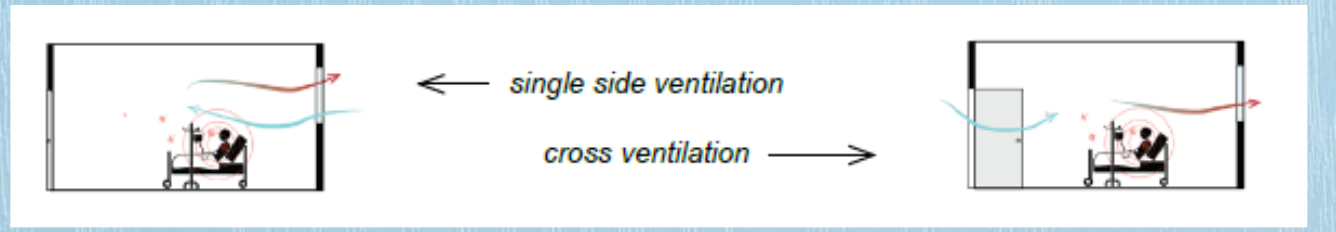
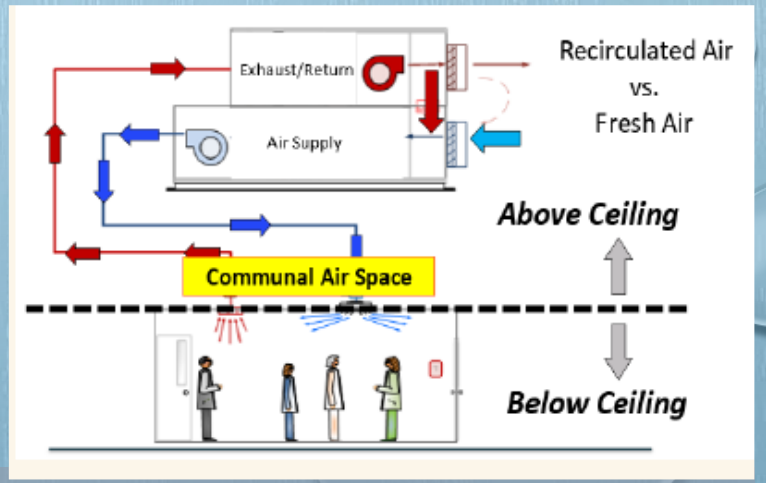
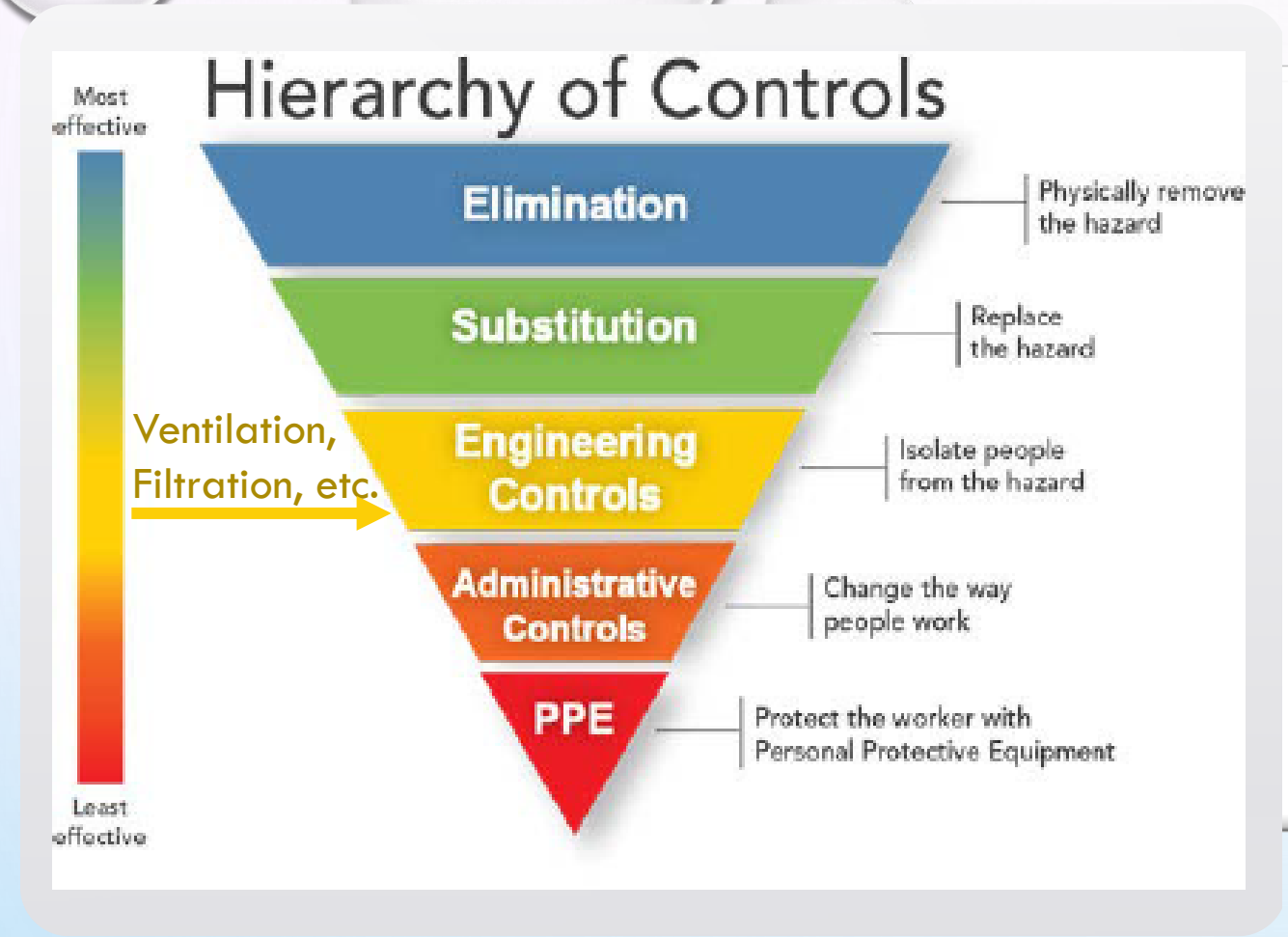


