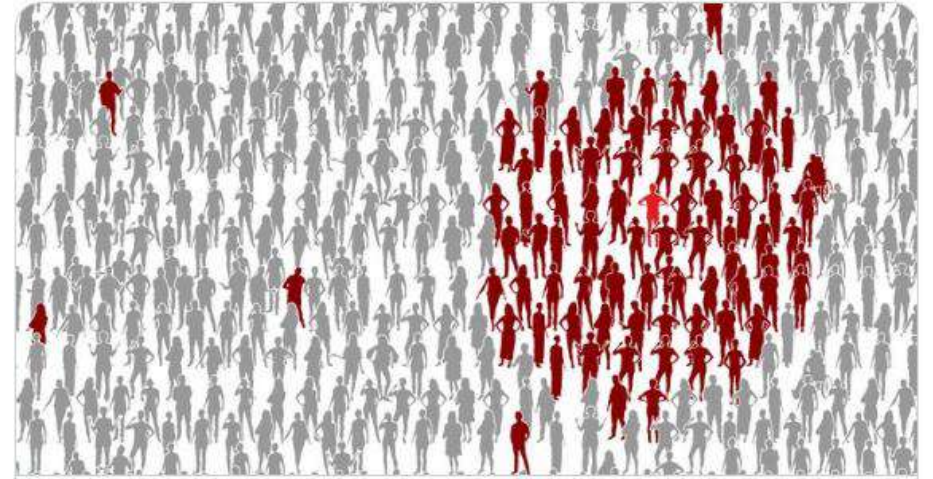
The risk is higher in places where these factors overlap.
Even as restrictions are lifted, consider where you are going and #StaySafe by avoiding the Three C's.

WHAT SHOULD YOU DO?

-  Avoid crowded places and limit time in enclosed spaces
-  Maintain at least 1m distance from others
-  When possible, open windows and doors for ventilation
-  Keep hands clean and cover coughs and sneezes
-  Wear a mask if requested or if physical distancing is not possible

If you are unwell, stay home unless to seek urgent medical care.

Avoid the superspreading events

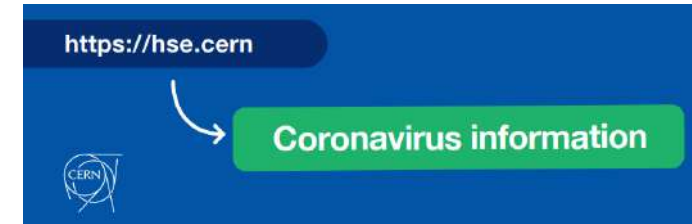


Not everyone becomes a 'superspreader' but **10-20% of these events** are responsible for **80% of transmission** [56]

... the best way to stop this?

- 1) Instruct public to 'avoid the 3 C's' or
- 2) **Lockdown !!**

CERN-specific instructions

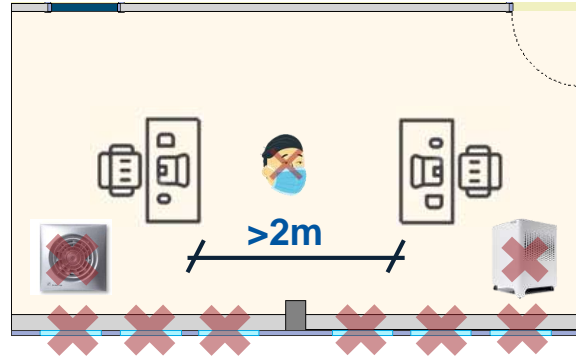


- **Keep windows open** as much as possible (*even if it is cold*)
- Make sure fresh air flow rates / ACH are enough or install HEPA filtration (*if applicable*)
- Avoid recirculation units as much as possible (e.g. A/C split for comfort)
- Keep mechanical ventilation (not A/C) on 24/7
- **Use masks as much as possible**
 - “Persons may remove their masks, while seated, in offices where the physical distance of 2m and proper venting with fresh air are ensured” – CERN COVID Instructions ^[17]
- **2m physical distance** (short range airborne transmission)
- Hand hygiene and other gestures
- Stay at home if you experience symptoms

Contact the HSE Unit in case of doubt with respect to Health & Safety Instructions at Workplace
WG-OHS-Covid19@cern.ch

Final Notes

Question:



2m distance but no ventilation in closed area...

*Are we out of the woods? **NO***

- Spread awareness & communication, not fear: Importance of airborne transmission and proper ventilation in indoor spaces
- **Include these aspects in our daily ‘protection measures’** (in addition to hand hygiene, physical distance and masks)

‘Do not forget all the rest, just remember airborne as well.’

Thank you for your attention



Acknowledgements to colleagues from:

HSE (D. Forkel-Wirth, S. La Mendola , W. Fadel, O. Rios, J. Madden)

SMB (C. Martel, T. Duverger)

EP (O. Beltramello, L. Di Giulio, J. Devine)

BE (P. Elson, N. Mounet, M. Rognlien, V. Baggiolini, G. Azzopardi)

CMS (E. Dimovasili)

Many others.... Including world leading scientists in this domain [@Manuel Gameiro](#), [@ShellyMBoulder](#), [@linseymarr](#), [@iljcolorado](#), [@Lidia Morawska](#), [@Yuguo Li](#) ...

