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Aéraulique et COVID-19

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Google Scholar, Lens et WoS

Reichert, F., Stier, O., Hartmann, A., Ruscher, C., Brinkmann, A., Grossegesse, M., *et al.*
Analysis of two choir outbreaks acting in concert to characterize long-range transmission risks through SARS-CoV-2, Berlin, Germany, 2020.
Plos one, Vol. **17** n°(11), (2022)

Background
Superspreading events are important drivers of the SARS-CoV-2 pandemic and long-range (LR) transmission is believed to play a major role. We investigated two choir outbreaks with different attack rates (AR) to analyze the contribution of LR transmission and highlight important measures for prevention.
Methods
We conducted two retrospective cohort studies and obtained demographic, clinical, laboratory and contact data, performed SARS-CoV-2 serology, whole genome sequencing (WGS), calculated LR transmission probabilities, measured particle emissions of selected choir members, and calculated particle air concentrations and inhalation doses.
Results
We included 65 (84%) and 42 (100%) members of choirs 1 and 2, respectively, of whom 58 (89%) and 10 (24%) became cases. WGS confirmed strain identity in both choirs. Both primary cases transmitted presymptomatically. Particle emission rate when singing was 7 times higher compared to talking. In choir 1, the median concentration of primary cases' emitted particles in the room was estimated to be 8 times higher, exposure at least 30 minutes longer and room volume smaller than in choir 2, resulting in markedly different estimated probabilities for LR transmission (mode: 90% vs. 16%, 95% CI: 80–95% vs. 6–36%). According to a risk model, the first transmission in choir 1 occurred likely after 8 minutes of singing.
Conclusions
The attack rate of the two choirs differed significantly reflecting the differences in LR transmission risks. The pooled proportion of cases due to LR transmission was substantial (81%; 55/68 cases) and was facilitated by likely highly infectious primary cases, high particle emission rates, and indoor rehearsing for an extended time. Even in large rooms, singing of an infectious person may lead to secondary infections through LR exposure within minutes. In the context of indoor gatherings without mask-wearing and waning or insufficient immunity, these results highlight the ongoing importance of non-pharmaceutical interventions wherever aerosols can accumulate.

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Sussman, R. A., Golberstein, E., Polosa, R.
Analytic modeling and risk assessment of aerial transmission of SARS-CoV-2 virus through vaping expirations in shared micro-environments.
Environmental Science and Pollution Research, Vol. **29** n°(55), (2022), pp. 83020-83044

It is well known that airborne transmission of COVID-19 in indoor spaces occurs through various respiratory activities: breathing, vocalizing, coughing, and sneezing. However, there is a complete lack of knowledge of its possible transmission through exhalations of e-cigarette aerosol (ECA), which is also a respiratory activity. E-cigarettes have become widely popular among smokers seeking a much safer way of nicotine consumption than smoking. Due to restrictive lockdown measures taken during the COVID-19 pandemic, many smokers and vapers (e-cigarette users) were confined to shared indoor spaces, making it necessary to assess the risk of SARS-CoV-2 virus aerial transmission through their exhalations. We summarize inferred knowledge of respiratory particles emission and transport through ECA, as well as a theoretical framework for explaining the visibility of exhaled ECA, which has safety implications and is absent in other respiratory activities (apart from

