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Indoor CO_2 Sensors for COVID-19 Risk Mitigation: Current Guidance and Limitations

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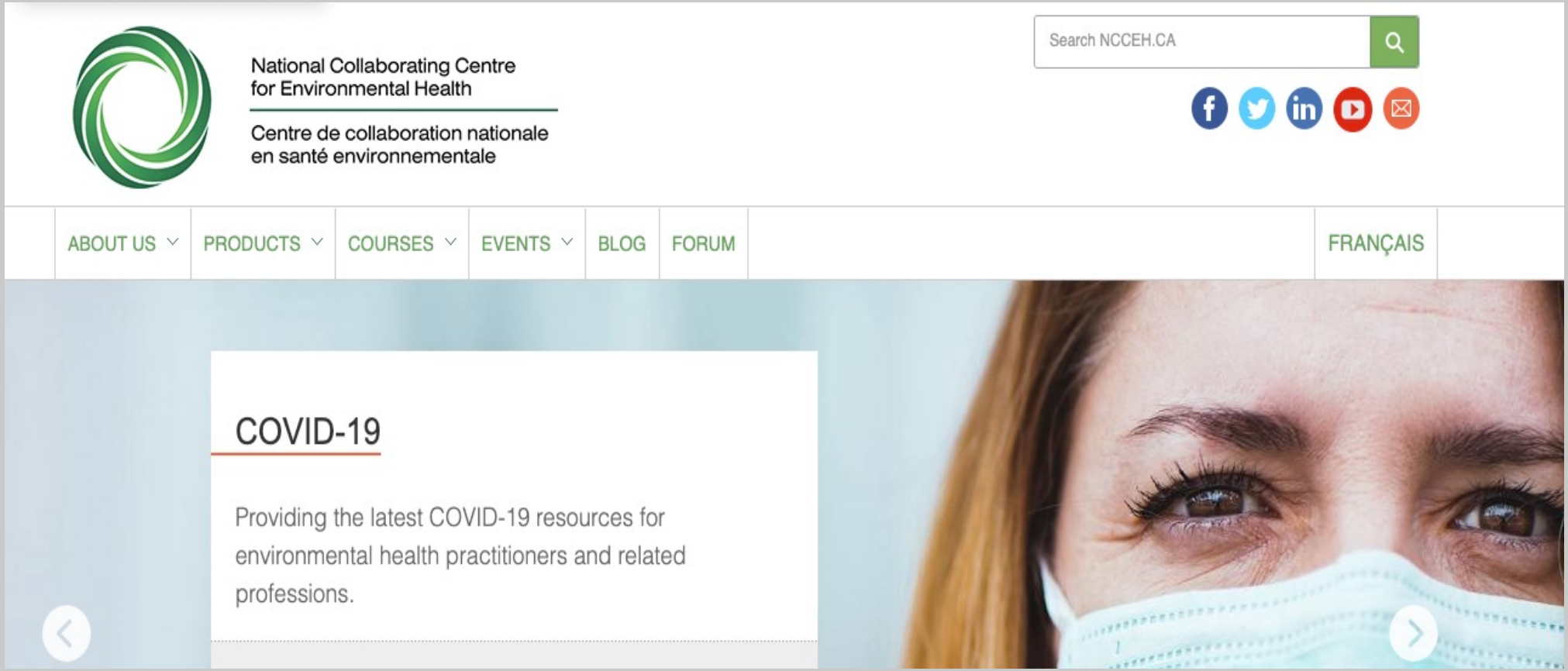
BC Centre for Disease Control
An agency of the Provincial Health Services Authority



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Environmental Health Resources for the COVID-19 Pandemic

Today

- Responding to the Pandemic…. Where are we at?
- CO_2 sensing for the Pandemic
- Key Concerns and Challenges
  - CO_2 Levels vs. COVID-19 risk
  - What are the challenges of using ventilation for risk mitigation?
- What role for CO_2 monitoring?