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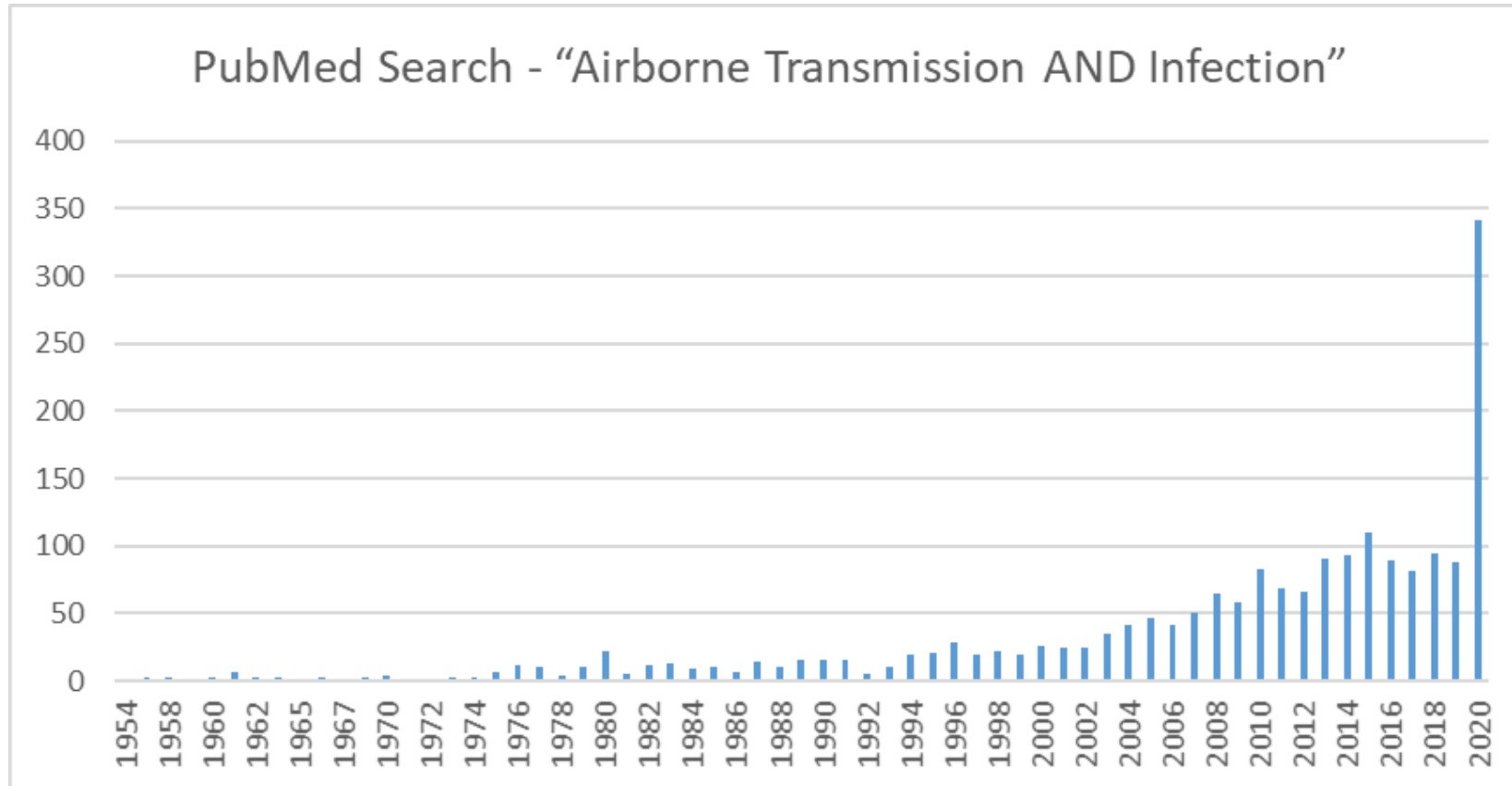
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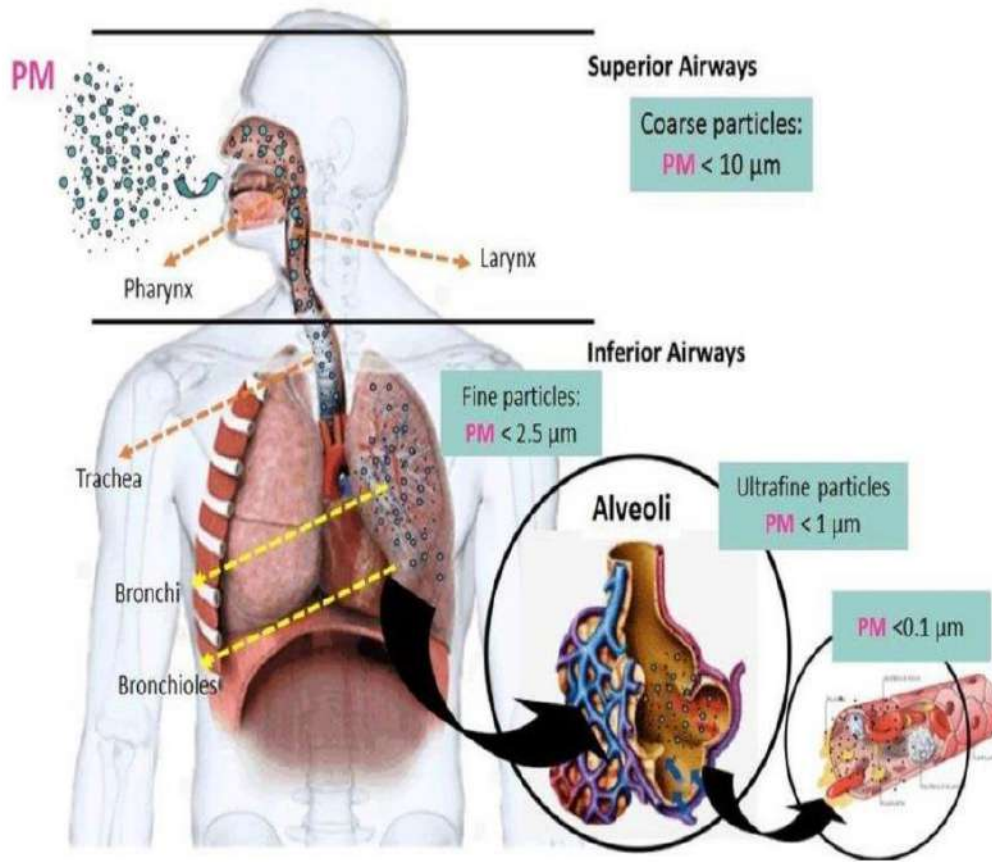
Spare slides