smoking). We also summarize and briefly discuss the effects of new SARS-CoV-2 variants, vaccination rates, and environmental factors that may influence the spread of COVID-19. To estimate the risk of SARS-CoV-2 virus aerial transmission associated with vaping exhalations, we adapt a theoretical risk model that has been used to analyze the risks associated with other respiratory activities in shared indoor spaces. We consider home and restaurant scenarios, with natural and mechanical ventilation, with occupants wearing and not wearing face masks. We consider as "control case" or baseline risk scenario an indoor space (home and restaurant) where respiratory droplets and droplet nuclei are uniformly distributed and aerial contagion risk might originate exclusively from occupants exclusively rest breathing, assuming this to be the only (unavoidable) respiratory activity they all carry on. If an infected occupant uses an e-cigarette in a home or restaurant scenarios, bystanders not wearing face masks exposed to the resulting ECA expirations face a 1 % increase of risk of contagion with respect the control case. This relative added risk with respect to the control case becomes 5 - 17% for high-intensity vaping, 44 - 176%, and over 260% for speaking for various periods or coughing (all without vaping). Infectious emissions are significantly modified by mechanical ventilation, face mask usage, vaccination, and environmental factors, but given the lack of empiric evidence, we assume as a working hypothesis that all basic parameters of respiratory activities are equally (or roughly equally) affected by these factors. Hence, the relative risk percentages with respect to the control state should remain roughly the same under a wide range of varying conditions. By avoiding direct exposure to the visible exhaled vaping jet, wearers of commonly used face masks are well protected from respiratory droplets and droplet nuclei directly emitted by mask-less vapers. Compared to the control case of an already existing (unavoidable) risk from continuous breathing, vaping emissions in shared indoor spaces pose just a negligible additional risk of COVID-19 contagion. We consider that it is not necessary to take additional preventive measures beyond those already prescribed (1.5 m separation and wearing face masks) in order to protect bystanders from this contagion.

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Scherer, P., Grigoletti, G. D. C.
Avaliação de estratégias de ventilação natural para salas de aula em clima subtropical úmido. (en portugais) Evaluation of natural ventilation strategies in school classrooms in a humid subtropical climate.
Ambiente Construído, Vol. **23** n°(1), (2023), pp. 23-57

Abstract Classrooms are long-stay environments, in which thermal comfort is fundamental to the teaching and learning process. In the context of Covid-19, higher rates of natural ventilation are required, which can affect thermal comfort. This research aimed to investigate 16 natural ventilation strategies in elementary school classrooms regarding energy efficiency, thermal comfort and quality of natural ventilation, in a humid subtropical climate, represented by the city of Santa Maria, RS, considering recommendations from the Federal Government and computer simulations with Ansys CFX ® and EnergyPlus. The following items were analysed: hours spent in thermal comfort, discomfort degree-hours, indoor air velocity, air renewal rates and air humidity. Strategies using cross ventilation and solar chimney, or north-south unilateral ventilation connected to open circulation met the criteria for air renewal, albeit with a 20% or more hours of discomfort due to cold. It was observed that sufficient natural ventilation causes discomfort due to excessive cold. The contribution of this project is to suggest more adequate natural ventilation strategies for classrooms located in humid subtropical climates, demonstrating that they can contribute to improve the quality of natural ventilation compared to conventional solutions.

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Lopez, L. R., Dessi, P., Cabrera-Codony, A., Rocha-Melogno, L., Kraakman, B., Naddeo, V.*, et al.*
CO2 in indoor environments: From environmental and health risk to potential renewable carbon source.
The Science of the total environment, Vol. **856** n°(Pt 2), (2023)

In the developed world, individuals spend most of their time indoors. Poor Indoor Air Quality (IAQ) has a wide range of effects on human health. The burden of disease associated with indoor air accounts for millions of premature deaths related to exposure to Indoor Air Pollutants (IAPs). Among them, CO2 is the most common one, and is commonly used as a metric of IAQ. Indoor CO2 concentrations can be significantly higher than outdoors due to human metabolism and activities. Even in presence of ventilation, controlling the CO2 concentration below the Indoor Air Guideline Values (IAGVs) is a challenge, and many indoor environments including schools, offices and transportation exceed the recommended value of 1000 ppmv. This is often accompanied by high concentration of other pollutants, including bio-effluents such as viruses, and the importance of mitigating the transmission of airborne diseases has been highlighted by the COVID-19 pandemic. On the other hand, the relatively high CO2 concentration of indoor environments presents a thermodynamic advantage for direct air capture (DAC) in comparison to atmospheric CO2 concentration. This review aims to describe the issues associated with poor IAQ, and to demonstrate the potential of indoor CO2 DAC to purify indoor air while generating a renewable carbon stream that can replace conventional carbon sources as a building block for chemical production, contributing to the circular economy.

