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Aéraulique et COVID-19

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Google Scholar, Lens et WoS

Zhao, H., Du, R., Liu, Y., Wang, D., Li, Y.
Assessing indoor PM2.5 microbial activity in a university campus environments in Beijing.
Building and Environment, Vol. **246**, (2023)

Most people spend 90 % of their time inside, indoor bioaerosols significantly impact human health. This study aimed to investigate the substantial impact of indoor bioaerosols, particularly the harmful small particle-size components within Particulate Matter 2.5 (PM2.5), on human health in a crowded campus setting. Conducted during the summer at a Beijing university, the research assesses microbial activity within PM2.5 in offices (occupied by both teachers and students) and student dormitories, encompassing bedrooms and common areas. The optimized Fluorescein Diacetate (FDA) hydrolysis method was employed for assessment. Indoor microbial activity ranged from 1.18 to 176.56 ng m(-3) sodium fluorescein while outdoor activity ranged from 6.14 to 90.15 ng m(-3) sodium fluorescein. Meteorological factors, including heavy rain and strong winds, influenced the correlation between indoor and outdoor microbial activity, contrasting with the effect of air pollution levels. Offices with high occupancy and outdoor environments with strong winds or heavy rain often resulted in an I/O ratio >2, and a negative correlation was observed between the I/O ratio and indoor microbial activity. The study underscores the significance of ventilation type (air conditioning vs. natural ventilation), emphasising the importance of maintenance and clean living habits in reducing indoor microbial loads. Furthermore, it identifies population density as a pivotal factor affecting microbial activity in office air. This study contributes to assessing Indoor Air Quality (IAQ) and controlling bioaerosol pollution, and provides an effective measure for rapidly evaluating biological air pollution in crowded indoor environments using the PM-based microbial activity.

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Lozano, D., Dohoo, C., Elfstrom, D., Carswell, K., Guthrie, J. L.
COVID-19 outbreak at a residential apartment building in Northern Ontario, Canada.
Epidemiology and Infection, (2024), 1-26 p.

In February 2021, a cluster of B.1.351 (Beta variant) COVID-19 cases were identified in an apartment building located in Northern Ontario, Canada. Most cases had no known contact with each other. Objectives of this multi-component outbreak investigation were to better understand the social and environmental factors that facilitated transmission of COVID-19 through this multi-unit residential building. A case-control study examined building-specific exposures and resident behaviours that may have increased the odds of being a case. A professional engineer assessed the building's heating, ventilation, and air conditioning systems. Whole genome sequencing and an in-depth genomic analysis were performed. Forty-five outbreak confirmed cases were identified. From the case-control study, being on the upper floors (OR: 10.4; 95% CI: 1.63-66.9) or within three adjacent vertical lines (OR: 28.3; 3.57-225) were both significantly associated with being a case of COVID-19, after adjusting for age. There were no significant differences in reported behaviours, use of shared spaces, or precautions taken between cases and controls. Assessment of the building's ventilation found uncontrolled air leakage between apartment units. A single genomic cluster was identified, where most sequences were identical to one another. Findings from the multiple components of this investigation are suggestive of aerosol transmission between units.

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Xu, J., Wang, C., Guo, H.

Effect of personalized air curtain combined with mixing ventilation on dispersion of aerosols released at different velocities from respiratory activities during close contact.
Journal of Building Engineering, (2024)

Release velocities of aerosols vary among people and respiratory activities. To better promote the application of personalized air curtain (PAC) in practice, this work investigated the performance of PAC combined with mixing ventilation in terms of dispersion of aerosols released at different velocities using a simulation approach of computational fluid dynamics (CFD). The healthy person (HP) and infected person (IP) were in face-to-face and face-to-back scenarios during close contact. Results showed that the aerosol dispersion was highly affected by aerosol release velocities. When aerosols were released from 2.0 m/s to 8.0 m/s, the deposition rate was increased by more than 3 times and 10 times in the face-to-face and face-to-back scenarios, respectively. The intake fraction was increased by over 3 times in the face-to-face scenario. PAC could significantly reduce the intake fraction and deposition rate. When aerosols were released at 8.0 m/s, PAC could reduce the intake fraction and deposition rate by 76% and 66% in the face-to-face scenario, respectively. A higher PAC velocity did not necessarily lead to a better performance. The appropriate PAC velocity of 3.0–5.0 m/s was suggested in this work. The significantly reduced intake fraction and deposition rate suggest that PAC as an advanced ventilation system can be a promising control measure to prevent the spread of respiratory diseases in indoor environments. Additionally, different performances of PAC indicate the importance of investigating the appropriate PAC velocities in relation to aerosol release velocities. Otherwise, more energy is consumed by PAC, but the best performance is not achieved.