AIRBORNE PRECAUTIONS FOR SCHOOLS AND WORKPLACES

AIR QUALITY, VENTILATION AND ENGINEERING SOLUTIONS TO REDUCE AEROSOL TRANSMISSION OF SARS-COV-2



STÉPHANE BILODEAU, ENG., PHD, FELLOW OF ENGINEERS CANADA
COORDINATOR OF THE INDOOR AIR QUALITY GROUP
AND THE **DIY** AIR CLEANER TASK FORCE AT THE WHN
sbilodeau@th2b.com
@smbilodeau



VENTILATION IS PART OF THE FUNDAMENTALS OF THE HIERARCHY OF CONTROL

AND THAT APPLIES TO COVID RISKS MITIGATION IN SCHOOLS, HEALTHCARE AND OTHER WORKPLACES

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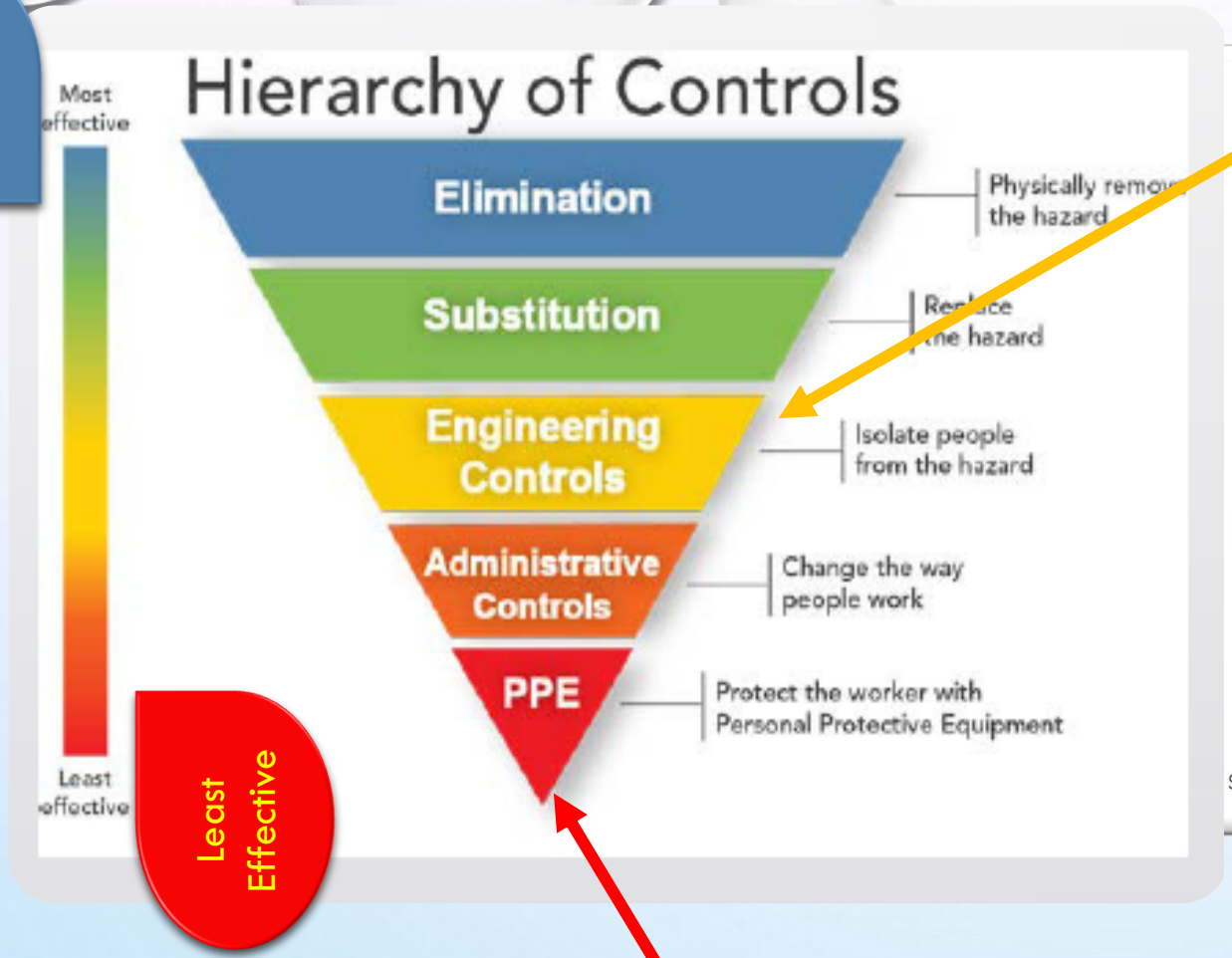
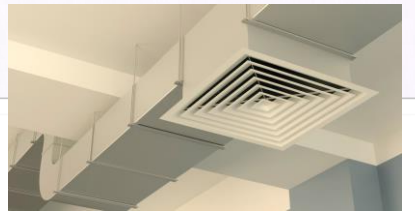
Most Effective



