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Aéraulique et COVID-19

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Google Scholar, Lens et WoS

Dixit, A. K., Espinoza, B., Qiu, Z., Vullikanti, A., Marathe, M. V.
Airborne disease transmission during indoor gatherings over multiple time scales: Modeling framework and policy implications.
Proceedings of the National Academy of Sciences, Vol. **120** n°(16), (2023)

Indoor superspreading events are significant drivers of transmission of respiratory diseases. In this work, we study the dynamics of airborne transmission in consecutive meetings of individuals in enclosed spaces. In contrast to the usual pairwise-interaction models of infection where effective contacts transmit the disease, we focus on group interactions where individuals with distinct health states meet simultaneously. Specifically, the disease is transmitted by infected individuals exhaling droplets (contributing to the viral load in the closed space) and susceptible ones inhaling the contaminated air. We propose a modeling framework that couples the fast dynamics of the viral load attained over meetings in enclosed spaces and the slow dynamics of disease progression at the population level. Our modeling framework incorporates the multiple time scales involved in different setups in which indoor events may happen, from single-time events to events hosting multiple meetings per day, over many days. We present theoretical and numerical results of trade-offs between the room characteristics (ventilation system efficiency and air mass) and the group's behavioral and composition characteristics (group size, mask compliance, testing, meeting time, and break times), that inform indoor policies to achieve disease control in closed environments through different pathways. Our results emphasize the impact of break times, mask-wearing, and testing on facilitating the conditions to achieve disease control. We study scenarios of different break times, mask compliance, and testing. We also derive policy guidelines to contain the infection rate under a certain threshold.

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Yoon, G. Y., Lee, S. J., Kwon, H., Kim, J. J.
Effect of flow structures on natural ventilation performance in office model.
Journal of Visualization, Vol. **26** n°(2), (2023), pp. 289-298

The recent Coronavirus Disease 2019 pandemic has highlighted the importance of indoor ventilation. In particular, ventilation is crucial in residential spaces and workspaces, where people spent most of their day. Natural ventilation is a cost-effective method for improving indoor ventilation. It can provide safe and comfortable residential and working environments without additional energy consumption. In this study, the ventilation performance was experimentally studied by measuring the concentration of ultrafine particulate matter according to the opening conditions of the windows and door of an office model in a wind tunnel. Furthermore, the internal flow structure in the office model was quantitatively analyzed through particle image velocimetry to determine the factors that affected the ventilation performance. The mean velocity inside the model and the ventilation performance increased with the opening angle of the windows. In particular, the opening condition of the door strongly affected the ventilation performance. This study is expected to provide a guideline for effectively improving the ventilation performance in indoor spaces.

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Veenstra, T., Van Schelven, P. D., Ten Have, Y. M., Swaan, C. M., Van Den Akker, W. M.
Extensive Spread of SARS-CoV-2 Delta Variant among Vaccinated Persons during 7-Day River Cruise, the Netherlands.
Emerging Infectious Diseases, Vol. **29** n°(4), (2023)

We investigated a large outbreak of SARS-CoV-2 infections among passengers and crew members (60 cases in 132 persons) on a cruise ship sailing for 7 days on rivers in the Netherlands. Whole-genome analyses suggested a single or limited number of viral introductions consistent with the epidemiologic course of infections. Although some precautionary measures were taken, no social distancing was exercised, and air circulation and ventilation were suboptimal. The most plausible explanation for introduction of the virus is by persons (crew members and 2 passengers) infected during a previous cruise, in which a case of COVID-19 had occurred. The crew was insufficiently prepared on how to handle the situation, and efforts to contact public health authorities was inadequate. We recommend installing clear handling protocols, direct contacts with public health organizations, training of crew members to recognize outbreaks, and awareness of air quality on river-cruise ships, as is customary for most seafaring cruises.

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Raymenants, J., Geenen, C., Budts, L., Thibaut, J., Thijssen, M., De Mulder, H.*, et al.*
Indoor air surveillance and factors associated with respiratory pathogen detection in community settings in Belgium.
Nature Communications, Vol. **14** n°(1), (2023)

Currently, the real-life impact of indoor climate, human behaviour, ventilation and air filtration on respiratory pathogen detection and concentration are poorly understood. This hinders the interpretability of bioaerosol quantification in indoor air to surveil respiratory pathogens and transmission risk. We tested 341 indoor air samples from 21 community settings in Belgium for 29 respiratory pathogens using qPCR. On average, 3.9 pathogens were positive per sample and 85.3% of samples tested positive for at least one. Pathogen detection and concentration varied significantly by pathogen, month, and age group in generalised linear (mixed) models and generalised estimating equations. High CO2 and low natural ventilation were independent risk factors for detection. The odds ratio for detection was 1.09 (95% CI 1.03–1.15) per 100 parts per million (ppm) increase in CO2, and 0.88 (95% CI 0.80–0.97) per stepwise increase in natural ventilation (on a Likert scale). CO2 concentration and portable air filtration were independently associated with pathogen concentration. Each 100ppm increase in CO2 was associated with a qPCR Ct value decrease of 0.08 (95% CI −0.12 to −0.04), and portable air filtration with a 0.58 (95% CI 0.25–0.91) increase. The effects of occupancy, sampling duration, mask wearing, vocalisation, temperature, humidity and mechanical ventilation were not significant. Our results support the importance of ventilation and air filtration to reduce transmission.

