RESPIRATORY PATHOGENS : PAST, PRESENT AND FUTURE

HSE SEMINAR

Come find out more about respiratory pathogens, with lessons learned from COVID-19 and practical insights into how to better manage future pandemics.

16 November 2022
2.00 pm – 4.00 pm
Council Chamber

With:
Julian Tang (Clinical Virologist, Honorary Associate Professor, University of Leicester)
Luca Fontana (Toxicologist, Technical Officer, WHO)
Romain Guichard (Engineer, Head of Aeraulic lab, INRS)

https://indico.cern.ch/event/1192997/

HSE
Occupational Health & Safety and Environmental Protection unit

Impact of COVID on workplace health & safety

Importance of **ventilation** and lessons learnt

Romain GUICHARD

Head of Aeraulic Engineering lab (IA)

National Institute of Research and Safety (INRS)

Our job:
making yours safer

Outline

- The INRS and the Aeraulic lab in brief
- Importance of ventilation in the workplace
- Assessing current airflow rates
- Estimating required airflow rates
- Preventing future pandemics: an opportunity to seize

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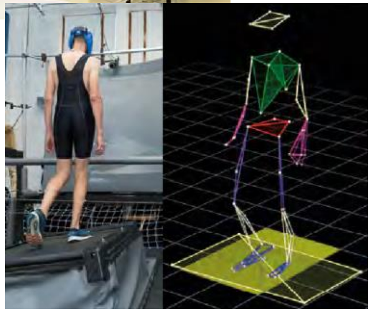
The INRS in brief

- Missions
  - To contribute to the prevention of occupational accidents and diseases through assistance, research and studies, training and information activities
    - > **identify** occupational risks and **highlight** hazards
    - > **analyze** their impact on health and safety at work
    - > **develop and promote** the means to control these risks out in the companies

- Scope
  - Biological risks
  - Chemical risks
  - Physical and mechanical risks
  - Risks related to organization and work situations



The Aeraulic lab in brief

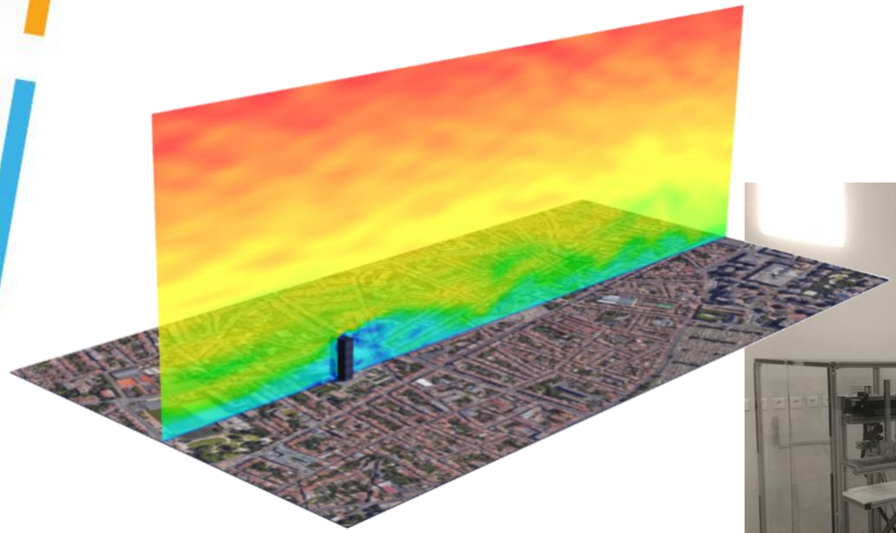
- Preventing **chemical** and **biological** risks
  - Using ventilation: source capture, enclosed areas, general ventilation
  - For various pollutants: welding fumes, asbestos fibers, wood dusts, VOCs, ammoniac, aerosols containing viruses, etc.

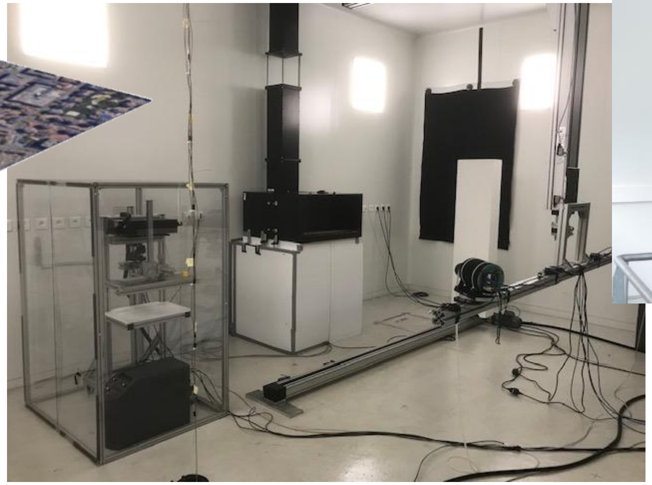
Fabrice Dimier

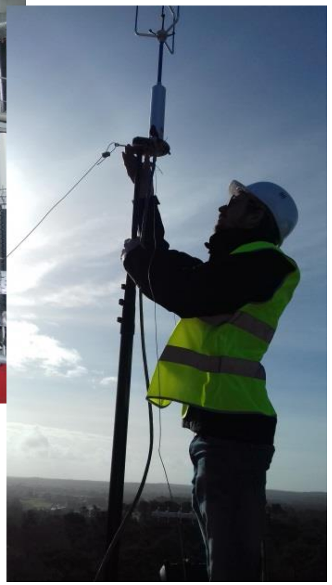
- Preventing exposure to **hot** and **cold** temperatures