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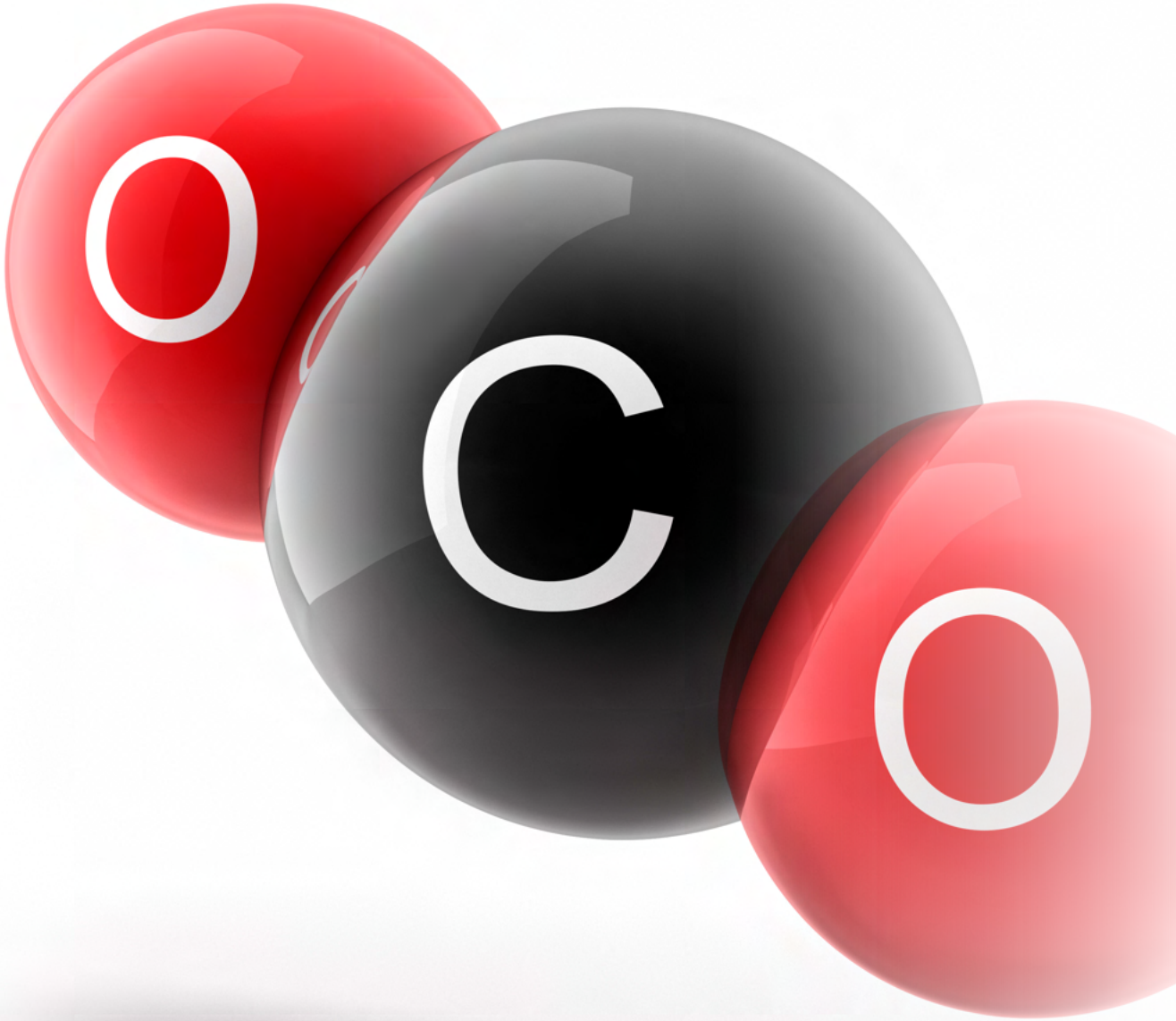
Welcome to your 441st day of the Pandemic!

- You're doing great!
- What will be the greatest EH challenge in the next 6 months?
- Longer-term: what lessons or behavioral changes can we leverage to improve PH?

Why the interest in CO_2 sensors?

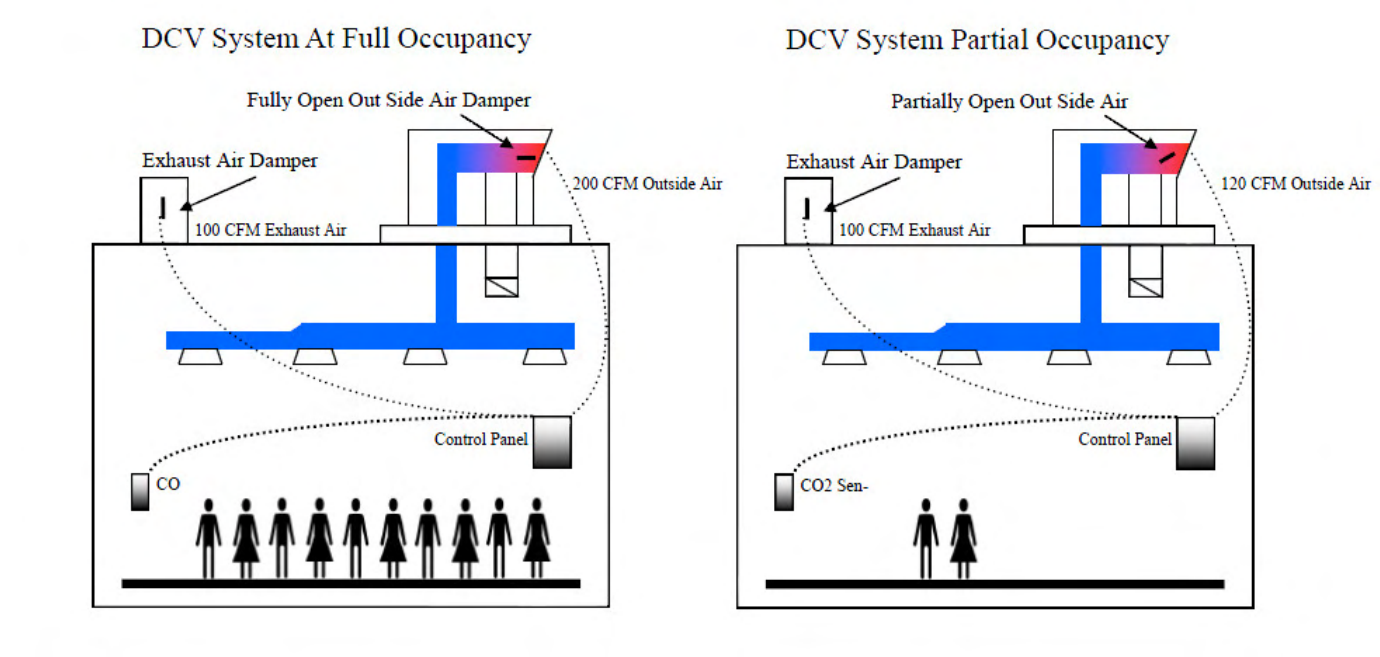
- Poor ventilation is a COVID-19 risk factor…. But how do people know when their space is “adequately ventilated?”
- CO_2 sensors have been used for years!
  - Demand controlled ventilation
  - School CO_2 studies
- CO_2 sensors are cheap/widely available