Least Effective

Ventilation
Filtration



FFP3 respirators protect healthcare workers against infection with SARS-CoV-2
https://www.authorea.com/users/421653/articles/527590-ffp3-respirators-protect-healthcare-workers-against-infection-with-sars-cov-2?commit=e567e67501cd6ee0dd1a6e8e4acdf2c4fd70e0ec

In Physics of Fluids (July 2021): *"While higher ventilation capacities are required to fully mitigate aerosol build-up, even relatively low air-change rates (2 ACH) lead to lower aerosol build-up compared to the best performing mask in an unventilated space."* https://aip.scitation.org/doi/pdf/10.1063/5.0057100

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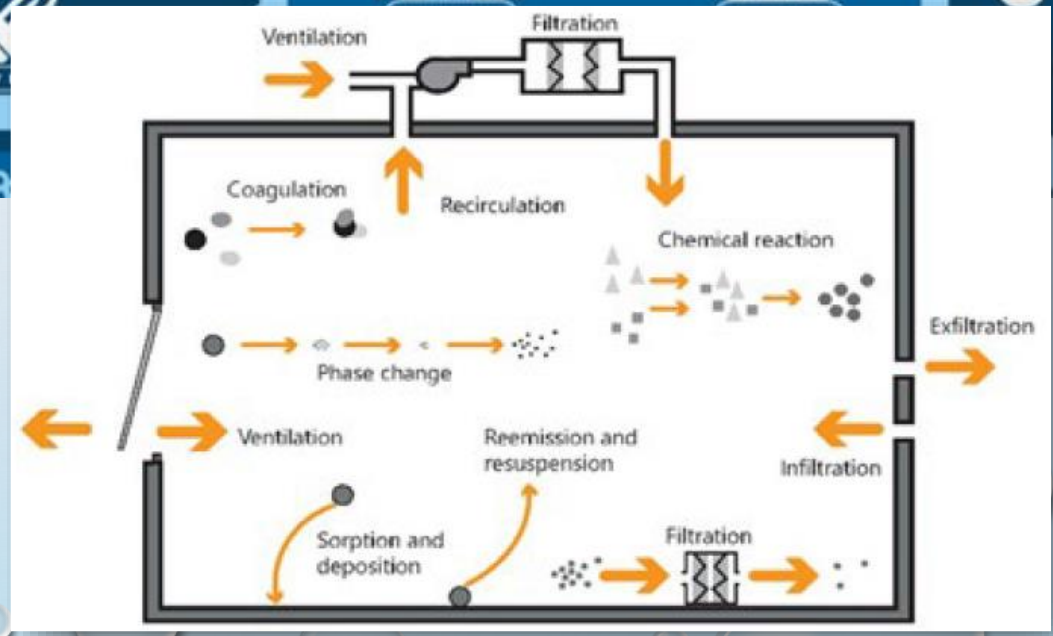
MANY PRACTICAL RECOMMENDATIONS EXISTS

ASHRAE EPIDEMIC TASK FORCE

Core Recommendations for Reducing Airborne Infectious Aerosol Exposure

https://www.ashrae.org/file%20library/technical%20resources/covid-19/core-recommendations-for-reducing-airborne-infectious-aerosol-exposure.pdf

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



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4 Practical recommendations for building services operation during an epidemic for infection risk reduction

MANY PRACTICAL RECOMMENDATIONS EXISTS

This REHVA guidance on building services operation covers 15 main items, as illustrated in Figure

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

REHVA Federation of European Heating, Ventilation and Air Conditioning Associations

https://www.rehva.eu/fileadmin/user_upload/REHVA_COVID-19_guidance_document_V4.1_15042021_01.pdf

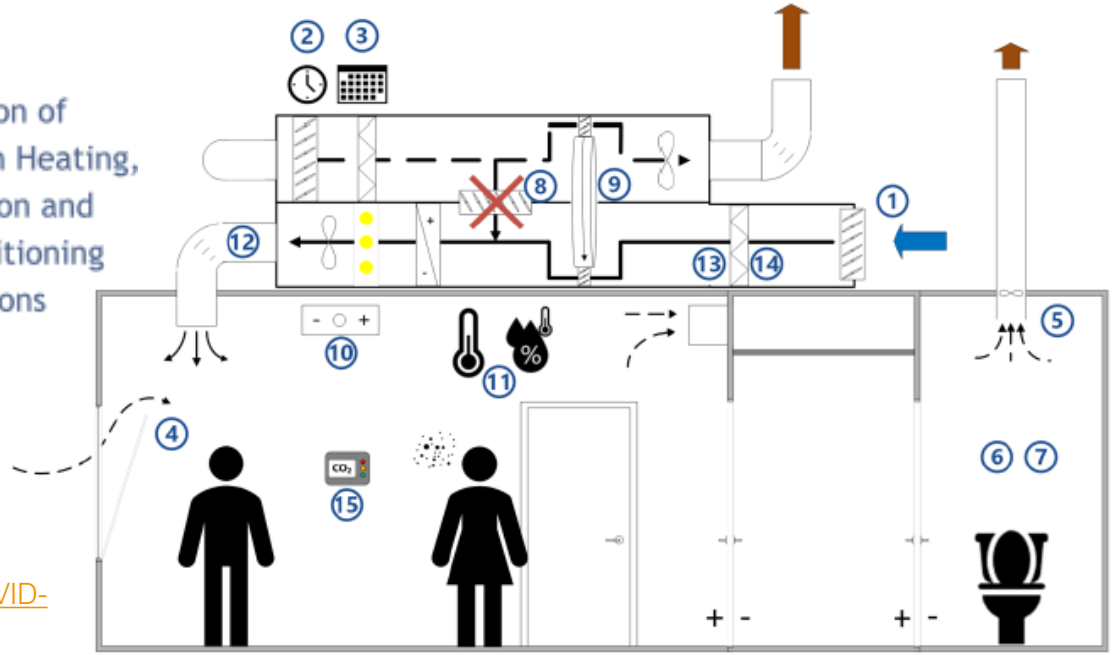


Figure 5. Main items of REHVA guidance for building services operation.