The Aeraulic lab in brief

- Technical tools
  - Wind tunnel / velocimetry measurements (PIV, LDA, etc.)
  - Particles / nanoparticles and gas measurements (SMPS, PTR-TOF-MS, etc.)
  - Computational Fluid Dynamics (RANS, LES, etc.)
  - Experimental ventilated rooms and site measurements







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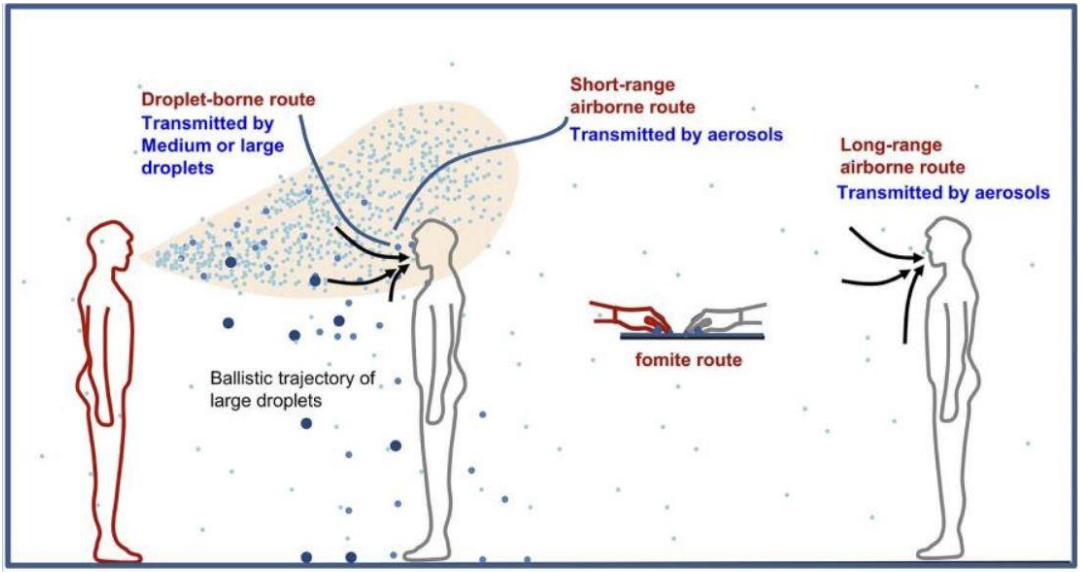
Importance of ventilation in the workplace

- Applying a prevention approach to airborne diseases transmission
  - Source elimination: limited in time and not applicable to everyone (lockdown, distance)
  - Source reduction: masks - with similar limitations - and personal hygiene
  - Source capture: not applicable
  - Collective protection: contaminant dilution using general ventilation
  - Personal protection: N95 respirators, vaccination, etc.



Wei et al, 2016

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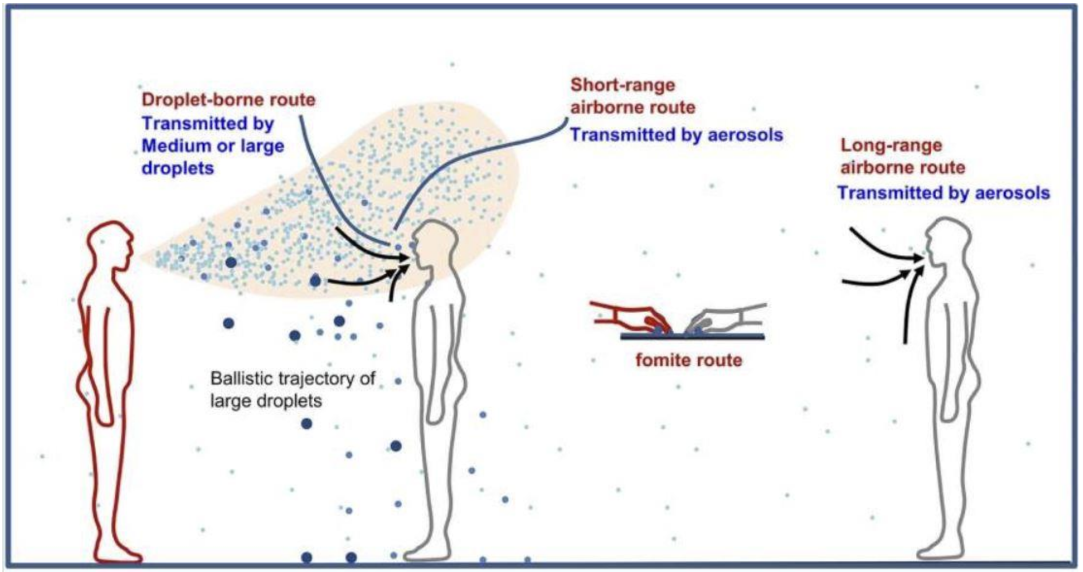

Wei et al, 2016

Importance of ventilation in the workplace

- Indoor transmission is 19x higher than outdoor transmission Bulfone et al., 2021
  - → Trying to create outdoor conditions by supplying outdoor air into indoor environ.