Publications on the topic



Airborne Particles – Human Airways



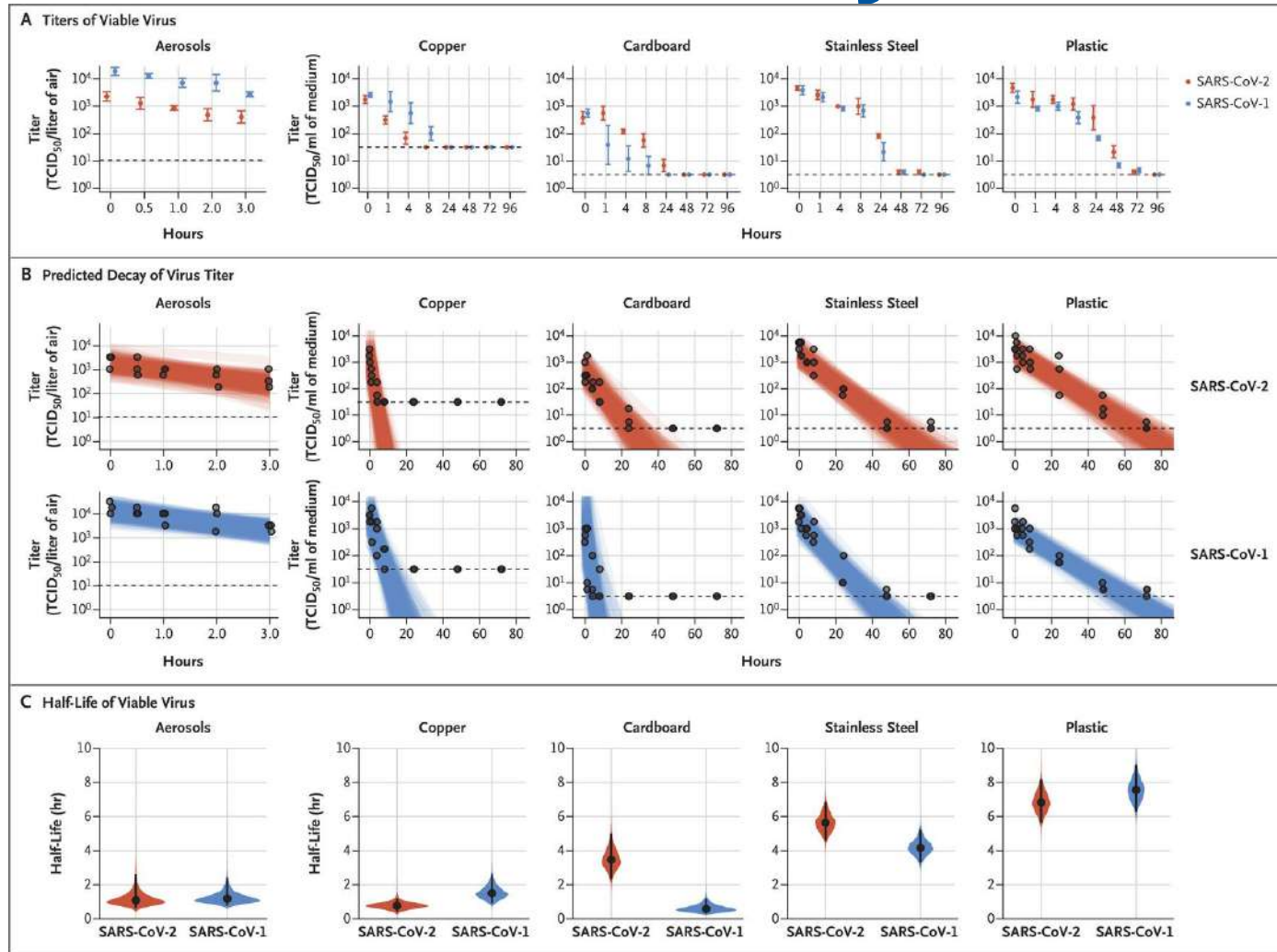
Diameter (μm)	Nível de Penetração	Classificação
> 7	Oral and Nasal Cavities	Inhalable
$4.7 - 7$	Larynx	
$3.3 - 4.7$	Trachea and Bronchi	Thoracics
$2.1 - 3.3$	Secondary Bronchioles	
$1.1 - 2.1$	Bronchioles	Breathable
$0.65 - 1.1$	Alveoli	

Smaller particles have a higher hazard index, can cause alveolar obstruction and impede respiratory function.

Courtesy of M. Gameiro da Silva [1]

$TCID_{50}$ is an endpoint dilution assay quantifying the amount of virus required to kill 50% of infected hosts (case cells)

SARS-CoV-2 viability



Decay from $10^{3.5}$ to $10^{2.7}$ in 3 h
Still 'active' after that time

Half-life in air
~ 1.2 h

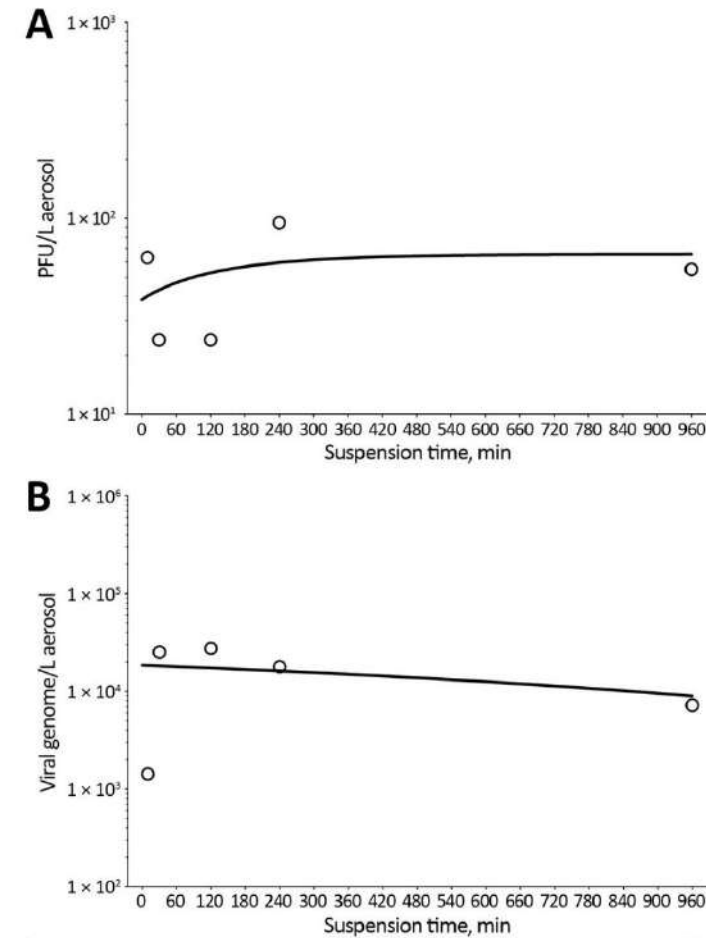
- Both SARS virus are similar in terms of viability
- Epidemiological differences probably arise from other factors: **high viral loads** in the upper respiratory tract; potential for persons infected with SARS-CoV-2 to **shed and transmit the virus while asymptomatic** [9]

Viability of SARS-CoV-1 and SARS-CoV-2 in Aerosols and on Various Surfaces [9]

SARS-CoV-2 viability

findings suggest retained infectivity and virion integrity for up **to 16 hours** in respirable-sized aerosols.

