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Aéraulique et COVID-19

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Google Scholar, Lens et WoS

Zheng, M., Fan, Y., Li, X., Lester, D., Chen, X., Li, Y.*, et al.*
Aerosol Exchange between Pressure-Equilibrium Rooms Induced by Door Motion and Human Movement (preprint).
SSRN preprint, (2023)

It is now widely recognised that aerosol transport is major vector for transmission of diseases such as COVID-19, and quantification of aerosol transport in the built environment is critical to risk analysis and management. Understanding the effects of door motion and human movement on the dispersion of virus-laden aerosols under pressure-equilibrium conditions is of great significance to the evaluation of infection risks and development of mitigation strategies. This study uses novel numerical simulation techniques to quantify the impact of these motions upon aerosol transport, and provides valuable insights into the wake dynamics of swinging doors and moving manikins. The results show that the wake flow of an opening swinging door delays aerosol escape, while that of an manikin walking out entrains aerosol out of the room. Aerosol escape caused by door motion mainly happens during the closing sequence which pushes the aerosols out. Parametric studies show that when an increased door swinging speed or manikin movement speed can enhance air exchange across the doorway, the cumulative aerosol exchange across the doorway is not clearly affected by the speeds.

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Kähler, C. J., Hain, R., Fuchs, T.
Assessment of Mobile Air Cleaners to Reduce the Concentration of Infectious Aerosol Particles Indoors.
Atmosphere, Vol. **14** n°(4), (2023)

Airborne transmission via aerosol particles without close human contact is a possible source of infection with airborne viruses such as SARS-CoV-2 or influenza. Reducing this indirect infection risk, which is mostly present indoors, requires wearing adequate respiratory masks, the inactivation of the viruses with radiation or electric charges, filtering of the room air, or supplying ambient air by means of ventilation systems or open windows. For rooms without heating, ventilation, and air conditioning (HVAC) systems, mobile air cleaners are a possibility for filtering out aerosol particles and therefore lowering the probability of indirect infections. The main questions are as follows: (1) How effectively do mobile air cleaners filter the air in a room? (2) What are the parameters that influence this efficiency? (3) Are there room situations that completely prevent the air cleaner from filtering the air? (4) Does the air cleaner flow make the stay in the room uncomfortable? To answer these questions, particle imaging methods were employed. Particle image velocimetry (PIV) was used to determine the flow field in the proximity of the air cleaner inlet and outlet to assess regions of unpleasant air movements. The filtering efficiency was quantified by means of particle image counting as a measure for the particle concentration at multiple locations in the room simultaneously. Moreover, different room occupancies and room geometries were investigated. Our results confirm that mobile air cleaners are suitable devices for reducing the viral load indoors. Elongated room geometries, e.g., hallways, lead to a reduced filtering efficiency, which needs to be compensated by increasing the volume flow rate of the device or by deploying multiple smaller devices. As compared to an empty room, a room occupied with desks, desk separation walls, and people does not change the filtering efficiency significantly, i.e., the change was less than 10%. Finally, the flow induced by the investigated mobile air cleaner does not reach uncomfortable levels, as by defined room comfort standards under these conditions, while at the same time reaching air exchange rates above 6, a value which is recommended for potentially infectious environments.

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Vandewiel, M. R.

CFD and Deep Learning Based Natural Ventilation Analysis in Buildings.

Master of Engineering Science, Civil and Environmental Engineering. Western University, Ontario, Canada. Thèse 2023

Natural ventilation is crucial for sustainable buildings and is also a promising solution for addressing indoor air quality (IAQ) issues such as those related to COVID-19. This thesis examines the efficacy of wind-driven cross-ventilation for a low-rise residential building with complex geometry and internal partitions typical of common constructions using computational fluid dynamics (CFD) simulations. Different wind speeds and directions with varying partition and window configurations are analyzed, as well as surrounding buildings consistent with Canadian suburban neighbourhoods. While CFD solvers are effective in predicting natural ventilation, they are limited by processing time, hardware and storage requirements, and specialized knowledge, which limits the number of designs tested and leads to suboptimal solutions. Therefore, user-friendly deep learning models are also developed to efficiently predict the velocity field within a cross-ventilated building, using both a Vanilla U-Net and a U-Net with an attention mechanism for the neural network architectures. The models obtain training data from CFD simulations performed on a generic building with multiple opening sizes and impacts from different wind directions. The results show that partition walls block airflow and create dead zones, but when openings are introduced on partition walls to form a network of openings, IAQ is significantly improved, especially in rooms that previously only had a doorway opening. Additionally, surrounding buildings should not be neglected when accounting for IAQ, as the air changes per hour (ACH) can be reduced by more than half, leading to a significant increase in the local mean age of air (MAA) (up to 215%) for the entire building. Furthermore, both deep learning models generate velocity contours much faster than CFD solvers while only sacrificing a small amount of error. However, the Vanilla U-Net model is recommended as it had superior performance in both qualitative and quantitative analyses.