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Malki-Epshtein, L., Adzic, F., Roberts, B., Hathway, E. A., Iddon, C., Mustafa, M.*, et al.*
CO2 monitoring methods for post-occupancy evaluation of ventilation effectiveness for rapid risk assessment of airborne disease transmission.
Building Services Engineering Research and Technology: an international journal, (2022)

To assess risk factors for COVID-19 transmission and address the closure of mass gathering events since March 2020, the UK Government ran the Events Research Programme (ERP), following which it reopened live events in sports, music, and culture in July 2021. We report the rapid post-occupancy evaluation of Indoor Air Quality (IAQ) and associated long-range airborne transmission risk conducted in the Environmental Study of the ERP. Ten large venues around the UK were monitored with CO2 sensors at a high spatial and temporal resolution during 90 events. An IAQ Index based on CO2 concentration was developed, and all monitored spaces were classified in bands from A to G based on their average and maximum CO2 concentrations from all events. High resolution monitoring and the IAQ Index depicted the overall state of ventilation at live events, and allowed identification of issues with ventilation effectiveness and distribution, and of spaces with poor ventilation and the settings in which long-range airborne transmission risk may be increased. In numerous settings, CO2 levels were found to follow patterns relating to event management and specific occupancy of spaces around the venues. Good ventilation was observed in 90% of spaces monitored for given occupancies.

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Downing, G. H., Hardalupas, Y., Archer, J., Symons, H. E., Baloglu, U. B., Schien, D.*, et al.*
Computational and experimental study of aerosol dispersion in a ventilated room.
Aerosol Science and Technology, (2022), pp. 1-13

AbstractFor many respiratory diseases, a primary mode of transmission is inhalation via aerosols and droplets. The COVID-19 pandemic has accelerated studies of aerosol dispersion in indoor environments. Most studies of aerosol dispersion present computational fluid dynamics results, which rarely include detailed experimental verification, and many of the computations are complex, making them hard to scale to larger spaces. This study presents a comparison of computational simulations and measurements of aerosol dispersion within a typical ventilated classroom. Measurements were accomplished using a custom-built low-cost sensor network composed of 15 commercially available optical particle sizers, which provided size-resolved information about the number concentrations and temporal dynamics of 0.3?40?µm diameter particles. Measurement results are compared to the computed dispersal and loss rates from a steady-state Reynolds-Averaged Navier?Stokes k-epsilon model. The results show that a newly developed aerosol-transport-model can accurately simulate the dispersion of aerosols and faithfully predict measured aerosol concentrations at different locations and

times. The computational model was developed with scalability in mind such that it may be adapted for larger spaces. The experiments highlight that the fraction of aerosol recycled in the ventilation system depends on the aerosol droplet size and cannot be predicted by the recycled-to-outside air ratio. Moreover, aerosol recirculation is not negligible, as some computational approaches assume. Both modeling and measurements show that, depending on the location within the room, the maximum aerosol concentration can be many times higher than the average concentration, increasing the risk of infection.

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Huang, L., Riyadi, S., Utama, I. K. a. P., Li, M., Sun, P., Thomas, G.
COVID-19 transmission inside a small passenger vessel: Risks and mitigation.
Ocean Engineering, Vol. **255**, (2022)

The global shipping industry has been severely influenced by the COVID-19 pandemic; in particular, a significant amount of passenger transportation has been suspended due to the concern of COVID-19 outbreak, as such voyages confine a dense crowd in a compact space. In order to accelerate the recovery of the maritime business and minimise passengers' risk of being infected, this work has developed a computational model to study the airborne transmission of COVID-19 viruses in the superstructure of a full-scale passenger vessel. Considering the vessel advancing in open water, simulations were conducted to study the particulate flow due to an infected person coughing and speaking, with the forward door open and closed. The results suggest that keeping the forward door closed will help prevent the external wind flow spreading the virus. When the forward door is closed, virus particles' coverage is shown to be limited to a radius of half a metre, less than a seat's width. Thus, an alternate seat arrangement is suggested. Furthermore, investigations were conducted on the influence of wall-mounted Air Conditioner (AC) on the virus transmission, and it was found that controlling the AC outlet direction at less than 15 degrees downward can effectively limit the virus spread. Meanwhile, it was demonstrated that an AC's backflow tends to gather virus particles in a nearby area, thus sitting farther from an opening AC may reduce the risk of being infected. Overall, this work is expected to inform hygienic guidelines for operators to counter COVID-19 and potentially similar viruses in the future.