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O'brien, S. M., Artigas, D., Alan, E.
Energy Implications of Increased Ventilation in Commercial Buildings to Mitigate Airborne Pathogen Transmission.
43rd AIVC - 11th TightVent - 9th venticool Conference - Copenhagen, Denmark - 4-5 October 2023

One proposed mitigation to reduce transmission of the SARS-CoV-2 virus and other airborne pathogens is to increase ventilation in buildings. This measure can be difficult to implement in existing buildings and has the potential environmental costs of increased energy consumption to condition the additional airflow, as well as other potential costs such as the disposal of existing serviceable mechanical equipment and the manufacture and delivery of new equipment. This paper focuses on the increased energy consumption caused by increased ventilation rates in commercial buildings to mitigate airborne pathogen transmission. We used energy modelling software to compare energy use in different typical commercial buildings in different climates at current standard ventilation rates to the energy use in the same buildings with increased ventilation rates and filtration. Our analysis shows that increased filtration has little effect on energy used for air conditioning, but that increased ventilation has a significant effect.

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Huang, W., Chen, C.
Fast prediction of particle transport in complex indoor environments using a Lagrangian-Markov chain model with coarse grids.
Energy and Buildings, Vol. **306**, (2024)

Fast calculation of person-to-person particle transport is essential for accelerating the evaluation and design of air distribution for reducing the risk of infection. This study developed a Lagrangian-Markov chain model with coarse grids for fast prediction of person-to-person particle transport in complex indoor environments. Detailed procedures and parameter determination approaches were developed. The proposed Lagrangian-Markov chain model was first validated with experimental data in two real-life cases of person-to-person particle transport, one in an aircraft cabin and the other in a COVID-19 isolation ward. The computing speed of the proposed model was then compared with the flux-based Markov chain, Eulerian, and Lagrangian models. The results show that the proposed Lagrangian-Markov chain model can predict person-to-person particle transport reasonably well in real-life cases with complex geometry and airflow fields. In terms of computing speed, the proposed LagrangianMarkov chain model with coarse grids can be tens to hundreds of times faster than the three existing models for the two evaluation cases. With its fast computing speed, the Lagrangian-Markov chain model can be applied in the fast design of air distribution for real-life complex indoor environments.

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Mostafavi Sani, H., Shokouhmand, H.

Integrating energy efficiency and health safety in building design: A multi-objective optimization approach to minimize virus transmission risk.

Journal of Building Engineering, Vol. **86**, (2024)

This study aims to develop an integrated design strategy for an office building in Tehran, optimizing energy efficiency and minimizing virus infection risk, addressing global challenges such as energy conservation and virus transmission. A multi-objective optimization model is developed to identify optimal design parameters for energy performance and infection risk reduction. Environmentally sustainable materials and energy-efficient equipment, such as solar panels, high-efficiency heat pump systems, and advanced air filtration techniques, are employed. The modified Wells-Riley Risk Model calculates infection risk, while energy efficiency is formulated based on the technologies used. Results showcase a significant 14% increase in energy efficiency and a 46% decrease in infection risk compared to traditional building designs, demonstrating the effectiveness of the proposed integrated approach. The optimal design parameters include ventilation rate, the number of solar panels, hot water pipe diameter, and heat pump condenser temperature. This study presents a practical, sustainable solution for designing office buildings that actively address pressing global concerns while fostering healthier, energy-efficient environments. The novelty of this research lies in the development of a multi-objective optimization model that synergizes infection control and energy efficiency, accounting for real equipment parameters and providing a new paradigm for HVAC design. This integrated strategy optimizes decision variables like ventilation rate, filtration level, solar panels, and heat pump operating conditions, offering a comprehensive approach to co-optimize infection control and energy performance.