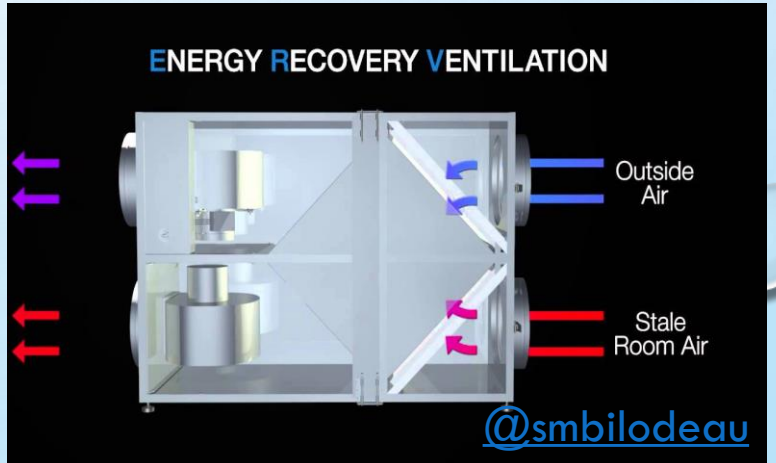
Massachusetts Institute of Technology

COVID-19 Indoor Safety Guideline

https://indoor-covid-safety.herokuapp.com/

Covid is Airborne

https://www.covidisairborne.org



- IMPORTANT ACHIEVEMENT BY THE OSPE:

SOME QUESTIONS (AND PARADIGMS) TO ADDRESS!

- THE BIG DROPLETS DOGMA – AEROSOL TRANPORT AND THE 15 MINUTES CASE…
- THE PLEXIGLASS
- THE AIR PURIFIERS
- WINDOWS OPENING

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AEROSOLS' TRANSPORT AND FLUID BEHAVIOR

FALL PATTERN OF LARGE AND SMALL PARTICLES

- THE SMALL DROPLET BEHAVIOR MEANS THEY HAVE MUCH HIGHER LIFETIMES THAN ISOLATED DROPLETS.
- IN FACT, 10 MM DROPLETS AT RH 50% AND 90% HAVE 60 TO 200 TIMES THE SURVIVAL TIMES OF THE WELLS VALUE. THESE MOVE SLOWER RELATED TO THE FLUID FLOW, AND SO SHRINK LESS DUE TO REDUCED CONVECTION AND EVAPORATION.

In 1934!

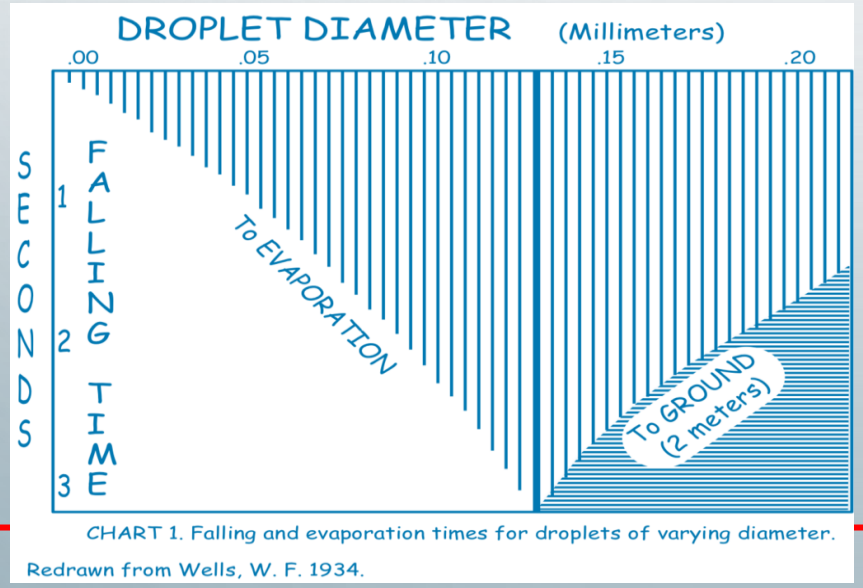
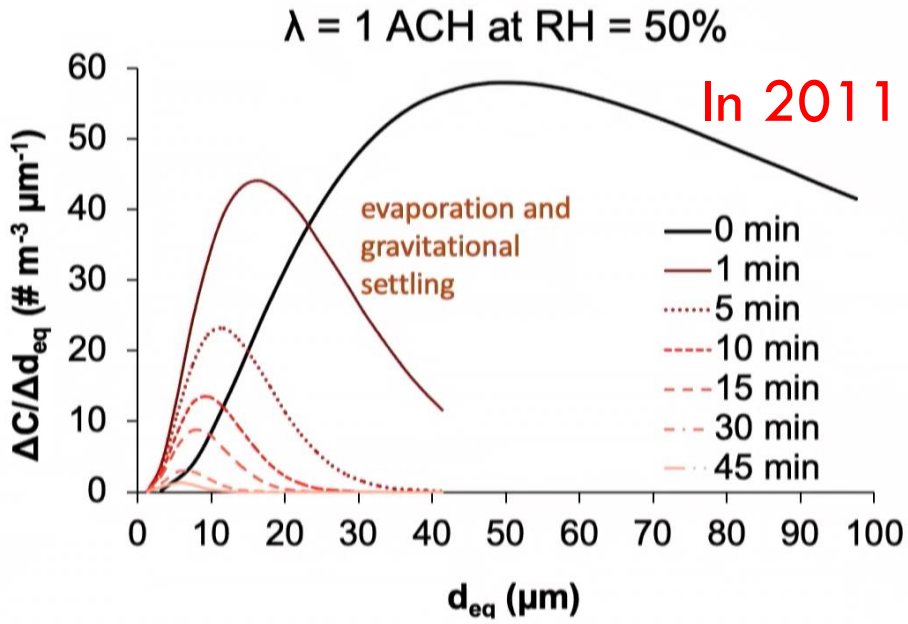


CHART 1. Falling and evaporation times for droplets of varying diameter.
Redrawn from Wells, W. F. 1934.