  - → Dilution of contaminants to avoid indoor accumulation over time
  - → Question: which airflow rate is relevant ? Assessing current airflow rates

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Assessing current airflow rates

- The French case
  - 25 m³/h of fresh air <u>per occupant</u> for an office room
  - Defined <u>in 1985</u> based on the assumption that a CO_2 concentration of 1000 ppm is an indicator of a good indoor air quality (to be discussed)

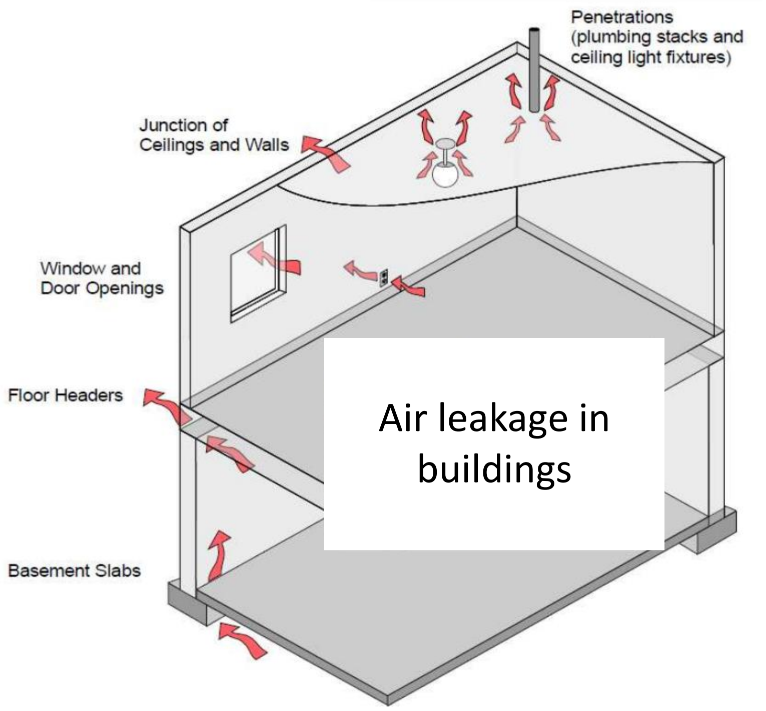
16,2 L/h

$$Q_{fresh\ air} = \frac{Q_{expired\ air} \cdot C_{expired\ air}}{C_{target} - C_{outside}}$$

23 m³/h

1000 ppm

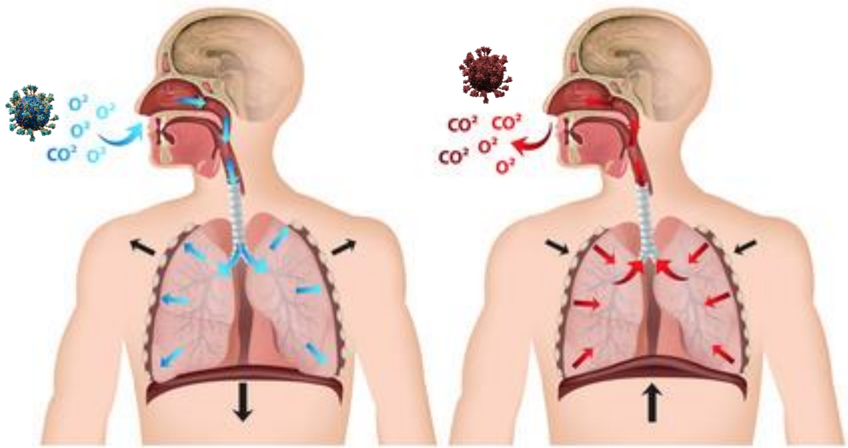
300 ppm



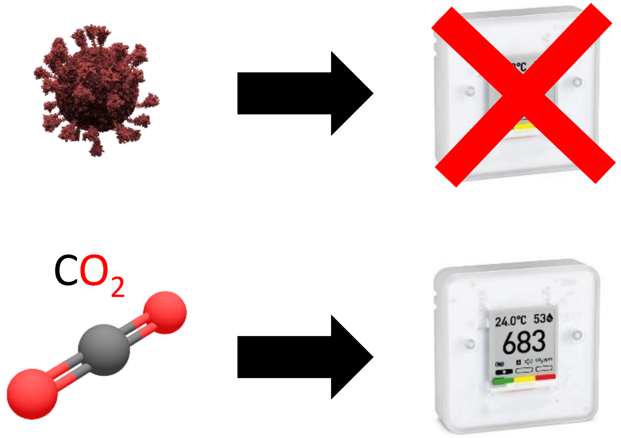
Air leakage in buildings

Assessing current airflow rates

- Why use the CO_2 concentration ?
  - Produced by human expiration, like potentially contaminated fine aerosols
  - Can be diluted by fresh air, with the limit of outdoor concentration
  - → Same source location and close physical behavior in the air
  - Can be "easily" measured in real-time thanks to NDIR sensors



Inhalation Exhalation



Assessing current airflow rates

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Rudnick and Milton, 2003

Risk of indoor airborne infection transmission estimated from carbon dioxide concentration

(2003 - not new !)

