Rapport de veille n° 56

Aéraulique et COVID-19

16/11/2022

Les bulletins de veille sont disponibles sur le portail documentaire de l'INRS. L'abonnement vous permet de recevoir une alerte mail lors de la publication d'un nouveau bulletin (bouton « M'abonner »).

Google Scholar et WoS

Kong, X., Chang, Y., Fan, M., Li, H.
Analysis on the thermal performance of low-temperature radiant floor coupled with intermittent stratum ventilation (LTR-ISV) for space heating.
Energy and buildings, Vol. **278**, (2023)

With increasing energy use and outbreaks of respiratory infectious diseases (such as COVID-19) in buildings, there is a growing interest in creating healthy and energy-efficient indoor environments. A novel heating system named low-temperature radiant floor coupled with intermittent stratum ventilation (LTR-ISV) is proposed in this study. Thermal performance, indoor air quality, energy and exergy performance were investigated and compared with conventional radiant floor heating (CRFH) and conventional radiant floor heating with mixing ventilation (CRFH+MV). The results indicated that LTR-ISV had a more uniform operative temperature distribution and overall thermal sensation, and air mixing was enhanced without generating additional draft sensation. Compared with CRFH and CRFH+MV, the indoor CO2 concentration in LTR-ISV can be reduced by 1355ppm and 400ppm, respectively. Airborne transmission risk can also be reduced by 5.35 times. The coefficient of performance for CRFH, CRFH+MV, and LTR-ISV during working hours was 4.2, 2.5, and 3.4, respectively. The lower value of LTR-ISV was due to the high energy usage of the primary air handing unit. In the non-working hours, LTR-ISV was 0.6 and 1.3 higher compared to CRFH and CRFH+MV, respectively. The exergy efficiency of LTR-ISV, CRFH, and CRFH+MV was 81.77%, 76.43%, and 64.71%, respectively. Therefore, the LTR-ISV system can meet the requirements of high indoor air quality and thermal comfort and provides a reference for the energy-saving use of low-grade energy in space heating.

****

Al Assaad, D., Sengupta, A., Breesch, H.
Demand-controlled ventilation in educational buildings: Energy efficient but is it resilient?
Building and Environment, Vol. **226**, (2022)

Educational buildings with smart ventilation are designed under known indoor and outdoor conditions. However, buildings can face sudden shocks that compromise IAQ. The characteristic that describes the extent to which buildings and their ventilation systems can maintain habitable conditions during shocks is “ventilation resilience”. This study aims to assess the ventilation resilience of demand-controlled ventilation (DCV) in an existing educational building. To reach those aims, a Modelica model of the building was developed and experimentally validated. Shocks were classified into mechanical (MS), internal (IS), and outdoor (OS) and quantified using the degree of shock (doS). Results showed that DCV had similar resilience to a constant air volume (CAV) regarding CO2, driving the DCV operation but 53–62% worse for VOCs. For CO2, for DCV and CAV, until doS < 0.045, IS was 29.5% and 56.1% more critical than MS and OS. For doS > 0.045, MS was the most critical, followed by IS and OS. For VOCs and CAV, until doS < 0.08, IS was the most critical, followed by MS and OS. For doS > 0.08, MS was the most critical, followed by IS and OS. For VOCs and DCV, MS was always the most critical. MS occurrence was critical during occupied periods only. IS occurrence had the same impact in similar classes with no prior build-up of contaminants. A morning OS was more critical than evening due to more occupancy.

****

Thornton, G. M., Kroeker, E., Fleck, B. A., Zhong, L., Hartling, L.
The impact of heating, ventilation and air conditioning (HVAC) design features on the transmission of viruses, including SARS-CoV-2: an overview of reviews.

Interactive journal of medical research, (2022)

