Prevention and control of COVID-19 transmission in the indoor environment

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The current global pandemic of the 2019 novel coronavirus disease COVID-19 has caused a serious global concern about human respiratory health.1,2 Particularly, the outbreak of the COVID-19 epidemic is found to be closely related to the transmission of infectious particles between persons in indoor environments, which highlights the importance of implementing strict and effective measures to prevent and control the transmission of infectious diseases.3–5 Measures for COVID-19 control should be established based on a clear understanding of transmission mechanisms and a full consideration of the context of use. The objective of this special issue is to explore potential measures for effective disease control in indoor environments, including homes, public buildings, hospitals, vehicles, etc. and to clarify their underlying mechanisms for mitigating the risk of the disease transmission. This special issue covers original research and review studies, mainly including the following topics:

- Mechanisms of the generation of infectious droplets from occupants’ respiratory activities
- Aerodynamic behaviours of the novel coronavirus and its potential for airborne transmission
- Viability of SARS-CoV-2 in the indoor environment and its influencing factors
- Epidemiological studies on COVID-19 indoor transmission pathways
- Dispersion and propagation characteristics of exhaled droplets in the indoor environment
- Intervention measures and their effect on prevention and control of the disease transmission in the indoor environment
- Evaluation of the exposure and infection risk of airborne disease for occupants
- Proper design and operation of Heating, Ventilation and Air Conditioning (HVAC) systems as a control measure to reduce airborne disease transmission
- Disinfection and air cleaning methods and their effectiveness for indoor airborne infection control

This special issue includes a total of 19 contributions from 7 different countries. The received papers underwent a rigid peer review procedure for publication in the Journal, Indoor and Built Environment. Papers included in this special issue have been carefully selected to present the recent new findings of research focusing on the above topics.

There are three review papers included in this special issue. The paper by Nielsen and Xu summarized multiple airflow patterns affecting the airborne transmission route in the micro-environment between people and highlighted the importance of understanding the complex flow dynamics and interactions to prevent and control short-ranged airborne transmission. Ye et al. provided a systematic investigation of the Chinese HVAC guidelines for different occasions (e.g. office buildings, schools, hotels, hospitals, etc.) to cope with the COVID-19 transmission and compared them with guidelines from other countries or institutions. The possibility of transformation of the HVAC system between normal time and epidemic period and the novel HVAC system designs aiming at reducing indoor infection risk were also discussed. Yun et al. reviewed different methods for sampling and detecting the airborne virus including SARS-CoV-2 and they pointed out the lack of standardization for sampling and detection of the virus.

Emission and dispersion of droplets from different respiratory activities like coughing, sneezing or breathing were studied by a number of authors in the following three papers. Pallares and Fabregat proposed a model to predict the shape and dimension of exhaled clouds containing droplets or droplet nuclei from coughing or sneezing. The model was validated by numerical simulations and experiments. Ge et al. used large-eddy simulation (LES) to study the two-phase coughing flow considering the change of mouth opening areas and behaviours of droplet breakup, evaporation, dispersion and drag force. The two stages

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of droplet penetration were found with logarithmic functions and the factors influencing the penetration distance were discussed. Cravero and Marsano simulated the indoor dispersion of droplets from coughing and sneezing by using a URANS CFD approach. The effects of different ventilation systems and the use of face masks were discussed based on the simulation results.

The virus inactivation characteristics in indoor air and on fabrics were studied by Yang et al. and Tracy et al., respectively. Yang et al. collected experimental data from medical studies and calculated the decay of the activity of aerosolized viruses. The influencing factors including the ambient air temperature, relative humidity and initial droplet size were analyzed. Tracy et al. studied two typical contract fabrics (polyester and wool) and cotton for HCoV-OC43 (ATCC #VR-1558) persistence up to 24 h using a modified ISO 18184 test protocol. Different virus inactivation properties were found among the three fabrics and the liquid absorption rate of the three materials might be the main reason contributing to the inactivation differences. The surface contamination level of SARS-CoV-2 in a rapidly built field hospital (Wuhan Leishenshan Hospital in China) was sampled by Wang et al. to provide on-site data on the environmental contamination in such a medical environment. This study highlighted the importance of surface disinfection and cleaning measures in these hospitals.

To predict and mitigate the airborne infection risk of SARS-CoV-2, a web tool of the Facility Infection Risk Estimator™ based on Wells-Riley model was proposed by Harmon and Lau to estimate a) the removal efficiencies of various strategies like ventilation, settling, filtration and inactivation and b) the associated probability of infection. Zhai and Li developed new formulae to calculate the non-uniform spatial distribution of infection risk by revising the original Wells-Riley model. This method can be helpful to estimate the airborne infection risk of respiratory diseases by using measured or simulated pathogen concentrations distributed in the indoor space. The potential infection risk of medical staff performing endotracheal intubation in a negative pressure isolation ward was estimated by Li et al. based on CFD simulations. Burridge et al. presented a method to determine the relative risk of airborne transmission that can be readily deployed with either modelled or monitored CO2 data and occupancy levels within an indoor space. The interpersonal transmission of expiratory aerosols in close proximity was measured by Fu et al. with two breathing thermal manikins and atomized particles as tracers. The size distribution of droplet nuclei and relative distances between occupants would significantly affect the intake fraction of the exposed occupant by inhalation. Chow and Chow proposed a two-stage quarantine scheme with quarantining people into units within blocks to control the spread of SARS-CoV-2 and to identify asymptomatic patients with a more targeted screening test.

Ventilation is considered an effective way to prevent and control the airborne transmission of SARS-CoV-2 in the indoor environment. The effectiveness of using a vertical laminar airflow system in a hospital patient room and the negative-pressure ventilation in isolation spaces in residential homes to prevent SARS-CoV-2 transmission were studied by Jeong et al. and Khan et al., respectively. Munuzuri et al. dealt with optimized natural ventilation times by incorporating local meteorological data with building parameters for the purpose of improving the epidemiological security of occupants.

Additionally, a case study was conducted by Li et al. from Peking University in China to investigate the social organisation of makeshift hospital patients so as to reveal the social and emotional ramifications of such emergency spaces on people.

As mentioned before, the goals of this special issue were to develop new knowledge of the transmission of COVID-19 and to effectively predict, prevent and control the infection risk of this disease. We hope the readers of the Indoor and Built Environment can help us to achieve these goals based on the papers included in this special issue.

Authors contribution
All authors contributed equally in the preparation of this article.

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