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Cho, J., Kim, J., Song, J., Jang, S.
Development of a non-contact modular screening clinic (NCMSC) for COVID-19.
CLIMA 2022 The 14th REHVA HVAC World Congress. 22-25 mai 2022, Rotterdam, Pays-Bas.

Under the global landscape of the prolonged COVID-19 pandemic, the number of individuals who need to be tested for COVID-19 through screening centers is increasing. However, there is a risk of cross-infection at each stage of the screening process. To address the risk of cross-infection in the screening center during the COVID-19 testing process, a non-contact modular screening center (NCMSC) was developed that uses biosafety cabinets and negative pressure booths to improve the problems of existing screening centers and enable safe, fast, and convenient COVID-19 testing. The main purpose of this study is to evaluate the effect of the cross-infection prevention of viruses and ventilation performance for rapid virus removal from the indoor space using both numerical analysis and experimental measurements. Computational fluid dynamics (CFD) simulations were used to determine the ventilation rate and pressure difference. We also characterized the airflow dynamics of NCMSCs using the particle image velocimetry (PIV). Moreover, design optimization was performed with three alternatives based on the air change rates and the balance of supply air (SA)/exhaust air (EA) as a ventilation strategy for preventing viral transmission.

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Nezu, Y., Oshima, Y.
Efforts to maintain research activities of our graduate school in COVID-19 pandemic.

Journal of Environment and Safety, Vol. **13** n°(2), (2022), pp. 21-24

Although it is important to implement prevention of infection for COVID-19, there is rarely information on the current ventilation conditions at the actual research and education sites. The purpose of this study is to investigate the actual ventilation conditions in lecture rooms, meeting rooms, and faculty or student rooms in the graduate school where the authors are, and discuss necessary measures to continue education and research activities based on the results. According to the survey of ventilation, there were some rooms which need to increase the volume of ventilation, on the other hand, it was difficult to adopt natural ventilation for the rooms. As a case study, CFD calculation was performed to elucidate the effect of installing an air purifier in a meeting room to improve to ventilation conditions. From these survey and analysis, problems of ventilation in research activities place were specified, potential risks and infection prevention method in ventilation were discussed in this study.

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Ha, M. A.
Evaluasi Penggunaan Energi HVAC pada Harsika Cafe Terhadap Penyebaran Coronavirus.
Perpustakaan Universitas Gadjah Mada. Thèse 2022

Building energy consumption accounts for 55% of electrical energy consumption. Where 11% of the electricity consumption is used for the air conditioning system. According to recent research, adequate ventilation rates in buildings to reduce the risk of spreading COVID-19 reach 4-6 air changes per hour. The increased ventilation rate has the potential to increase the energy consumption of the air conditioning system. This condition prompted the author to conduct research on energy consumption of the air conditioning system related to the spread of COVID-19. The first step of this research is to look at the results of the building energy consumption to validate the simulation results. Then evaluation of the performance of the building's air conditioner is carried out in 3 stages. The first stage is to compare the specifications of the room's air conditioner with the room's average monthly peak load. The next step is to compare the performance of the room's air conditioner with the room's sensible load. The third step is comparing the simulation results of room temperature in annual extreme weather with the setpoint on the thermostat. The simulation results have an error rate of 7.3%. The use of an exhaust fan increases the intensity of annual energy consumption by 4% or 7239.45 kwh. The air conditioner in the Harsika Cafe is only able to condition 43.5% of the heat load at peak load. The use of an exhaust fan increases the peak load by 30 W.