BACKGROUND: Background: The 2019 novel coronavirus or severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) outbreak was declared a pandemic by the World Health Organization (WHO) in March 2020. Almost two years later (early-February 2022), the WHO reported over 383 million cases of the disease caused by the virus with over 5.6 million deaths worldwide. Debate regarding routes of transmission was substantial early in the pandemic; however, airborne transmission emerged as an important consideration. Infectious airborne agents can spread within the built environment through heating, ventilation, and air conditioning (HVAC) systems. Multiple features of HVAC systems can influence transmission (e.g., ventilation, filtration, ultraviolet radiation, humidity). Understanding how HVAC features influence airborne transmission is critical to mitigate the spread of infectious agents. OBJECTIVE: Objective: Given airborne transmission of SARS-CoV-2, an overview of reviews was conducted to understand what is already known from the scientific literature about how virus transmission may be affected by HVAC design features in the built environment. METHODS: Methods: Ovid MEDLINE and Compendex were searched from inception to January 2021. Two reviewers independently screened titles and abstracts and full text of potentially relevant reviews, using a priori inclusion criteria. Inclusion criteria were systematic reviews examining effects of HVAC design features on virus transmission. Two reviewers independently assessed methodological quality using AMSTAR2. RESULTS: Results: Searching identified 361 citations, 45 were potentially relevant, and 7 were included. Reviews were published between 2007 and 2021, and included 47 virus studies. Two earlier reviews (2007, 2016) of 21 studies found sufficient evidence that mechanical ventilation (airflow patterns, ventilation rates) plays a role in airborne transmission; however, both found insufficient evidence to quantify minimum mechanical ventilation requirements. One review (2017) of 9 studies examining humidity and indoor air quality found that influenza virus survival was lowest between 40% and 80% relative humidity; authors noted that ventilation rates were a confounding variable. Two reviews (2021) examined mitigation strategies for coronavirus transmission, finding that transmission decreased with increasing temperature and relative humidity. One review (2020) identified 14 studies examining coronavirus transmission in air conditioning systems, finding HVAC systems played a role in virus spread during previous coronavirus outbreaks. One review (2020) examined virus transmission interventions on public ground transportation, finding ventilation and filtration to be effective. CONCLUSIONS: Conclusions: Seven reviews synthesizing 47 studies demonstrate a role for HVAC in mitigating airborne virus transmission. Ventilation, humidity, temperature, and filtration can play a role in viability and transmission of viruses, including coronaviruses. Recommendations for minimum standards were not possible due to few studies investigating a given HVAC parameter. This overview examining HVAC design features and their effects on airborne transmission of viruses serves as a starting point for future systematic reviews and identifying priorities for primary research.

****

Hadavi, I., Hashemi, M., Asadikaram, G., Kalantar-Neyestanaki, D., Hosseininasab, A., Darijani, T.*, et al.*
Investigation of SARS-CoV-2 Genome in the Indoor Air and High-Touch Surfaces.
International Journal of Environmental Research, Vol. **16** n°(6), (2022)

This study aimed to investigate the presence/absence of SARS-CoV-2 genome in the air and high-touch surfaces. This cross-sectional study was conducted from late-2020 to mid-2021 in the sections of Intensive Care Unit (ICU), emergency, infectious disease ward, and nursing station of the COVID-19 patient reception center in Kerman, Iran. The presence/absence of SARS-CoV-2 genome in the 60 samples of high-touch surfaces and 23 air samples was analyzed by reverse transcription polymerase chain reaction (RT-PCR). Fisher's exact test was used to compare the number of positive samples in different sampling sites. The genome of SARS-CoV-2 was found in the eight samples (13.32%) taken from the high-touch surfaces (two samples in COVID-19 ICU, two samples in general ICU, two samples in emergency ward, and two samples in nursing station) and two air samples (8.70%) (one sample in the general ICU and one sample in the emergency ward). Statistical analysis showed that there was no significant difference between the type of sampling site

and the positive cases of SARS-CoV-2 in the surface samples (p value = 0.80) and air samples (p value = 0.22). According to the results, the SARS-CoV-2 can find in the high-touch surfaces and indoor air of the COVID-19 patient reception centers. Therefore, suitable safety and health measures should be taken, including regular and accurate disinfection of surfaces and equipment and proper ventilation to protect healthcare workers and prevent disease transmission. More studies are recommended to investigate the SARS-CoV-2 concentration in the high-touch surfaces and air samples in the similar researches, efficacy of different disinfectants used on the high-touch surfaces and compare the effect of type of ventilation (natural or mechanical) on the viral load.

****

Torres-Teran, M. M., Cadnum, J. L., Donskey, C. J.
Is ventilation in grocery stores adequate to minimize the risk for airborne transmission of severe acute respiratory syndrome coronavirus 2 ?
Antimicrobial Stewardship & Healthcare Epidemiology, Vol. **2** n°(1), (2022)