Figure 2



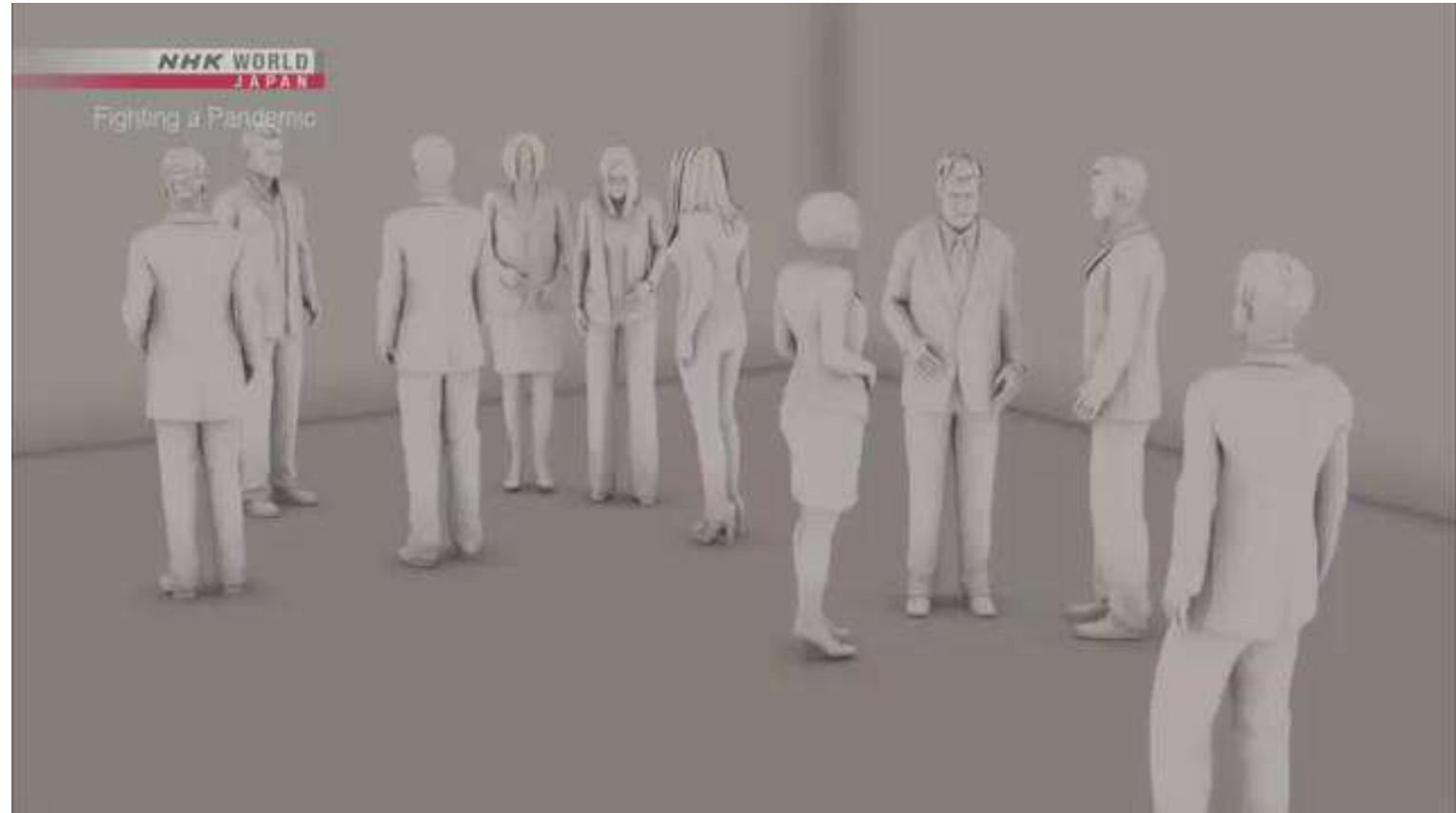
Airborne Transmission

NHK World Japan Documentary:
Fighting a Pandemic – Micro-droplets
<https://www.youtube.com/watch?v=H2azcn7MqOU>

Full:
<https://www3.nhk.or.jp/nhkworld/en/ondemand/video/5001289/>

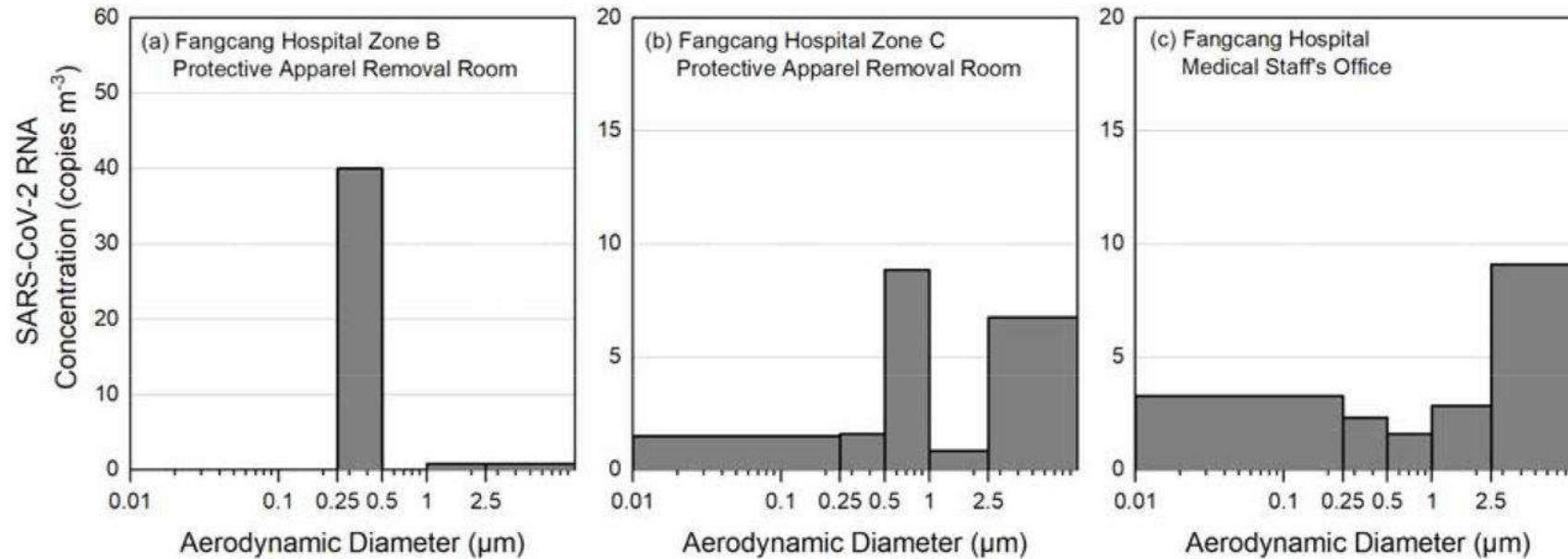
- 10 people – 1 coughs
- Poor ventilated area
- Micro-droplets spread after a cough

