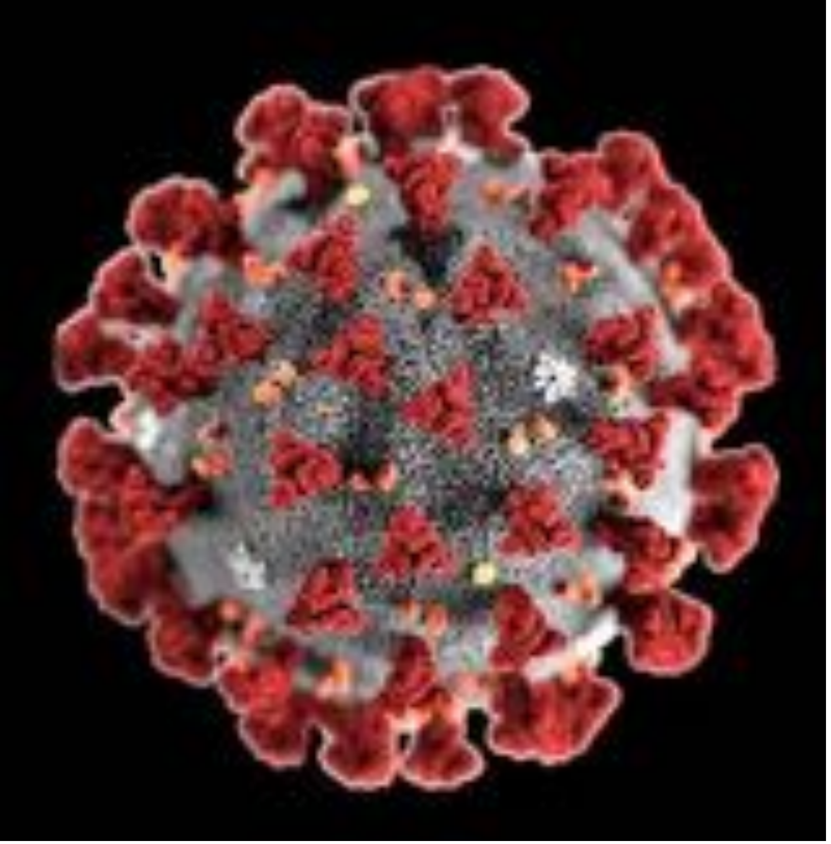
Estimating airborne infection risks in classrooms from CO_2 measurements

Carolanne Vouriot, Henry Burridge, Cath Noakes, Paul Linden

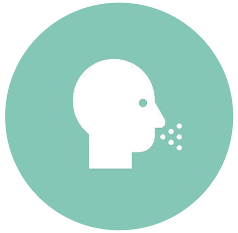
  

Introduction

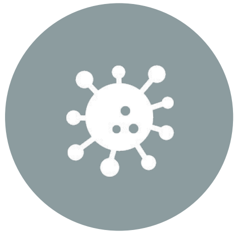
- What roles do schools play ?
- How do you estimate risk ?
- What is the effect of seasons ?

COVID-19 transmission routes

CONTACT OR TOUCH



DROPLET OR SPRAY



AEROSOL OR AIRBORNE

- Focus on far-field airborne transmission.
- Small infected respiratory droplets and aerosols remain suspended.
- Mixed and transported by ventilation.

Assessing the risk of airborne infection

Wells-Riley for steady state:

$$P_I = 1 - \exp(-Iqpt/Q)$$

- q: quanta generation rate
- I: number of infected people
- p: pulmonary ventilation rate
- Q: room ventilation rate
- t: exposure time

