Rapport de veille n° 50

Aéraulique et COVID-19

17/08/2022

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Google Scholar, Lens et WoS

Li, B.
Advanced demand-controlled ventilation strategies for ACMV systems.
Nanyang Technological University, Thèse 2022

This thesis presents a detailed investigation into the demand-controlled ventilation (DCV) for ACMV systems. Four advanced DCV strategies have been proposed to improve the ventilation control performance in terms of control accuracy, energy efficiency, and practicability. Several key research issues in this field have been addressed in this study. The main contributions of the thesis are summarized as follows: For occupancy-based DCV (air balancing), we proposed two non-iterative air balancing control methods.

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Wang, F., Chen, F., Zhang, T.
An aisle displacement ventilation system for twin-aisle commercial airliner cabin.
Building and Environment, Vol. **223**, (2022)

The environmental control system in most commercial airliner cabins supplies air from shoulder and ceiling level and exhausts air at floor level on both sides of walls. The ventilation system mixes air in the cabins to create a uniform air temperature distribution that is great for thermal comfort. However, the mixing ventilation also enhances airborne contaminant transfer. Displacement ventilation has been proposed for use in cabins, but they may create high air temperature stratification and draft. This investigation developed an aisle displacement ventilation (ADV) system that can reduce air temperature stratification and be easily installed in cabins. By installing the system in a five-row, twin-aisle cabin mockup, our study found that ADV can create a low air velocity distribution in the cabin and can maintain an acceptable air temperature stratification without draft. The system created an uprising flow that can effectively remove airborne contaminant generated from respiratory activities. The experimental data were used to validate a computational-fluid-dynamics (CFD) program. The validated CFD program was used to compare the ADV with the under-seat displacement ventilation (USDV) and the underfloor air distribution (UFAD) along the aisles. The ADV had better thermal comfort than the other two systems, but the cabin air quality of the three ventilation systems was similar.

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Schmeling, D., Kuehn, M., Schiepel, D., Dannhauer, A., Lange, P., Kohl, A.*, et al.*
Analysis of aerosol spreading in a German Inter City Express (ICE) train carriage.
Building and Environment, Vol. **222**, (2022)

This paper focuses on the propagation of aerosols in a rolling stock passenger compartment. Extensive measurements were carried out in our stationary test vehicle DIRK, an ICE 2 rail car, operated in a climate chamber.It is shown that the propagation of aerosols only occurs for a distance of a few seat rows. Furthermore, the maximum percentage of particles exhaled by a passenger and inhaled by another passenger is less than 0.35%. A mouth-nose-protection (surgical mask) at the aerosol source reduces this value to a maximum of 0.25%. Moreover, the use of a mouth-nose-cover reduced the propagation lengths. Here, only the effect of the mask at the source was considered, a further reduction of inhaled aerosols will be achieved when the receivers also wear masks.It is concluded that, for this type of passenger coach, the indirect propagation of aerosols, i.e., via the HVAC system, is nearly irrelevant compared to the direct propagation from one passenger to another. However, there is a non-zero aerosol transport via the HVAC system, resulting

in local inhaled particles far away from the source of around 0.015-0.026%, which is more than one order of magnitude lower than on the most highly contaminated seats.

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Muelas, A., Remacha, P., Pina, A., Tizne, E., El-Kadmiri, S., Ruiz, A.*, et al.*
Analysis of different ventilation strategies and CO2 distribution in a naturally ventilated classroom.
Atmospheric Environment, Vol. **283**, (2022)

CO2 monitoring has proven to be an effective and affordable way of controlling air ventilation rates, a paramount task for minimizing airborne contagions in indoor shared spaces. In this work, the CO2 distribution in a naturally-ventilated classroom has been thoroughly characterized, gaining information not only on the effectiveness of diverse ventilation strategies but also on the expected differences between CO2 values when varying the sampling location within the room. The results confirm that an adequate renewal of the air in the room requires the use of cross-ventilation, with openings in different walls. Furthermore, it was found that ventilation is optimized, for a given total opening area, when the openings are distributed as much as possible among different windows. For most of the studied conditions, a global windows opening area of 1.24 m(2) with an open door was typically enough to yield CO2 concentrations below 700 ppm. The CO2 readings displayed a noticeable and consistent dependency on the sampling height, with below-average values at 0.75 m, the highest concentrations at 1.5 m, and levels close to the average when sampling at a height of 2.2 m. For a given height, the influence of the sampling location within the room was weaker, and more dependent on the specific ventilation strategy applied. However, the tests consistently showed CO2 records significantly lower for sensors installed on the walls. Besides a detailed spatial and temporal characterization of the ventilation process under different ventilation strategies, these results are thought to provide useful and novel information for a judicious placement of CO2 monitoring systems.

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Niu, R. P., Chen, X., Liu, H.
Analysis of the impact of a fresh air system on the indoor environment in office buildings.
Sustainable Cities and Society, Vol. **83**, (2022)

This study conducted objective physical tests and subjective questionnaire surveys related to the operation of a fresh air system in an office building in Beijing before the outbreak of the coronavirus disease 2019 (COVID-19). The long-term tests on indoor environmental parameters included air temperature, relative air humidity, air velocity, CO(2)concentration, PM2.5 concentration, and fresh air volume, and the questionnaire surveyed the satisfaction of office workers in the indoor environment. The results showed that the indoor environmental parameters conformed to the values specified in relevant design standards; however, the satisfaction with the indoor environmental parameters was generally low. The probability of infection of indoor personnel with the virus causing COVID-19 under two existing fresh air system operation modes was calculated and compared, and it was less than 5%. A gray correlation analysis of the measured data with the questionnaire results identified indoor air temperature and quality as the main factors affecting the subjective satisfaction, which was consistent with the results of the questionnaire analysis. A new operation and maintenance method for fresh air systems was proposed for regular epidemic prevention and control to ensure the normal operation of the office building and the health of indoor personnel.

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Tarifa, E. E., Dosso, L. A., Vera, C. R.
Analysis of Virus Sanitization Alternatives and Optimization of a Thermal Air Purifier for SARS-CoV-2.
Open Journal of Applied Sciences, Vol. **12** n°(7), (2022), pp. 1152-1173

Air sanitization acquired renewed interest during the COVID-19 outbreak, especially in hospital rooms and intensive care units. In this work, mathematical analysis was done of the convenience of sanitizing the air of whole rooms or personalized isolation tents. Centralized air sanitization was found to have low effectiveness due to three reasons: 1) the constant virus emission from patients; 2) the practical upper limits of air recycle flowrates; 3) the low value of the minimum infective dose of SARS-CoV-2. Personalized air sanitization was the best option. Virus inactivation by thermal effect was then revisited, and a steady-state model was formulated for an efficient and personalized thermal sterilizer. An analytical solution was obtained for temperature and virus concentration in different parts of the sterilizer. Cell temperature was found to be the main variable for sterilization due to the Arrhenius-like form of the kinetic constant of virus deactivation. An objective cost function was written and subjected to conditions of minimum patient ventilation rate and minimum virus removal effectiveness. Numerical optimization gave an optimal design with the intrinsic advantages of thermal sanitization, i.e., simplicity, robustness, minimum maintenance and high sanitization rate.