Practical Implications
The likelihood of airborne transmission of infection indoors can be estimated using continuous CO_2 measurements and the risk equation developed in this paper without assuming that the concentration of an infectious agent has reached steady-state and without measuring the outdoor air supply rate or assuming that it remains constant over time.

Assessing current airflow rates

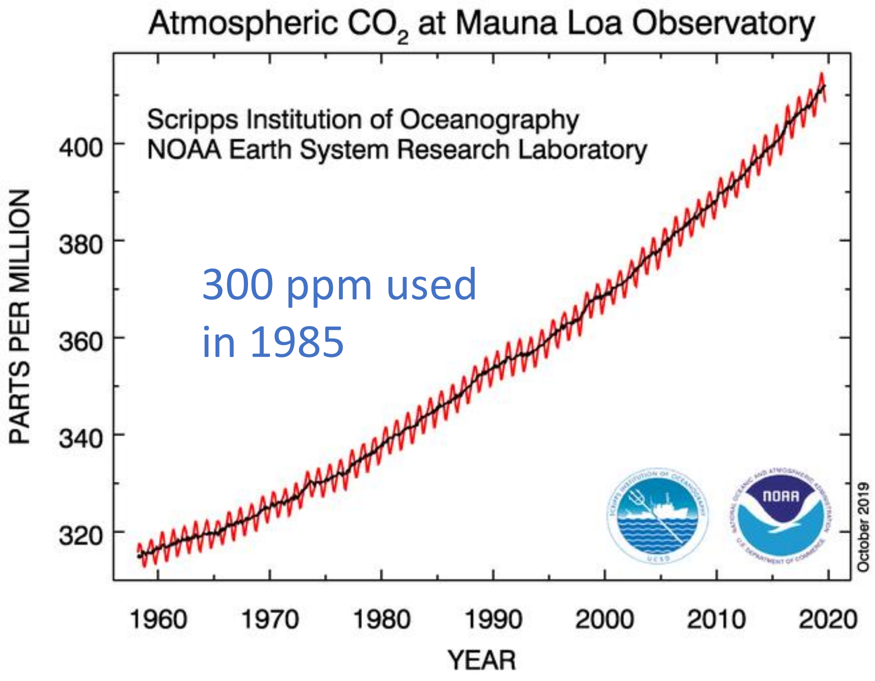
- The French case
  - 25 m³/h of fresh air <u>per occupant</u> for an office room
  - Defined <u>in 1985</u> based on the assumption that a CO_2 concentration of 1000 ppm is an indicator of a good indoor air quality (to be discussed)

Gids and Wouters, 2010

An office worker expires about 20,2 L/h of CO_2

16,2 L/h used in 1985

Moujalled et al., AIVC 2017



Assessing current airflow rates

- The French case
  - 25 m³/h of fresh air per occupant for an office room
  - Defined in 1985 based on the assumption that a CO_2 concentration of 1000 ppm is an indicator of a good indoor air quality (to be discussed)

  - Updating calculation with 2022 values

20,2 L/h

$$Q_{fresh\ air} = \frac{Q_{expired\ air} \cdot C_{expired\ air}}{C_{target} - C_{outside}}$$

34 m³/h

1000 ppm

400 ppm

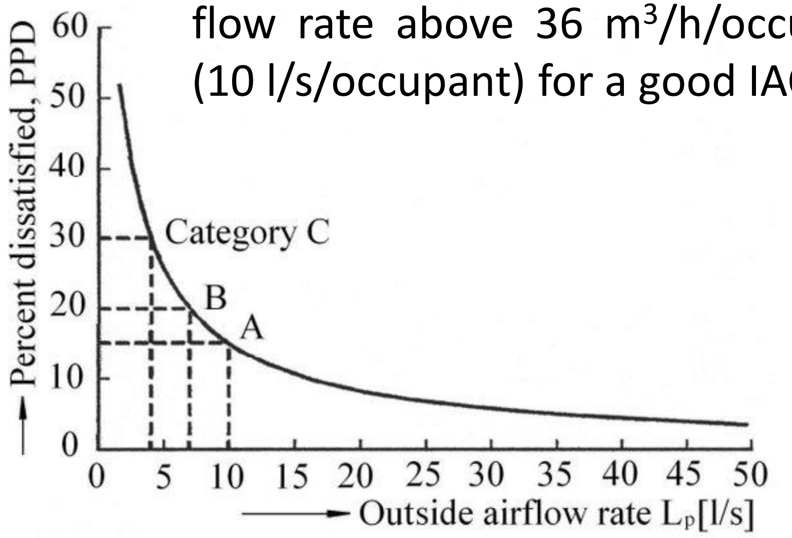
Assessing current airflow rates

- An European investigation made in 2013 (The HealthVent Project)

Country	Flow rate [m³/h/occupant]
Germany	90 (72 ?)
Hungary	90
Finland	65
Portugal	60
Slovenia	53
Czech Republic	50
Norway	50
The Netherlands	43
Italy	40
Bulgaria	36
Lithuania	36
United Kingdom	36
France	25
Greece	25
Romania	25
Poland	20

Many studies and standards justify a flow rate above 36 m^3/h/occupant (10 l/s/occupant) for a good IAQ