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Rajendran, R. R., Turcanu, F. E., Tawfiqur, R. M., Askarpour, H.

Computational fluid dynamic analysis of corona virus patients breathing in an airplane.

Physics of Fluids, Vol. **35** n°(3), (2023)

Effective ventilation systems are essential to control the transmission of airborne aerosol particles, such as the SARS-CoV-2 virus in aircraft cabins, which is a significant concern for people commuting by airplane. Validated computational fluid dynamic models are frequently and effectively used to investigate air distribution and pollutant transport. In this study, the effectiveness of different ventilation systems with varying outlet vent locations were computationally compared to determine the best ventilation system for minimizing the risk of airborne transmission. The cabin air conditioning system was optimized to determine how design variables (air inlet temperature, outlet valve width and location, and mass flow rate) affect output parameters, including particle residence time, age of air, and thermal comfort conditions. Inlet mass flow rate was observed to be an influential variable impacting all output parameters, especially on age of air, where it was the most influential. In contrast, the least effective variable was width of the outlet valve, which only affected the particle residence time. Also, Predicted Mean Vote and Predicted Percentage Dissatisfied indices were the most affected by air inlet temperature, which had an inverse relation, while the outlet valve location had the greatest effect on particle residence time.

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Cai, J. N., Chen, J. L., Hu, Y. Q., Li, S., He, Q.

Digital twin for healthy indoor environment: A vision for the post-pandemic era.

Frontiers of Engineering Management, (2023)

Indoor environment has significant impacts on human health as people spend 90% of their time indoors. The COVID-19 pandemic and the increased public health awareness have further elevated the urgency for cultivating and maintaining a healthy indoor environment. The advancement in emerging digital twin technologies including building information modeling (BIM), Internet of Things (IoT), data analytics, and smart control have led to new opportunities for building design and operation. Despite the numerous studies on developing methods for creating digital twins and enabling new functionalities and services in smart building management, very few have focused on the health of indoor environment. There is a critical need for understanding and envisaging how digital twin paradigms can be geared towards healthy indoor environment. Therefore, this study reviews the techniques for developing digital twins and discusses how the techniques can be customized to contribute to public health. Specifically, the current applications of BIM, IoT sensing, data analytics, and smart building control technologies for building digital twins are reviewed, and the knowledge gaps and limitations are discussed to guide future research for improving environmental and occupant health. Moreover, this paper elaborates a vision for future research on integrated digital twins for a healthy indoor environment with special considerations of the above four emerging techniques and issues. This review contributes to the body of knowledge by advocating for the consideration of health in digital twin modeling and smart building services and presenting the research roadmap for digital twin-enabled healthy indoor environment.

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Cortellessa, G., Canale, C., Stabile, L., Grossi, G., Buonanno, G., Arpino, F.
Effectiveness of a portable personal air cleaner in reducing the airborne transmission of respiratory pathogens.
Building and Environment, Vol. **235**, (2023)

The airborne transmission in indoor environments represents the main pathway of respiratory pathogens, and most of the indoor environments do not have adequate ventilation to contain the risk of infection. This is particularly relevant for gathering spaces such as restaurants, schools, offices, etc. due to the long exposure times and high crowding levels. In this paper we investigated the effectiveness of a novel patented personal air cleaner in reducing the airborne transmission of respiratory pathogens both in close proximity (considering a typical face-to-face configuration at a conversational distance) and in shared indoor environments despite maintaining distancing (lecture room). The effectiveness of the portable protection device was investigated using complex transient 3D Computational Fluid Dynamics (CFD) numerical simulations. The mathematical model employed, validated through experimental measurements, is based on a Eulerian-Lagrangian approach, describing the air flow as the continuous phase and infectious respiratory particles as the discrete phase. The CFD analyses revealed that the air cleaner could strongly reduce the inhalation of respiratory pathogens in both the investigated scenarios. The air cleaner effectiveness in the case of a close proximity scenario, expressed as relative reduction of volume of infectious respiratory particles inhaled by the exposed subject, resulted >92%. In the case of use in a shared indoor environment, instead, during a 2-h lesson, the relative reduction of volume concentration of infectious particles in the breathing zone of the exposed subject was >99%.