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Melikov, A. K.

Mitigation of airborne transmission of respiratory viruses by ventilation–past, present and future.

43rd AIVC - 11th TightVent - 9th venticool Conference - Copenhagen, Denmark - 4-5 October 2023

The importance of ventilation of spaces for occupants' health has been known for many years. Ancient Egyptians used natural ventilation to remove dust and thus to reduce respiratory diseases of stone carvers working indoors (Janssen 1999). In the past ventilation has been used to reduce airborne transmission of respiratory generated infectious agents in buildings. In the book "Natural and Artificial Methods of Ventilation" (Robert Byle & Son, London 1899), chapter X it is stated "The report on the influenza epidemic presented to Parliament by the Local Government Board indicates the extreme importance of proper ventilation – especially in schools – which is pronounced to be the only real safeguard against that disease.". Several ventilation solutions in classroom and hospital patient rooms are suggested in the book with focus on the clean air distribution. Thus, already two centuries ago the importance of clean air distribution for fulfilling the main goal of ventilation, namely to provide occupants with clean air for breathing has been considered...

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Kanté, D. S. I., Jebrane, A., Boukamel, A., Hakim, A.

A multiscale model to investigate the impact of the ventilation airflow type on the risk to contract COVID-19 in a closed environment.
AIP Conference Proceedings, Vol. **3034** n°(1), (2024)

The superspreading of covid 19 in closed environments has been an obstacle to the control of the pandemic. This article gives insight into the estimates of the virus concentration inhaled by susceptible people in a closed environment with an air conditioning system that might bring in fresh air and exhaust stale air. The study integrates displacements and interactions in the environment. We implemented a spatio-temporal multi-scale modeling approach that relies on the coupling of an advection-reaction-diffusion equation to describe the viral concentration in the environment and a social forces model to govern agent dis-placement. Three scenarios were discussed: one with an uniform air flow from a ventilation system, one with variable air flow, and one without an air conditioner at all. The effectiveness of non-pharmaceutical interventions in limiting the risk of infection is evaluated for each scenario. According to the findings, the virus concentrations inhaled by susceptible people decreases by 98 %, compared to the scenario where there is no ventilation. Additionally, the results recommend maintaining a social distance inside a closed environment without ventilation systems, and that using masks in combination with a good conditioning system with ventilation improves the effectiveness of mask use.

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Khan, O., Parvez, M., Seraj, M., Yahya, Z., Devarajan, Y., Nagappan, B.
Optimising building heat load prediction using advanced control strategies and Artificial Intelligence for HVAC system.
Thermal Science and Engineering Progress, Vol. **49**, (2024)

Amid the dynamic challenges posed by the COVID-19 era, this study offers a nuanced exploration, delving into the complexities of optimising building heat load prediction. This study addresses the imperative challenge of optimising building heat load prediction by implementing advanced control strategies and integrating Artificial Intelligence (AI) into air conditioning systems. The study emphasises the need to design HVAC devices for minimal energy consumption without compromising comfort conditions. The study introduces an intelligent predictive adaptive neuro-fuzzy inference system (ANFIS) model that proves highly capable of accurately predicting HVAC performance outcomes while contributing to the development of a comprehensive dataset. The uncertainty percentage is evaluated across various membership functions, with the trapezoidal membership exhibiting the lowest error rate, followed by the Gaussian membership function. Weather parameters crucial to ventilation efficiency and heat load are examined, leading to the identification of an optimal combination involving 45 % relative humidity, 13 °C dry bulb temperature, and 5 km/h wind speed. The current system demonstrates significant efficiency improvements, with ventilation and heat load rates reaching 93 % and 97 %, respectively, compared to pre-COVID-19 conditions. The findings underscore the importance of considering these parameters in future HVAC designs, particularly in the context of COVID-19 guidelines (75 % and 79 %, respectively).

