Covid airborne risk: online tool to develop healthy buildings

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SUMMARY

Airborne transmission has been widely proven to be the main means of contagion of SARS-CoV-2 (Severe Acute Respiratory Syndrome Coronavirus 2) , as multiple studies have established (Greenhalgh et al., 2021; Miller et al., 2021; Lidia Morawska & Cao, 2020; Tang et al., 2021; World Health Organization, 2021), Furthermore, the main documented COVID-19 outbreaks have occurred indoors (Qian et al., 2021; Randall et al., 2021; Wang et al., 2022), with medium and long-range transmission —beyond 1.5 m— as a especially relevant transmission way in poorly bad ventilated spaces (Li, 2021; Z. Peng et al., 2022).
Thus, it is necessary to promote healthy indoor spaces through self-protection practices and an adequate indoor air quality (IAQ). In this way, the removal of the virus-containing aerosols from indoor air —either by ventilation, air filtration or UV radiation— must be an essential part of the prevention strategy.
One of the main ways to assess the degradation of the IAQ in occupied spaces —with no other significant sources or sinks of indoor carbon dioxide (CO_2) — is monitoring the indoor CO_2 level. This parameter can be a good proxy —affordable and easy to handle— to evaluate and control the aforementioned ventilation rates, especially in spaces with high occupancy density (American National Standards Institute and American Society of Heating Refrigerating and Air-Conditioning Engineers, 2019; Pavilonis, Ierardi, Levine, Mirer, & Kelvin, 2021; Z. Peng et al., 2022; Persily & de Jonge, 2017; Zhu et al., 2020). Given that virus-containing aerosols are emitted during the respiratory process as CO_2 does, the measurement of the excess CO_2 level exhaled (ΔCO_2) can also be used to estimate the airborne transmission risk of respiratory diseases such SARS-CoV-2, tuberculosis, or measles.
Thus, the estimation of the COVID-19 infection risk indoors —strictly via aerosols— can be performed with the online tool COVID Risk ^{airborne} (https://www.covidairbornerisk.com/), a non-profit software developed by Campano et al. (Campano-Laborda et al., 2021) and based on the adaptation of the Wells-Riley model (Rudnick & Milton, 2003) performed by Peng and Jiménez (Jimenez Palacios & Peng, 2021; Zhe Peng & Jimenez, 2021). The methodology on which this tool is based has been validated by comparison with existing COVID-19 outbreaks (Z. Peng et al., 2022).
This tool (Figure 1), which has been designed to be used both by scientists and technicians (detailed calculation) and by nonprofessional users (simplified calculation), uses the average excess CO_2 level exhaled (ΔCO_2) during a given event as a proxy to calculate how many 'quanta' inhaled each occupant (a 'quanta' can be considered as the minimum infectious dose of the aerosol pathogen whose inhalation leads to infection in 63% of vulnerable people). Inhalation of quanta depends on:

- SARS-CoV-2 variant under analysis.
- Room dimensions and environmental conditions (rate of decay of infection intensity and surface deposition rate).
- Removal/inactivation of aerosols from the environment (filtering, UV exposure, face masks).
- Number of people present, number of infectious occupants, activity involved (metabolic and vocalization) and immunity to the infection (by vaccines or previous infections).
- Event duration.
- Ventilation rate / Mean ΔCO_2 value during the event.

Figure 1: Landing page of COViD Risk ^{airborne}.

With this data input, this tool can estimate both the number of secondary cases in the given event, and the Risk of Infection (H) —in terms of the size of the outbreak—, but it can also calculate two additional risk indicators, which are not referred to the number of vulnerable occupants (those who are liable to contract the disease), so they can be used regardless of the number of people vaccinated or the effectiveness of the different vaccines:

- Attack rate (*AR*): The proportion of occupants in the event who could have inhaled a 'quanta'.
- Relative risk of infection (H_r): Number of 'quanta' emitted by a single infected person which are inhaled by a single person for a given exposure time and premises of the volume specified. There are three categories of risk (low, medium, and high) for H_r, according to previous studies of different indoor scenarios and existing documented outbreaks (Z. Peng et al., 2022; Zhe Peng & Jimenez, 2021).

Among the various considerations made by this tool, it should be noted that:

- The model EXCLUDES droplet and contact/fomite transmission and assumes that 2 m (6 ft) social distancing is honoured. Otherwise, the infection rates calculated would be higher.
- As the model also assumes the atmosphere in the premises/room at issue to be uniformly distributed, it does not accommodate the thermal stratification or floatability characteristic of very high clearance indoor spaces.
- The increased transmissibility of the SARS-CoV-2 variants is obtained from the reports of the European and North American Centres for Disease Control and Prevention (Campbell et al., 2021; Centers for Disease Control and Prevention, 2022).
- The estimation of the airborne viral emission is performed through the expiratory activity, which depends on the metabolic and vocalization activities (Buonanno, Stabile, & Morawska, 2020; L. Morawska et al., 2009).
- The evaluation of the average ventilation rate and the recommended short-term exposure values for inhalation, in m^3/h per occupant, are calculated through the metabolic rate, which depends on activity, age and gender (Z. Peng et al., 2022; Wang, Wang, Wei, Wang, & Duan, 2011), as well as the CO_2 emission (Persily & de Jonge, 2017).
- The decay rate of the virus infectivity in aerosols depends on the Air Temperature (T_a), Relative Humidity of the air (*HR*), the UV index and the deposition of virus-containing aerosols to surfaces (Schuit et al., 2020; Smither, Eastaugh, Findlay, & Lever, 2020; van Doremalen et al., 2020).
- The theoretical aerosol retention efficiency of masks, respirators and face shields depends on the type of the mask and its fitting (Davies et al., 2013; Melikov, 2015; Milton, Fabian, Cowling, Grantham, & McDevitt, 2013).

In conclusion, this online tool proposes a validated and precise method for simulating SARS-CoV-2 disease propagation, strictly via aerosols. One possible purpose would be to determine the risk of infection under circumstances defining a given planned event and the possibility of lowering such risk. Whilst it is not an epidemiological model, it can be used as a component of such approaches to estimate variations in aerosol propagation across a range of inputs. Thus, it can be very useful to scientists, technicians, building managers, designers, and citizens to reduce the risk of airborne transmission of SARS-CoV-2 in indoor events.

KEYWORDS

CO_2 concentration; Indoor spaces; SARS-CoV-2; Airborne transmission; COVID-19 infection risk

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