What's the theory?

- Human exhaled breath is ~40,000 ppm.
- Each additional person in the space will bump CO_2 levels relative to ambient (outdoor levels, ~450 ppm).
- CO_2 levels roughly dependent on # occupants and activity level.
- If fresh air exchange is insufficient, CO_2 will accumulate.

This is extremely useful information!



https://www.advancedcontrolsolutions.com/Demand-Control-Ventalation-and-Energy-Savings

- Demand controlled ventilation: uses CO_2 to automatically +/- outdoor air ventilation rates as occupancy changes
- Energy efficient, easier to maintain comfort.
- *Pandemic conditions* advised to turn off!

During the pandemic, can we use CO_2 monitoring to improve ventilation indoors and decrease COVID-19 transmission?

Who is currently recommending this?

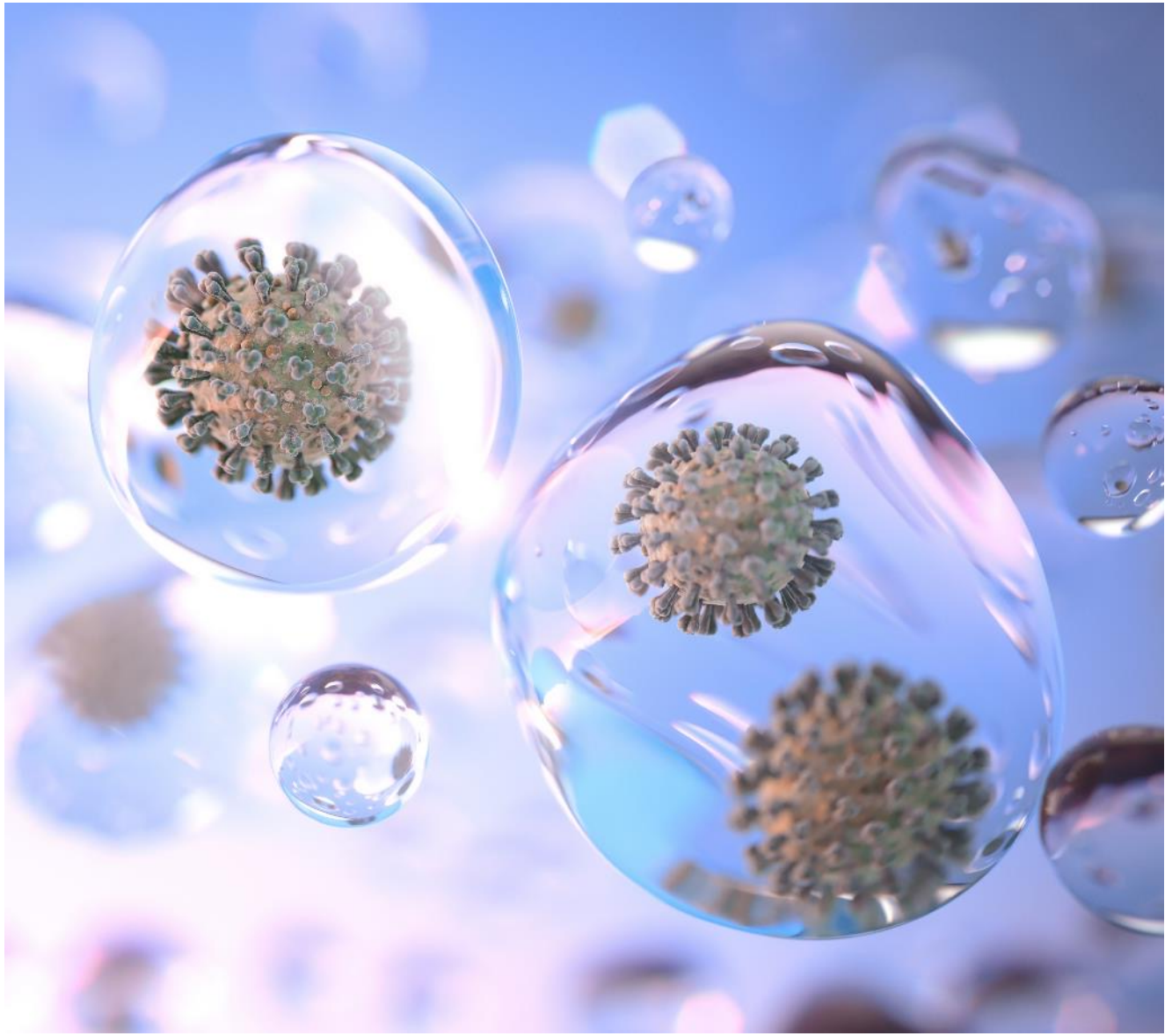
- REHVA: recommends CO_2 traffic lights in schools
- Germany: recommends CO_2 traffic lights in schools
- US CDC: useful for raising awareness
- MN Dept of Health: CO_2 monitoring in schools
- Washington Dept of Health: are open air spaces really open to the air?
- UK SAGE-EMP: useful to prioritize poorly ventilated spaces for remediation