Micro-droplets: ~10 to 0.1 μm



Video

Airborne transmission in hospital

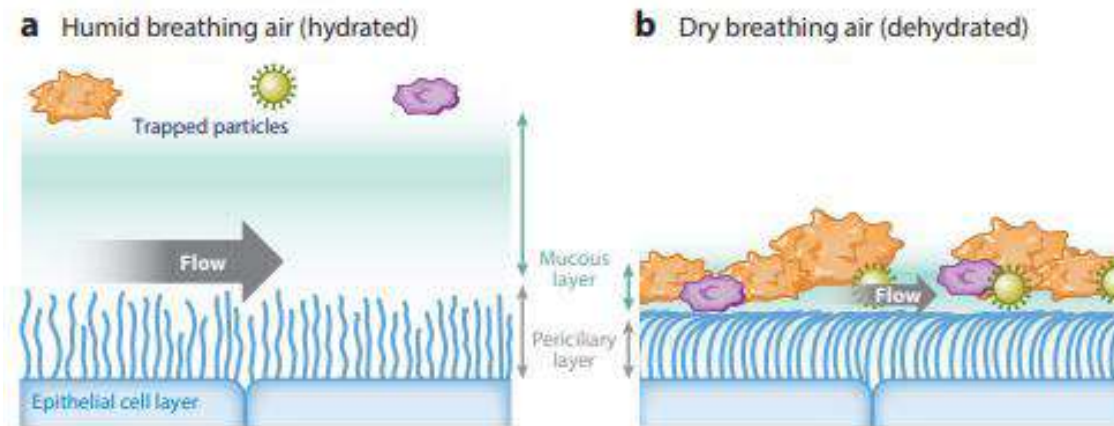


Concentration of airborne SARS-CoV-2 RNA in different aerosol sizes in two hospitals in Wuhan, China [24]

- The majority of viral RNA in air was associated with aerosols smaller than 2.5 μm [24]
- In patients' rooms the largest concentration was in a temporary toilet, 1 m² and without ventilation (19 copies m⁻³) [24]
- The levels were high enough in crowded public areas to **result in inhalation exposure to 1 copy of viral RNA in about 15 minutes** [24]

Increased infection during winter – why?

- Persons tend to stay inside more and avoid venting with cold outdoor air
- Due to low relative humidity of the air:
 - Increase dehydration / evaporation of droplets, i.e. smaller diameter droplets results in a larger amount of airborne droplet nuclei in a given volume (compared to summer)
 - Dry mucous layer in the respiratory tract, i.e. inability to protect against virus attaching to cells



Effect of dry air on mucociliary clearance

Mitigation measures – use of masks

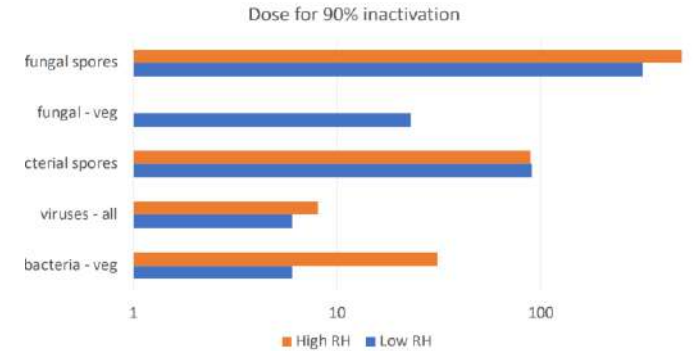
- The mask is very important to prevent the projection of large droplets
- Traces of micro-droplets released from the top part of the mask could be suspended in the air



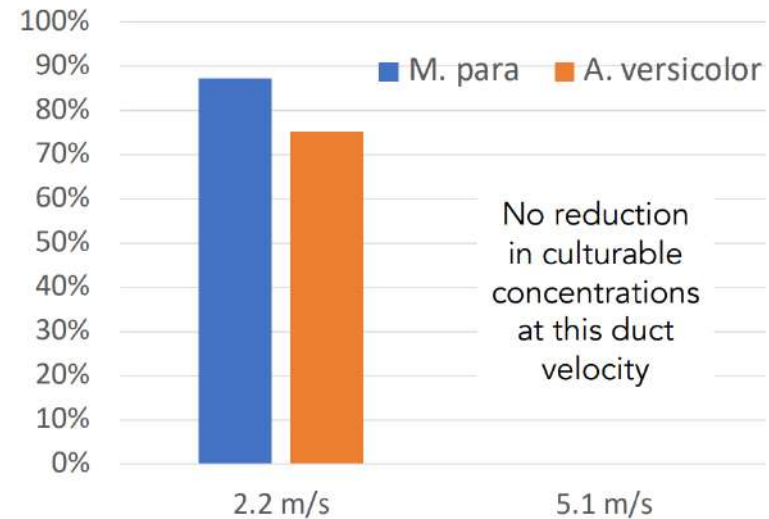
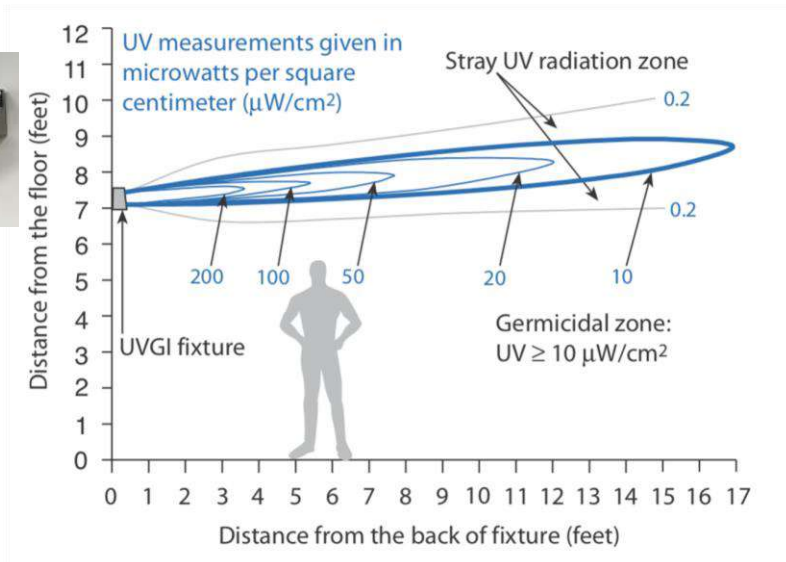
Videos: The importance of wearing a mask (to prevent the transmission of influenza)
Source: MHLWchannel - https://www.youtube.com/watch?v=9Mkb4TMT_Cc

UVC Disinfection

- Most efficient use of UVGI is for 'Upper-Room Air Disinfection' in crowded environments where unsuspected infectious persons may be present (e.g. jails, homeless shelters, hospital waiting rooms) [41]
- Useful where HVAC retrofits are difficult (e.g. hospital ERs, treatment and isolation rooms) [41]
- In-duct UV disinfection only efficient for small velocities [41]