Dynamics of Virus in Air



There is a size shift due to loss of larger droplets by gravitational settling.

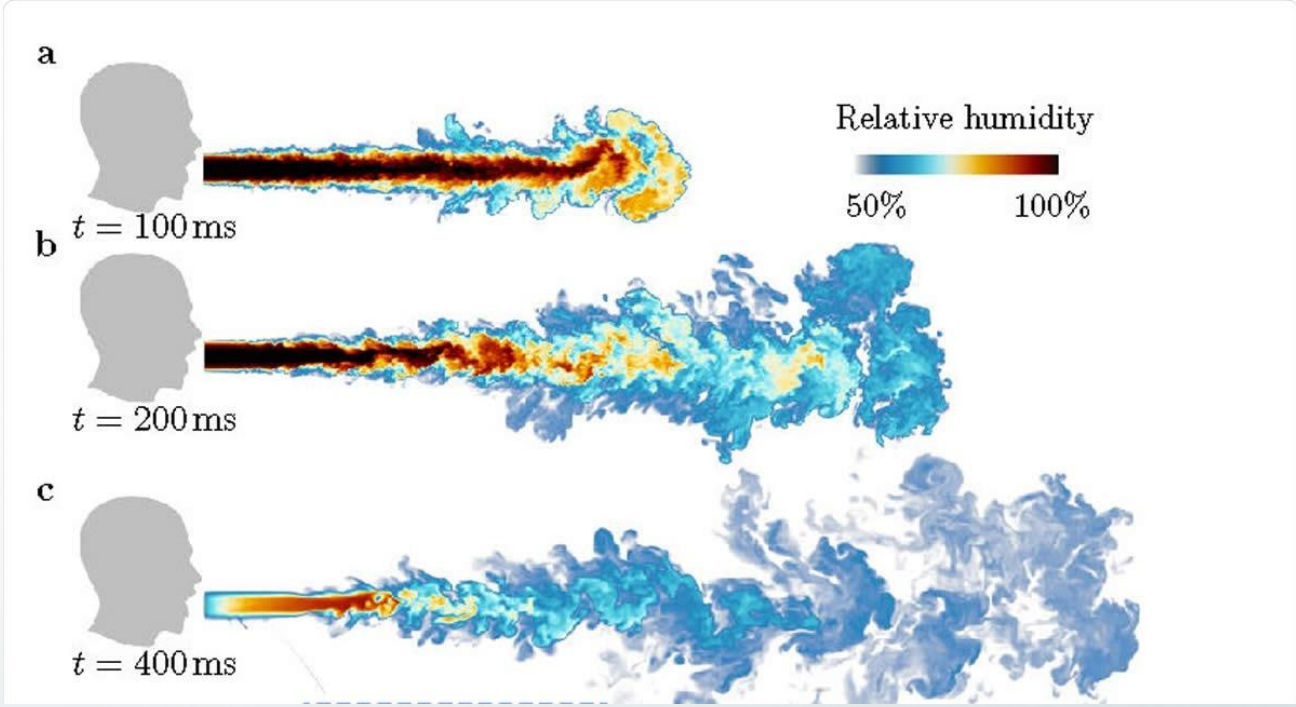
(1) Yang, W., Marr, L.C., 2011, Dynamics of airborne influenza A viruses indoors and dependence on humidity, *Plos One*

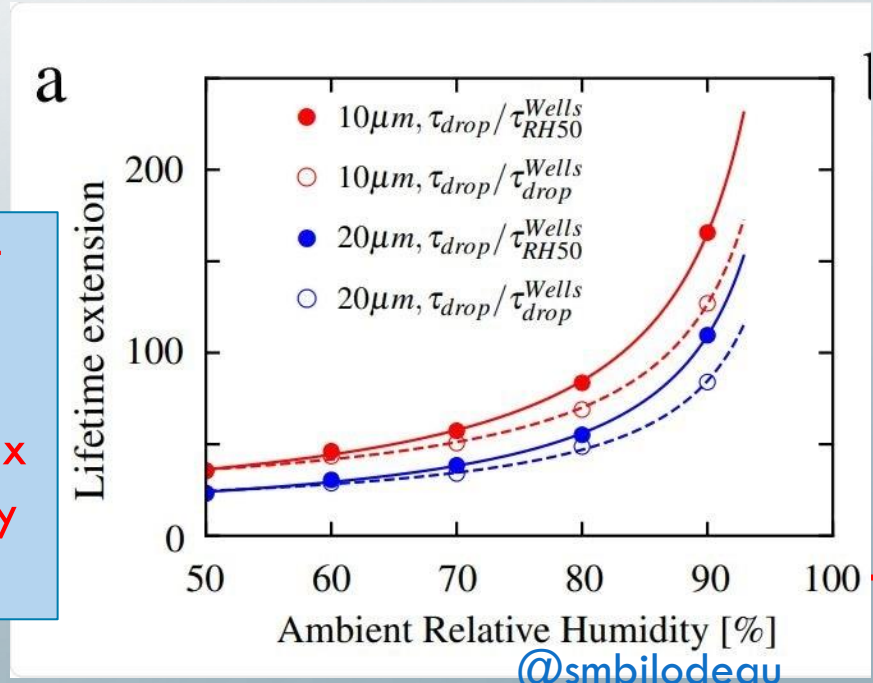
In 1934: With successive coughs, the puff may reach over 2 m from the source at the leading edge, with most of the smaller droplets being in humid surroundings and thus living longer.