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Stavreva, S., Hristovska, E., Andreevski, I., Popovska-Vasilevska, S.
Impact of Covid-19 on Heating, Ventilation and Air-Conditioning Systems.
TEM Journal. TECHNOLOGY, EDUCATION, MANAGEMENT, INFORMATICS, Vol. **11** n°(4), (2022), pp. 1563-1568

People spend much of their lives indoors, so air quality is particularly important to their health, ability to work, and well-being. The COVID -19 pandemic has heightened people's awareness of the importance of maintaining high indoor air quality. Such an emergency has underscored the need for adequate heating, ventilation and air conditioning systems that can provide a good indoor air quality, especially ventilation systems as important players in preventing and reducing the risk of airborne infections. In this paper, we review natural and mechanical ventilation and their roles in dealing with coronavirus, focusing on key factors for healthy indoor air. Two pillars are critical for ventilation: increased air exchange rate and air filtration in ventilation systems.

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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.
medRxiv, (2022)

Background:
The 2019 novel coronavirus (SARS-CoV-2) outbreak was declared a pandemic in March 2020.
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 heating, ventilation and air conditioning (HVAC) design features in the built environment.
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:
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:
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.

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Baselga, M., Alba, J. J., Schuhmacher, A. J.
Impact of needle-point bipolar ionization system in the reduction of bioaerosols in collective transport.
Science of the Total Environment, Vol. **855**, (2023)

The transmission rate of SARS-CoV-2 is higher in collective transport than in other public environments. Transport companies require preventive strategies to mitigate airborne risk of contagion which not imply responsible use at the individual level. Air purification systems, such as UV-C or needle-tip bipolar ionization, are attractive alternatives. However, only a few studies addressing the validation of this technology against bioaerosols in actual operation conditions have been published so far. In this work, the efficiency of a bipolar ionization unit in the Zaragoza Tram has been evaluated. Against environmental bioaerosols, ionization (-25.7 center dot 109 ions/m3, on average) reduced the concentration of colony-forming units (CFU) by -46 % and -69 % after 30 and 90 min. No clear benefits were obtained against microorganisms on inner tram surfaces (seats, grab bars, walls, and windows). 'Pre-pandemic' filtration equipment located in the HVAC based on a Coarse 45 %-type filter removed -73 and - 92 % of aerial CFU by itself after 30 and 90 min. Microscopic visualization of the CFUs revealed that they were mostly >1 mu m, much larger than the SARSCoV-2 virion (-100 nm) and SARS-CoV-2-loaded bioaerosols (from 0.25 mu m). Then, we studied the filter behavior under

normalized laboratory methods. The filters efficiency against submicron particles was limited (between 5 and 12 % against 0.1 to 0.3 mu m NaCl particles). Another ionization strategy was to generate aerosol agglomerates to enhance filtration performance, but the combined action of ionization and filtration did not improve substantially. The effect of these technologies was also characterized using the clean air delivery rate (CADR). Relative to untreated air (CADR = 0.299 m3/min), ionization and filtration reduce ambient CFUs (CADR = 5.153 and 9.261 m3/min, respectively; and CADR = 13.208 m3/min, combined) which implies that it has a substantial impact on indoor bioaerosols.

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Baharudin, F. N. A., Ab Aziz, N. A., Malek, M. R. A., Ghazali, A. K., Ibrahim, Z.
Indoor Comfort and Energy Consumption Optimization Using an Inertia Weight Artificial Bee Colony Algorithm.
Algorithms, Vol. **15** n°(11), (2022)

A comfortable indoor environment contributes to a better quality of life and wellbeing for its occupants. The indoor temperature, lighting, and air quality are the main controlling factors of user comfort levels. The optimum control of the lighting, air conditioners, and air ventilators helps in maximizing the user's comfort level. Nonetheless, the energy consumption of these appliances needs to be taken into consideration to minimize the operational cost and at the same time provide an environmentally friendly system. Comfort level maximization and energy consumption minimization are optimization problems. This issue is becoming more important due to the lifestyle changes caused by the COVID-19 pandemic that resulted in more time spent at home and indoors. Inertia weight artificial bee colony (IW-ABC) algorithms using linearly increasing, linearly decreasing, and exponentially increasing inertia are proposed here for the optimization of the indoor comfort index and energy usage. The multi-objective problem is tackled as a weighted single objective optimization problem. The proposed solution is tested using a dataset of 48 environmental conditions. The results of the simulation show that the IW-ABC performs better than the original ABC and other benchmark algorithms and the IW-ABC with linear increasing inertia weight has the most improved convergence behavior.