Inadequately ventilated indoor spaces pose a risk for acquisition of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and other respiratory viruses.Therefore, it has been recommended that commercial buildings and schools take measures to assess and improve ventilation. The Centers for Disease Control and Prevention (CDC) and experts in aerosol science have recommended passive carbon dioxide monitoring as a practical tool to assess ventilation in occupied indoor environments. The concentration of carbon dioxide in outdoor air is ~400 parts per million (ppm) versus ~40,000 ppm in exhaled breath. Thus, carbon dioxide levels rise in occupied spaces that are inadequately ventilated for the number of people present. Carbon dioxide monitoring has been used to assess and improve ventilation in areas such as schools, dental offices, and motor vehicles. Grocery stores provide an essential service and could potentially pose a risk for SARS-CoV-2 transmission. Based on computational fluid dynamics simulations, the design of ventilation systems in stores may substantially affect the risk of aerosol exposure, with some designs creating local “hot spots” with reduced ventilation and increased risk. Simulations have also indicated that airflow in grocery stores could enhance dispersal of aerosol particles beyond 2 m of an infected source patient. Here, we assessed ventilation in several grocery stores in northeastern Ohio using carbon dioxide monitoring.

****

Urschel, B., Fazlic, L. B., Morgen, M., Machhamer, R., Dartmann, G., Gollmer, K. U.
A Machine Learning Approach for Optimal Ventilation based on Data from CO2 Sensors.
In: 2022 Sensor Data Fusion: Trends, Solutions, Applications (SDF) 09 November 2022, Bonn, Germany.

Decision support systems for controlling ventilation and fully automatic ventilation systems are used in various applications. Ventilation is very relevant for offices and companies, but also for private homes. Various gases such as CO2 can accumulate in enclosed spaces, caused by the respiration of living beings. The COVID-19 pandemic in particular has shown that aerosols containing viruses are also released, especially when people speak [1], [2]. Measurement of CO2 can indirectly infer exposure to aerosols in the air [2], [3]. Thus, measurement of CO2 can estimate the risk of such infection. Researchers in recent study [4] developed a predictive and retrospective model that indicates that risk of COVID-19 varies widely with activity level and environmental conditions. In addition to reducing infections from respiratory viruses, efficient indoor ventilation is important for preventing headaches, increased fatigue, and also reduced work performance [5]. The problem here is that CO2 is odorless and invisible. Especially in times of climate and energy crises, ventilation should be be done in an energy-efficient way. It should be ventilated only when it is necessary. However, the ventilation time for window-only ventilation depends on various environmental influences. These include, for example, winds and the temperature difference between indoors and outdoors [6]–[8]. The type of window opening also plays a decisive role. A remedy is the use of CO2 measuring devices based on inexpensive sensors. Therefore, Morawska et al. propose in [9] an Indoor Air Quality (IAQ) display in buildings, which can serve to improve air quality and create awareness of good indoor air quality. These displays often

use a CO2 sensor. Above a certain gas concentration, such displays recommend ventilation so that air exchange can occur. Thus, high CO2 concentrations can be reduced and also infection incidence can be improved. The authors in [10] developed a new occupant-centric heating, ventilation and air conditioning (HVAC) control approach where they compared six machine learning algorithms to forecast CO2 concentration. In a recent study [11], the authors developed sensor-based machine learning approach using Decision Tree, Random Forest, Ridge regression and Multilayer Perceptron for modeling the future concentration of CO2 in indoors. A novel ventilation strategy to limit the spread of COVID-19 in the indoor environment is developed in recent study [12]. Using a CO2 sensor network, the authors in [13] used generalized linear mixed models and dynamic time warping for prevention of Covid-19 airborne transmission.

****

Wei, H.-Y., Chang, C.-P., Liu, M.-T., Mu, J.-J., Lin, Y.-J., Dai, Y.-T.*, et al.*
Probable Aerosol Transmission of SARS-CoV-2 through Floors and Walls of Quarantine Hotel, Taiwan, 2021.
Emerging infectious diseases, Vol. **28** n°(12), (2022)

We investigated a cluster of SARS-CoV-2 infections in a quarantine hotel in Taiwan in December 2021. The cluster involved 3 case patients who lived in nonadjacent rooms on different floors. They had no direct contact during their stay. By direct exploration of the space above the room ceilings, we found residual tunnels, wall defects, and truncated pipes between their rooms. We conducted a simplified tracer-gas experiment to assess the interconnection between rooms. Aerosol transmission through structural defects in floors and walls in this poorly ventilated hotel was the most likely route of virus transmission. This event demonstrates the high transmissibility of Omicron variants, even across rooms and floors, through structural defects. Our findings emphasize the importance of ventilation and integrity of building structure in quarantine facilities.