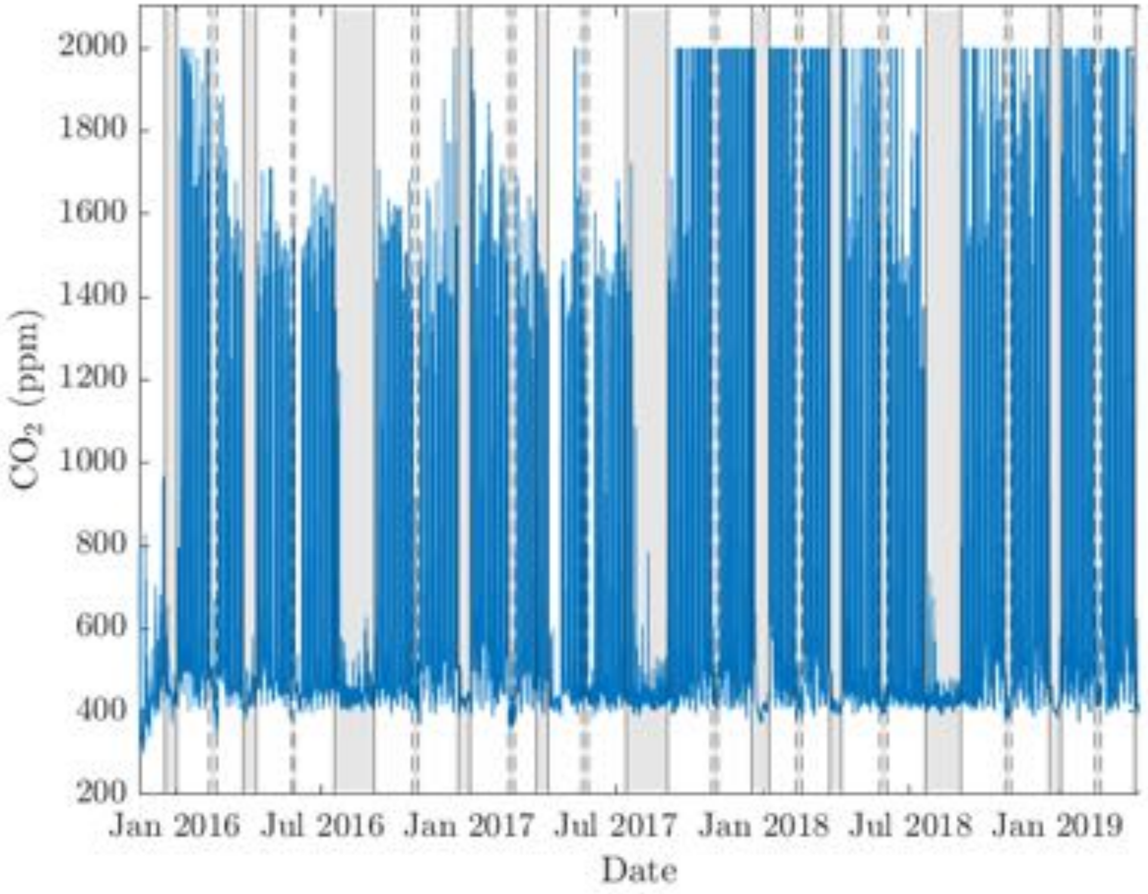
- Number of infectious airborne particle required to infect someone
- Varies with disease, individual and activity levels
- Has to be estimated from the analysis of outbreaks

Rudnick & Milton (2003) :

$$P = 1 - \exp(f\,Iqt/N)$$

- N: number of occupants
- f : rebreathed fraction

CO_2 measurements



- Rebreathed fraction $f = C - C_{out} / C_a$
- C : measured CO_2.
- C_{out} : ambient CO_2 (average between 05:00 and 06:00).
- C_a : CO_2 in the exhaled breath (=37,500 ppm).

- Measurements obtained for 45 classrooms in England[1]

School	Type	County	Rooms	Data span
1	Primary	Yorkshire	22	Nov/15 – Mar/19
2	Secondary	Berkshire	1	Nov/19 – Mar/20
3	Primary	Somerset	1	May/17 – Mar/18
4	Primary	Surrey	1	Dec/17 – May/18
5	Primary	Cambridgeshire	2	Aug/17 – Jan/18
6	Primary	Not disclosed	3	Dec/18 – Feb/19
7	Primary	Essex	4	Oct/16 – Dec/17
8	Secondary	Kent	1	Mar/18 – Apr/19
9	Primary	Surrey	4	Aug/17 – Aug/18
10	Primary	Kent	1	Aug/17 – Jul/18
11	Secondary	Hertfordshire	5	Sep/18 – Mar/20

(1) DATA provided by Monodraught, with the assistance of Nick Hopper and Nyssa Hayes, and by the K2n platform, with the assistance of Professor Ian Knight.

Number of secondary infections

- Adapted from Rudnick & Milton (2003), likelihood of infection when the space is occupied (0 otherwise):