Kowalski, W. 2010

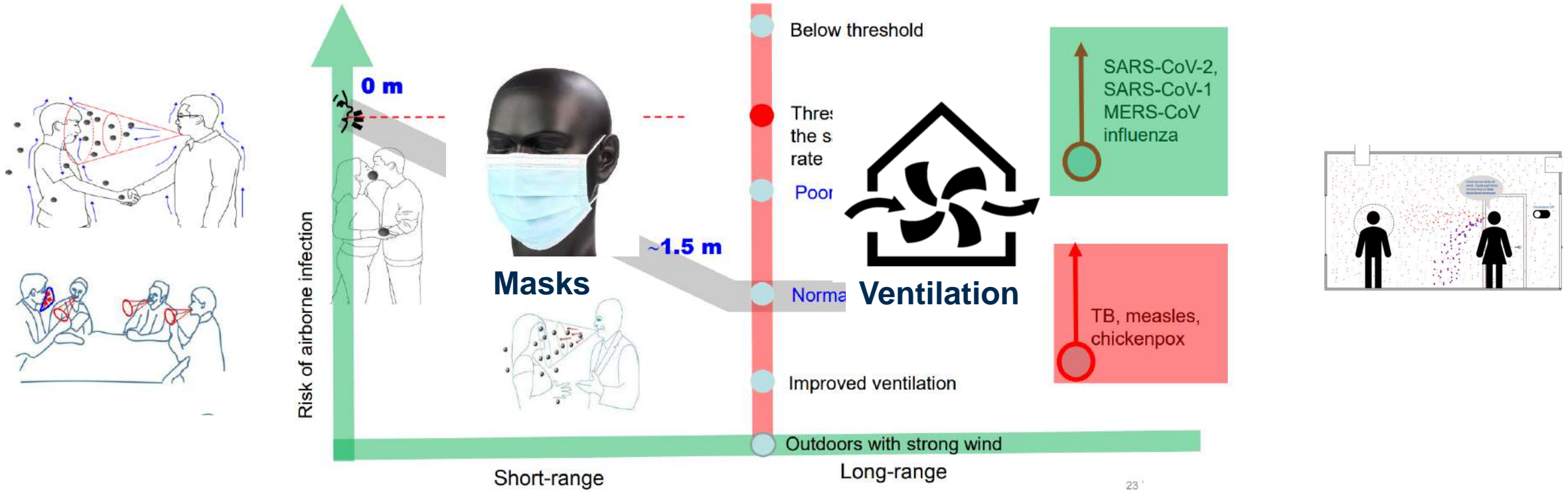


Prof. S. Miller. Germicidal Ultraviolet Light (Radiation) for Reducing Disease Transmission [41]

Effect of other modes of transmission

- Fomites (surface contamination):
 - WHO: no specific evidence [15]
 - CDC: possible but not major way [42]
 - Lipid-enveloped viruses don't survive long on human hands [43]
 - Hand-hygiene policies only led to a 16% reduction in acute respiratory infections [44]
- Large droplets
 - Never directly demonstrated for any disease [12]
 - Droplets need to be $\sim 300 \mu\text{m}$ to be efficient at reaching others, but very few of that size when talking [45]

Short and long-range airborne transmission

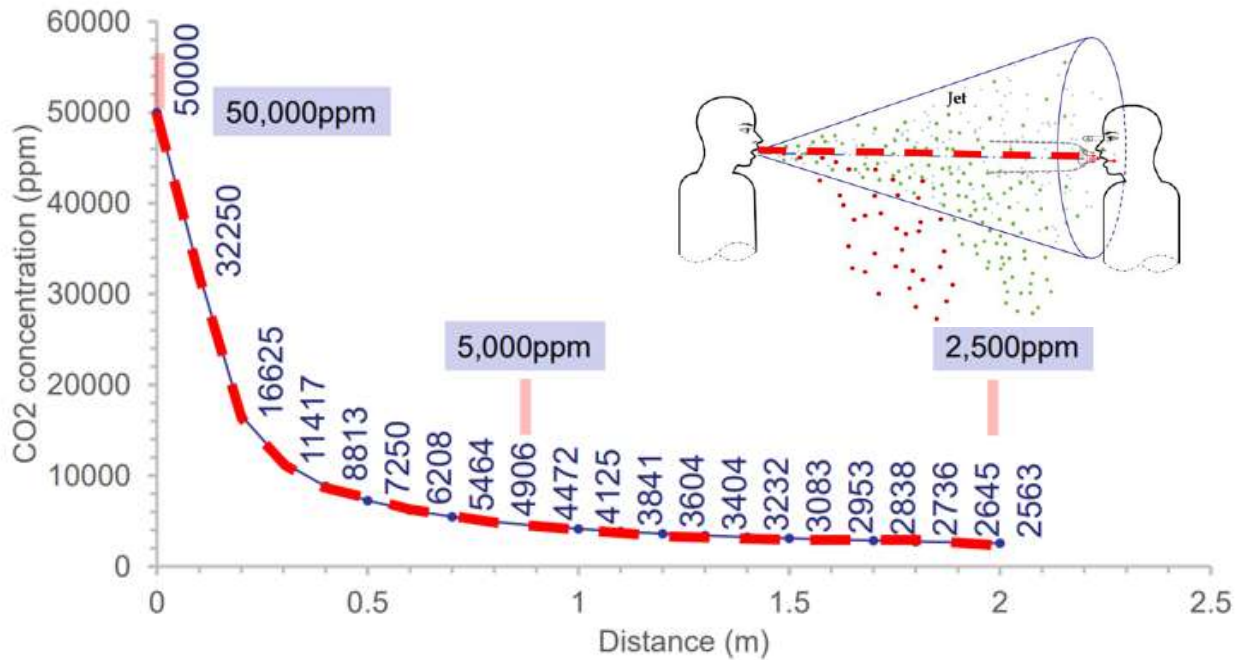


23

Li, Yuguo (2020). SARS-CoV-2 airborne transmission is opportunistic and ventilation works. University of Hong Kong. COVID-19 zoom conference. [33]