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Clements, N., Arvelo, I., Arnold, P., Heredia, N. J., Hodges, U. W., Deresinski, S.*, et al.*
Informing Building Strategies to Reduce Infectious Aerosol Transmission Risk by Integrating DNA Aerosol Tracers with Quantitative Microbial Risk Assessment.
Environmental science & technology, Vol. **57** n°(14), (2023), pp. 5771-5781

Using aerosol-based tracers to estimate risk of infectious aerosol transmission aids in the design of buildings with adequate protection against aerosol transmissible pathogens, such as SARS-CoV-2 and influenza. We propose a method for scaling a SARS-CoV-2 bulk aerosol quantitative microbial risk assessment (QMRA) model for impulse emissions, coughing or sneezing, with aerosolized synthetic DNA tracer concentration measurements. With point-of-emission ratios describing relationships between tracer and respiratory aerosol emission characteristics (i.e., volume and RNA or DNA concentrations) and accounting for aerosolized pathogen loss of infectivity over time, we scale the inhaled pathogen dose and risk of infection with time-integrated tracer concentrations measured with a filter sampler. This tracer-scaled QMRA model is evaluated through scenario testing, comparing the impact of ventilation, occupancy, masking, and layering interventions on infection risk. We apply the tracer-scaled QMRA model to measurement data from an ambulatory care room to estimate the risk reduction resulting from HEPA air cleaner operation. Using DNA tracer

measurements to scale a bulk aerosol QMRA model is a relatively simple method of estimating risk in buildings and can be applied to understand the impact of risk mitigation efforts.

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Nazari, A., Wang, C., He, R., Taghizadeh-Hesary, F., Hong, J.
Numerical Investigation of Airborne Infection Risk in an Elevator Cabin under Different Ventilation Designs.
arXiv preprint, (2023)

Airborne transmission of SARS-CoV-2 via virus-laden aerosols in enclosed spaces poses a significant concern. Elevators, commonly utilized enclosed spaces in modern tall buildings, present a challenge as the impact of varying heating, ventilation, and air conditioning (HVAC) systems on virus transmission within these cabins remains unclear. In this study, we employ computational modeling to examine aerosol transmission within an elevator cabin outfitted with diverse HVAC systems. Using a transport equation, we model aerosol concentration and assess infection risk distribution across passengers' breathing zones. We calculate particle removal efficiency for each HVAC design and introduce a suppression effect criterion to evaluate the effectiveness of the HVAC systems. Our findings reveal that mixing ventilation, featuring both inlet and outlet at the ceiling, proves most efficient in reducing particle spread, achieving a maximum removal efficiency of 79.40% during the exposure time. Conversely, the stratum ventilation model attains a mere removal efficiency of 3.97%. These results underscore the importance of careful HVAC system selection in mitigating the risk of SARS-CoV-2 transmission within elevator cabins.

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Kapsalaki, M.
Proposed Non-infectious Air Delivery Rates (NADR) for Reducing Exposure to Airborne Respiratory Infectious Diseases.
The Lancet COVID-19 Commission Task Force on Safe Work, Safe School, and Safe Travel 2023

In November 2022, the Lancet COVID-19 Commission Task Force on Safe Work, Safe School, and Safe Travel released a report proposing new Non-infectious Air Delivery Rates (NADR) for Reducing Exposure to Airborne Respiratory Infectious Diseases, exceeding the current minimum standards, and aiming to help mitigate infection risk and promote health.
The results from their study confirm that enhanced ventilation, filtration, and air disinfection are effective in reducing exposure risks for SARS-CoV-2 and other respiratory infectious diseases, as well as providing other benefits, such as improved cognitive function, fewer allergic reactions and unscheduled asthma visits for children, better subclinical cardiopulmonary health etc.

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Xie, H., Li, Y., Liu, Y., Zhong, P., Liu, H., Li, C.*, et al.*
The transformation of microclimate adaption in public spaces by smart ventilation approach: a case study of Eastern Banlieue memory industrial Park, China.
Journal of Asian Architecture and Building Engineering, (2023)

With the normalization of the COVID-19 pandemic prevention and control, there is an urgent need to develop a healthy urban public space. However, because of the fast urbanization process with a series of problems, such as PM2.5 air pollution, the Urban Heat Island, and the relatively high frequency of static winds under the influence of its topography, the ventilation problem in the public spaces of Chengdu is of great importance. Along these lines, in this work, the history of theoretical research on urban ventilation is summarized and reviewed first to evaluate the urban wind environment. Second, so far, qualitative methods are mainly adopted for the evaluation methods of microclimate adaptation. However, the practical application has achieved few results. Meanwhile, there is still a lack of comprehensive and unified research on the multi-

element of human microclimate comfort in public space. For this reason, the urban ventilation assessment system was established in this work according to the physical, physiological, and psychological aspects, with 9 indices selected and ranked. Then, an optimization strategy for rebuilding the urban public space was proposed for improving the wind environment microclimate adaption on three levels: macro city-regional level, meso block linear space, and micro space node. By taking Eastern Banlieue Memory Industrial Park as an example, the statistical data were systematically investigated on the spot from the results of 249 wind environment questionnaires, and 30 Delphi expert consultation questionnaires. Combined with the Computational Fluid Dynamics (CFD) simulation, the results reveal that most public spaces in the study area were below 0.6 m/s in more than 80% of the public space, and wind-based environmental problems obviously exist without any ventilation improvement measures. Combined with the background of the carbon peak era, the ventilation environment of the urban public space is not conducive to using active ventilation equipment. The solution of a complete set of regional intelligent ventilation systems was thoroughly discussed here, while some innovative sustainable systematic solutions and urban ventilation furniture combined with a geothermal heat pump and cloud data platform were formulated.

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