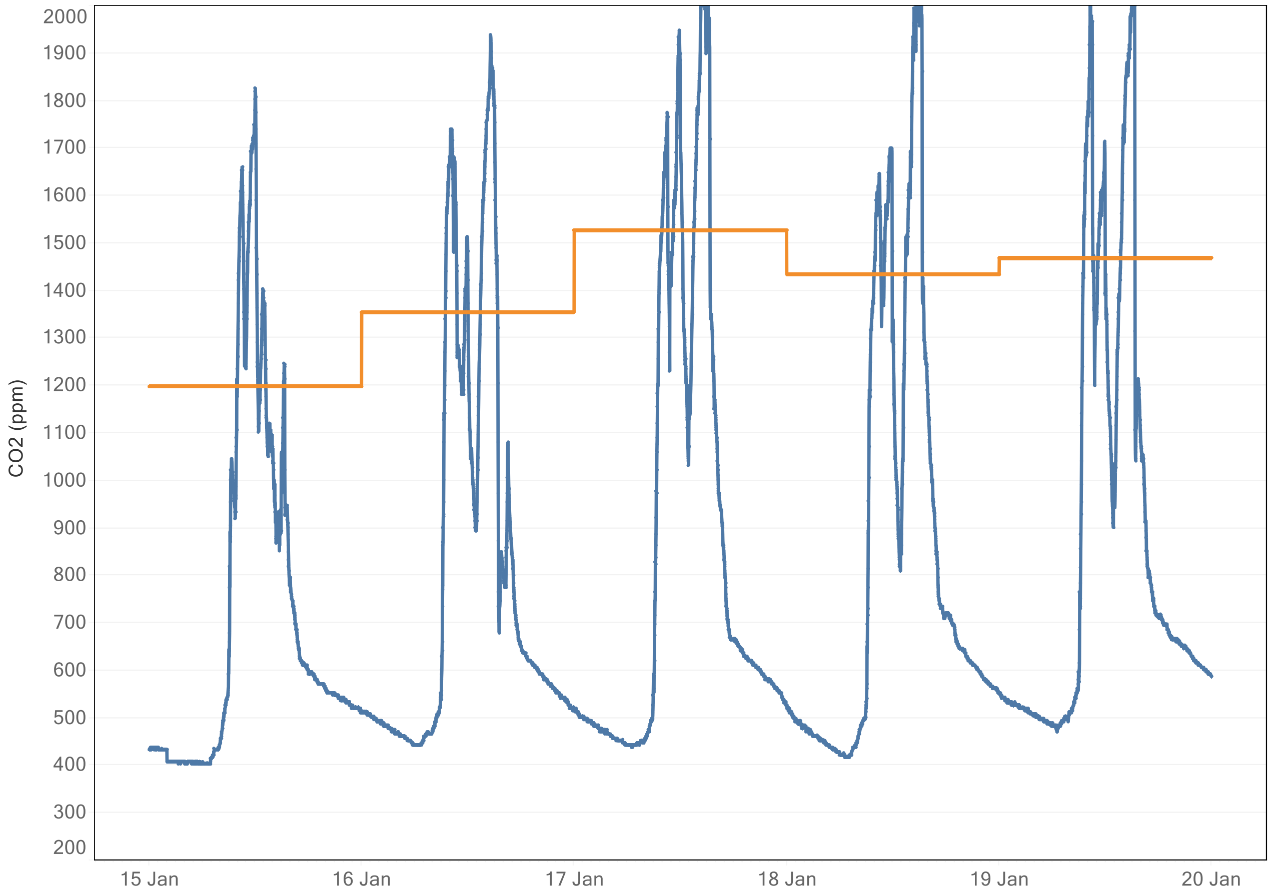
$$P_A = 1 - \exp\left(-\frac{1}{N}\int_0^T f\,q\,dt\right)$$