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Lee, T., Barone, T., Yantek, D. S., Portnoff, L., Zheng, Y.
Evaluation of a Prototype Local Ventilation System to Mitigate Retail Store Worker Exposures to Airborne Particles.
Journal of Occupational and Environmental Hygiene, (2023), pp. 1-22

The objective of this study is to evaluate a prototype local ventilation system (LVS) intended to reduce retail store workers? exposures to aerosols. The evaluation was carried out in a large aerosol test chamber where relatively uniform concentrations of polydisperse sodium chloride and glass-sphere particles were generated

to test the system with nano- and micro-size particles. In addition, a cough simulator was constructed to mimic aerosols released by mouth breathing and coughing. Particle reduction efficiencies of the LVS were determined in four different experimental conditions using direct reading instruments and inhalable samplers. The particle reduction efficiency (%) depended on the position beneath the LVS, but the percentage was consistently high at the LVS center as follows: 1) > 98% particle reduction relative to background aerosols, 2) > 97% in the manikin?s breathing zone relative to background aerosols, 3) > 97% during mouth breathing and coughing simulation, and 4) > 97% with a plexiglass barrier installation. Lower particle reduction (<70%) was observed when the LVS airflow was disturbed by background ventilation airflow. The lowest particle reduction (<20%) was observed when the manikin was closest to the simulator during coughing.

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Paterson, J., George, G., George, S., Jarman, J.
High levels of CO2 found in small study of early childhood centres: Improving ventilation in the time of COVID-19.
Report. Public Health Communication Centre (PHCC), New Zealand 2023

Good ventilation is considered to be an important way to reduce the transmission of respiratory viruses in indoor spaces where people gather and spend time.
In this study run by medical students, the CO2 levels were measured in six randomly chosen early childhood centres in northern Taranaki during June and July 2022. High levels of CO2 (over 1,500ppm) were found in four out of the six early childhood education centres (ECE).
While schools throughout Aotearoa New Zealand have been supplied with CO2 monitors, ECEs have not despite being known to have high levels of respiratory virus transmission at times.

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Zhang, S., Yun, W. G., Lin, Z.
Integrated system of exhaust air heat pump and advanced air distribution for energy-efficient provision of outdoor air.
Applied Thermal Engineering, Vol. **217**, (2022)

A large outdoor air supply is required to control the airborne infection risk of respiratory diseases (e.g., COVID 19) but causes a high energy penalty. This study proposes a novel integrated system of the exhaust air heat pump and advanced air distribution to energy-efficiently provide outdoor air. The system energy performances are evaluated by the experimentally validated thermodynamic model of heat pump and heat removal efficiency model of advanced air distribution. Results show the exhaust air heat pump with advanced air distribution can save energy because of three mechanisms. First, the exhaust air heat pump reuses the exhaust air to reduce the condensation temperature, thereby improving the coefficient of performance. Second, advanced air distribution reduces ventilation load. Third, advanced air distribution reduces the condensation temperature and enhances the evaporation temperature, thereby improving the coefficient of performance. The exhaust air heat pump saves energy by 18%, advanced air distribution saves energy by 36%, and the integrated system of the exhaust air heat pump and advanced air distribution can save energy by 45%. As a specific application, compared with the conventional system (i.e., the outdoor air heat pump with mixing ventilation), the exhaust air heat pump with stratum ventilation saves energy by 21% -35% under various outdoor air ratios and outdoor air temperatures. The proposed integrated system of the exhaust air heat pump and advanced air distribution contributes to the development of low-carbon and healthy buildings.

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Ren, C., Zhu, H. C., Wang, J. Q., Feng, Z. B., Chen, G., Haghighat, F.*, et al.*
Intelligent operation, maintenance, and control system for public building: Towards infection risk mitigation and energy efficiency.

Sustainable Cities and Society, Vol. **93**, (2023)

During the post-COVID-19 era, it is important but challenging to synchronously mitigate the infection risk and optimize the energy savings in public buildings. While, ineffective control of ventilation and purification systems can result in increased energy consumption and cross-contamination. This paper is to develop intelligent operation, maintenance, and control systems by coupling intelligent ventilation and air purification systems (negative ion generators). Optimal deployment of sensors is determined by Fuzzy C-mean (FCM), based on which CO2 concentration fields are rapidly predicted by combing the artificial neural network (ANN) and self-adaptive lowdimensional linear model (LLM). Negative oxygen ion and particle concentrations are simulated with different numbers of negative ion generators. Optimal ventilation rates and number of negative ion generators are decided. A visualization platform is established to display the effects of ventilation control, epidemic prevention, and pollutant removal. The rapid prediction error of LLM-based ANN for CO2 concentration was below 10% compared with the simulation. Fast decision reduced CO2 concentration below 1000 ppm, infection risk below 1.5%, and energy consumption by 27.4%. The largest removal efficiency was 81% when number of negative ion generators was 10. This work can promote intelligent operation, maintenance, and control systems considering infection prevention and energy sustainability.