Eini et al, 2021



Updated France value (34)
Found Switzerland value (36)

Assessing current airflow rates

- Partial conclusions
  - Current air flowrates imposed in regulation **should be updated**, even out of a pandemic situation
    > First step before trying to change regulation: updating standards
  - CO_2 concentration is a **practical indicator** which can be useful to know if fresh air supply is relevant regarding to room occupation
  - The indicator is **independent of ventilation means** (windows / doors opening - natural ventilation - mechanical ventilation)
  - A value of **36 m^3/h/occupant** corresponds to a minimal value for a good Indoor Air Quality (IAQ), equivalent to a CO_2 concentration of 1000 ppm

- Shall we change current airflow rates in case of pandemic ?
  - Estimating airflow rates required to significantly reduce airborne diseases transmission

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Estimating required airflow rates

- Estimations and feedback related to airborne transmission
  - Wells-Riley equation used significantly in the literature, or other approaches based on the evaluation of biological risk
    - > Wells-Riley equation

$$C = S\left[1 - \exp\left(\frac{-Iqpt}{Q}\right)\right]$$

C = new infections
S = number of susceptibles
I = number of infectors
q = number of infectious doses
p = pulmonary ventilation rate
t = exposure time
Q = fresh airflow rate

    - > Tools like CAiMIRA

  - Reported cases used for validation (bias: often superspreading / maximizing events)
    - > Skagit Valley Chorale (COVID)
    - > Restaurant in China (COVID)
    - > Bus ride in China (COVID)

Estimating required airflow rates

- Estimations and feedback related to airborne transmission
  - Another example with tuberculosis (infectious disease caused by a bacterium)
    - > Taipei University: 27 initial cases → 1665 contaminated cases
    - > CO_2 concentration peaks above 3200 ppm (poor ventilation)
    - > CO_2 concentration reduced to 600 ppm (highly improved ventilation)
    - > Second reported cases wave → 0 contaminated case
    - > Multifactorial analysis: contribution of improved ventilation at 97 %

Du et al, 2019

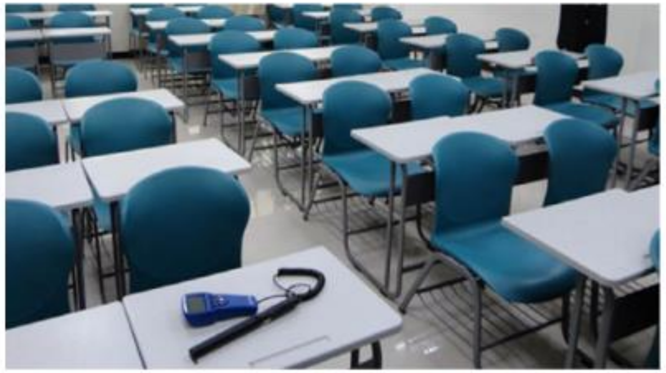
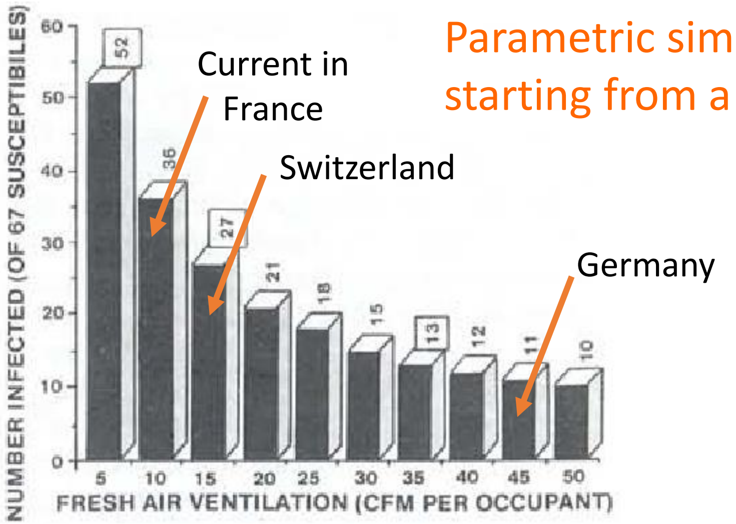


FIGURE 2 One of the crowded and poorly ventilated 56-seat underground classrooms, where the index case had attended class, with a carbon dioxide level up to 2936 parts per million (ppm) at peak hours (the photograph was taken after the students have left)