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Li, Y., Lu, Y., Wang, Y., Liu, L., Zhou, H., Lin, B.*, et al.*
Investigation on the effectiveness of ventilation dilution on mitigating COVID-19 patients' secondary airway damage due to exposure to disinfectants.
Building and environment, (2022)

Chlorine-containing disinfectants are widely used in hospitals to prevent hospital-acquired severe acute respiratory syndrome coronavirus 2 infection. Meanwhile, ventilation is a simple but effective means to maintain clean air. It is essential to explore the exposure level and health effects of coronavirus disease 2019 patients' inhalation exposure to by-products of chloride-containing disinfectants under frequent surface disinfection and understand the role of ventilation in mitigating subsequent airway damage. We determined ventilation dilution performance and indoor air quality of two intensive care unit wards of the largest temporary hospital constructed in China, Leishenshan Hospital. The chloride inhalation exposure levels, and health risks indicated by interleukin-6 and D-dimer test results of 32 patients were analysed. The mean ± standard deviation values of the outdoor air change rate in the two intensive care unit wards were 8.8 ± 1.5 h-1 (Intensive care unit 1) and 4.1 ± 1.4 h-1 (Intensive care unit 2). The median carbon dioxide and fine particulate matter concentrations were 480 ppm and 19 mug/m3 for intensive care unit 1, and 567 ppm and 21 mug/m3 for intensive care unit 2, all of which were around the average levels of those in permanent hospitals (579 ppm and 21 mug/m3). Of these patients, the median (lower quartile, upper quartile) chloride exposure time and calculated dose were 26.66 (2.89, 57.21) h and 0.357 (0.008, 1.317) mg, respectively. A statistically significant positive correlation was observed between interleukin-6 and D-dimer concentrations. To conclude, ventilation helped maintain ward air cleanliness and health risks were not observed.

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Ratliff, K. M., Oudejans, L., Archer, J., Calfee, W., Gilberry, J. U., Hook, D. A.*, et al.*
Large-scale evaluation of microorganism inactivation by bipolar ionization and photocatalytic devices.
Building and environment, Vol. **227**, (2023)

The COVID-19 pandemic has raised awareness in the spread of disease via airborne transmission. As a result, there has been increasing interest in technologies that claim to reduce concentrations of airborne pathogens in indoor environments. The efficacy of many of these emerging technologies is not fully understood, and the testing that has been done is often conducted at a small scale and not representative of applied settings. There is currently no standard test method for evaluating air treatment technologies, making it difficult to compare results across studies or technology types. Here, a consistent testing approach in an operational-scale test chamber with a mock recirculating heating, ventilation, and air conditioning (HVAC) system was used to evaluate the efficacy of bipolar ionization and photocatalytic devices against the non-enveloped bacteriophage MS2 in the air and on surfaces. Statistically significant differences between replicate sets of technology tests and control tests (without technologies active) are apparent after 1h, ranging to a maximum of 0.88 log10 reduction for the bipolar ionization tests and 1.8 log10 reduction for the photocatalytic device tests. It should be noted that ozone concentrations were elevated above background concentrations in the test chamber during the photocatalytic device testing. No significant differences were observed between control and technology tests in terms of the amount of MS2 deposited or inactivated on surfaces during testing. A standardized, large-scale testing approach, with replicate testing and time-matched control conditions, is necessary for contextualizing laboratory efficacy results, translating them to real-world conditions, and for facilitating technology comparisons.