AEROSOLS' TRANSPORT AND FLUID BEHAVIOR

Impact of conditions

This study deals with the accumulating nature of aerosols, which remains infectious indoors over hours and with the contribution of humidity.
Because of the immense difficulty in tracing the movement of thousands of tiny droplets in space and over time, while simultaneously keeping track of or adjusting the conditions such as flow rate, distribution width of the droplets, temperature, and relative humidity, the researchers chose to use numerical simulations instead.





« Floating » aerosols can last for long period of time and travel long distances.
P.S. The 15 min and/or 2m max are not making sense for many « aerosol-based » situation.

Extended lifetime of respiratory droplets in a turbulent vapou puff and its implications on airborne disease transmission
Kai Leong Chong, Chong Shen Ng, Naoki Hori, Rui Yang, Roberto Verzicco, Detlef Lohse
doi: https://doi.org/10.1101/2020.08.04.20168468
Now published in *Physical Review Letters* doi: 10.1103/physrevlett.126.034502

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PLEXIGLASS! SURELY NOT EVERYWHERE…

- RESEARCH AND ANALYSIS - **EMG: ROLE OF SCREENS AND BARRIERS IN MITIGATING COVID-19 TRANSMISSION, 1 JULY 2021,** PAPER PREPARED BY THE ENVIRONMENTAL MODELLING GROUP (EMG).

In a very large US study in classrooms: "desk screens are associated with an **increase** in COVID-19 risk"

Epidemiological Evidence for the Impact of Screens and Barriers

There are very few studies that consider the impact of screens and barriers on the risk of disease. A study looking at schools in Georgia, US suggested that the impact of distancing between desks and use of barriers have a very minimal effect compared to measures such as ventilation or masks (Gettings et al 2021). Analysis from a very large US online survey of self-reported school-based mitigations in the US suggests that desk screens are associated with an increase in COVID-19 risk (Lessler et al 2021). A small amount of data from the NHS suggests that screens placed between beds increased nosocomial transmission compared to increasing spacing between beds (HOCI/EMG paper).

Pre-pandemic, Bagherirad et al. (2014) reviewed a cluster of tuberculosis cases in a commercial office in Australia and noted cubicle dividers as one of the factors that may have contributed to transmission. Studies of other respiratory diseases suggest higher rates of transmission in open-plan offices, but do not comment specifically on screens and dividers (Zivich et al 2018, Richardson et al. 2017)

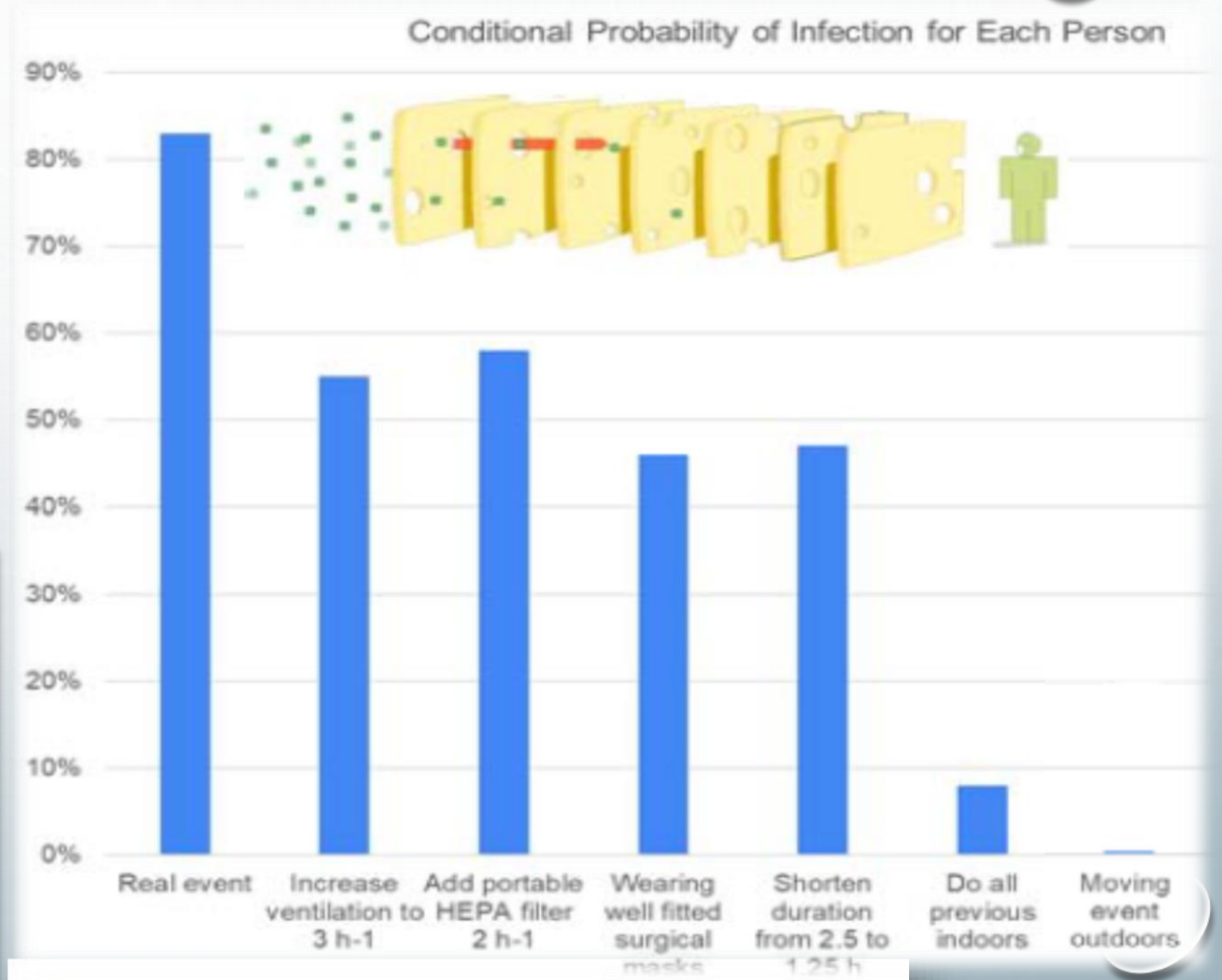
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1007489/S1321_EMG_Role_of_Screens_and_Barriers_in_Mitigating_COVID-19_transmission.pdf