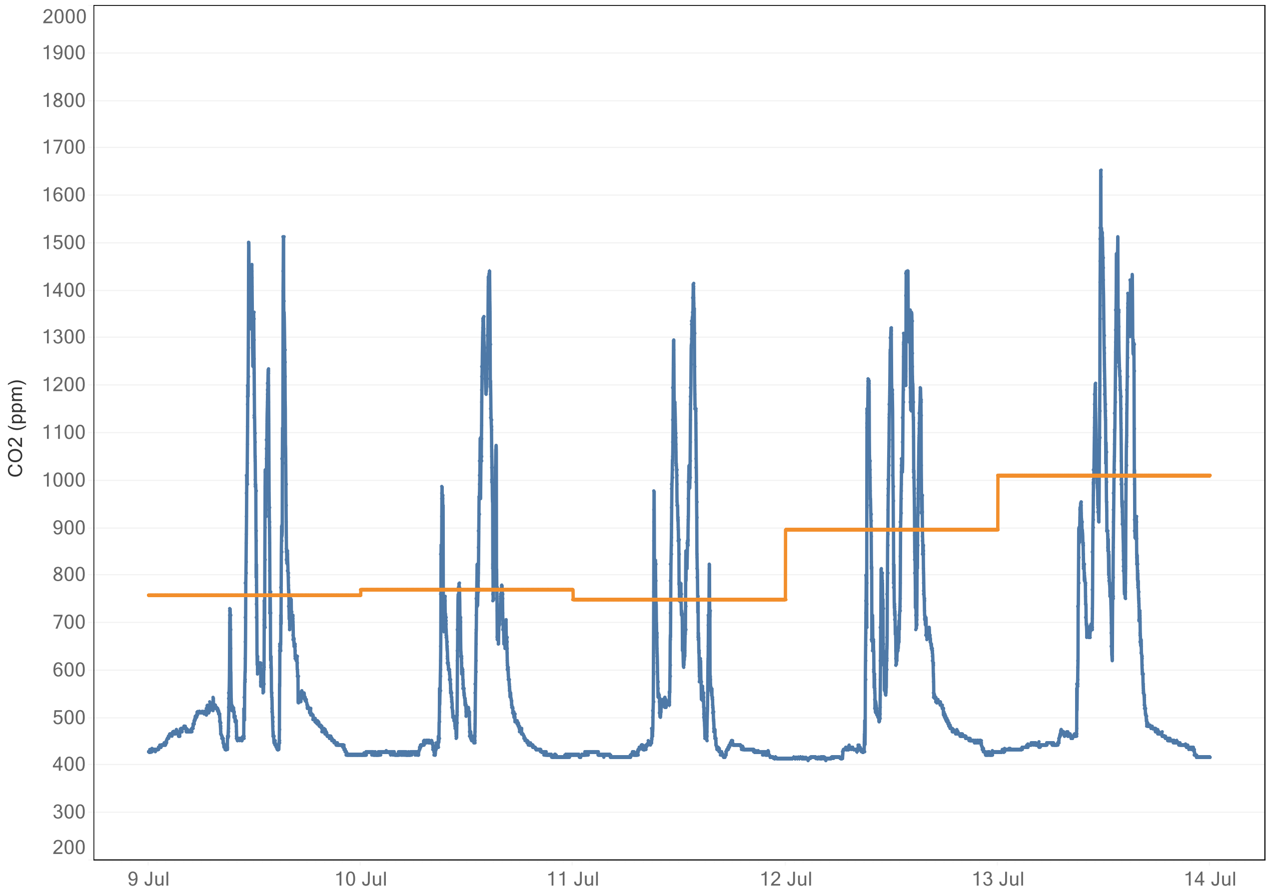
- N: total number of occupants (32 in a UK classroom)
- q: quanta generation rate (1 quanta/hr from Buonanno *et al.*, 2020)
- T: exposure time (5 weekdays)
- f: rebreathed fraction

Number of secondary infections: $S_I = (N-1)P_A$

Example over a week (January and July 2018)

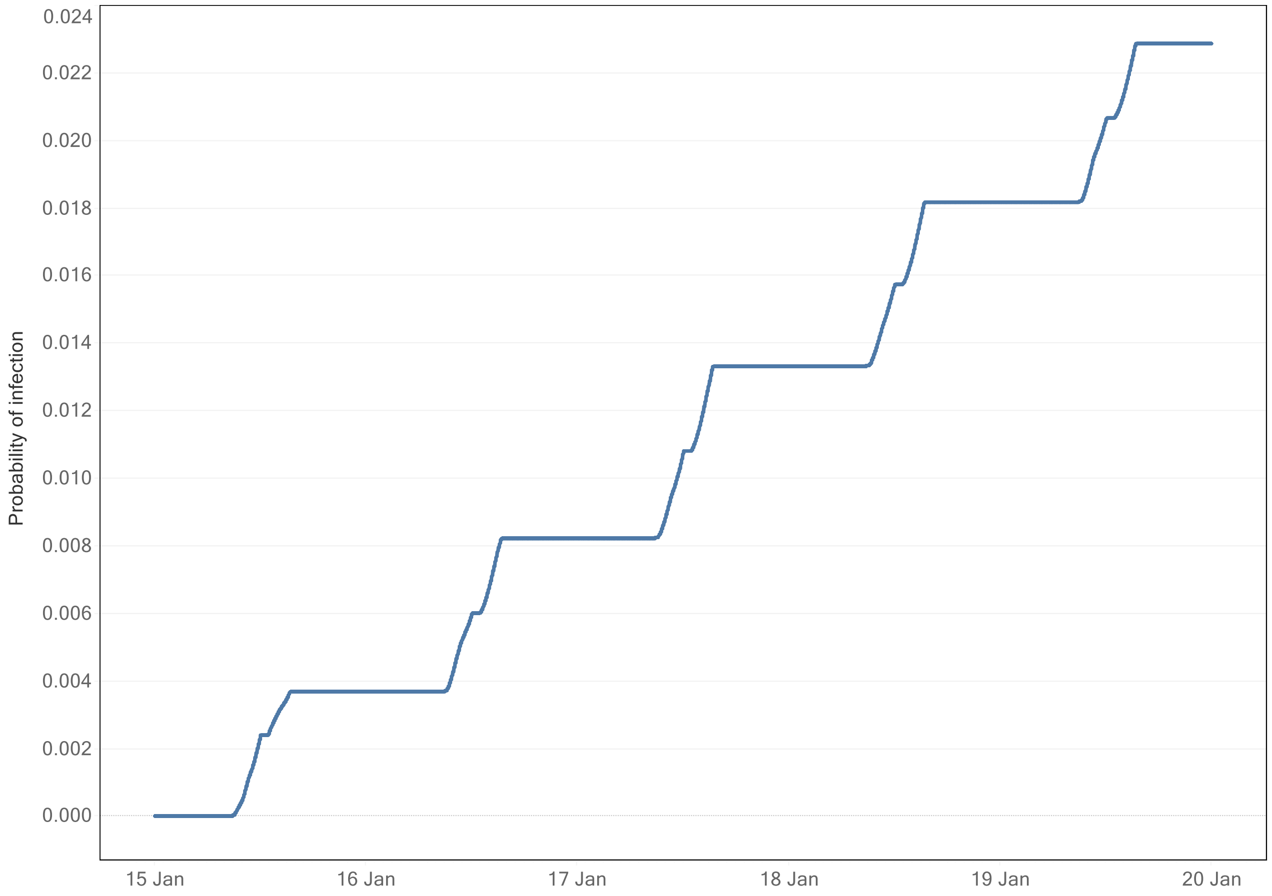
CO_2 variations in a given classroom. Daily average is shown in orange.