****

Sonmez, N., Cavka, B. T.
Recommendations for the transformation of patient rooms into isolated patient rooms in the process of the COVID-19 pandemic.
Journal of the Faculty of Engineering and Architecture of Gazi University, Vol. **38** n°(1), (2023), pp. 175-187

In order to prevent the spread of Covid-19 and improve the treatment process, interest in hospital design and in-hospital transformation has increased worldwide. Since Covid-19 is not believed to be the last infectious health threat for communities around the world, it is of great importance to study existing hospital adaptations and work on obtaining more planning and design strategies for treatment and wellbeing areas. In this study it is aimed to make constructive recommendations on the basis of in-space planning and mechanical ventilation, which can be applied in hospital transformations for pandemic processes. Published guidelines and literature studies for hospitals to prevent the spread of infection have been examined, structured and unstructured interviews were conducted with architects and engineers specialized in hospital design. Also, a survey was conducted with 35 hospital workers and 4 people from the hospital management to analyze the changes made in the hospital during the Covid-19 process. Afterwards, the design plans of one of the two private hospitals studied in Turkey and the steps that can be applied in the transformation of patient rooms were explained in this article with the case study. Interdisciplinary work was carried in order to ensure infection control in hospital transformations, since it is required to make in-hospital space planning (separation/ transformation of spaces, interior zoning) and ventilation (filtration, zoning of mechanical ventilation) in harmony. Suggestions were developed that could play a role in ensuring the consistency of mechanical and architectural planning in order to successfully complete hospital transformation practices to prevent the spread of infections in pandemic processes. As the transformation scenarios in this study were performed through an exemplary private hospital room in accordance with the criteria of the Turkish Ministry

of Health, ventilation plans on the standard room project were detailed and shown in the conclusion section, where the transformation steps can also be adapted to other hospitals.

****

Fleming, R., Madson, K. M., Perkins, B.

Reducing the spread of COVID-19 transmission through analysis of the evolving building ventilation systems guidance.

Facilities, (2022)

Purpose The purpose of this study was to examine how data from the World Health Organization, United States Environmental Protection Agency and Center for Disease Control have evolved with relation to engineering controls for heating, ventilation and air-conditioning (HVAC) systems to mitigate the spread of spread of aerosols (specifically related to the COVID-19 pandemic) in occupied buildings. Design/methodology/approach A document analysis of the pandemic-focused position documents from the aforementioned public health agencies and national HVAC authorities was performed. This review targeted a range of evidence from recommendations, best practices, codes and regulations and peer-reviewed publications and evaluated how they cumulatively evolved over time. Data was compared between 2020 and 2021. Findings This research found that core information provided early in the pandemic (i.e. early 2020) for engineering controls in building HVAC systems did not vary greatly as knowledge of the pandemic evolved (i.e. in June of 2021). This indicates that regulating agencies had a good, early understanding of how airborne viruses spread through building ventilation systems. The largest evolution in knowledge came from the broader acceptance of building ventilation as a transmission route and the increase in publications and ease of access to the information for the general public over time. Originality/value The promotion of the proposed controls for ventilation in buildings, as outlined in this paper, is another step toward reducing the spread of COVID-19 and future aerosol spread viruses by means of ventilation.

****

Rodriguez-Vidal, I., Martin-Garin, A., Gonzalez-Quintial, F., Rico-Martinez, J. M., Hernandez-Minguillon, R. J., Otaegi, J.

Response to the COVID-19 Pandemic in Classrooms at the University of the Basque Country through a User-Informed Natural Ventilation Demonstrator.

International journal of environmental research and public health, Vol. **19** n°(21), (2022)

The COVID-19 pandemic has generated a renewed interest in indoor air quality to limit viral spread. In the case of educational spaces, due to the high concentration of people and the fact that most of the existing buildings do not have any mechanical ventilation system, the different administrations have established natural ventilation protocols to guarantee an air quality that reduces risk of contagion by the SARS-CoV-2 virus after the return to the classrooms. Many of the initial protocols established a ventilation pattern that opted for continuous or intermittent ventilation to varying degrees of intensity. This study, carried out on a university campus in Spain, analyses the performance of natural ventilation activated through the information provided by monitoring and visualisation of real-time data. In order to carry out this analysis, a experiment was set up where a preliminary study of ventilation without providing information to the users was carried out, which was then compared with the result of providing live feedback to the occupants of two classrooms and an administration office in different periods of 2020, 2021 and 2022. In the administration office, a CO2-concentration-based method was applied retrospectively to assess the risk of airborne infection. This experience has served as a basis to establish a route for user-informed improvement of air quality in educational spaces in general through low-cost systems that allow a rational use of natural ventilation while helping maintain an adequate compromise between IAQ, comfort and energy consumption, without having to resort to mechanical ventilation systems.