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Matsubara, S., Ozawa, S., Kameyama, S., Takada, M., Tanaka, G.
Optimization of Suction Device Installation for Control of Aerosol Dispersion in Otorhinolaryngology Examination Rooms.
Advanced Biomedical Engineering, Vol. **13**, (2024), 73-81 p.

The global spread of COVID-19 in 2020 had a significant impact on the population. Healthcare workers who have unpreventable contact with infected individuals are at high risk of infection. We therefore proposed “infection control methods in high-risk environments” and demonstrated that appropriate placement of suction devices in otorhinolaryngology examination rooms is effective for aerosol control [Takada M, Fukushima T, Ozawa S, Matsubara S, Suzuki T, Fukumoto I, Hanazawa T, Nagashima T, Uruma R, Otsuka M, Tanaka G: Sci Rep. 12(1), 18230, 2022]. As a further study of the previous research, this study analyzed the specific environmental factors that contribute to reducing the risk of infection by optimizing the manner in which suction devices are set up. The models of a patient and doctor were placed in an examination room. A steady flow of 2.5 m/s was applied to the patient's mouth as exhalation. Aerosol diffusion was analyzed using computational fluid dynamics. The optimization parameters were the position and angle of suction inlet, and suction speed. The objective evaluation was the “maximum number of particles aspirated from the suction inlet”. A total of 150 designs were tested, and the search for the optimal positions was performed in the examination room. The optimization results showed that the maximum particle removal rate was 98.6%. There were six cases in which the particle removal rate was at least 98%. These positions were within the range of x = 0.120 to 0.159 m in the horizontal direction from the patient's mouth to the suction inlet. The suction inlet was placed laterally in front of the patient, along the trajectory of the particles emitted from the patient's mouth. Particle removal rates of over 98% at various suction speeds indicates that the position and direction of the suction inlet are more important than the suction speed. The adjustment of suction devices based on the results of this study would help reduce the risk of infection in healthcare settings.

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Kurnitski, J., Kiil, M., Mikola, A., Võsa, K.-V.
Point source ventilation effectiveness in infection risk-based post-COVID ventilation design.
43rd AIVC - 11th TightVent - 9th venticool Conference - Copenhagen, Denmark - 4-5 October 2023

Measurement method for ventilation effectiveness, more specifically, for contaminant removal effectiveness with a point source corresponding to infector is analysed in this study with tracer gas measurements and infection risk calculations. Ventilation effectiveness is needed in infection risk-based ventilation design to take into account air distribution methods deviating from fully mixing. Tracer gas measurements were conducted with two source location in six non-residential spaces. Ventilation effectiveness calculated based on the infection risk probability assessment for every measurement point in the room was compared with calculation from the average concentration and calculation method proposed by REHVA accounting only 50% of measurement points with highest concentration. To conduct infection risk calculation, Wells-Riley model modification providing a relation between infection risk probability and ventilation rate at fully mixing was applied together with infection risk control concept based on the basic reproduction number R0 = 1 during pre-symptomatic infectious period. By applying the required ventilation rate at fully mixing and individual probability of infection in each measurement point, ventilation effectiveness value corresponding to given event reproduction number was solved. With the method developed, the airflow rate at fully mixing and the airflow rate with actual air distribution, calculated with ventilation effectiveness, provide the same event reproduction number. Results show considerable differences compared to calculation based on average measured concentration, which overestimated the ventilation effectiveness and underestimated design ventilation rate. The method proposed by REHVA, taking into account only 50% of measurement points with highest concentration, revealed to be conservative in all studied cases, as ventilation effectiveness values ranged in between 0.34 – 1.29 compared to 0.62 – 1.44 solved from individual risk of all measurement points. Especially in the large open plan office, REHVA method considerably overestimated the design ventilation rate while in smaller spaces all three methods provided similar results. Results indicate that ventilation effectiveness determination from tracer gas measurements with a point source is not a trivial task. Calculation method developed, utilising individual probability of infection in each measurement point can be proposed to improve prediction accuracy.