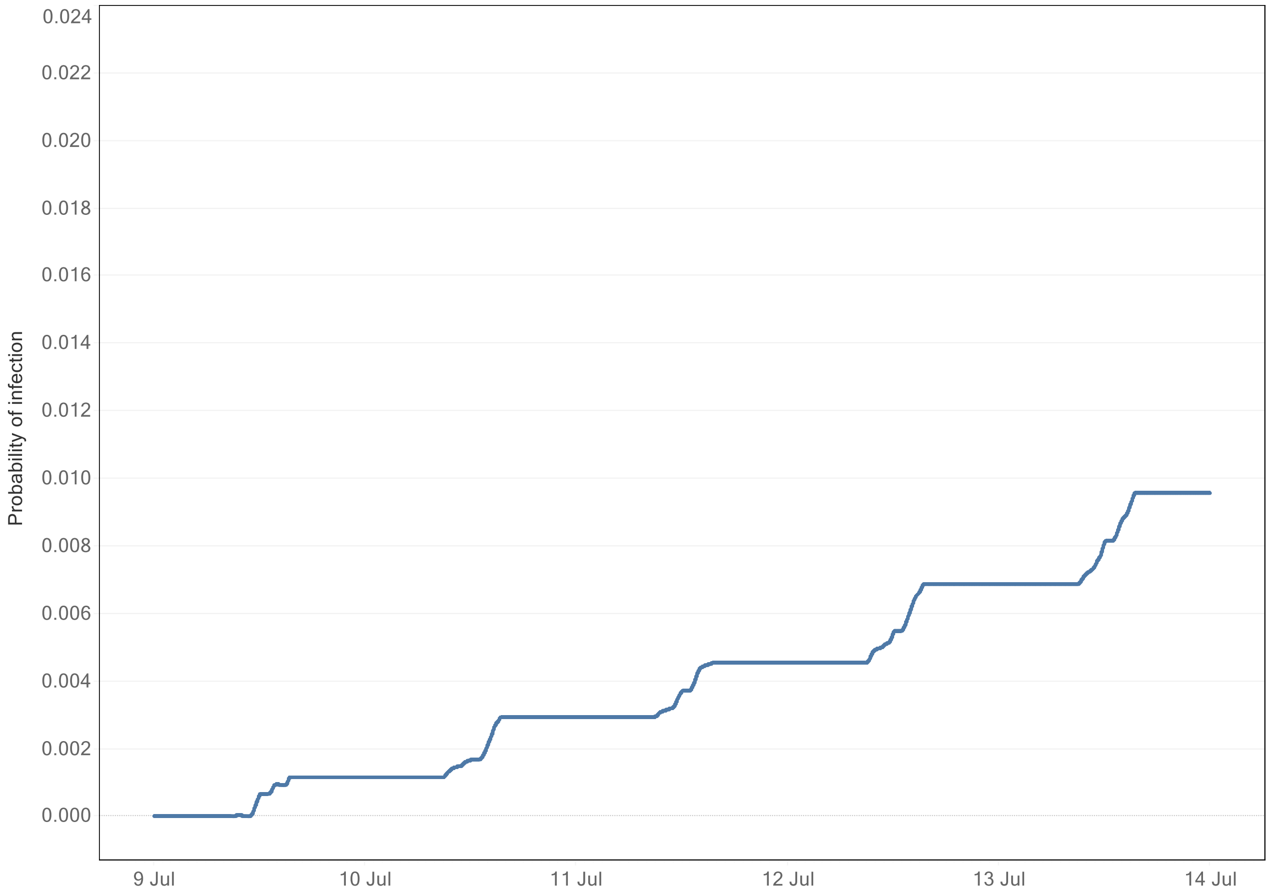




Example over a week (January and July 2018)