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Srikrishna, D.
Can 10* cheaper, lower-efficiency particulate air filters and box fans complement High-Efficiency Particulate Air (HEPA) purifiers to help control the COVID-19 pandemic?
The Science of the total environment, Vol. **838** n°(Pt 1), (2022)

Public health departments such as CDC and California Department of Public Health (CA-DPH) advise HEPA-purifiers to limit transmission of SARS-CoV-2 indoor spaces. CA-DPH recommends air exchanges per hour (ACH) of 4-6 air for rooms with marginal ventilation and 6-12 in classrooms often necessitating multiple HEPA-purifiers per room, unaffordable in under-resourced community settings. Pressure to seek cheap, rapid air filtration resulted in proliferation of lower-cost, Do-It-Yourself (DIY) air purifiers whose performance is not well characterized compared to HEPA-purifiers. Primary metrics are clean air delivery rate (CADR), noise generated (dBA), and affordability ($$). CADR measurement often requires hard-to-replicate laboratory experiments with generated aerosols. We use simplified, low-cost measurement tools of ambient aerosols enabling scalable evaluation of aerosol filtration efficiencies (0.3 to 10 mum), estimated CADR, and noise generation to compare 3 HEPA-purifiers and 9 DIY purifier designs. DIY purifiers consist of one or two box fans coupled to single MERV 13-16 filters (1-5 thick) or quad filters in a cube. Accounting for reduced filtration efficiency of MERV 13-16 filters (versus HEPA) at the most penetrating particle size of 0.3 mum, estimated CADR of DIY purifiers using 2 (67%), 4 (66%), and 5 (85%) filters at lowest fan speed was 293 cfm ($35), 322 cfm ($58), and 405 cfm ($120) comparable to best-in-class, low-noise generating HEPA-purifier running at maximum speed with at 282 cfm ($549). Quad filter designs, popularly known **Corsi-Rosenthal boxes**, achieved gains in estimated CADR below 80% over single filter designs, less than the 100% gain by adding a second DIY purifier. Replacing one of the four filters with a second fan resulted in gains of 125%-150% in estimated CADR. Tested DIY alternatives using lower-efficiency, single filters compare favorably to tested HEPA-purifiers in estimated CADR, noise generated at five to ten times lower cost, enabling cheap, rapid aerosol removal indoors.

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Drossinos, Y., Reid, J. P., Hugentobler, W., Stilianakis, N. I.
Challenges of integrating aerosol dynamics into SARS-CoV-2 transmission models.
Aerosol Science and Technology, (2022), pp. 1-8

In response to the COrona VIrus Disease 2019 (COVID-19) pandemic, extensive research has been conducted to explore, understand, and model the dynamics of expelled respiratory droplets during transmission events. The impetus for these efforts was the realization that respiratory droplets are the carriers of the infectious pathogen Severe Acute Respiratory Syndrome-Corona Virus 2 (SARS-CoV-2). The importance of respiratory droplets, and in particular those that are airborne, in transmitting pathogens responsible for respiratory

infectious diseases was known to scientists prior to the COVID-19 pandemic (Morawska 2006, Weber and Stilianakis 2008, Drossinos and Stilianakis 2020). Nevertheless, the concerted effort of numerous aerosol scientists during the COVID-19 pandemic promulgated this knowledge to a broader audience with significant scientific and public policy repercussions (Morawska and Milton 2020).

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Dias, A. M., Meggiolaro, E. D. A., Oliveira, L. M. F., Veloso, É. M., Soares, M. P. S.
Climatization systems for Brazilian dental teaching clinics: a narrative review in the context of the COVID-19 pandemic.
Revista da ABENO, Vol. **22** n°(2), (2022)

COVID-19 outbreack has reaffirmed the need to maintain ventilation of dental environments properly. This study was carried out to encourage a reflective analysis of the risks of air contamination in Brazilian dental clinics. A narrative review of the literature was carried out on the recommendations of heating, ventilation and air conditioning (HVAC) systems in dental environments, considering the risks of air contamination in Brazilian dental teaching clinics. The literature research was conducted in the PubMed and Google Scholar databases and the main studies that evaluated the climatization systems and portable high efficiency particulate air filtration (HEPA) units in dental environments were included. Furthermore, it were analyzed the guidelines of the Centers for Disease Control and Prevention, the Brazilian National Health Surveillance Agency, the Brazilian Ministry of Health and important institutions of the different countries. After the initial research, a review of the guidelines and articles that assess the use of HEPA units to improve air cleanliness. This analysis was done by different groups of researchers. All documents mentioned that the air quality of the dental offices must follow the protocols in current legislation to ensure the safety of the environs. They reaffirmed that the COVID-19 pandemic makes it imperative that dental environments equipped with air conditioning have mechanical air renewal devices. An alternative for Brazilian dental teaching clinics equipped with mini-splits or window air conditioning could be the installation of exhaust fans and portable HEPA filter units to exchange air and reduce aerosols inside the environments.

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Abbas, G. M., Dino, I. G.
COVID-19 dispersion in naturally-ventilated classrooms: a study on inlet-outlet characteristics.
Journal of Building Performance Simulation, Vol. **15** n°(5), (2022), pp. 656-677

Infectious aerosol dispersion poses significant infection risks (i.e., COVID-19) in classrooms due to dense and long occupancy. Natural ventilation is an effective strategy to reduce airborne infection transmission. The building-related parameters, particularly openings, determine the natural ventilation effectiveness in reducing contaminant dispersion, necessitating an inquiry due to complex dispersion and airflow patterns. This paper investigates the correlation between window height, natural ventilation, and COVID-19 dispersion. A simulation pipeline involving a parametric 3D design environment, computational fluid dynamics (CFD), and energy simulations is developed and implemented on nine design scenarios representing different inlet-outlet heights of a free-running (no heating, cooling or mechanical ventilation) classroom. The inlet height and the inlet-outlet height difference have a considerable impact on indoor infection risk confirming that stack ventilation and the Bernoulli effect decrease indoor contaminant concentration. Proximity to openings does not ensure lower contamination levels. Proximity to the contaminant does not result in higher contamination levels.

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Choi, J. J. E., Chen, J., Choi, Y. J., Moffat, S. M., Duncan, W. J., Waddell, J. N.*, et al.*
Dental high-speed handpiece and ultrasonic scaler aerosol generation levels and the effect of suction and air supply.

Infection Control & Hospital Epidemiology, (2022), pp. 1-8

Objective:
Exposure to aerosol spray generated by high-speed handpieces (HSHs) and ultrasonic scalers poses a significant health risk to oral health practitioners from airborne pathogens. Aerosol generation varies with different HSH designs, but to date, no study has measured this.
Materials and methods:
We measured and compared aerosol generation by (1) dental HSHs with 3 different coolant port designs and (2) ultrasonic scalers with no suction, low-volume evacuation (LVE) or high-volume evacuation (HVE). Measurements used a particle counter placed near the operator's face in a single-chair, mechanically ventilated dental surgery. Volume concentrations of aerosol, totaled across a 0.3–25-µm size range, were compared for each test condition.
Results:
HSH drilling and scaling produced significantly high aerosol levels ($P < .001$) with total volume concentrations 4.73×108µm3/m3 and 4.18×107µm3/m3, respectively. For scaling, mean volume of aerosol was highest with no suction followed by LVE and HVE ($P < .001$). We detected a negative correlation with both LVE and HVE, indicating that scaling with suction improved operator safety. For drilling, simulated cavity preparation with a 1-port HSH generated the most aerosol ($P < .01$), followed by a 4-port HSH. Independent of the number of cooling ports, lack of suction caused higher aerosol volume (1.98×107 µm3/m3) whereas HVE significantly reduced volume to −4.47×105 µm3/m3.
Conclusions:
High concentrations of dental aerosol found during HSH cavity preparation or ultrasonic scaling present a risk of infection, confirming the advice to use respiratory PPE. HVE and LVE both effectively reduced aerosol generation during scaling, whereas the new aerosol-reducing 'no air' function was highly effective and can be recommended for HSH drilling.

