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Reducing infection risk and optimization of airing concepts for indoor air quality by accurate aerosol and CO_2 measurement

Shortly after the outbreak of the SARS-CoV-2 pandemic, the route of virus transmission via aerosols became obvious (Morawska and Milton, 2020; Li et al., 2020; WHO, 2020; CDC, 2020). Indoor air quality is a major topic regarding efforts to contain the spreading of SARS-CoV-2 in the population.

Most infection risk calculations rely exclusively on CO_2 as a proxy for exhaled aerosols. Rudnick and Milton (2003) derived an equation to calculate the basic reproductive number R_{A0} from the Wells-Riley equation using CO_2 as a proxy for the concentration of exhaled aerosol.

$$R_{A0} = (n-1) \cdot \left[1 - \exp(-\frac{\bar{f} \cdot q \cdot t}{n})\right]$$

In this equation, n represents the number of persons in the room, $\bar{f}$ is the rebreathed fraction of air averaged over the residence time t of the persons, and q represents the infectious quanta exhaled (the number of infection „doses“ exhaled by an infected person per unit of time).

Taking only CO_2 into account is obviously inadequate once air filtration devices are used, i.e., the actual measured aerosol concentration needs to be introduced into calculating indoor infection risk. To close this gap, we introduce the relative aerosol number concentration a into Rudnick and Milton's equation to account for the effect of air filtration when calculating the reproductive number R.

$$R_{A0} = (n-1) \cdot \left[1 - \exp(-\frac{\bar{f} \cdot \bar{a} \cdot q \cdot t}{n})\right]$$

$$\text{with } a(t) = \frac{C_N(t)}{C_{N,(t_0)}}$$

Practical measurements were carried out using Palas® AQ Guard air quality monitors in 9 classrooms in a public school in Germany. AQ Guard is a single particle counting aerosol spectrometer, capable of detecting particles down to 180 nm, combined with a CO_2 sensor. Results show that taking only CO_2 into account would overestimate the actual infection risk by 20% in the studied cases without air filtration, and by 60% with air filtration in use.

Measurement results varied strongly between different classrooms and also within the same room at constant occupation density, even though the same ventilation rules were applied. This indicates that the ventilation of the rooms following general guidelines, as applied during our measurements, is insufficient for ensuring healthy conditions in the classrooms. Effects of room geometry and available window number/area should be investigated further. In general, lower occupation density and use of an air purifier lead to lower values of the reproductive number R.