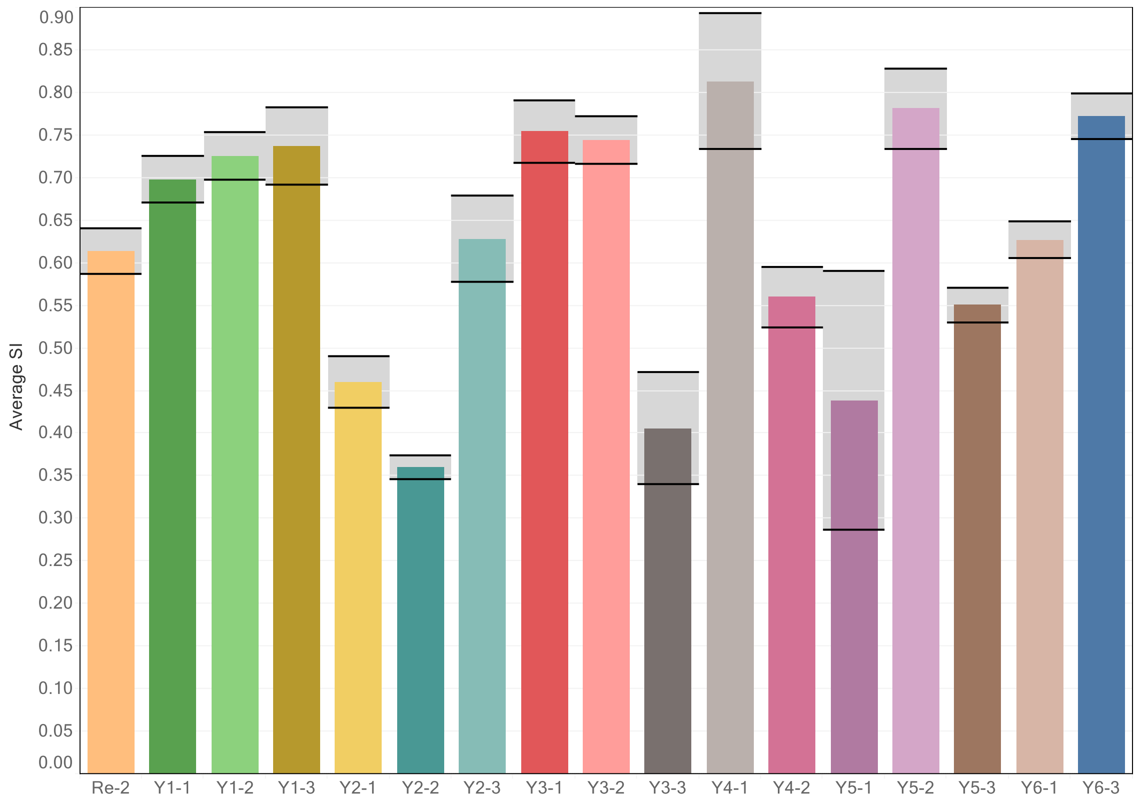
Calculated probability of infection in a given classroom.