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Rodr, J. L., Guez, F., Ndez, Diz-Bugar, J.*, et al.*
Didactic Model for the optimization of ventilation in rooms with the presence of CO2.
2022 Congreso de Tecnología, Aprendizaje y Enseñanza de la Electrónica (XV Technologies Applied to Electronics Teaching Conference)

This project arises from the need to contribute to the improvement of ventilation in buildings with multiple rooms. The COVID-19 pandemic forces us to look for alternatives to natural ventilation for energy savings as well as creating more comfortable work spaces without sacrificing the health of users. The mock-up presents a model of extraction ventilation. Optimizes the flow depending on the quality of the air. This work carried out at the IES Escolas Proval is part of an Innovation Project awarded in the current 2020-21 academic year with the participation of the IES Val Minor and the company Hermes Smart Control.

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Osman, O., Madi, M., Ntantis, E. L., Kabalan, K. Y.
Displacement ventilation to avoid COVID-19 transmission through offices.
Computational Particle Mechanics, (2022)

Respiratory infections such as COVID-19 can be spread by respiratory droplets with a diameter larger than 5–10 µm or by droplet nuclei with a diameter smaller than 5 µm. Besides wearing masks, fresh air should be supplied frequently in closed rooms to avoid infections. Constructing and operating new isolation rooms require time, money, and maintenance cost, which are scarce in the current pandemic and in many communities. Displacement ventilation may be a feasible and secure option in temporary hospitals and other buildings to control the disease. This paper investigates using CFD simulations how displacement ventilation

systems can deliver high air quality, and thermal comfort and minimize the risk of COVID-19 infection in enclosed spaces.

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Yuce, B. E.
The effect of elevator cabin size on infectious droplet dispersion.
Heat Transfer Research, Vol. **53** n°(11), (2022), pp. 17-29

The coronavirus pandemic has spread all over the world and has greatly affected societies. During the pandemic, closed environments have become a major risk factor. As a result of many studies, it is understood that the small indoor space and insufficient ventilation create a favorable environment for the spread of the virus. In this study, the dispersion of droplets formed due to the sneezing of a person who does not wear a mask, in elevator cabins for 4, 5, 6, and 8 people, which are widely used in apartment buildings, is examined numerically. Different elevator cabins are modeled and divided into finite volumes. SARS-CoV-2 virus information was obtained from the academic literature and used as boundary conditions in droplet modeling. Evaporation of the droplets was also taken into account in the numerical modeling. The natural convection heat transfer mechanism is considered between the cabin walls and the thermal manikin surface. Then, conservation equations in finite volumes were solved by the computational fluid dynamics (CFD) method. According to the results, droplets adhered to a surface or evaporated within 8 s in all elevators. The structure of the droplet jet varied according to the cabin size, and as a result, it was understood that the elevator size had a significant effect on the droplet density adhered to the surfaces.

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Pal, A., Biswas, R., Sarkar, S., Mukhopadhyay, A.
The effect of ventilation and climatic conditions on covid-19 transmission through respiratory droplet transport via both airborne and fomite mode inside an elevator.
Physics of Fluids, (2022)

A numerical analysis using OpenFOAM has been performed in this work to investigate the infection risk due to droplet dispersal in an enclosed environment resembling an elevator, since infection risk in such confined places are very high. The effect of two scenarios on droplet dispersal, namely the quiescent and the fan-driven ventilation, both subjected to various climatic conditions (of temperature and humidity) ranging from cold-humid (15{degree sign}C, 70% relative humidity) to hot-dry (30{degree sign}C, 30% relative humidity) have been studied. A risk factor derived from a dose-response model constructed upon the temporally-averaged pathogen quantity existing around the commuter's mouth is used to quantify the risk of infection through airborne mode. It is found that the hot, dry quiescent scenario poses the greatest threat of infection (spatio-averaged risk factor 42%), whereas the cold humid condition poses the least risk of infection (spatio-averaged risk factor 30%). The proper Fan speed is determined for the epidemiologically safe operation of the elevator. The Fan ventilation scenario with 1100 RPM (having a spatio-averaged risk factor of 10%) decreases the risk of infection by 67% in a hot, dry climatic condition as compared to a quiescent scenario and significantly in other climatic ambiences as well. The deposition potential of aerosolized droplets in various parts of the respiratory tract namely the Extrathoracic and the Alveolar and Bronchial regions has been analyzed thoroughly. Besides the airborne mode of infection, the fomite mode of infection (infection through touch) has also been investigated for both the ventilation scenarios.

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Ueki, H., Ujie, M., Komori, Y., Kato, T., Imai, M., Kawaoka, Y.
Effectiveness of HEPA Filters at Removing Infectious SARS-CoV-2 from the Air.
mSphere, (2022)

Air filtration simulation experiments quantitatively showed that an air cleaner equipped with a HEPA filter can continuously remove SARS-CoV-2 from the air. The capture ratios for SARS-CoV-2 in the air when the air cleaner was equipped with an antiviral-agent-coated HEPA filter were comparable to those with the conventional HEPA filter, and there was little effect on SARS-CoV-2 in the air that passed through the antiviral-reagent-coated HEPA filter. Coronavirus disease 2019 (COVID-19) spreads by airborne transmission; therefore, the development and functional evaluation of air-cleaning technologies are essential for infection control. Air filtration using high-efficiency particulate air (HEPA) filters may be effective; however, no quantitative assessment of the effectiveness of these filters in the removal of infectious severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) from the air has been reported. To evaluate the removal effect of HEPA filtration on airborne SARS-CoV-2, here, we disseminated infectious SARS-CoV-2 aerosols in a test chamber in a biosafety level 3 facility and filtered the air with a HEPA-filtered air cleaner in the chamber. The air cleaner with the HEPA filter continuously removed the infectious SARS-CoV-2 from the air in a running-time-dependent manner, and the virus capture ratios were 85.38%, 96.03%, and >99.97% at 1, 2, and 7.1 ventilation volumes, respectively. The air-cleaning performance of a HEPA filter coated with an antiviral agent consisting mainly of a monovalent copper compound was also evaluated, and the capture ratio was found to be comparable to that of the conventional HEPA filter. This study provides insights into the proper use and performance of HEPA-filtered air cleaners to prevent the spread of COVID-19. IMPORTANCE Air filtration simulation experiments quantitatively showed that an air cleaner equipped with a HEPA filter can continuously remove SARS-CoV-2 from the air. The capture ratios for SARS-CoV-2 in the air when the air cleaner was equipped with an antiviral-agent-coated HEPA filter were comparable to those with the conventional HEPA filter, and there was little effect on SARS-CoV-2 in the air that passed through the antiviral-reagent-coated HEPA filter.