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Roussel, I.
La pandémie et le changement climatique revisitent la notion d'habitat favorable à la santé.
Bulletin de l'association de géographes français. Géographies, Vol. **99** n°(99-4), (2023), pp. 534-552

Les enjeux environnementaux planétaires interrogent de multiples façons les modalités de l'habiter et demandent de les repenser en profondeur… Le logement est une des clés ouvrant à la gestion du changement climatique à travers à la fois l'adaptation et la mitigation. C'est aussi un espace clos, favorisant la propagation du virus selon la densité d'occupation et les caractéristiques de l'aération. Mais le regard a changé, la recherche de la protection par l'artificialisation a laissé la place à une meilleure cohabitation entre les humains, la faune et la flore en acceptant de vivre avec les aléas climatiques et en prenant en compte le risque infectieux. L'été 2022 avec son cortège de canicules et sécheresses montre l'ampleur des transformations qu'il faudrait opérer en ville pour générer de nouvelles formes d'habitat favorables à la santé. En effet, il est indispensable de s'adapter à un nouveau contexte environnemental qui devient de jour en jour plus menaçant et se déploie à toutes les échelles. La prise en compte du bien-être individuel trop inégalement partagé tout en s'assurant d'un bon fonctionnement collectif, est essentielle.

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Oh, J. H., Martinez, A. D., Cao, H. X., George, G. W., Cobb, J. S., Sharma, P.*, et al.*
Radio Frequency Heating of Washable Conductive Textiles for Bacteria and Virus Inactivation.
Acs Applied Materials & Interfaces, Vol. **14** n°(38), (2022), pp. 43732–43740

The ongoing COVID-19 pandemic has increased the use of single-use medical fabrics such as surgical masks, respirators, and other personal protective equipment (PPE), which have faced worldwide supply chain shortages. Reusable PPE is desirable in light of such shortages; however, the use of reusable PPE is largely restricted by the difficulty of rapid sterilization. In this work, we demonstrate successful bacterial and viral inactivation through remote and rapid radio frequency (RF) heating of conductive textiles. The RF heating behavior of conductive polymer-coated fabrics was measured for several different fabrics and coating compositions. Next, to determine the robustness and repeatability of this heating response, we investigated the textile's RF heating response after multiple detergent washes. Finally, we show a rapid reduction of bacteria and virus by RF heating our conductive fabric. 99.9% of methicillinresistant Staphylococcus aureus (MRSA) was removed from our conductive fabrics after only 10 min of RF heating; human cytomegalovirus (HCMV) was completely sterilized after 5 min of RF heating. These results demonstrate that RF heating

conductive polymer-coated fabrics offer new opportunities for applications of conductive textiles in the medical and/or electronic fields.

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Zhao, X., Yin, Y., Liu, X., Zuo, J.
Ventilation performance of multi-room in residential building with the proposed novel mechanical ventilation system: A case study.
Indoor and Built Environment, (2023)

Poor indoor air quality in residential buildings always threatens human health, such as sick building syndrome (SBS), respiratory diseases and low sleep quality. Although fresh air can dilute the concentration of air pollution, the widely used natural ventilation is uncontrolled and its ventilation rate is usually insufficient. Even in the indoor environments of residential buildings where the mechanical ventilation system is installed, different forms of ventilation systems have their unique problems. To create a healthy indoor environment, this investigation proposed a novel push-relay-pull mechanical ventilation system (fresh air supplying system) achieved by combining the mechanical air supply system (push), intermediate relay system (relay) and mechanical exhaust system (pull). This investigation further quantitatively evaluated the performance of the proposed system by comparing it with the traditional mechanical fresh air ventilation system using the age of air, infection risk and carbon dioxide (CO2) concentration indexes. The proposed system only needs to install one set of ducts as the traditional mechanical ventilation systems. It can ensure that all rooms would maintain good air quality, and also prevent the spread of pollutants, reduce the average infection risk of people inside a residential building and are conducive to epidemic prevention and control.

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