CO_2 monitoring as an IAQ vs. Public Health tool

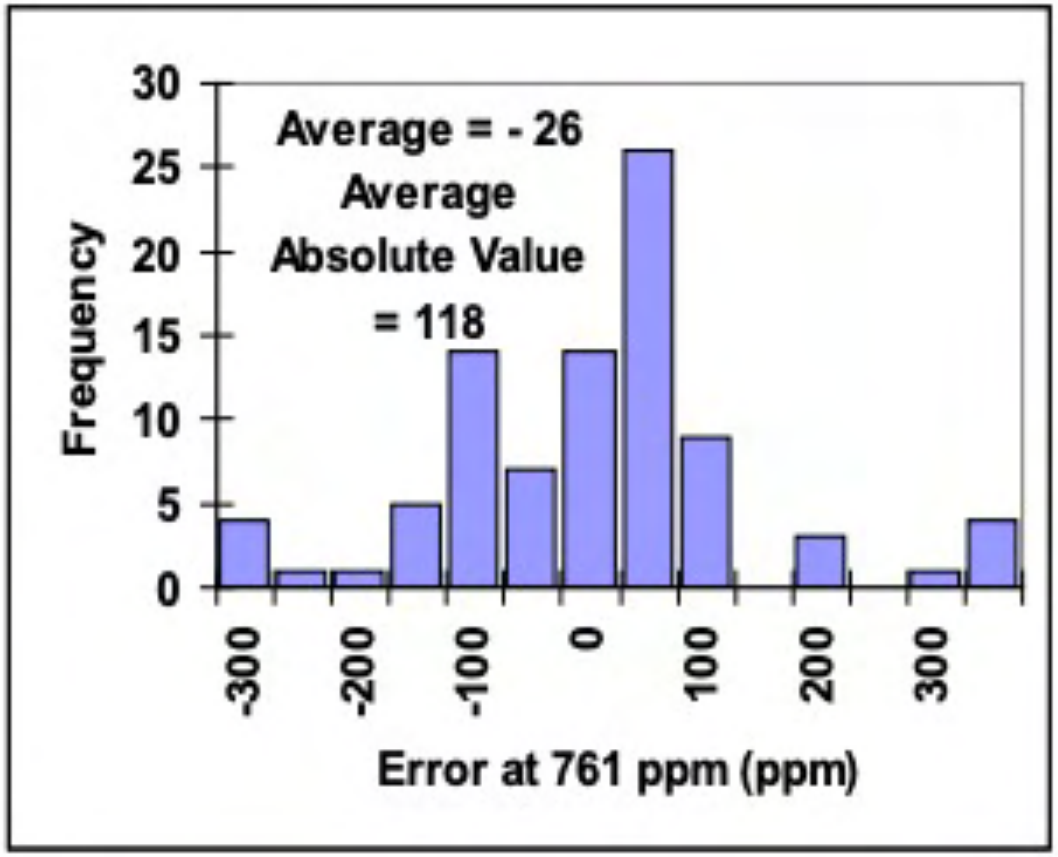
- **IAQ Tool:**
  - Designed/installed/used professionals
  - ”Set it and forget it” systems
  - Objective: making HVAC systems more efficient, people more comfortable.
- **As a public health tool:**
  - Can the devices be used/interpreted by non-expert occupants?
  - Objective is to prevent transmission of respiratory disease by increasing ventilation in badly ventilated spaces…. Are there better tools?

What are the key concerns with CO_2 monitoring?

- Monitor quality varies widely
- Choosing a threshold is problematic
- People will equate CO_2 with COVID-19 risk.
- How will occupants react?