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Narayan, R., Kundu, D., Ghatak, A., Tripathi, S., Datta, S.
Efficient Elimination of Airborne Pathogens: A Study on aerosolized Mycobacterium tuberculosis and SARS-CoV-2 using ZeBox Technology.
Journal of Hospital Infection, (2022)

Summary Background Despite multifactorial evidence, the safe and effective elimination of free-floating microorganisms remain a significant scientific challenge. ZeBox Technology exploits microbial Zeta Potential, to extract and eliminate them from free-flowing air, using a non-ionizing electric field, in combination with a microbicidal surface. Aim Evaluation of ZeBox Technology against aerosolized SARS-CoV-2 and Mycobacterium tuberculosis under controlled conditions. Methods SARS-CoV2 and Mycobacterium tuberculosis: H37Ra were used in this study. Individual microorganisms were aerosolized using a Collison nebulizer inside an air-sealed test chamber. Air samples were collected from the chamber onto a Mixed Cellulose Ester membrane, at various time points, and used for enumeration. SARS-CoV2 was enumerated using qRT-PCR, while Mycobacterium tuberculosis H37Ra, was quantified using standard microbiological procedures. Findings We established a viable aerosolized microbial load of ~10E9 and ~10E6 for SARS-CoV-2 and Mycobacterium tuberculosis H37Ra respectively inside the test chamber. Under ideal conditions, the floating microbial load was at a steady-state level of 10E9 for SARS-CoV-2 and 10E6 for Mycobacterium tuberculosis. When the ZeBox Technology enabled device was operated, the microbial load reduced significantly. A reduction of ~10E4.7 was observed for Mycobacterium tuberculosis, while ~10E7 for SARS-CoV2 within a short duration. The reduction in airborne SARS-CoV-2 load was qualitatively and quantitatively measured using fluorescence analysis and qRT-PCR method respectively. Conclusion This validation testifies the efficacy of the developed technology against two of the deadliest microorganism, claiming millions of lives worldwide. In conjunction with the existing reports, the present validation proved the true broad-spectrum elimination capability of ZeBox technology.

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Donovan, C. V., Worrell, M. C., Steinberg, J., Montgomery, B. K., Young, R., Richardson, G.*, et al.*
An Examination of SARS-CoV-2 Transmission Based on Classroom Distancing in Schools With Other Preventive Measures in Place—Missouri, January–March 2021.
Public Health Reports, (2022)

Objectives:
Classroom layout plays a central role in maintaining physical distancing as part of a multicomponent prevention strategy for safe in-person learning during the COVID-19 pandemic. We conducted a school investigation to assess layouts and physical distancing in classroom settings with and without in-school SARS-CoV-2 transmission.
Methods:
We assessed, measured, and mapped 90 K-12 (kindergarten through grade 12) classrooms in 3 Missouri public school districts during January–March 2021, prior to widespread prevalence of the Delta variant; distances between students, teachers, and people with COVID-19 and their contacts were analyzed. We used whole-genome sequencing to further evaluate potential transmission events.
Results:
The investigation evaluated the classrooms of 34 students and staff members who were potentially infectious with COVID-19 in a classroom. Of 42 close contacts (15 tested) who sat within 3 ft of possibly infectious people, 1 (2%) probable transmission event occurred (from a symptomatic student with a longer exposure period [5 days]); of 122 contacts (23 tested) who sat more than 3 ft away from possibly infectious people with shorter exposure periods, no transmission events occurred.
Conclusions:
Reduced student physical distancing is one component of mitigation strategies that can allow for increased classroom capacity and support in-person learning. In the pre–Delta variant period, limited physical distancing (<6 ft) among students in K-12 schools was not associated with increased SARS-CoV-2 transmission.

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Zhuang, X., Xu, Y., Zhang, L., Li, X., Lu, J.
Experiment and numerical investigation of inhalable particles and indoor environment with ventilation system.
Energy and buildings, Vol. **271**, (2022)

After the outbreak of COVID-19, the indoor environment has become particularly important in closed spaces, being a common concern in environmental science and public health, and of great significance for the building environment. To improve the indoor air quality and control the spread of viruses, the analysis of inhalable particles in indoor environments is critical. In this research, we study standards focused on inhalable particles and indoor environmental quality, as well as analyzing the movement and diffusion of indoor particles. Based on our analysis, we conduct an experimental study to determine the distribution of indoor inhalable particles of different sizes before and after diffusion under the conditions of underfloor air distribution. Furthermore, the mathematical modeling method is adopted to simulate the indoor flow field, particle trajectories, and pollutant dispersion process. The k-epsilon two-equation model is applied as the turbulence model in the numerical simulation, while the Lagrangian discrete phase model is adopted to trace the motion of particles and analyze the distribution characteristics of indoor particles. The results demonstrate that fine particles (i.e., those with size less than 0.5mum) have a significant impact on the indoor particle concentration, while coarse particles (i.e., with size above 2.5mum) have a greater influence on the total mass concentration of indoor particles. Small-sized particles can easily follow the airflow and diffuse to upper parts of the room. Overall, the effects of indoor particles on indoor air quality, including the potential threat of aerosol transmission of respiratory infectious diseases, are non-negligible. Application of the presented research can contribute to improving the health-related aspects of the building environment.

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Mousavi, E., Grosskopf, K., Arnold, P., Lautz, R., Lau, J.
Experimental measurement of bioaerosol concentrations and containment in long-term care environments.
Building and Environment, Vol. **223**, (2022)

Although many long-term care (LTC) facilities have implemented measures to isolate infectious residents from the general population, most are not designed for airborne infection control, and guidance for retrofitting existing LTC spaces for airborne isolation is limited. The purpose of this study was to evaluate the effect of ventilation, negative pressure, airflow barriers, and other retrofit measures on bioaerosol concentration and movement within long-term care LTC environments. To that end, a series of bioaerosol measurements was performed in an LTC facility under various pressurization and airflow configurations. We arranged active air sampling of DNA-tagged solutions release in the LTC environment, followed by quantitative polymerase chain reaction (qPCR) techniques to measure the released DNA in various spatial locations. Results from aerosol testing in an actual LTC facility suggest that increasing both total and outside ventilation rate had a modest and disproportional effect on the containment of bioaerosols, yet it significantly reduced the time necessary to remove 99% of aerosols from 3 h to approximately 40 min. Significant reductions in aerosol mobility between resident rooms, corridors, and common spaces were also observed with respect to negative room pressurization and anterooms.

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Zhang, D., Bluyssen, P. M.
Exploring the possibility of using CO2 as a proxy for exhaled particles to predict the risk of indoor exposure to pathogens.
Indoor and Built Environment, (2022)

Airborne transmission has been confirmed as one of three principal ways of SARS-CoV-2 transmission. To reduce the transmission of SARS-CoV-2 indoors, understanding the distribution of respiratory droplets (or aerosols) present in human breath seems therefore important. To study whether the CO2 concentration can be used as a proxy for the number of exhaled particles present in an occupied space, the distribution of particles with different diameters (0.3, 0.5, 1.0, 2.5, 5.0 and 10 mu m) and CO2 concentrations were monitored in a classroom setting with six healthy subjects. Additionally, numbers of particles with the same sizes were measured in the breath of the same six healthy subjects separately. Results showed that (1) on the contrary to CO2, the main source of indoor particles came from outdoor air, and not from occupants; (2) the impacts of ventilation regimes on indoor particle numbers were different to the impacts on CO2 concentrations; and (3) almost no significant relationship between the number of indoor particles and CO2 concentration was observed. Based on these results, this study could therefore not conclude that the CO2 concentration in a classroom can be used as a proxy for the number of exhaled particles by the occupants.