WHAT IS THE VALUE OF AIR PURIFIERS?

- EFFECTIVENESS OF HEPA OR MERV 13+ FILTERS
  - MEASURED IMPACT OF HEPA FILTERS ON INFECTION RATES FOR DIFFERENT SYSTEMS FOR 2 ROOM CONFIGURATIONS (FROM THE SAGE-EMG NOVEMBER 2020 REPORT)
  - DIY OR COMMERCIAL: IMPORTANT TO HAVE GOOD FILTER(S) AND PROPER CAPACITIES

The best air purifiers (sometimes known as "air cleaners") help to eliminate dust, pollen, smoke and other irritants from the air, but a good air purifier could also go a long way towards eliminating dangerous airborne threats.

- The CDC says air purifiers "can help reduce airborne contaminants, including viruses, in a home or confined space."
- The EPA (Environmental Protection Agency) adds that air purifiers are helpful "when additional ventilation with outdoor air is not possible"



Calculated with:
https://tinyurl.com/covid-estimator
Swiss cheese graphic from Dr. Ian McKay

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Things to look at before more complex options:

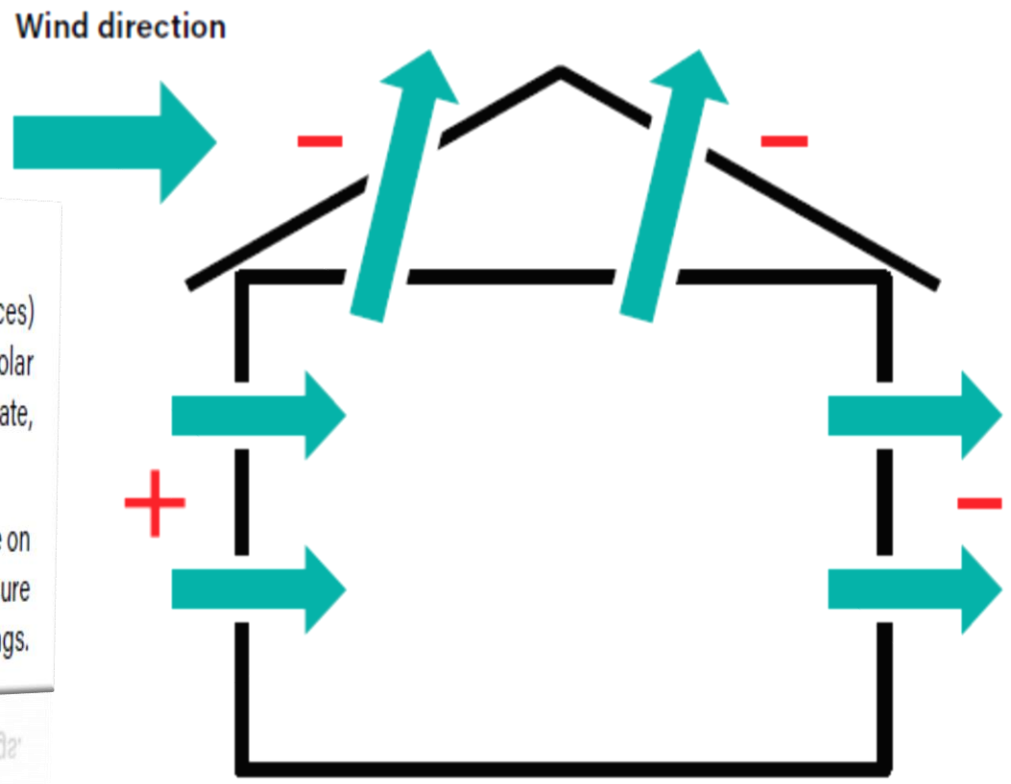
1. Increasing ventilation when possible (l/s)
2. Better control fresh air intake
3. Invest in CO2 monitoring
4. Improve Temperature and Humidity control
5. Think about Air Cleaner/HEPA filters
6. Open windows (last)

LIMITS TO WINDOWS' OPENING!

Natural ventilation

Natural forces (e.g. winds and thermal buoyancy force due to indoor and outdoor air density differences) drive outdoor air through purpose-built building envelope openings, such as windows, doors, solar chimneys, wind towers and trickle ventilators. This natural ventilation of buildings depends on climate, building design and human behaviour *(8)*.

When wind strikes a building, it induces a positive pressure on the windward face and negative pressure on the leeward face. This drives the air to flow through windward openings into the building to the low-pressure openings at the leeward face (Figure 5). It is possible to estimate the wind pressures for simple buildings.