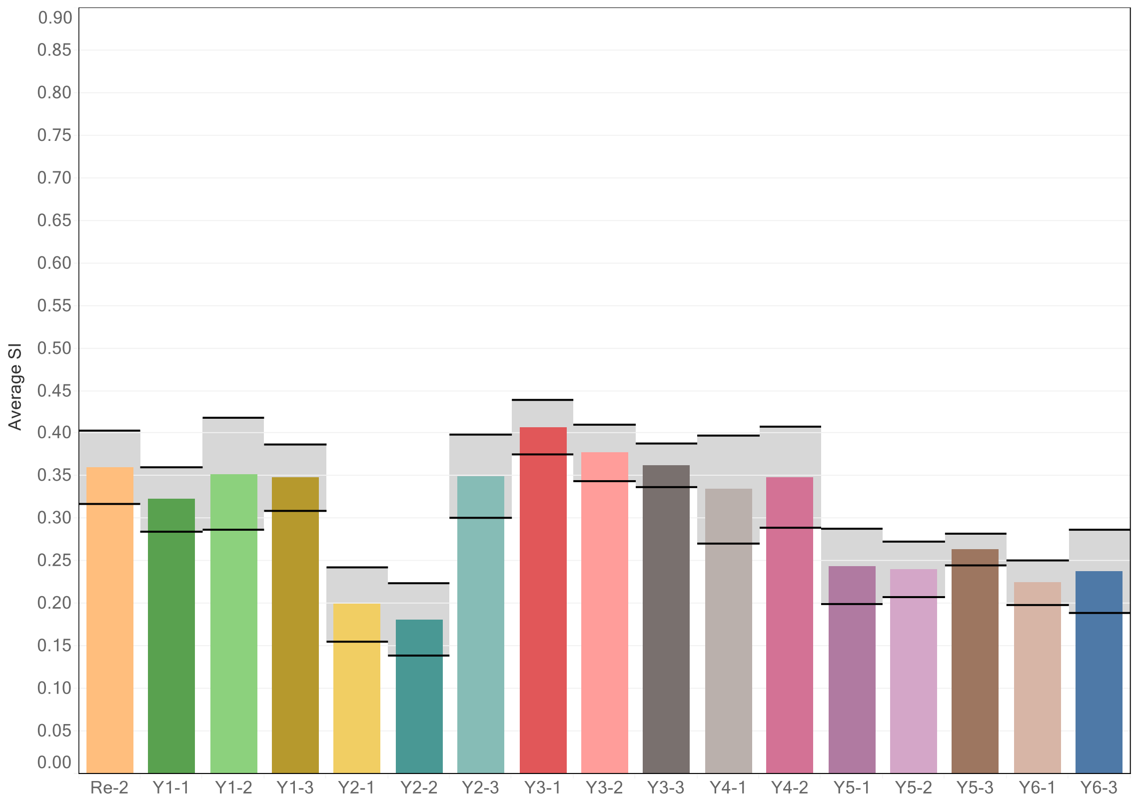




Variations within a school

Classrooms within the same building and supplied with the same ventilation system