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Sutherland, A., Ackley, A., Phipps, R., Longley, I., Mackenzie, S., Chen, S.*, et al.*
The Impact of Natural Ventilation During Winter on Thermal Comfort: A systematic literature review.
NZ Ministry of Education, Report 2022

The COVID-19 pandemic has highlighted the importance of ventilation as a transmission mitigation strategy. However, there is a widely-held concern that a drop in outdoor temperatures during wintertime may impact thermal comfort in the context of naturally ventilated classrooms. This is a concern which has not been widely investigated by peer-reviewed empirical studies. The aim of this paper is to review the available literature on the impact of natural ventilation during winter on thermal comfort. Using the replicable search processes of a systematic literature review adopted from medical research practice, 142 articles were retrieved from four search databases (Science direct, Scopus, PubMed, and Google Scholar). Analysis of these 142 articles

revealed that most studies have particularly focused on the assessment of ventilation conditions, especially in non-naturally ventilated spaces, and that there were only 5 articles that empirically investigated the impact of natural ventilation on thermal comfort during winter in sufficient detail. This shows a significant gap within the body of literature, meaning that the findings from this study can only be treated as tentative, with further research required.

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Ashrafi, R., Azarbayjani, M., Tabkhi, H., Sheikhshahrokhdehkordi, M.
The influence of covid related ventilation rate changes on the energy consumption and infection probability of the buildings: underfloor and overhead air distribution systems.
ANNSIM '22, July 18-20, 2022, San Diego, CA, USA

The COVID-19 pandemic has urged the need to reconsider how our built environments influence our health conditions. The new guidelines have highlighted the importance of environmental settings in the virus transmission process. Given that external air ventilation is a major element of a building's energy performance, it is necessary to investigate the influence of the new settings on the building's energy consumption. This study aims to determine the energy performance and infection risk of underfloor air distribution UFAD and overhead systems OH when exposed to varying levels of external air ventilation. The findings indicate that raising the rate of outside ventilation increases a building's energy usage in all climates. It is also shown that the UFAD system shows its energy-saving potential the most in cold climates and higher ventilation rates. These findings suggest that it is critical to consider distinct ventilation techniques to prevent rising energy consumption rates while lowering the risk of viral transmission.

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Niknahad, A., Lakzian, E., Saeedi, A.
Investigation of the effects of mechanical and underfloor heating systems on the COVID-19 viruses distribution.
European Physical Journal Plus, Vol. **137** n°(7), (2022)

Investigation of the spread of pollutants and especially pathogenic particles in the interior of today's buildings has become an integral part of the design of such buildings. When the Coronavirus is prevalent in the world, it is necessary to pay attention to the spread of the virus in the interior of residential apartments. In the present study, the Coronavirus particles emitted from the sneezing of a sick person in the bedroom of a residential apartment were tracked. Meanwhile, the degree of exposure of a mannequin that has been placed in the living room playing the role of a healthy person is examined. In this research, a segregated solution of steady-state flow and an unsteady particle solution have been separately used: a suitable, accurate, and optimal solution in particle studies. A comparison of the results shows that underfloor heating creates a healthier space around the healthy person's respiratory system, but instead, we will see more polluted areas around the sick person. According to the PRE results, the PRE value for a mechanical heating system is higher than a floor heating system. Therefore, it is recommended to use mechanical heating system in the apartments where the person with COVID-19 is hospitalized.

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Pistochini, T., Mande, C., Chakraborty, S.
Modeling impacts of ventilation and filtration methods on energy use and airborne disease transmission in classrooms.
Journal of Building Engineering, Vol. **57**, (2022)

Lowering the potential of airborne disease transmission in school buildings is especially important in the wake of the COVID-19 pandemic. The benefits of increased ventilation and filtration for reducing disease

transmission compared to drawbacks of reduced thermal comfort and increased energy consumption and electricity demand are not well described. A comprehensive simulation of outdoor air ventilation rates and filtration methods was performed with a modified Wells-Riley equation and EnergyPlus building simulation to understand the trade-offs between infection probability and energy consumption for a simulated classroom in 13 cities across the US. A packaged heating, ventilation, and air conditioning unit was configured, sized, and simulated for each city to understand the impact of five ventilation flow rates and three filtration systems. Higher ventilation rates increased energy consumption and resulted in a high number of unmet heating and cooling hours in most cities (excluding Los Angeles and San Francisco). On average, across the 13 cities simulated, annual energy consumed by an improved filtration system was 31% lower than the energy consumed by 100% outdoor air ventilation. In addition, the infection probability was 29% lower with improved filtration. An economizer, which activates cooling based on an outdoor temperature setpoint, increased ventilation and reduced both energy consumption and infection probability. It was also concluded that ventilation and filtration measures better reduced absolute infection probability when the quanta generation rate for an infectious disease was higher. Dynamic outdoor airflow rate controls and filtration technologies that consider both health and energy consumption are an important area for further research.

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Dbouk, T., Drikakis, D.
Natural Ventilation and Aerosol Particles Dispersion Indoors.
Energies, Vol. **15** n°(14), (2022)

Aerosol pollutant particles indoors significantly affect public health. The conventional wisdom is that natural ventilation will alleviate the dispersion of airborne or aerosol particles. However, we show that the problem is far more complex and that natural ventilation should be applied under specific conditions to be effective. We performed several simulations of a simplified (and easily reproducible) room with a window opening and aerosol particles stratified layers. Opening a window can scatter particles present in stratified layers indoors and potentially contribute to the degradation of indoor air quality for a significant period of time. Moreover, we show that thermal instabilities arising from the temperature gradients due to temperature differences between the indoor and outdoor environment spread the particles randomly indoors, adversely affecting air quality and architectural design. Recommendations for more efficient natural ventilation minimizing aerosol pollutant particles dispersed indoors are provided.

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Zabihi, M., Li, R., Brinkerhoff, J., Little, J., Winkler, J.
Numerical Investigation of Aerosol Transmission in A Classroom.
Canadian Society for Mechanical Engineering International Congress 2022. June 5-8, 2022, Edmonton, AB, Canada

The present study investigates aerosol transport and surface deposition in a realistic classroom environment using computational fluid-particle dynamics simulations. Effects of particle size, aerosol source location, glass barriers, and windows are explored. While aerosol transport in air exhibits some stochasticity, it is found that a significant fraction (24%–50%) of particles smaller than 15 μm exit the system within 15 min through the air conditioning system. Particles larger than 20 μm almost entirely deposit on the ground, desks, and nearby surfaces in the room. Source location strongly influences the trajectory and deposition distribution of the exhaled aerosol particles and affects the effectiveness of mitigation measures such as glass barriers. Glass barriers are found to reduce the aerosol transmission of 1 μm particles from the source individual to others separated by at least 2.4 m by ∼92%. By opening windows, the particle exit fraction can be increased by ∼38% compared to the case with closed windows and reduces aerosol deposition on people in the room. On average, ∼69% of 1 μm particles exit the system when the windows are open.

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Goldman, C., Czaja, C., Moses, X. J. E., Van Dyke, M.
Nursing Home Adoption of CDC and ASHRAE COVID-19 Built Environment Recommendations: A Characterization Study of Colorado Nursing Home Facilities.
Herd-Health Environments Research & Design Journal, (2022)

Background: During the COVID-19 pandemic, the Centers for Disease Control and Prevention (CDC) and ASHRAE provided infection control recommendations for the built environments and ventilation systems of nursing homes (NHs). The level of adoption of the suggested strategies is unknown, as little information has been obtained from NHs identifying the strategies that were implemented. Objective: The primary goal of our study was to characterize the built environments of Colorado NHs during the COVID-19 pandemic to assess the level of adoption of CDC and ASHRAE recommendations. Our secondary goal was to identify opportunities and barriers that NHs face as they work to create health-protective built environments in the future. Method: We used the Nursing Home Built Environment survey to obtain data related to three main categories of CDC and ASHRAE recommendation for Colorado NHs: Resident Isolation, Improved Indoor Air Quality, and Staff Separation/Support. Results: Key findings included: (1) On average, NHs had 34% of their beds located in single-occupancy rooms; (2) seven (9%) NHs had designated COVID-positive "neighborhoods"; (3) 14 (20%) NHs had common area ventilation systems that were utilizing filters with a minimum efficiency reporting value 13 rating, or higher. Conclusion: Most Colorado NHs did not fully implement the COVID-19 built environment strategies recommended by CDC and ASHRAE. While there are barriers to the adoption of many of the strategies, there are also opportunities for immediate improvements that can support the health of vulnerable NH populations as we continue to see high rates of aerosolized infectious disease spread in NH facilities.