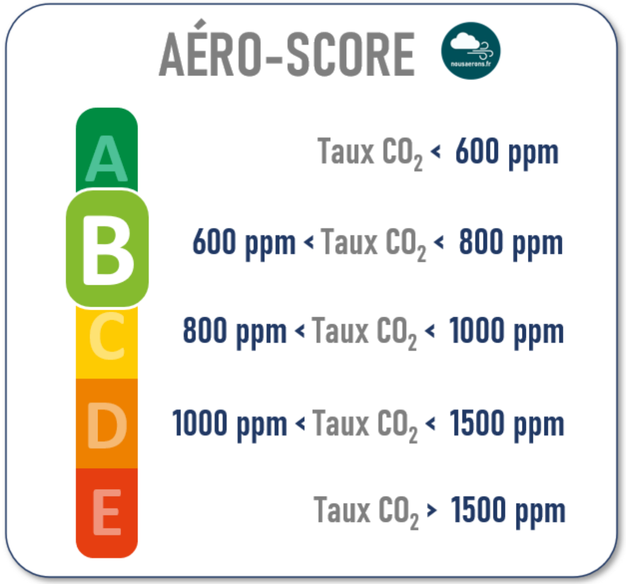
Nardell et al, 1991

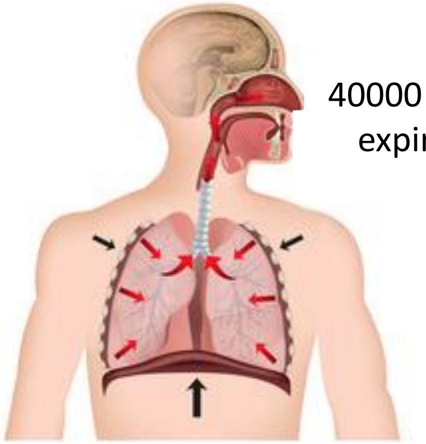


Parametric simulations starting from a real case

Estimating required airflow rates

- Towards a consensus around 800 ppm (or a 400 ppm increase)
  - For both prevention of COVID transmission and a better IAQ
  - Update of standard NF X 35-102 “Ergonomic design of office workspaces” in 2022
    - > The air supply guarantees, in normal conditions, an increase of indoor CO_2 concentration below or equal to 400 ppm compared to outside concentration. The indoor air quality is considered as “good” according to standard NF EN 16798-1.





40000 ppm expired

1 % dilution

800 ppm measured (minus 400 ppm outside) namely a 400 ppm increase

Estimating required airflow rates

- Observation of a threshold overrun: not a means of prevention
  - This would suppose an instantaneous reaction, which is not possible in practice

So far, so good…

So far, so good…

Too late !

Elapsed time

Estimating required airflow rates

- Observation of a threshold overrun: not a prevention mean
  - → We need predictive tools

Estimating required airflow rates

- Simple prediction tools of indoor CO_2 concentration
  - Equation solved as a function of time

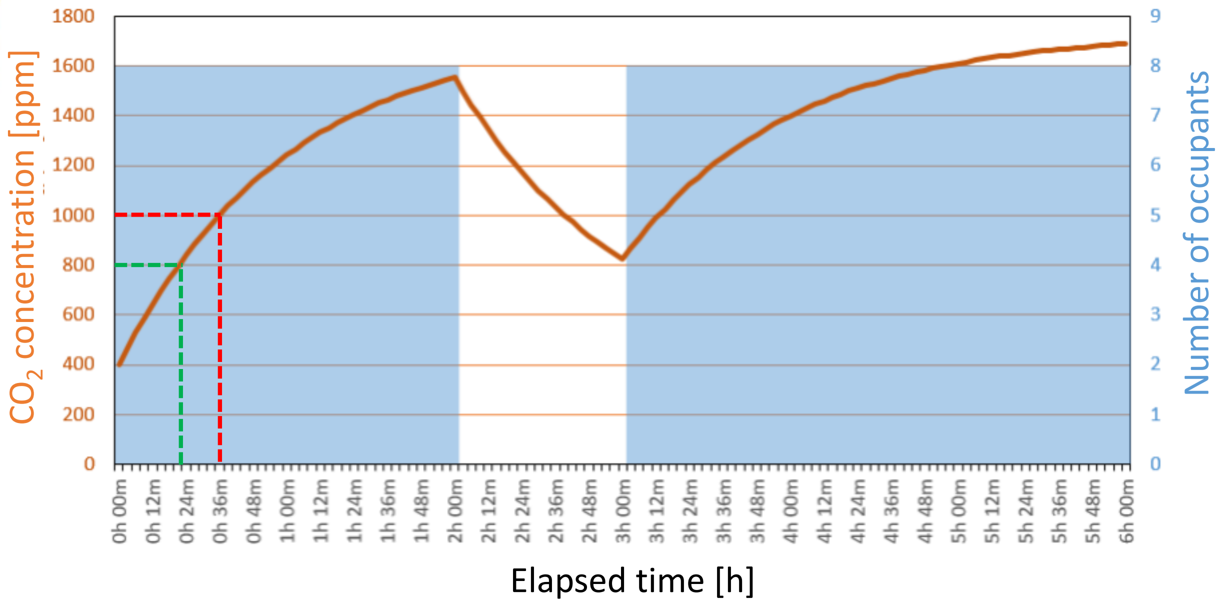
$$\begin{cases} C_{indoor}(t) = \left(\dfrac{Q_{expired\ air} \cdot C_{expired\ air}}{Q_{fresh\ air}} + C_{outside}\right) . (1 - e^{-\tau.t}) + C_{initial} . e^{-\tau.t} \\ \tau = \dfrac{Q_{fresh\ air} \cdot N_{occupants}}{V_{room}} \end{cases}$$

Air Change Rate [1/h]