Monitor Accuracy



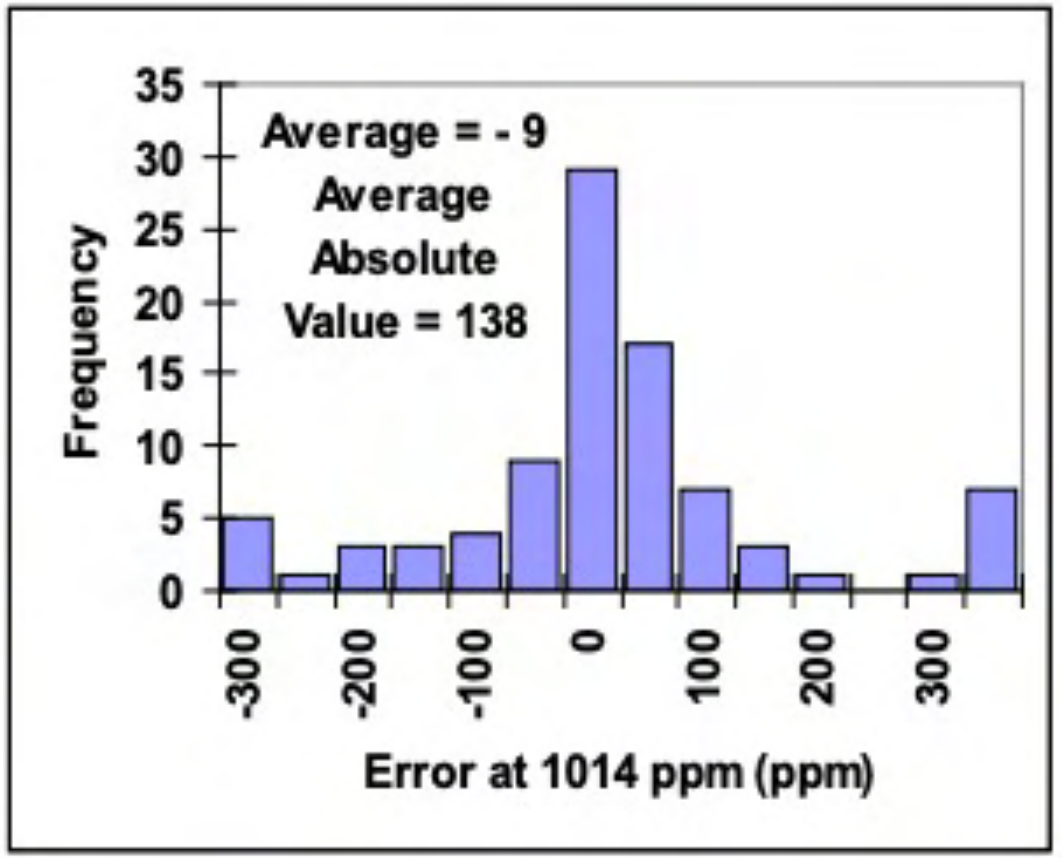


Fig. 2.3.1 from Fisk et al. 2012. Demand controlled Ventilation and Classroom Ventilation. Available from: https://eta-publications.lbl.gov/sites/default/files/rpt83133.pdf

How to deal with monitor inaccuracy?

- Develop criteria for choosing a monitor
- REHVA: highlighted this particular model
- Need to have a plan for maintenance/re-calibration if these will be in place over the long term

Choosing an action limit

- CO_2 thresholds and ventilation rates based on comfort, **not infection control.**
- Health Canada: new CO_2 guideline(1000 ppm) based on fatigue, performance, etc.
- What CO_2 concentration (or more accurately ventilation rate) will protect against disease transmission?

Government of Canada. Residential Indoor Air Quality Guidelines: Carbon Dioxide (For Public Consultation). Ottawa, ON; 2020

Source	CO_2 Action Limit
ASHRAE	1000-1200 ppm.
German Umweltbundesamt[8]	Lower threshold at 1000 ppm, upper at 2000 ppm.
Minnesota Dept of Health[9]	Keep rooms below 800 ppm.
REHVA	Notes that green-yellow threshold should be reduced to 800 ppm for pandemic conditions.
UK SAGE-EMP	Spaces with CO_2 levels >1500 ppm should be prioritized for remediation. Spaces with aerosol-generating activities should aim for 800 ppm CO_2.
US CDC	Use portable air cleaner for spaces that cannot be maintained below 800 ppm.
Washington State Dept of Health	If seated occupants are exposed to > 450 ppm for 15 min, they must be moved to a better ventilated table.

How effective is ventilation against disease transmission?

- Lack of ventilation is associated with respiratory disease transmission
  - Opportunistic spread → COVID-19, influenza, common cold
- Adding mechanical or natural ventilation to unventilated spaces can reduce transmission
  - Zhu et al. 2020: ARIs in college residences

How effective is ventilation against disease transmission?

Shajahan et al. 2019. Effects of indoor environmental parameters related to building heating, ventilation, and air conditioning systems on patients' medical outcomes. *Indoor Air 29:* 161–76.