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Saccani, C., Pellegrini, M., Guzzini, A.
Perspective Chapter: Analysis of SARS-CoV-2 Indirect Spreading Routes and Possible Countermeasures.
In: SARS-CoV-2 Variants - Two Years After. 2022.

The research community agrees that the main indirect way the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) spreads among people who do not keep social distance is through the emission of infected respiratory droplets. Infected people exhale droplets of different sizes and emission velocities while breathing, talking, sneezing, or coughing. Complex two-phase flow modeling considering evaporation and condensation phenomena describes droplets' trajectories under the specific thermofluid dynamic boundary conditions, including air temperature, relative humidity, and velocity. However, public health organizations simply suggest a safe distance in the range of 1–2 m regardless of the effect of boundary conditions on droplets' motion. This chapter aims to highlight open research questions to be addressed and clarify how framework conditions can influence safe distance in an indoor environment and which technical countermeasures (such as face masks wearing or heating, ventilation, and air conditioning (HVAC) control) can be adopted to minimize the infection risk.

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Kumar, A., Raj, A., Gupta, A., Gautam, S., Kumar, M., Bherwani, H.*, et al.*
Pollution free UV-C radiation to mitigate COVID-19 transmission.
Gondwana research : international geoscience journal, (2022)

The high rate of transmission of the COVID-19 virus has brought various types of disinfection techniques, for instance, hydrogen peroxide vaporization, microwave generating steam, UV radiation, and dry heating, etc. to prevent the further transmission of the virus. The chemical-based techniques are predominantly used for sanitization of hands, buildings, hospitals, etc. However, these chemicals may affect the health of humans and

the environment in unexplored aspects. Furthermore, the UV lamp-based radiation sanitization technique had been applied but has not gained larger acceptability owing to its limitation to penetrate different materials. Therefore, the optical properties of materials are especially important for the utilization of UV light on such disinfection applications. The germicidal or microorganism inactivation application of UV-C has only been in-use in a closed chamber, due to its harmful effect on human skin and the eye. However, it is essential to optimize UV for its use in an open environment for a larger benefit to mitigate the virus spread. In view of this, far UV-C (222nm) based technology has emerged as a potential option for the sanitization in open areas and degradation of microorganisms present in aerosol during the working conditions. Hence, in the present review article, efforts have been made to evaluate the technical aspects of UV (under the different spectrum and wavelength ranges) and the control of COVID 19 virus spread in the atmosphere including the possibilities of the human body sanitization in working condition.

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Adzic, F., Roberts, B. M., Hathway, E. A., Kaur Matharu, R., Ciric, L., Wild, O.*, et al.*
A post-occupancy study of ventilation effectiveness from high-resolution CO2 monitoring at live theatre events to mitigate airborne transmission of SARS-CoV-2.
Building and environment, Vol. **223**, (2022)

Mass-gathering events were closed around the world in 2020 to minimise the spread of the SARS-CoV-2 virus. Emerging research on the transmission of SARS-CoV-2 emphasised the importance of sufficient ventilation. This paper presents the results of an indoor air quality (IAQ) monitoring study over 82 events in seven mechanically ventilated auditoria to support the UK government Events Research Programme. Indoor carbon dioxide concentration was measured at high resolution before, during, and after occupancy to allow for assessment of the ventilation systems. Generally, good indoor air quality was measured in all auditoria, with average IAQ found to be excellent or very good for 70% of spaces. In some auditoria, spatial variation in IAQ was identified, indicating poor mixing of the air. In addition, surface and air samples were taken and analysed for the presence of bacteria by culture and SARS-CoV-2 using RT-qPCR in one venue. SARS-CoV-2 RNA was detected on a small number of surfaces at very low copy numbers, which are unlikely to pose an infection risk. Under the ventilation strategies and occupancy levels investigated, it is likely that most theatres pose a low risk of long-range transmission of COVID-19.

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Vyas, D., Umemoto, K. K., Vyas, A., Bhatt, D. L.
Procedure room innovation during the COVID-19 crisis: Protecting healthcare workers while learning from history.
iScience, Vol. **25** n°(8), (2022)

The impact of the recent pandemic on healthcare workers highlights the need to improve the working environment in hospitals. This is especially true in procedural rooms such as the operating and delivery rooms, which inherently require extended exposure to the virus, allows no social distancing, and generates aerosolized virus into the room through the use of the equipment. While reviewing the history of the development of the current Heating, Ventilation, and Air Conditioning Systems (HVAC), we identified inadequacies in the architecture and regulations of the system that resulted in insufficient protection during the current pandemic. Thus, we worked with building/facilities management, the operating room and nursing staff, and learned from research on airplane cabin air circulation to modify HVAC systems to address this issue. The modification includes calculating and implementing appropriate air changes per hour of the HVAC system. Modifying the existing system allows sufficient exchange of air within the procedure room to reduce the amount of exposure to viruses which results in safer working environments for healthcare workers. In the future, there will continue to be more pandemics, thus it is important to start creating safer working

environments now, such as revisiting the hospital architecture and HVAC system, so that they can be improved upon and so that we are more prepared for the future.

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Vergerio, G., Becchio, C.
Pursuing occupants' health and well-being in building management: Definition of new metrics based on indoor air parameters.
Building and environment, (2022)

The spread of COVID-19 has affected the lives of millions of people. Pandemic has made people more sensitive to health issues. In particular, the growing concern of the virus spread in confined spaces has promoted the necessity to improve indoor air quality. Literature is stressing how buildings must be designed and operated pursuing occupants' health and well-being, with a particular attention for indoor air parameters. This poses the challenge of monitoring and assessing these aspects through proper metrics. In this paper the approach towards a multi-step assessment procedure embedding in buildings assessment health and well-being related variables and indicators is elaborated. They are intended to inform a building manager of the potential influence of air conditions on human health and well-being. Moreover, a set of monetary metrics (i.e., impacts) is proposed to translate energy and indoor air related building performances into euros, putting the basis for a comprehensive economic evaluation. The application of the set of proposed metrics to an Italian hotel (i.e., Italian pilot of H2020 MOBISTYLE project), enabled to map some indoor air conditions causing health concerns, and to identify clusters of guests with best and worst indoor air conditions, to be targeted by new management strategies. Despite case study specific limitations, the application exemplified how the methodology can expand the traditional energy-based performance assessment for building management towards indoor air domain and the related economic impacts, with implication on results in terms of overall economic performance of the building from both a private and public perspective.