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Elsarraj, M., Mahmoudi, Y., Keshmiri, A.
Quantifying indoor infection risk based on a metric-driven approach and machine learning.
Building and Environment, Vol. **251**, (2024)

To quantify the risk of infection in a typical office space, this study proposes a new 'probability of infection' metric which accounts for the particle number, accumulated viral load, and relevant clinical data. This is achieved by utilising computational fluid dynamics (CFD) and the Eulerian-Lagrangian model. Additionally, the simulations employ models for the exhaled CO2 and the age of air (a function of the ventilation effectiveness) to understand how the flow field influences the transport of both airborne infectious particles and CO2. The distribution of the CO2 concentration in the room shares similarities to that of airborne infectious particles, but there are differences, with 'smearing' from high to low concentrations observed. This study demonstrates that the new metric should be used to quantify and assess the risk of cross-infection instead of the widely used CO2 concentration. The crucial parameter in reducing indoor virus transmission and CO2 levels was found to be the ventilation effectiveness, which is dependent on the ventilation system design, also influencing the amount of fresh air required to lower both quantities. Through the optimised random forests regression model, the CO2 concentration and the supply ventilation rate were utilised as inputs to predict the quantifiable infection risk. The model prediction boasted a coefficient of determination of 0.99 and a root mean square a of 0.025. Thus, a computational framework is established for the development of intelligent building systems with CO2 sensors that can automatically counter airborne infection risk by adaptively varying the ventilation rate.

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Matsui, H., Sugamata, M., Endo, H., Suzuki, Y., Takarabe, Y., Yamaguchi, Y., *et al.*

SARS-CoV-2 Contamination on Healthy Individuals' Hands in Community Settings During the COVID-19 Pandemic.

Cureus, Vol. **16** n°(2), (2024)

Hand hygiene is an infection control measure for COVID-19 in our daily lives; however, the contamination levels of SARS-CoV-2 in the hands of healthy individuals remain unclear. Thus, we aimed to evaluate SARS-CoV-2 contamination levels by detecting viral RNA and viable viruses in samples obtained from the hands of 925 healthy individuals.

Methods

Swab samples were collected from the palms and fingers of healthy participants, including office workers, public officers, university students, university faculty and staff, and hospital staff between December 2022 and March 2023. The collected swab samples were analyzed using reverse transcription-quantitative polymerase chain reaction (RT-qPCR) for SARS-CoV-2 RNA detection. Viral RNA-positive samples were subjected to plaque assay to detect viable viruses.

Results

We collected 1,022 swab samples from the hands of healthy participants. According to the criteria for data collection, 97 samples were excluded, and 925 samples were analyzed using RT-qPCR. SARS-CoV-2 RNA was detected in three of the 925 samples. The viral RNA detection rate was 0.32% (3/925), and the viral RNA copy numbers ranged from 5.0×103 to 1.7×105 copies/mL. The RT-qPCR-positive samples did not contain viable viruses, as confirmed by the plaque assay results.

Conclusions

The detection rate of SARS-CoV-2 RNA from the hands of healthy individuals was extremely low, and no viable viruses were detected. These results suggest that the risk of contact transmission via hands in a community setting is extremely rare.

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Douglas, I. J., Peh, J., Mansfield, K. E., Trelfa, A., Fowler, T., Boulter, M., *et al.*

A self-controlled case series study to measure the risk of SARS-CoV-2 infection associated with attendance at sporting and cultural events: the UK Events Research Programme events.

BMC Med, Vol. **22** n°(1), (2024)

In 2021, whilst societies were emerging from major social restrictions during the SARS-CoV-2 pandemic, the UK government instigated an Events Research Programme to examine the risk of COVID-19 transmission from attendance at cultural events and explore ways to enable people to attend a range of events whilst minimising risk of transmission. We aimed to measure any impact on risk of COVID-19 transmission from attendance at events held at or close to commercially viable capacity using routinely collected data.

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Du, C., Chen, Q.

Static and dynamic airflow and contaminant transport in a full-scale elevator-lobby mockup.