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Aguilar, A. J., De La Hoz-Torres, M. L., Ruiz, D. P., Dolores Martinez-Aires, M.
Monitoring and Assessment of Indoor Environmental Conditions in Educational Building Using Building Information Modelling Methodology.
International Journal of Environmental Research and Public Health, Vol. **19** n°(21), (2022)

Managing indoor environmental quality (IEQ) is a challenge in educational buildings in the wake of the COVID-19 pandemic. Adequate indoor air quality is essential to ensure that indoor spaces are safe for students and teachers. In fact, poor IEQ can affect academic performance and student comfort. This study proposes a framework for integrating occupants' feedback into the building information modelling (BIM) methodology to assess indoor environmental conditions (thermal, acoustic and lighting) and the individual airborne virus transmission risk during teaching activities. The information contained in the parametric 3D BIM model and the algorithmic environment of Dynamo were used to develop the framework. The IEQ evaluation is based on sensor monitoring and a daily schedule, so the results show real problems of occupants' dissatisfaction. The output of the framework shows in which range the indoor environmental variables were (optimal, acceptable and unacceptable) and the probability of infection during each lecture class (whether or not 1% is exceeded). A case study was proposed to illustrate its application and validate it. The outcomes provide key information to support the decision-making process for managing IEQ and controlling individual airborne virus transmission risks. Long-term application could provide data that support the management of ventilation strategies and protocol redesign.

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Xu, R., Wu, F., Li, X., Yu, C., Li, H., Wu, R.*, et al.*
Numerical comparison of ventilation modes on the transmission of coughing droplets in a train compartment.
Journal of Wind Engineering and Industrial Aerodynamics, Vol. **231**, (2022)

The ventilation system in the indoor environments plays a significant role in controlling the cross-infection of viruses and the risk of infection. This work investigated the effects of prevailing high-speed train ventilation modes on the spatial distribution features of droplets through computational fluid dynamics (CFD) simulation. The results revealed that under the current ventilation modes, the airflow barrier was formed in the middle of the aisle, and more than 77.36% of the released droplets were limited to accumulate in the releasing side. Moreover, we found that the strong recirculation flows appeared in the circumstance of top air supply mode suppressed the longitudinal transport of droplets. Also, compared to the standard ventilation case of mixed air supply mode, the suspending droplet fraction in the breathing zone decreased by 37.9% for 10 µm after 60 s under top air supply mode, while those decreased by 33.7% for 50 µm. Therefore, the potential infection risk in the high-speed train was less when the air-condition unit implemented top air supply mode. The research outcomes can be useful to optimize air-conditioning flow and reduce the contagion risk in high-speed trains and other public transport environments with similar air supply strategies.

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Gabriel, M., Alves, F., Oliveira-Dias, C., Pinto, M., Monteiro, H., Aguiar, A.*, et al.*
Promoção da Qualidade do Ar Interior em Portugal para a Prevenção e Controlo de Doenças. (en portugais) Promoting Better Indoor Air Quality in Portugal for Disease Prevention and Control.
Acta medica portuguesa, (2022)

A ventilação, enquanto promotora de uma adequada qualidade do ar interior (QAI), tem vindo progressivamente a ser reconhecida como uma medida não-farmacológica fundamental para a abordagem à COVID-191-4 a par de outras, como o uso de máscaras, o distanciamento físico ou a higienização das mãos e de superfícies. Num momento em que a conjun-tura epidemiológica permitiu o levantamento da obrigatoriedade de medidas, é importante o investimento em estratégias de prevenção de risco ambiental, como a promoção da QAI. O outono e o inverno podem ser críticos no que diz respeito à proliferação de doenças respiratórias em ambientes fechados, nomeadamente pelo aumento do tempo passado em espaços interiores pouco ventilados. Uma ventilação ade-quada deve ser uma das principais estratégias de redução do risco de transmissão dosagentes infeciosos transmitidos por aerossóis, como o SARS-CoV-2.

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Chen, C.-Y., Chen, P.-H., Chen, J.-K., Su, T.-C.
Recommendations for Ventilation of Remodeled Negative-Pressure Isolation Wards for COVID-19 Patients : A Comparison of International Guidelines.
Journal of the Formosan Medical Association, (2022)

This mini-review provides the practice guideline recommendations for ventilation of remodeled negative-pressure isolation wards for COVID-19 Patients. Remodeled "quasi-negative-pressure" isolation wards had been proved a feasible, inexpensive, safe, and effective measure to contain nosocomial outbreaks. We should first determine the minimum required ventilation volume of an isolation ward based on the severity of COVID-19 patients. Mechanical ventilation remains the mainstay for achieving the requirement, while the assistance of recirculation is also helpful. Beyond adequate ventilation volume, the "clean to less-clean" directional airflow remains the golden rule for the solution of indoor ventilation. The virus-laden exhaust should be treated with HEPA/UV device or be kept away from living organisms, buildings, and air inlets.