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Leal, J., Farkas, B., Mastikhina, L., Flanagan, J., Skidmore, B., Salmon, C.*, et al.*
Risk of transmission of respiratory viruses during aerosol-generating medical procedures (AGMPs) revisited in the COVID-19 pandemic: a systematic review.
Antimicrobial Resistance & Infection Control, Vol. **11** n°(1), (2022)

In many jurisdictions healthcare workers (HCWs) are using respirators for aerosol-generating medical procedures (AGMPs) performed on adult and pediatric populations with all suspect/confirmed viral respiratory infections (VRIs). This systematic review assessed the risk of VRIs to HCWs in the presence of AGMPs, the role respirators versus medical/surgical masks have on reducing that risk, and if the risk to HCWs during AGMPs differed when caring for adult or pediatric patient populations.

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Goodlad, C., Collier, S., Davenport, A.
Spread of Covid-19 in hemodialysis centres; the effects of ventilation and communal transport.
Artificial organs, (2022)

AIMS: Hemodialysis (HD) patients are at increased risk of respiratory infections, due to increased use of communal travel, waiting areas, close proximity to others when dialysing, and contact with healthcare personnel. We wished to determine the major factors associated with transmission of COVID-19 within dialysis centres. METHODS: We compared the differences in the number of COVID-19 infections in patients and staff in 5 dialysis centres during the 1st COVID-19 pandemic between March and June 2020, and analyzed differences between centres. Isolation policies and infection control practices were identical between centres. RESULTS: 224 (30.3%) patients tested positive for COVID-19, by reverse transcriptase polymerase chain

reaction, ranging from 4.8% (centre 1 size 55 patients) to 41.5% (centre 5-248 patients) p=0.007. Communal transport had a significant effect; with 160 of 452 (35.4%) patients using communal testing positive compared to 22.2% of those not using communal transport (X214.5, p<0.001). Staff sickness varied; 35 of 36 (97.3% centre 5) dialysis staff contracting COVID-19, compared to 60% from centre 4 (189 patients 30 staff) (p<0.001). Whereas centre 5 had no natural ventilation, and fan assisted ventilation did not meet standards for air changes and air circulation, centre 4 met ventilation standards. CONCLUSIONS: Although there are many potential risk factors accounting for the increased risk of COVID-19 infection in hemodialysis patients, we found that differences in communal transport for patients and ventilation between centres was a major contributor accounting for the differences in patients testing positive for COVID-19 and staff sickness rates. This has important practical applications for designing kidney dialysis centres.

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Waheeb, M. I., Hemeida, F. A.

Study of natural ventilation and daylight in a multi-storey residential building to address the problems of COVID-19.

Energy Reports, Vol. **8**, (2022), pp. 863-880

Many issues have emerged more clearly than before in multi-storey residential buildings during quarantine and lockdown caused by the global pandemic COVID-19. Among these problems is the deterioration in people's mental and physical health inside the home caused by quarantine and closure. This deterioration is due to inadequate passive ventilation, natural lighting, and the lack of green open spaces in and around traditional multi-storey residential buildings. Also, one of the most severe problems is the airborne infection transmission from a positive covid-19 person to others due to the lack of control in the entrance of buildings against an infected person. In this paper, we modified the shape of a traditional multi-storey residential building. Using Design-Builder and Autodesk CFD software, we create a simulation to compare the amount of natural ventilation and lighting before and after modifying the building's shape. This work aims to increase the passive ventilation and daylight inside the building. Also, to achieve the biophilic concept to provide open spaces for each apartment to improve the mental and physical health of the residents. In addition, it protects the building users from infection with the virus. Through this study, we found that passive ventilation and daylight achieved more efficiency in the building that we have modified in its shape, which led to a 38% reduction in energy consumption. In summary, these findings suggest that by modifying the mass of the traditional multi-storey residential building with open green spaces provided for each apartment, the natural connection with the inhabitants of the building was sufficiently provided. Moreover, all this will significantly help improve residents' mental and physical state, and it will also help prevent the spread of various diseases inside the homes.

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Corzo, S. F., Ramajo, D. E., Idelsohn, S. R.

Study of ventilation and virus propagation in an urban bus induced by the HVAC and by opening of windows.

Computer Methods in Applied Mechanics and Engineering, (2022)

The external and internal airflow and air renewal inside urban buses have taken especial relevance since the COVID-2 pandemic. Computational fluid dynamics (CFD) simulations, which focus on the estimation of indoor airflow are not conclusive about the impact of using Heat, Ventilation and Air Conditioning (HVAC) systems on diseases' transmission risk while travelling with open windows has shown to be a good strategy to renew the indoor air. In order to estimate the COVID-2 airborne transmission by aerosols, a real urban bus was simulated by CFD. Twenty passengers (containing the driver) were included in the model with a typical inhalation–exhalation breathing cycle. The concentrations of air exhaled by ten of them were tracked during 30 min using Eulerian scalar tracer, and the concentrations inhaled by the twenty passengers were monitored. Then, the

well-known Wells & Riley risk model was applied in order to estimate the cumulative inhaled viruses and the subsequent transmission risk. Four scenarios were considered: HVAC off with closed windows (Case 1), HVAC on with closed windows and 100% of air recirculation (Case 2), HVAC on with closed windows and 75% of air recirculation (Case 3), and HVAC off and the bus moving at 20 km/h with some windows opened (Case 4). Results clearly showed that the motionless condition (Case 1) caused the highest transmission risk around the emitters with negligible risk far from them. On the contrary, the HVAC on reduced the maximum risk to only 6% (Case 2) and 3% (Case 3) of the risk estimated for Case 1. Finally, travelling with some open windows promotes a large air renewal, reducing almost completely the transmission risk.

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Kuwahara, R., Kim, H.
Studying the Indoor Environment and Comfort of a University Laboratory: Air-Conditioning Operation and Natural Ventilation Used as a Countermeasure against COVID-19.
Buildings, Vol. **12** n°(7), (2022)

In this study, the indoor air quality and thermal environment of a university facility were analyzed when an air conditioner was operated and natural ventilation was provided; the most effective natural ventilation method was also evaluated. The research conditions were established by adjusting the temperature of the air conditioner, and frequency of window openings every hour. The area around the windows that is open for natural ventilation was easily affected by outdoor air temperature and humidity. However, since the air conditioner was operating, there was only a brief period during which the environment was uncomfortable. Therefore, the participants in the questionnaire survey expressed neutrality or slight satisfaction for the thermal environment of the entire space. Setting the room temperature to 25 degrees C in summer was highly comfortable and generated a satisfactory indoor thermal environment. When the room temperature was set to 20 degrees C in winter, the thermal comfort level was higher than in the other conditions. Providing natural ventilation for 5 min every 30 min was determined to be effective in maintaining an indoor CO2 concentration of 1 000 ppm or less. Facilitating natural ventilation for 10 min every 60 min allowed the entry of a large amount of fresh air; however, due to the extended period in which the windows and doors were closed, there were instances when the indoor CO2 concentration exceeded 1 000 ppm. Therefore, providing frequent natural ventilation with short time intervals is effective for improving indoor air quality.