- But OVER-ventilating can also increase the risk of transmission
  - Airflow dynamics,
  - Distribution/ mixing,
  - Displacement vs. Mixing vs. personalized ventilation
  - Relative position and posture of occupants
- Difficult to specify a minimum ventilation rate to prevent disease transmission

Choosing an action limit

- Typical indoor guideline is 1000 ppm CO_2 or ~7 L/s per person
- Pandemic conditions: scaled down to 800 ppm CO_2, which is ~9.5 L/s per person.
- Should consider activities in the space and what is practicable

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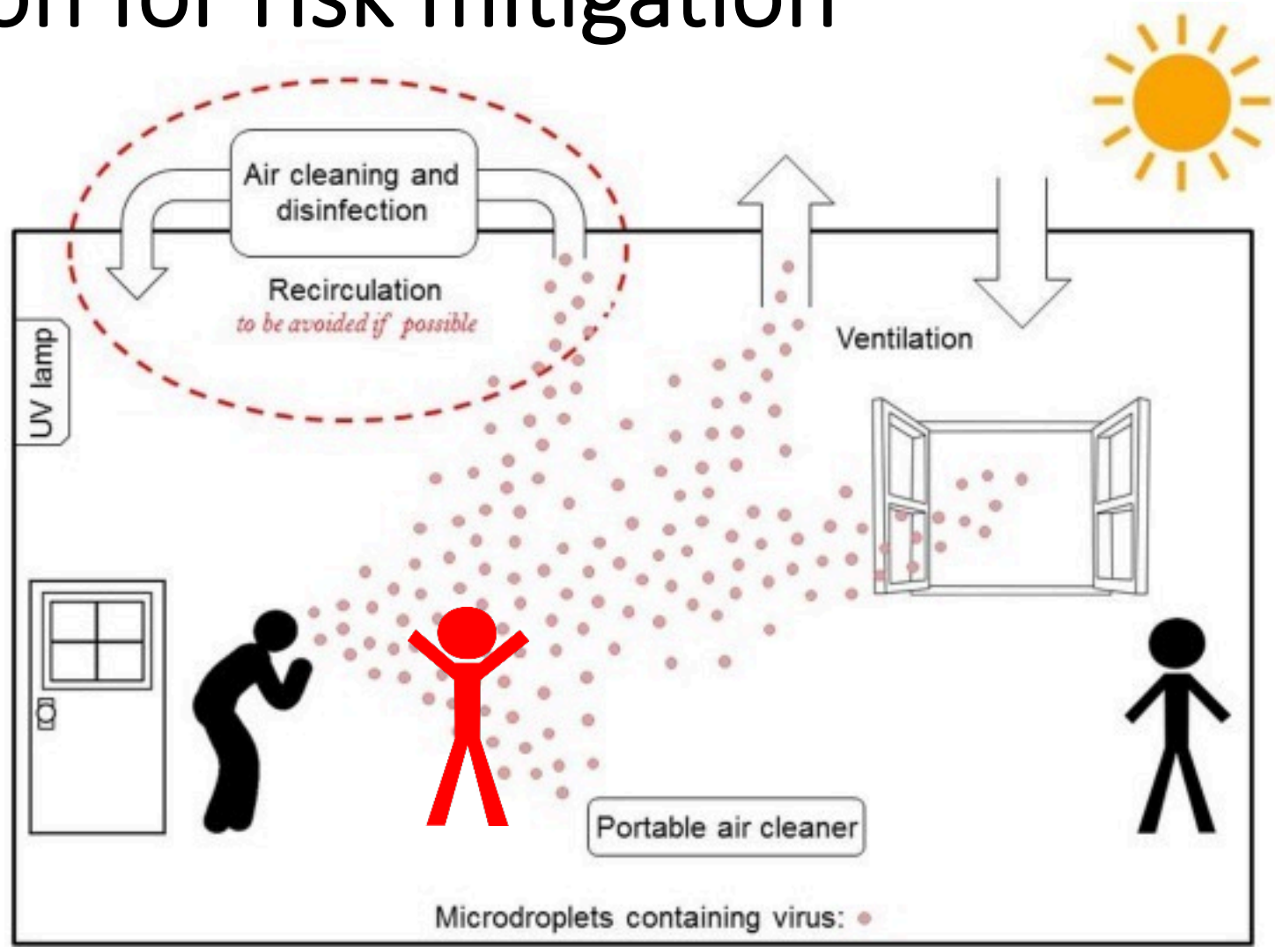
Limits of ventilation for risk mitigation