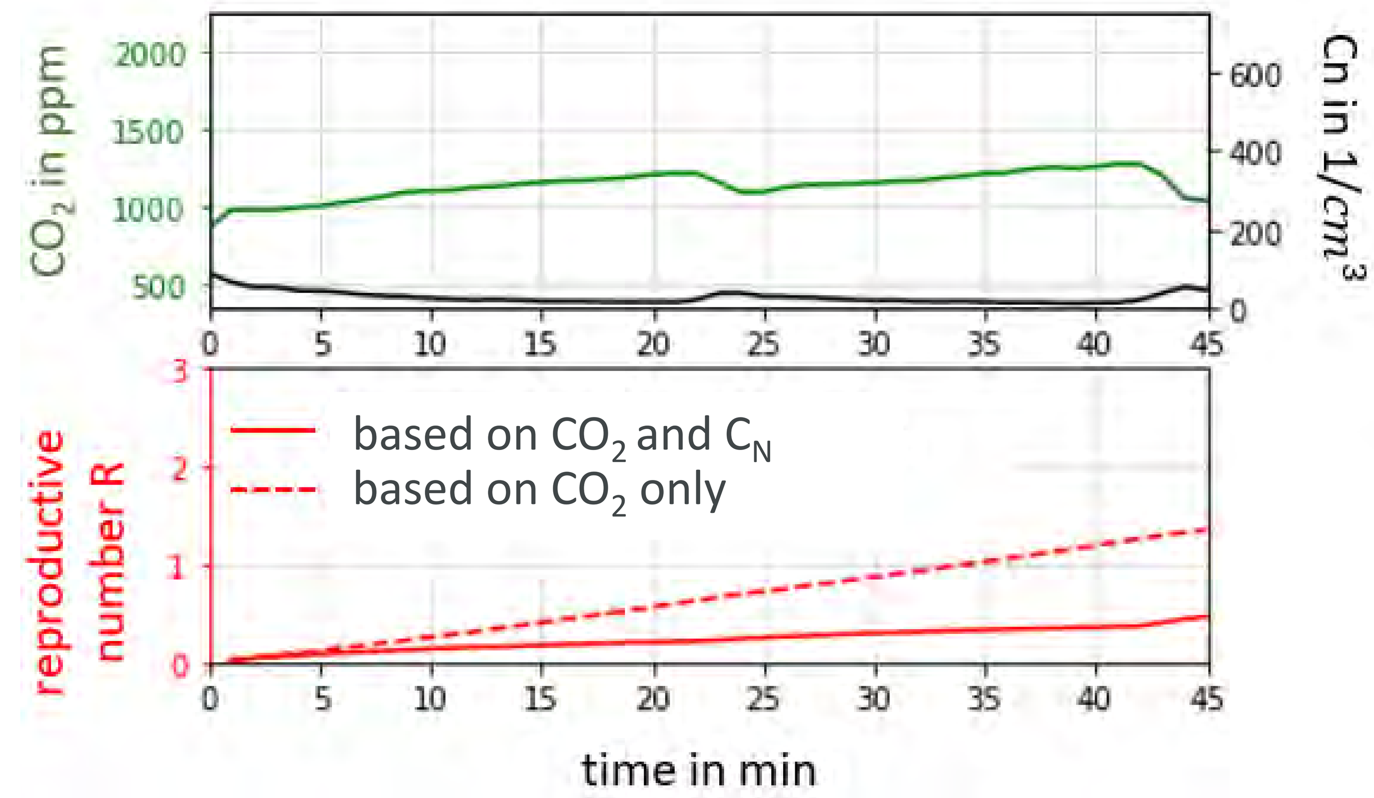

Fig. 1: Example curves of CO_2 (top, green) and aerosol (top, black) particle number concentrations measured during class, and resulting reproductive number R (bottom, red dashed line: based on CO_2 only; red solid line: aerosol concentration taken into account). Air purifier (Wolf AirPurifier) in operation.

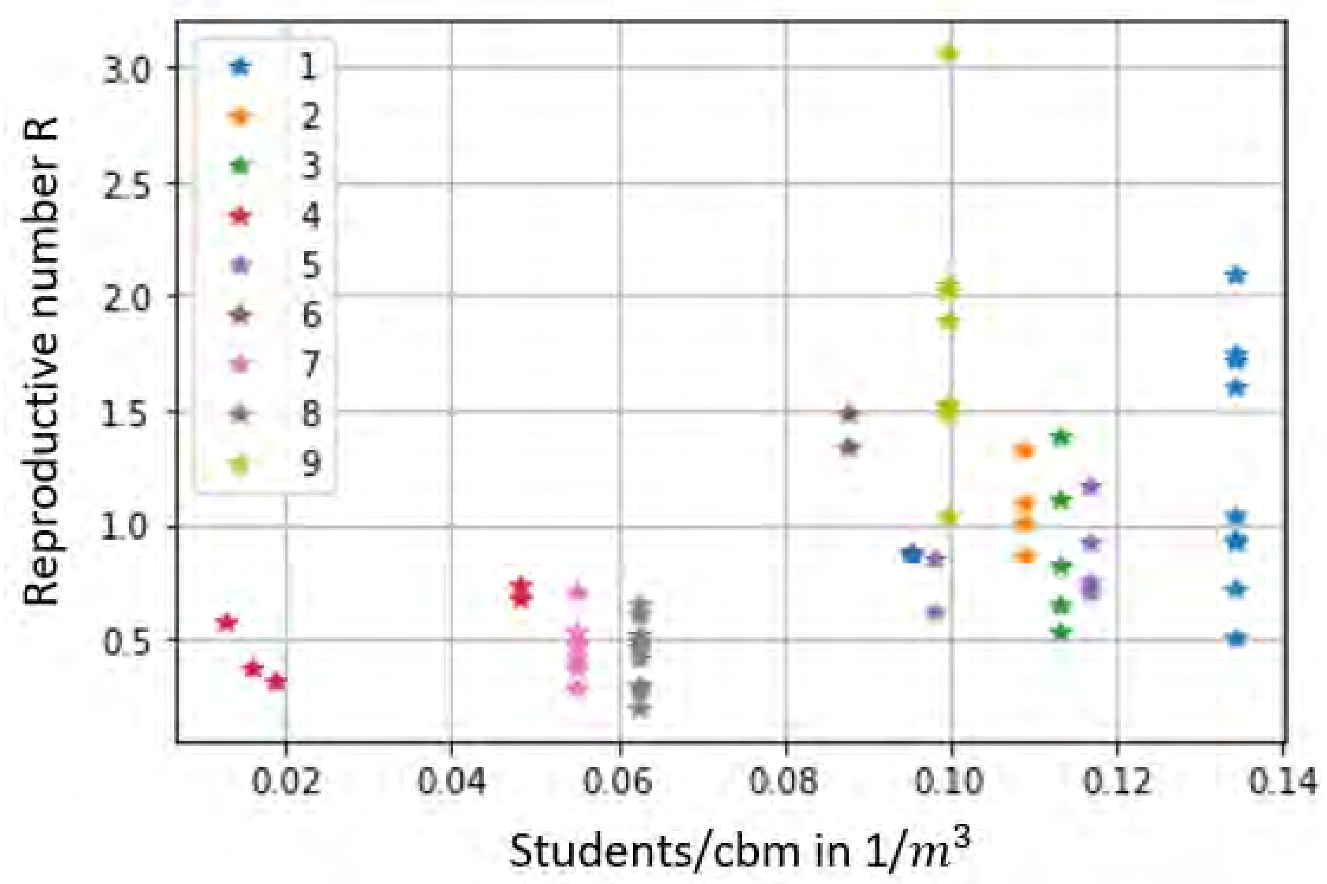

Fig. 2: Overview of all results for the reproductive number R, plotted over room occupation density. Each color/number represents a classroom.

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