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Assessing Indoor Air Quality and ventilation to limit the spread of airborne pathogens – a review

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Extended abstract. The corona pandemic underlined a lack of Indoor Air Quality (IAQ) and ventilation. Consequently, to limit the spread of the virus, researchers explored several indicators that, through different approaches, assess IAQ and ventilation performance in indoor spaces. This paper gives an overview of those indicators and assessment methods used to evaluate IAQ and ventilation regimes focusing specifically on airborne pathogens. This review considers studies from before and during the COVID-19 pandemic. The indicators found fit into three categories: dose, building, and occupant-related indicators. Studies exploring assessment methods found in this review are grouped according to their themes: aerosol dispersion, ventilation, infection risk, design parameters, and human behaviour. The review showed a need for a holistic definition for IAQ indicators that includes all indicators and a holistic approach of studying IAQ including all five themes.

Background. At the start of the COVID-19 outbreak, the airborne transmission of the virus was rejected based on the low reproduction number of the virus. However, after admitting that the virus is airborne, the weaknesses in Indoor Air Quality (IAQ) and ventilation, that researchers have been underlining for years, became the centre of attention. To quantify the lack of IAQ and ventilation, researchers explored several indicators that, through different approaches, assess the IAQ and the ventilation performance in indoor spaces.

Aims. To provide an overview of the indicators and assessment methods used to evaluate IAQ and ventilation regimes focusing specifically on airborne pathogens (Hobeika et al. 2023).

Methods. This review considers studies from before and during the COVID-19 pandemic. Scopus, Google Scholar, ScienceDirect, Wiley, SpringerLink, PubMed, and the TU Delft library books were used to search for six concepts: airborne diseases, ventilation, air quality, schools or offices, indicator, and assessment approaches. Papers that mainly dealt with energy consumption and ventilation were left out.

IAQ Indicators. The indicators found fit into three categories: dose, occupant, and building-related indicators. Dose-related indicators include CO_2 concentrations, used as proxy for the virus (Zhang et al., 2022; Hou et al., 2021), properties related to the physics of particles and airflow (Bluyssen et al., 2021; Nielsen, 2008; Melikov et al., 2002), temperature and relative humidity (Dbouk and Drikakis, 2020b; Aliabadi et al., 2010). Occupant-related indicators used are the infection or exposure risk (Peng and Jimenez, 2021; Zivelonghi and Lai, 2021), relative position between source and receptor (Blocken et al., 2020; Nielsen 2012), and duration of stay (Peng et al., 2022; Sun and Zhai, 2020). Lastly, building-related indicators are the opening of windows and doors (Park et al., 2021), the position and configuration of the inlet and outlet of mechanical ventilation (Lipinski et al. 2020), and the layout (Afshari et al., 2021) and volume of the studied space (Peng et al., 2022).

Assessment methods. Studies exploring assessment methods found in the review are grouped according to their themes: aerosol dispersion, ventilation, infection risk, design parameters, and human behaviour. Aerosol dispersion studies encompass aerosol-generating tasks under

different conditions (Ortiz et al., 2021; Dbouk and Drikakis, 2020a). Ventilation studies assess pollutants' concentration or the airflow patterns and their space distributions (Zhang et al., 2022; Lipinski, 2020). Infection risk assessment studies quantify the infection probability of a disease (Peng and Jimenez, 2020) and test preventive control strategies (Xu et al. 2022). Studies that include design parameters focus on the impact of room size and volume and the size and position of doors, windows, air inlets and outlets of the ventilation system (Faleiros et al., 2022; Peng et al., 2022). Finally, studies that cover human behaviour include the movement of individuals and the opening and closing of windows (Blocken et al., 2021; Vuorinen et al., 2020).

Results. The review showed a predominant use of the dose-related indicators over the building and occupant-related indicators, leading to the need for a holistic definition for IAQ indicators that includes all indicators, whether related to air properties, occupant's health, or building parameters (see Figure 1).

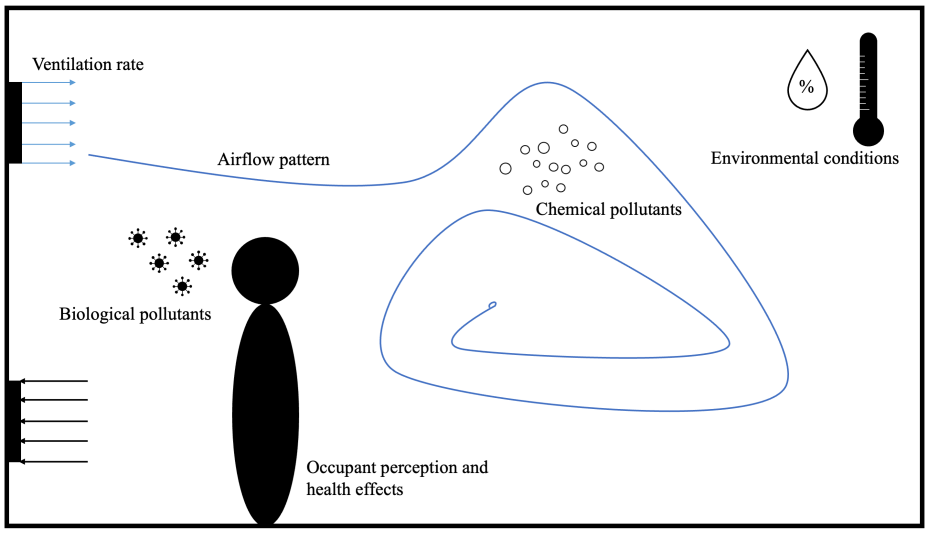
The review also presented multiple set-ups for numerical simulations that differ between studies depending on the aim and the scope of the research. It also revealed a lack of an optimisation tool for a room's design parameters tailored to minimise the spread of airborne pathogens. Additionally, grouping the assessment methods according to five main themes revealed a scarcity of literature addressing, on one part, ventilation and aerosol dispersion and, on the other part, design parameters and human behaviour. This shows a lack of coordination between different fields that hinders a better understanding of airborne transmission and thus limits the proposed solutions.

Conclusions. This literature review aims to present an overview of indicators and assessment methods that are used to study airborne transmission of pathogens and ventilation in indoor spaces. The conclusions are as follows:

- There is a need for a more holistic definition for IAQ indicators.
- There is a lack of an optimisation tool for a room's design parameters tailored to minimise the spread of airborne pathogens.
- Ultimately, to reach the desired indoor air quality, that minimises the spread of airborne pathogens, a better coordination between different fields is also needed.

Keywords. indoor air quality, aerosol dispersion, ventilation, numerical modelling, computational fluid dynamics, assessment.

Figure 1 IAQ indicators presented holistically (source: Hobeika et al. 2023)



Remark

A full version of this review can be found in Hobeika et al. (2023).

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