Sustainable Cities and Society, Vol. **101**, (2024)

Elevators facilitate people's movement in daily life. The confined space with high population density in elevators, however, assists the transmission of infectious diseases. To study disease transmission under various transit and boarding-period scenarios, this study used a full-scale elevator mockup with a connected lobby area. This investigation measured both static and dynamic distributions of air velocity/temperature and contaminant concentration. The static experiment involved the closed elevator cabin with mixed ventilation, while the dynamic measurements were conducted in the elevator with the door open to the adjacent lobby area when a passenger exited the elevator. The dynamic experiment showed that high-frequency instruments and better background airflow design could increase the data quality. The experimental data was then used to validate a computational fluid dynamics (CFD) model. This study compared the average and individual experimental data to minimize the uncertainties caused by the initial conditions and instrument limitations. The simulation results revealed that an in-transit elevator cabin is characterized by relatively uniform distributions of air temperature and contaminant concentration. The airflow in the dynamic case was greatly affected by the wake generated by passenger movement. This wake effect was short in duration, but it drew contaminants farther along the direction of movement.

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Brimmo, A. T., Glia, A., Barajas-Gamboa, J. S., Abril, C., Rodríguez, J., Kroh, M., Qasaimeh, M. A.

Ventilation-Based Strategy to Manage Intraoperative Aerosol Viral Transmission in the Era of SARS-CoV-2.

Life, Vol. **14** n°(3), (2024)

In operating theaters, ventilation systems are designed to protect the patient from airborne contamination for minimizing risks of surgical site infections (SSIs). Ventilation systems often produce an airflow pattern that continuously pushes air out of the area surrounding the operating table, and hence reduces the resident time of airborne pathogen-carrying particles at the patient’s location. As a result, patient-released airborne particles due to the use of powered tools, such as surgical smoke and insufflated CO2, typically circulate within the room. This circulation exposes the surgical team to airborne infection—especially when operating on a patient with infectious diseases, including COVID-19. This study examined the flow pattern of functional ventilation configurations in view of developing ventilation-based strategies to protect both the patient and the surgical team from aerosolized infections. A favorable design that minimized particle circulation was deduced using experimentally validated numerical models. The parameters adapted to quantify circulation of airborne particles were particles’ half-life and elevation. The results show that the footprint of the outlet ducts and resulting flow pattern are important parameters for minimizing particle circulation. Overall, this study presents a modular framework for optimizing the ventilation systems that permits a switch in operation configuration to suit different operating procedures.

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Alqarni, Z., Rezgui, Y., Petri, I., Ghoroghi, A.

Viral infection transmission and indoor air quality: A systematic review.

The Science of the total environment, Vol. **923**, (2024)

Respiratory disease transmission in indoor environments presents persistent challenges for health authorities, as exemplified by the recent COVID-19 pandemic. This underscores the urgent necessity to investigate the dynamics of viral infection transmission within indoor environments. This systematic review delves into the methodologies of respiratory infection transmission in indoor settings and explores how the quality of indoor air (IAQ) can be controlled to alleviate this risk while considering the imperative of sustainability. Among the 2722 articles reviewed, 178 were retained based on their focus on respiratory viral infection transmission and IAQ. Fifty eight articles delved into SARS-CoV-2 transmission, 21 papers evaluated IAQ in contexts of other pandemics, 53 papers assessed IAQ during the SARS-CoV-2 pandemic, and 46 papers examined control strategies to mitigate infectious transmission. Furthermore, of the 46 papers investigating control strategies, only nine considered energy consumption. These findings highlight clear gaps in current research, such as analyzing indoor air and surface samples for specific indoor environments, oversight of indoor and outdoor parameters (e.g., temperature, relative humidity (RH), and building orientation), neglect of occupancy schedules, and the absence of considerations for energy consumption while enhancing IAQ. This study distinctly identifies the indoor environmental conditions conducive to the thriving of each respiratory virus, offering IAQ trade-offs to mitigate the risk of dominant viruses at any given time. This study argues that future research should involve digital twins in conjunction with machine learning (ML) techniques. This approach aims to enhance IAQ by analyzing the transmission patterns of various respiratory viruses while considering energy consumption.

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