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Faulkner, C. A., Castellini Jr, J. E., Lou, Y., Zuo, W., Lorenzetti, D. M., Sohn, M. D.
Tradeoffs among indoor air quality, financial costs, and CO2 emissions for HVAC operation strategies to mitigate indoor virus in US office buildings.
Building and Environment, Vol. **221**, (2022)

Adapting building operation during the COVID-19 pandemic to improve indoor air quality (IAQ) while ensuring sustainable solutions in terms of costs and CO2 emissions is challenging and limited in literature. Our previous study investigated different HVAC operation strategies, including increased filtration using MERV 10, MERV 13, or HEPA filters, as well as supplying 100% outdoor air into buildings for a system initially sized for MERV 10 filtration. This paper significantly extends that research by systematically analyzing the potential financial and environmental impact for different locations in the U.S. The previous medium office building system model is improved to account for operation in different climates. New evaluation metrics are created to consider the comprehensive impact of improving IAQ on costs and CO2 emissions, using dynamic emission factors for electricity generation depending on the location. HVAC operation strategies are studied in five different locations across the United States, with distinct climates and electricity sources. In four of the five locations, MERV 13 filtration offers the best improvement in IAQ per increase in costs and emissions relative to MERV 10. The exception is the mildest climate of San Diego, where use of 100% outdoor air provides the best IAQ

with a limited increase in costs and emissions. A system not sized for HEPA filtration can lead to increased costs and emissions without much improvement in IAQ.

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Hosseini, P., Mueller, W., Rhodes, S., Pembrey, L., Van Tongeren, M., Pearce, N.*, et al.*
Transmission and control of SARS-CoV-2 in the food production sector: A rapid narrative review of the literature.
FigShare, (2022)

The food production sector has drawn attention over the duration of the COVID-19 pandemic due to a large number of cases reported across different facilities, particularly during the early stages of the pandemic. This review aimed to provide an overview of the literature assessing the extent of transmission in the food processing sector along with the risk factors associated with COVID-19 infection/mortality rates in this setting, and the preventive measures used to reduce transmission. An electronic search was conducted using various scientific databases, including Web of Science, OVID, PubMed and Medrxiv. The search strategy identified 26 papers that met the inclusion criteria. Six of these total studies were based in the UK and the country with the most papers was the USA, with a total of nine papers. Findings showed some evidence of a high transmission level of SARS-CoV-2 within some areas of the food production sector. Risk factors associated with the spread included poor ventilation, lack of social distancing, lack of sick pay and ethnicity. The preventative measures taken were also outlined, and included social distancing, testing, adequate ventilation, cleaning regimes and access to personal protective equipment. Additional research focusing on the food production sector could help to provide further understanding surrounding the variations in transmission and risk between each sub-sector. Similarly, future research focusing on the application of various preventative measures and their efficacy by sub-sector would be beneficial, while further qualitative research could help provide in-depth information regarding enablers and barriers to transmission, risk factors and mitigation.

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Garg, H., Ringe, R. P., Das, S., Parkash, S., Thakur, B., Delipan, R.*, et al.*
UVC-based air disinfection system for rapid inactivation of SARS-CoV-2 present in the air.
bioRxiv, (2022)

The novel coronavirus disease 2019 (COVID-19) infections have rapidly spread throughout the world, and the virus has acquired an ability to spread via aerosols even at long distances. Hand washing, face-masking, and social distancing are the primary preventive measures against infections. With mounting scientific evidence, World Health Organisation (WHO) declared COVID-19 an air-borne disease. This ensued the need to disinfect air to reduce the transmission. Ultraviolet C (UVC) comprising the light radiation of 200-280 nm range is a commonly used method for inactivation of pathogens. The heating, ventilation, and air conditioning (HVAC) systems are not beneficial in closed spaces due to poor or no ability to damage circulating viruses. Therefore, standard infection-prevention practices coupled with a strategy to reduce infectious viral load in air substantially might be helpful in reducing virus transmissibility. In this study, we implemented UV light-based strategies to combat COVID-19 and future pandemics. We tested various disinfection protocols by using UVC-based air purification systems and currently installed such a system in workspaces, rushed out places, hospitals and healthcare facilities for surface, air, and water disinfection. In this study, we designed a prototype device to test the dose of UVC required to inactivate SARS-CoV-2 in aerosols and demonstrate that the radiation rapidly destroys the virus in aerosols. The UVC treatment renders the virus non-infectious due to chemical modification of nucleic acid. We also demonstrate that UVC treatment alters the Spike protein conformation that may further affect the infectivity of the virus. We show by using a mathematical model based on the experimental data that UVC-based air disinfection strategy can substantially reduce the risk of virus transmission. The systematic treatment by UVC of air in the closed spaces via ventilation systems could be helpful in reducing the active viral load in the air.Competing Interest StatementThe patent on UV-C-based

in-duct designs have been filed in India on which HG, SD, SP, SAR, AK, and RPR are the inventors. The patent on air disinfection and purification system for indoor applications has been filed on which NBB, TA, AKu, CSM, KSK, SG, and SD are inventors.

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Lu, Y., Niu, D., Zhang, S., Chang, H., Lin, Z.
Ventilation indices for evaluation of airborne infection risk control performance of air distribution.
Building and Environment, Vol. **222**, (2022)

Air distribution is an effective engineering measure to fight against respiratory infectious diseases like COVID-19. Ventilation indices are widely used to indicate the airborne infection risk of respiratory infectious diseases due to the practical convenience. This study investigates the relationships between the ventilation indices and airborne infection risk to suggest the proper ventilation indices for the evaluation of airborne infection risk control performance of air distribution. Besides the commonly used ventilation indices of the age of air (AoA), air change effectiveness (ACE), and contaminant removal effectiveness (CRE), this study introduces two ventilation indices, i.e., the air utilization effectiveness (AUE) and contaminant dispersion index (CDI). CFD simulations of a hospital ward and a classroom served by different air distributions, including mixing ventilation, displacement ventilation, stratum ventilation and downward ventilation, are validated to calculate the ventilation indices and airborne infection risk. A three-step correlation analysis based on Spearman's rank correlation coefficient, Pearson correlation coefficient, and goodness of fit and a min-max normalization-based error analysis are developed to qualitatively and quantitatively test the validity of ventilation indices respectively. The results recommend the integrated index of AUE and CDI to indicate the overall airborne infection risk, and CDI to indicate the local airborne infection risk respectively regardless of the effects of air distribution, supply airflow rate, infectivity intensity, room configuration and occupant distribution. This study contributes to airborne transmission control of infectious respiratory diseases with air distribution.

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Ferrari, S., Blazquez, T., Cardelli, Z. a. R., Puglisi, G., Suarez, R., Mazzarella, L.
Ventilation strategies to reduce airborne transmission of viruses in classrooms: A systematic review of scientific literature.
Building and Environment, Vol. **222**, (2022)

The recent pandemic due to SARS-CoV-2 has brought to light the need for strategies to mitigate contagion between human beings. Apart from hygiene measures and social distancing, air ventilation highly prevents airborne transmission within enclosed spaces. Among others, educational environments become critical in strategic planning to control the spread of pathogens and viruses amongst the population, mainly in cold conditions. In the event of a virus outbreak - such as COVID or influenza - many school classrooms still lack the means to guarantee secure and healthy environments. The present review examines school contexts that implement air ventilation strategies to reduce the risk of contagion between students. The analysed articles present past experiences that use either natural or mechanical systems assessed through mathematical models, numerical models, or full-scale experiments. For naturally ventilated classrooms, the studies highlight the importance of the architectural design of educational spaces and propose strategies for aeration control such as CO2-based control and risk-infection control. When it comes to implementing mechanical ventilation in classrooms, different systems with different airflow patterns are assessed based on their ability to remove airborne pathogens considering parameters like the age of air and the generation of airflow streamlines. Moreover, studies report that programmed mechanical ventilation systems can reduce risk-infection during pandemic events. In addition to providing a systematic picture of scientific studies in the field, the findings of this review can be a valuable reference for school administrators and policymakers to implement the best strategies in their classroom settings towards reducing infection risks.

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