Importance of Distance

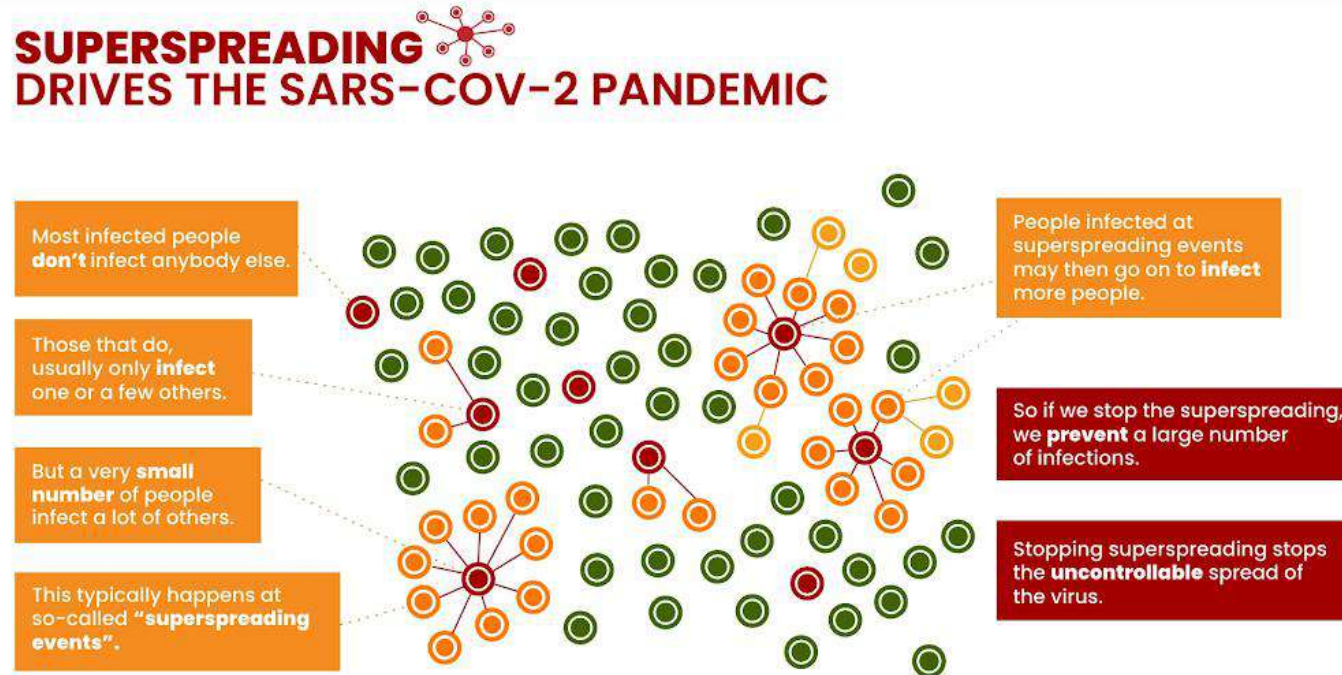
Use exhaled CO₂ as surrogate to exhaled viruses... (note: just to give an idea)
Only looking at aerosol transmission, not droplets !



- Dilution effect with the ambient air:
- Concentration **10x lower** at 1m
 - Concentration **20x lower** at 2m

Li, Yuguo (2020). SARS-CoV-2 airborne transmission is opportunistic and ventilation works. University of Hong Kong. COVID-19 zoom conference. [46]

Stop Superspreading to Stop Pandemic



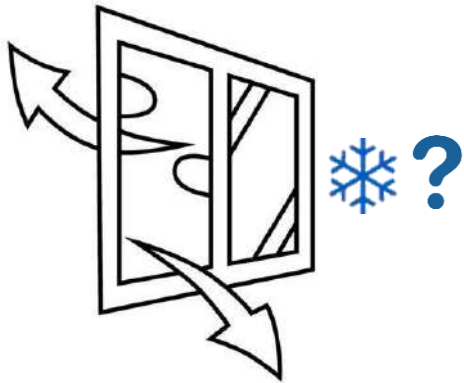
<https://www.stopsuperspread.com/p/infographic.html>

Video: <https://www.stopsuperspread.com/p/video.html>

CARA: Comparison – Summer vs Winter with periodic venting

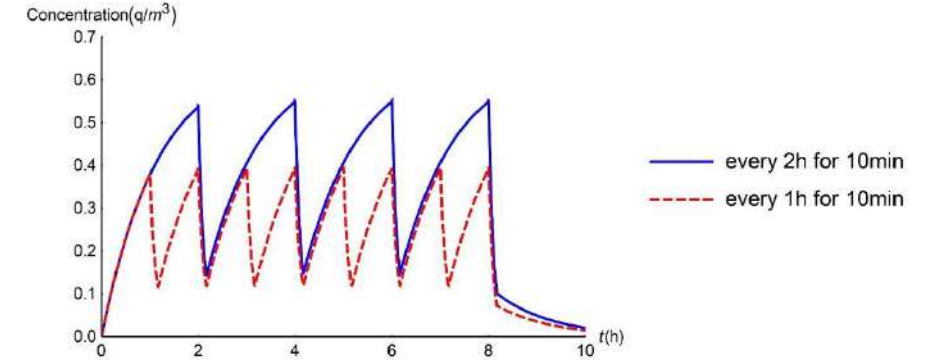
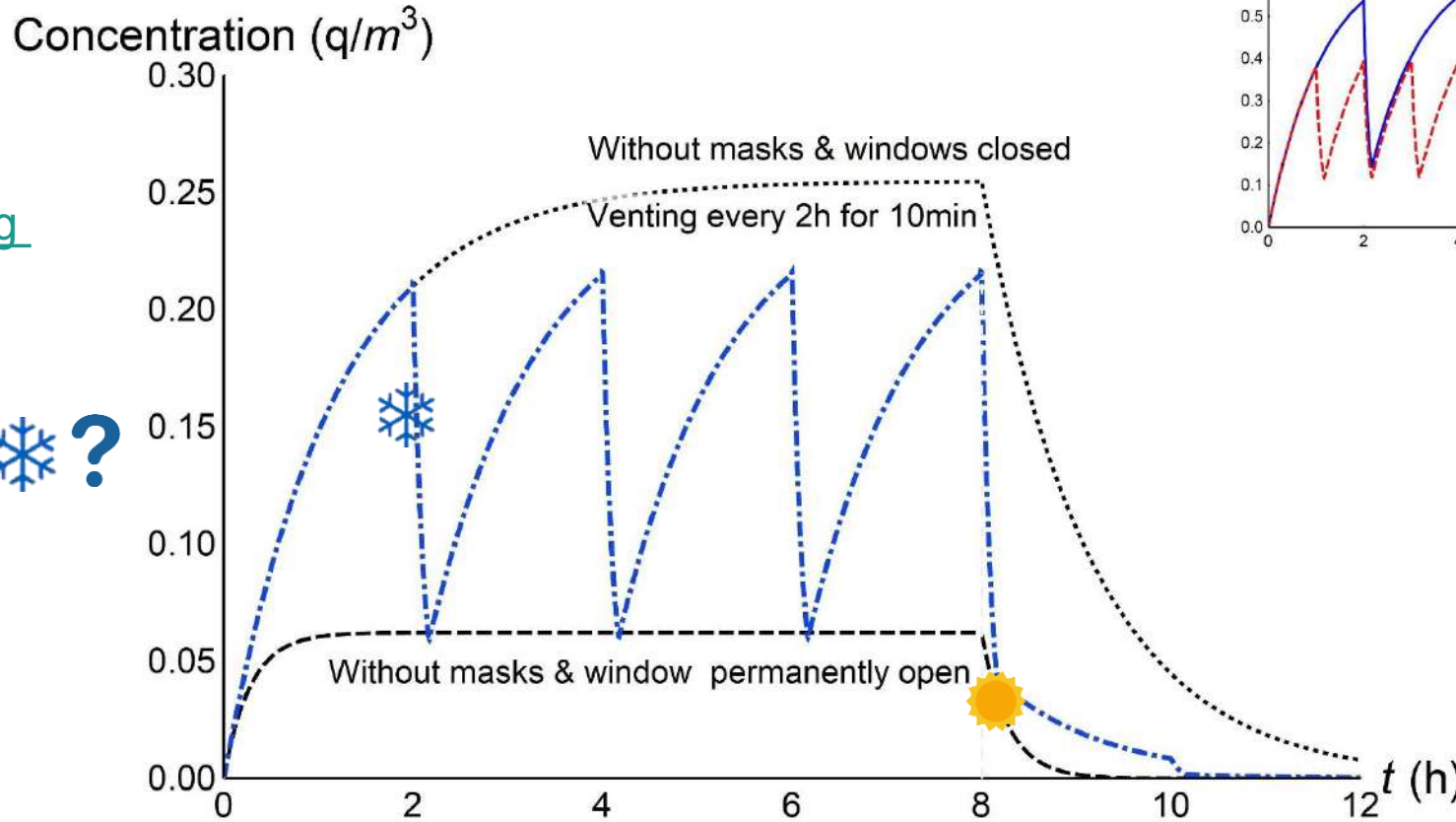
Values are representative for a certain office layout