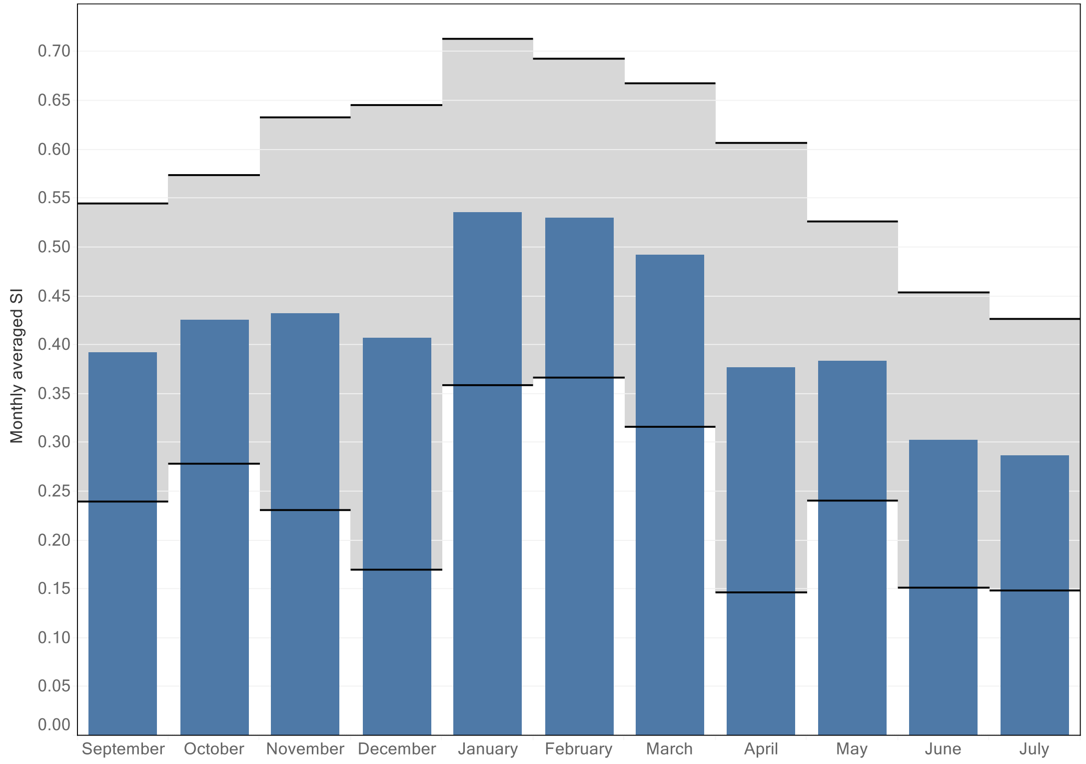


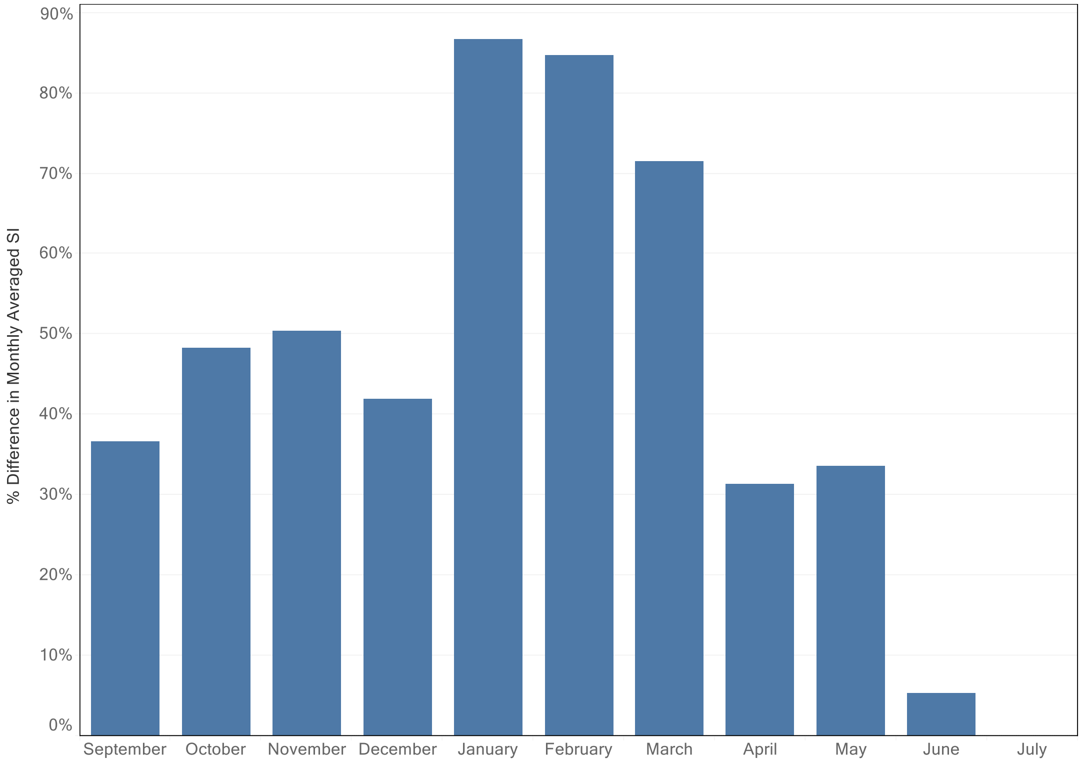


Average number of secondary infections in each classroom in January (left) and July (right) 2018. Standard deviations are shown in grey.

Seasonal variations

Due to changes in environmental conditions





Absolute (left) and relative (right) monthly averaged number of secondary infections in all 45 classrooms over the period November 2015 to March 2020.

- More details here: Vouriot, C.V.M., Burridge, H.C., Noakes, C.J. and Linden, P.F., 2021. Seasonal variation in airborne infection risk in schools due to changes in ventilation inferred from monitored carbon dioxide. *Indoor Air*. https://doi.org/10.1111/ina.12818

CoSchools

Tools for healthy schools

COVID-19 Assistance for schools tool (CAST)

- CO-TRACE project (COvid-19 Transmission Risk Assessment Case Studies - education Establishments).
- Share our findings in an online tool for teachers.
- Guidance based tool.
- First version available on https://www.coschools.org.uk/
- Any feedback @CoSchoolsTools

Conclusions

CO_2 measurements are useful to estimate airborne risk infection.

Wide variations observed between schools, classrooms and across seasons.

There is still a lot more to understand.

Drive to improve indoor air quality in schools and beyond.

https://www.coschools.org.uk/

Vouriot, C.V., Burridge, H.C., Noakes, C.J. and Linden, P.F., 2021. Seasonal variation in airborne infection risk in schools due to changes in ventilation inferred from monitored carbon dioxide. *Indoor air*. https://doi.org/10.1111/ina.12818

CO-TRACE

Covid Transmission Risk Assessment Case studies – Education establishments

- Henry Burridge, Chris Pain (Imperial College London), Prashant Kumar (Surrey University), Paul Linden (University of Cambridge).
- Monitor schools measuring CO2 and PM
- Laboratory and CFD studies
- Mathematical modelling of transmission risk
- Advice to schools on reducing risk
- Link to TAPAS and CoSchools