  - Many tools available in many languages

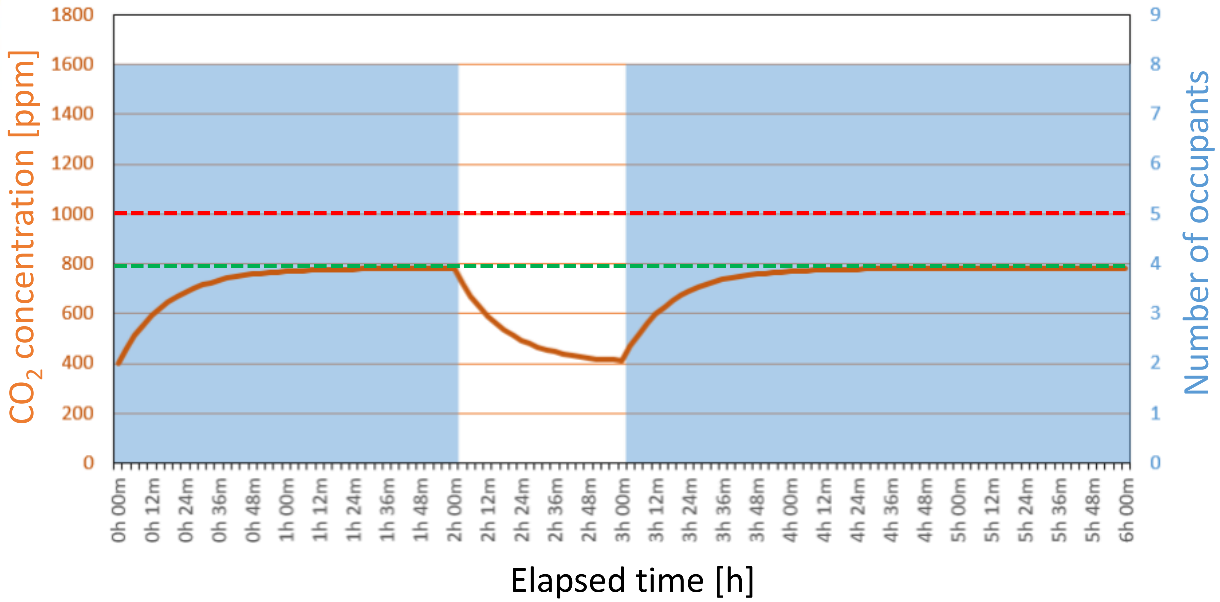
Estimating required airflow rates

- Application to a meeting room
  - **Before** – Insufficient ventilation (120 m³/h for 8 people)
    > Training for 2 hours – Break for 1 hour – Training for 3 hours



Estimating required airflow rates

- Application to a meeting room
  - **After** – Improved ventilation (420 m³/h for 8 people)
    - > Training for 2 hours – Break for 1 hour – Training for 3 hours



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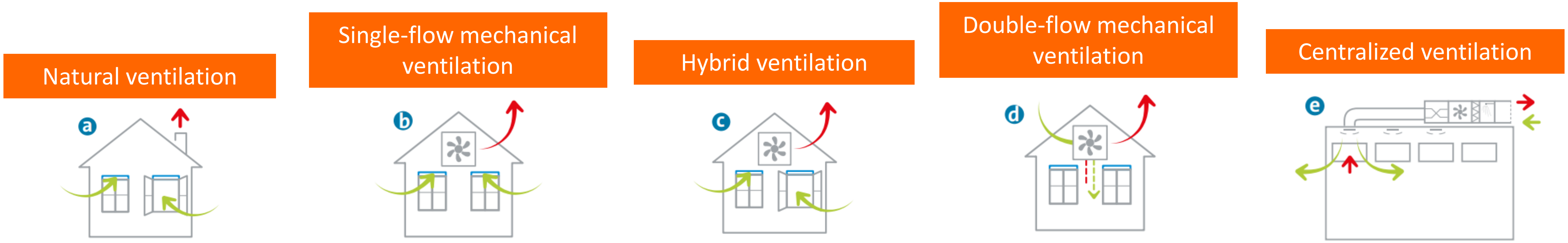
Preventing future pandemics: an opportunity to seize

- Practical advantage of indoor CO_2 concentration prediction and tracking
  - Fresh air supply in agreement with room occupation and health situation
  - Relevant whatever the considered ventilation system



- → Increases overall indoor air quality
- → Reduces the risk of diseases airborne transmission
- → Clearer recommendations in case of pandemic

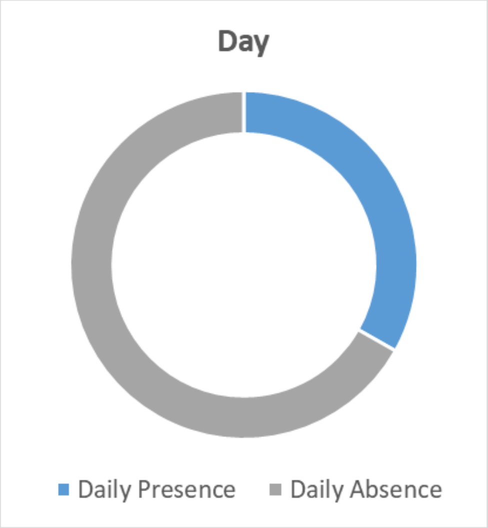
Preventing future pandemics: an opportunity to seize