Periodic opening



- 0.6 m opening $\Delta T = 2 K$
- 0.6 m opening $\Delta T = 20 K$

8h office exposure



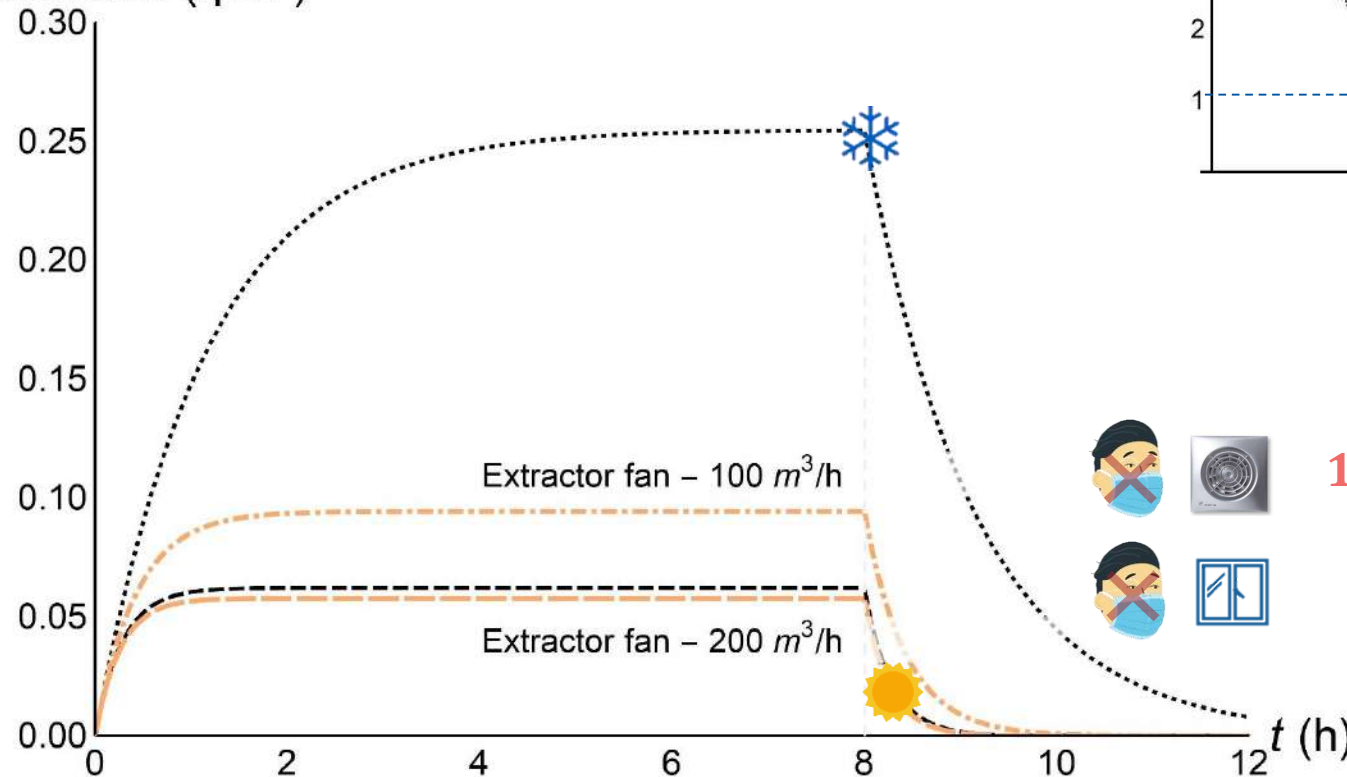
	R_0
	2.4
	1.9
	0.9

Alternative measures to the use of masks during winter

Values are representative for a certain office layout

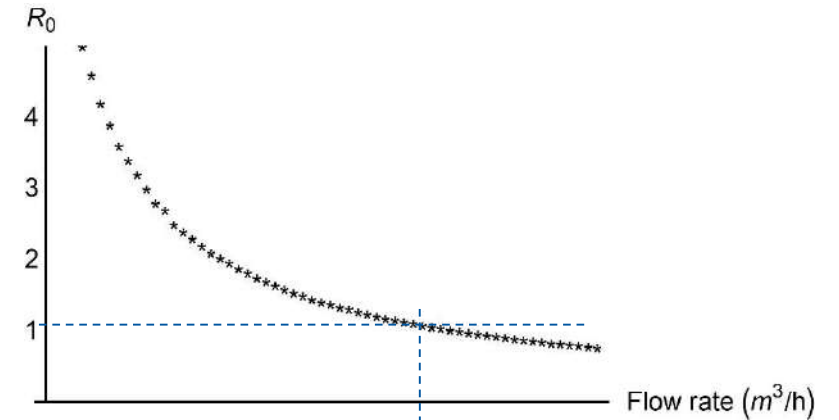
8h office exposure

Concentration (q/m^3)



Wall/Window-mounted
Extractor

100 m³/h;
200 m³/h





R_0

1.3 - 0.9

0.9



-  Without masks & windows closed
-  Without masks & windows permanently open

Wearing masks at all times ?

Values are representative for a certain office layout

Note: The concentration for the blue curve is higher, although the effect of the mask also impacts the amount of viruses inhaled by the exposed person. This is not reflected in the graph but in the R_0

Example: 8h office exposure