****

Aldekheel, M., Altuwayjiri, A., Tohidi, R., Jalali Farahani, V., Sioutas, C.

The Role of Portable Air Purifiers and Effective Ventilation in Improving Indoor Air Quality in University Classrooms.

International Journal of Environmental Research and Public Health, Vol. **19** n°(21), (2022)

In this study we investigated the effectiveness of air purifiers and in-line filters in ventilation systems working simultaneously inside various classrooms at the University of Southern California (USC) main campus. We conducted real-time measurements of particle mass (PM), particle number (PN), and carbon dioxide (CO2) concentrations in nine classrooms from September 2021 to January 2022. The measurement campaign was carried out with different configurations of the purifier (i.e., different flow rates) while the ventilation system was continuously working. Our results showed that the ventilation systems in the classrooms were adequate in providing sufficient outdoor air to dilute indoor CO2 concentrations due to the high air exchange rates (2.63–8.63 h−1). The particle penetration coefficients (P) of the investigated classrooms were very low for PM (<0.2) and PN (<0.1), with the exception of one classroom, corroborating the effectiveness of in-line filters in the ventilation systems. Additionally, the results showed that the efficiency of the air purifier exceeded 95% in capturing ultrafine and coarse particles and ranged between 82–88% for particles in the accumulation range (0.3–2 µm). The findings of this study underline the effectiveness of air purifiers and ventilation systems equipped with efficient in-line filters in substantially reducing indoor air pollution.

****

Aboulnaga, M., Maryam, E.

The Role of Shading, Natural Ventilation, Daylighting, and Comfort in Enhancing Indoor Environmental Quality and Liveability in the Age of COVID-19.

In: Achieving Building Comfort by Natural Means. Springer International Publishing; 2022. pp. 183-218

The Coronavirus (COVID-19) pandemic has catastrophic impacts worldwide between 2020 and 2021. Such a pandemic highlighted the importance of healthy spaces in all types of buildings, particularly: public, commercial, educational, and residential buildings during the lockdown periods in 2020 and 2021. In light of the urgent need for healthy spaces amid COVID-19, indoor environmental quality (IEQ) is significantly vital to provide healthy buildings and cities. Thus, it is imperative to ensure and guarantee thermal comfort, natural ventilation/cross ventilation, daylighting, and sunlight provision to ensure better IEQ and attain liveability. This book chapter presents a review on the impacts of COVID-19 on buildings in terms of IEQ and liveability in the age of COVID-19. It also highlights benefits of IEQ in providing healthy buildings including thermal comfort, natural ventilation, and daylighting and sunlight. This chapter addresses the benchmark for IEQ in the time of COVID-19. Additionally, global examples of best practices are highlighted to deduce the best lessons, standards, and practice models. This chapter also depicts selected contemporary buildings vs. traditional ones that include the main features to attain IEQ and draw the lessons learned from such traditional buildings. The chapter seeks to answer a main question – Can IEQ achieve liveability in the age of COVID-19? – and presents a comparative analysis of assessed buildings (case studies).

****

Mao, Y., Wang, S., Liang, J., Mao, S., Han, Y., Zhang, S.

Stratum Ventilation: Enabling Simultaneous Energy Conservation and Air Purification in Subway Cars.

International journal of environmental research and public health, Vol. **19** n°(21), (2022)

The supply of fresh air for underground rail transit systems is not as simple as opening windows, which is a conventional ventilation (CV) measure adopted in aboveground vehicles. This study aims to improve contaminant dilution and air purification in subway car ventilation systems and the safety of rail transit post-

coronavirus disease pandemic era. We designed an air conditioning (AC) terminal system combined with stratum ventilation (SV) to enable energy consumption reduction for subway cars. We experimentally tested the effectiveness of a turbulence model to investigate ventilation in subway cars. Further, we compared the velocity fields of CV and SV in subway cars to understand the differences in their airflow organizations and contaminant removal efficiencies, along with the energy savings of four ventilation scenarios, based on the calculations carried out using computational fluid dynamics. At a ventilation flow rate of 7200 m3/h, the CO2 concentration and temperature in the breathing areas of seated passengers were better in the SV than in the CV at a rate of 8500 m3/h. Additionally, the energy-saving rate of SV with AC cooling was 14.05%. The study provides new ideas for reducing the energy consumption of rail transit and broadens indoor application scenarios of SV technology.

****