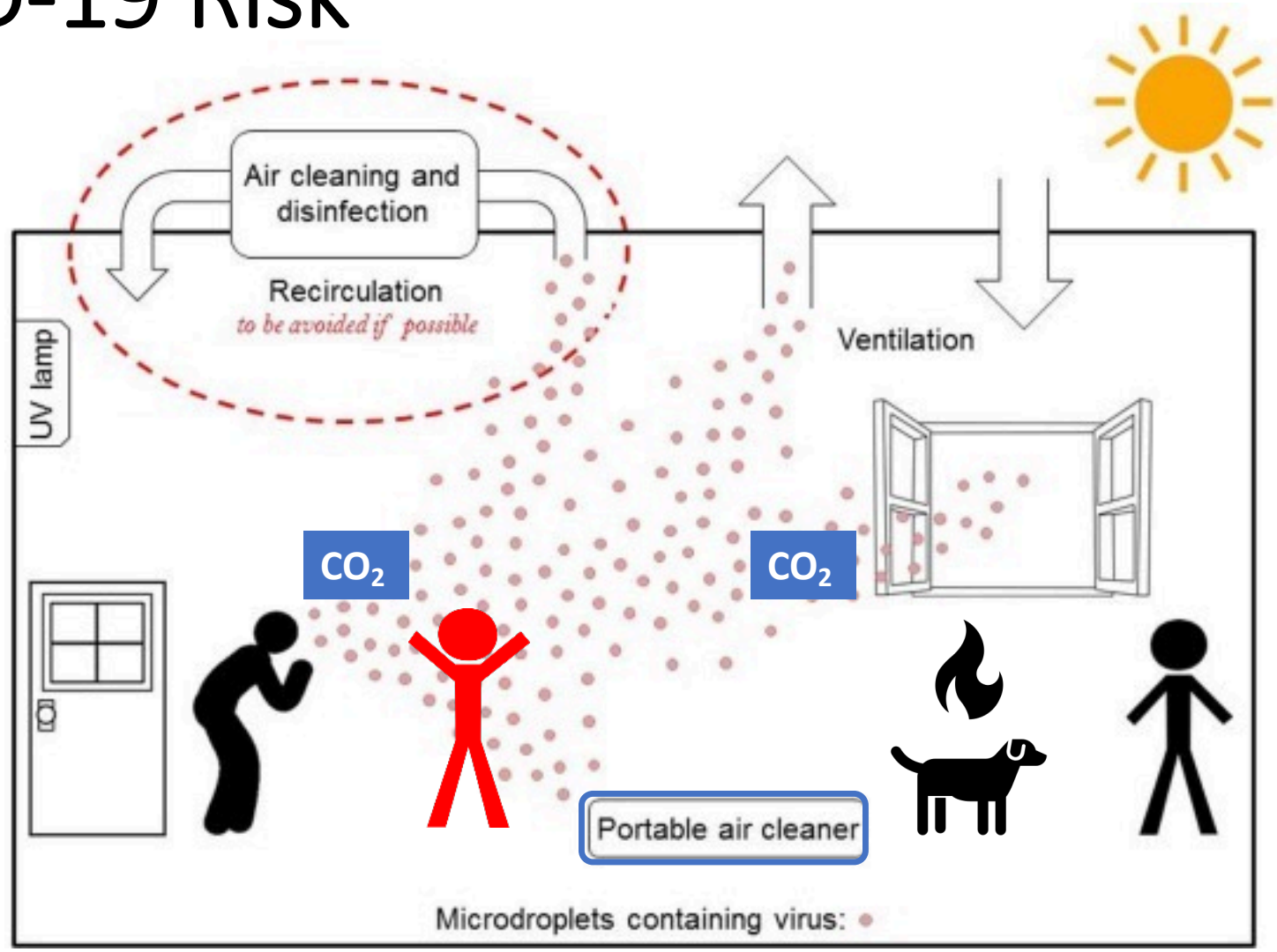
- Prevents accumulation
- Will reduce exposure if you are **farther** away
- Will **not** protect you in "the hot zone"
- Ventilation is a support, not a solution!
- Must reduce crowding



Adapted from Morawska et al. 2020

CO_2 Level ≠ COVID-19 Risk

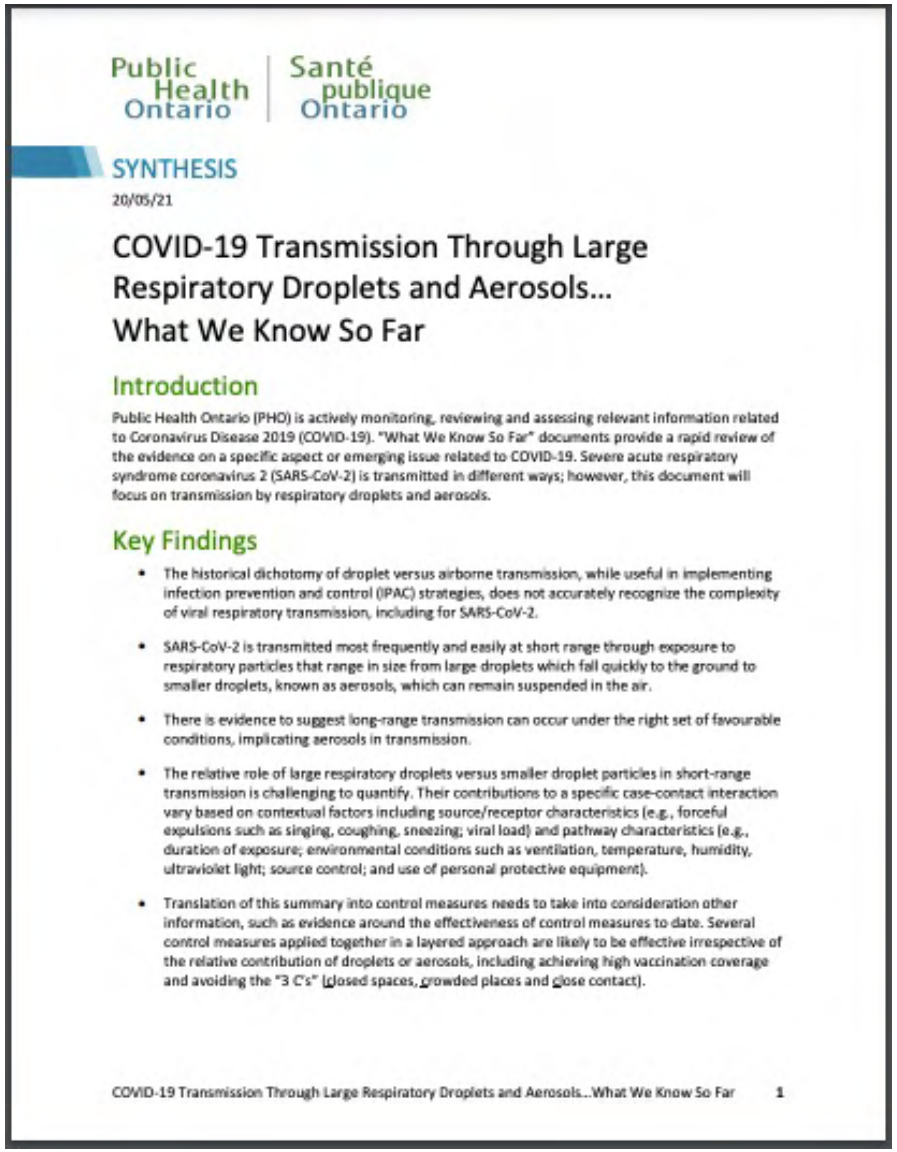
- Many factors can affect [CO_2] but not COVID risk, and vice versa.
- Being exposed to high CO_2 does not mean you will get COVID-19 and having low CO_2 doesn't mean you can't!