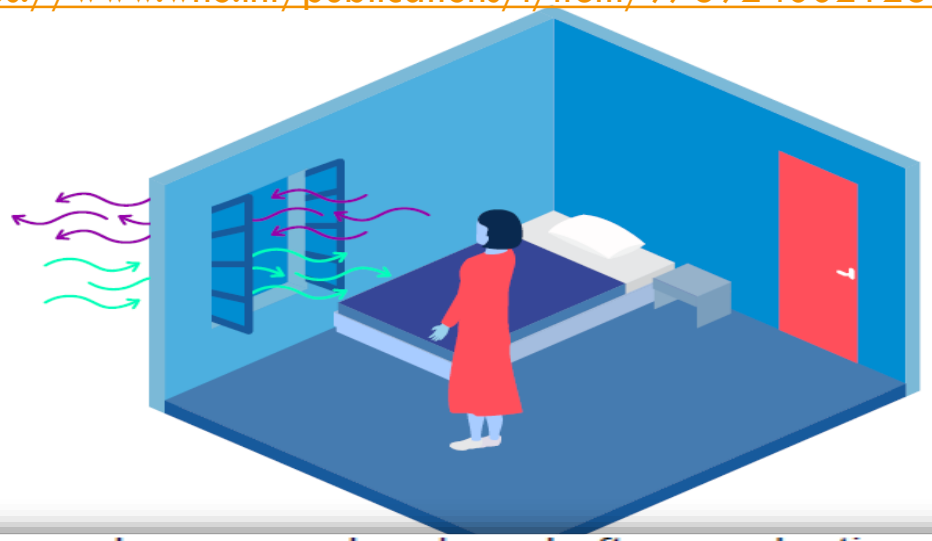
Source: Atkinson J, Chartier Y, Pessoa-Silva CL, Jensen P, Li Y. Natural ventilation for infection control in health-care settings. Geneva: World Health Organization; 2009.

Hint: If you need to open windows to ensure a minimum fresh air flowrate in the room, think of using bathroom or kitchen exhaust fans (as much as possible on the opposite side) to maximize aerosols and contaminants dilution.

A ROADMAP RATHER THAN A ONE-SIZE-FITS-ALL SOLUTION FOR A MORE COMPREHENSIVE SOLUTION TO INDOOR AIR QUALITY.

Roadmap to improve and ensure good indoor ventilation in the context of COVID-19

https://www.who.int/publications/i/item/9789240021280



The roadmap was developed after conducting a scoping review of the available literature and an assessment of the available guidance documents from the major internationally recognized authorities on building ventilation. The available evidence and guidance were retrieved, collated and assessed for any discrepancies by international expert members of the World Health Organization (WHO) Environment and Engineering Control Expert Advisory Panel

World Health Organization

Executive summary

Context

The risk of getting COVID-19 is higher in crowded and inadequately ventilated spaces where infected people spend long periods of time together in close proximity. These environments are where the virus appears to spread by respiratory droplets or aerosols more efficiently, so taking precautions is even more important.

Understanding and controlling building ventilation can improve the quality of the air we breathe and reduce the risk of indoor health concerns including prevent the virus that causes COVID-19 from spreading indoors.

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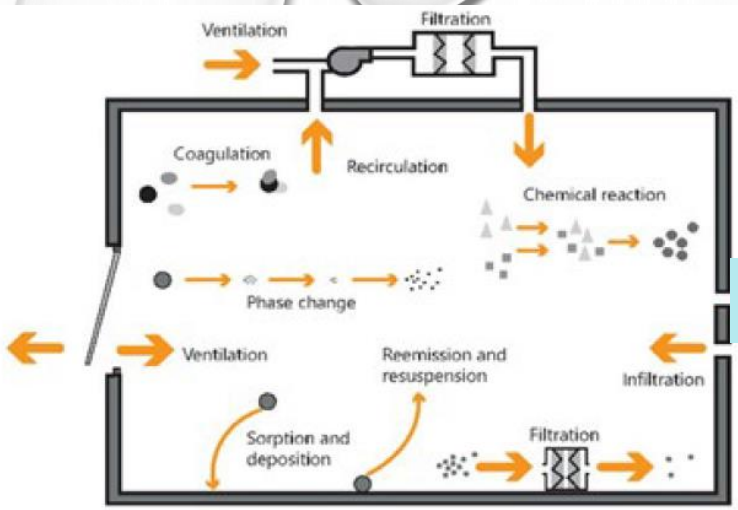

HOW TO IDENTIFY SOLUTIONS PROPERLY ADAPTED THE SITUATION?

A roadmap rather than a one-size-fits-all solution!

https://www.who.int/publications/i/item/9789240021280

Things to look at before more complex options:

1. Increasing ventilation when possible (l/s)
2. Better control fresh air intake
3. Invest in CO2 monitoring
4. Improve Temperature and Humidity control
5. Think about Air Cleaner/ HEPA or MERV13+ filters
6. Open windows (last)

With an Interdisciplinary Mindset: Facility Managers, Public Health, Occupational Health and Safety, with Engineering Support in a joint effort to implement solutions.

On top of the OSPE Recommendations and guidelines, some other notable guidelines and resources:

1) The **ACIGH** Ventilation for Industrial Settings during the COVID-19 Pandemic https://www.uwsp.edu/rmgt/Documents/ehs/COVID-19/ACGIH_White_Paper_on_Ventilation_for_Industrial_Settings_During_Covid-19_2020_08.pdf
2) The "Ventilation and air conditioning during the coronavirus (COVID-19) pandemic" by the **UK Health & Safety Executive** (HSE) group https://www.hse.gov.uk/coronavirus/equipment-and-machinery/air-conditioning-and-ventilation/assesssment-of-fresh-air.htm
3) The **ASHRAE** guide from their "ASHRAE Epidemic Task Force" https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-covid19-infographic-.pdf