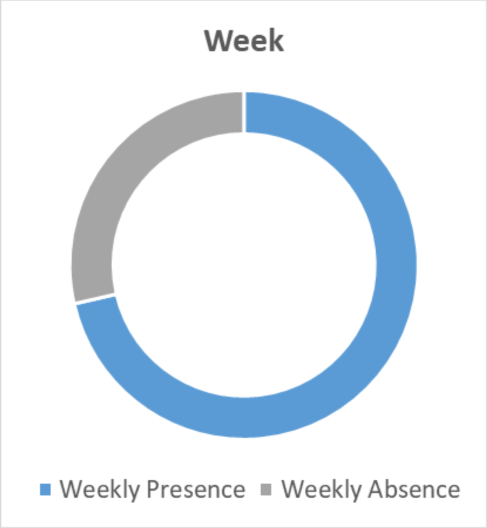
- But we have a new challenge today…

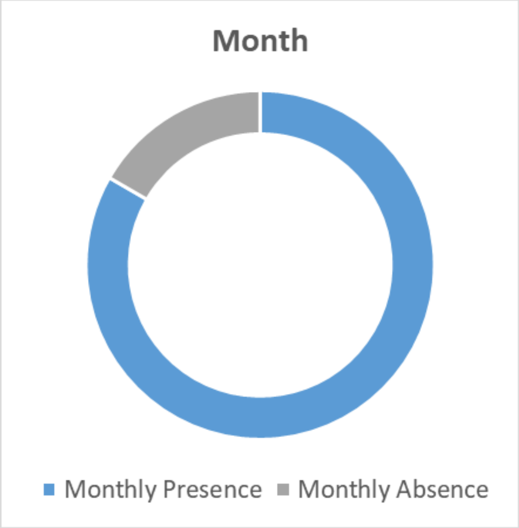
Preventing future pandemics: an opportunity to seize

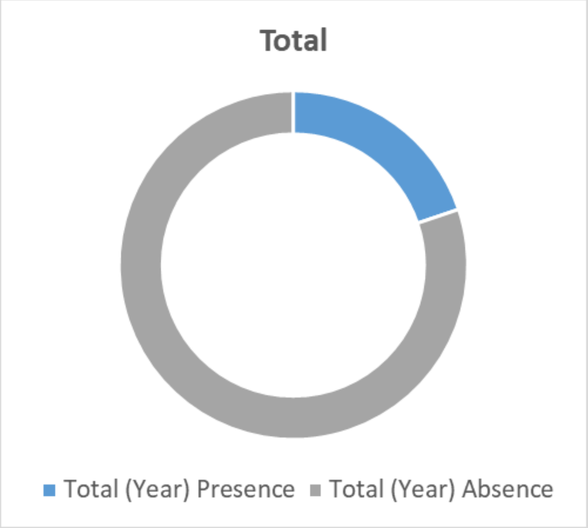
- But we have a new challenge today…

- … and solutions !
  - Many workspaces are empty most of the time, while often heated and ventilated
    - > Meeting and office rooms, some industries and labs, etc.
    - > An office room is empty more than 80 % of the time



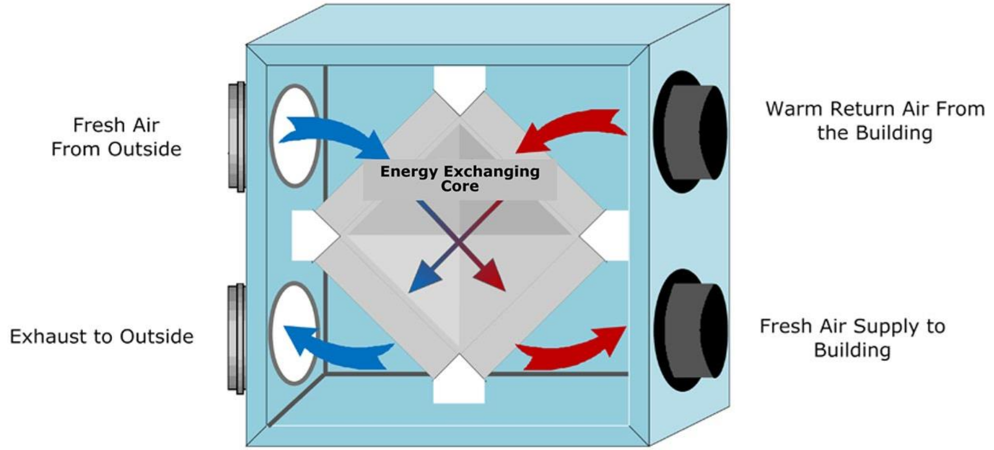






Preventing future pandemics: an opportunity to seize

- Proposals for combining energy sufficiency and biological risk prevention
  - Evaluate main energy consumption items
    - > Can be surprising, HVAC is not necessarily the most energy-intensive
  - Ventilate with higher airflow rates, but only when useful (with anticipation)
    - > Occupant-based ventilation: energy demand can be reduced by a factor of 5 in some cases
    - > Wide spread of connected sensors and building management systems
  - Always take advantage of energy recovery
    - > It is generally worth it, even at short-term



Our job: making yours safer

Thanks for your attention

www.inrs.fr

Appendix: investigation of poorly ventilated workplaces

- Ventilation of site sheds and portable lunchrooms
  - Very high CO_2 concentrations reached quickly → high risk of disease transmission

Contours of CO_2 concentration above 800 ppm (one color per occupant)