Adapted from Morawska et al. 2020

How does COVID-19 spread?

- NEW document from Public Health Ontario
- Rapid review of modelling, field simulation, and epi evidence around COVID-19 transmission.



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SYNTHESIS

20/05/21

COVID-19 Transmission Through Large Respiratory Droplets and Aerosols… What We Know So Far

Introduction

Public Health Ontario (PHO) is actively monitoring, reviewing and assessing relevant information related to Coronavirus Disease 2019 (COVID-19). "What We Know So Far" documents provide a rapid review of the evidence on a specific aspect or emerging issue related to COVID-19. Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is transmitted in different ways; however, this document will focus on transmission by respiratory droplets and aerosols.

Key Findings

- The historical dichotomy of droplet versus airborne transmission, while useful in implementing infection prevention and control (IPAC) strategies, does not accurately recognize the complexity of viral respiratory transmission, including for SARS-CoV-2.
- SARS-CoV-2 is transmitted most frequently and easily at short range through exposure to respiratory particles that range in size from large droplets which fall quickly to the ground to smaller droplets, known as aerosols, which can remain suspended in the air.
- There is evidence to suggest long-range transmission can occur under the right set of favourable conditions, implicating aerosols in transmission.
- The relative role of large respiratory droplets versus smaller droplet particles in short-range transmission is challenging to quantify. Their contributions to a specific case-contact interaction vary based on contextual factors including source/receptor characteristics (e.g., forceful expulsions such as singing, coughing, sneezing; viral load) and pathway characteristics (e.g., duration of exposure; environmental conditions such as ventilation, temperature, humidity, ultraviolet light; source control; and use of personal protective equipment).
- Translation of this summary into control measures needs to take into consideration other information, such as evidence around the effectiveness of control measures to date. Several control measures applied together in a layered approach are likely to be effective irrespective of the relative contribution of droplets or aerosols, including achieving high vaccination coverage and avoiding the "3 C's" (closed spaces, crowded places and close contact).

COVID-19 Transmission Through Large Respiratory Droplets and Aerosols…What We Know So Far 1

COVID-19 Transmission is Multi-factorial

- Community transmission
- Individual factors
- **Proximity** and **duration** of interaction
- Indoor, unventilated spaces
- Environmental factors
- Particle-generating activities
- Fomites
- **Public health uses layered measures that address multiple factors and multiple routes of transmission.**

Anticipating Occupant Behavior

- People will focus on the monitor and not on other health protective actions.
- People will panic/misinterpret when comparing data
- People will only act when they hit the action limit, not before.
- People will not stick with it.

CO_2 Classroom Study

- Looked at effect of three interventions on CO_2 levels in 81 classes in 20 Dutch primary schools
  - Ventilation advice alone
  - Ventilation advice plus a CO_2 sensor with warning light
  - Ventilation advice plus ventilation-themed lesson plans

Geelen et al. 2008. Comparing the effectiveness of interventions to improve ventilation behavior in primary schools. Indoor Air. 18(5): 416-424.

CO_2 Classroom Study

- CO_2 warning device helped, BUT… not enough and only as long as the device was in place.
- The ventilation-themed lesson plan helped to enlist the young students in ventilation action, had a lasting effect.
- Just telling people to ventilate not effective!
- Draftiness, distraction meant that teachers did not stick with it.
- Still, useful until facilities can be ugraded.

So what role then does CO_2 monitoring play during the Pandemic?

- Emergency measure to create IAQ awareness and stimulate ventilation behavior, like opening windows and taking breaks to air out the room.
- It's a two-fer: improve ventilation AND collect data on public spaces
- Reduce risk of respiratory diseases generally.
- Buy time to develop a national indoor air strategy that builds on what we learned in this pandemic **and make changes**.
- Emergency measure to roll out during next pandemic?

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Thank you!
Questions?

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