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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.

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Otter, J. A., Zhou, J., Price, J. R., Reeves, L., Zhu, N., Randell, P.*, et al.*
SARS-CoV-2 surface and air contamination in an acute healthcare setting during the first and second pandemic waves.
Journal of Hospital Infection, (2022)

Summary Background Surfaces and air in healthcare facilities can be contaminated with SARS-CoV-2. In a previous study, we identified SARS-CoV-2 RNA on surfaces and air in our hospital during the 'first wave' of the COVID-19 pandemic (April 2020). Aim To explore whether the profile of SARS-CoV-2 surface and air contamination had changed between April 2020 and January 2021. Methods A prospective, cross-sectional, observational study in a multisite London hospital. In January 2021, surface and air samples were collected from comparable areas to those sampled in April 2020 comprising six clinical areas and a public area. SARS-CoV-2 was detected using RT-PCR and viral culture. Sampling was additionally undertaken in two wards with only natural ventilation. The ability of the prevalent variants at the time of the study to survive on dry surfaces was evaluated. Findings No viable virus was recovered from surfaces or air. 5% (14) of 270 surfaces and 4% (1) of 27 air samples were positive for SARS-CoV-2, which was significantly lower than in April 2020 (52% (114) of 218 of surfaces and 48% (13) of 27 air samples ($p<0.001$, Fisher's Exact Test)). There was no clear difference in the proportion of surfaces and air samples positive for SARS-CoV-2 RNA based on the type of ventilation in the ward. All variants tested survived on dry surfaces for at least 72 hours with a <3-log10 reduction in viable count. Conclusion Our study suggests that enhanced infection prevention measures have reduced the burden of SARS-CoV-2 RNA on surfaces and air in healthcare.

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Tian, M.-W., M. Abed, A., E. Anqi, A., Guo, W., Wae-Hayee, M., Fayed, M.*, et al.*
A simplified economic model and case study for recovery ventilation based on SPECO method.
Case Studies in Thermal Engineering, Vol. **40**, (2022)

Covid-19 further revealed the significance of ventilation by air conditioning systems. Most common split heaters and resistance heaters recirculate the indoor air without ventilation process. Ventilation wastes energy consumption by the building. However, adding an air-to-air heat recovery unit seems a quick solution to reduce the wasted heat of the ventilation process. Nonetheless, recovery unit means further pumping power (pressure drop through the air-to-air heat exchanger), capital cost, additional fans and their electricity

consumption, exergy costs and so on. Hence, the profitability of the recovery unit depends on outdoor temperature, desired indoor temperature, electricity price of the region, exergy loss and also the aforementioned factors. In this research the general standard Specific Exergy Costing theory is employed and simplified as an economic strategy for recovery ventilation. The model not only is able to predict the profitability of the ventilation process using air-to-air heat exchanger, but also it is an optimization tool for air-to-air heat recovery units as provided as a case study in this paper.

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Axon, C. J., Dingwall, R., Evans, S., Cassell, J. A.
The Skagit County Choir Covid-19 Outbreak – Have we got it Wrong?
Public Health, (2022)

Objectives Over time, papers or reports may come to be taken for granted as evidence for some phenomenon. Researchers cite them without critically re-examining findings in the light of subsequent work. This can give rise to misleading or erroneous results and conclusions. We explore whether this has occurred in the widely reported outbreak SARS-CoV-2 at a rehearsal of the Skagit Valley Chorale in March 2020, where it was assumed, and subsequently asserted uncritically, that the outbreak was due to a single infected person. Study design Review of original report and subsequent modelling and interpretations. Method We reviewed and analysed original outbreak data in relation to published data on incubation period, subsequent modelling drawing on the data, and interpretations of transmission characteristics of this incident. Results We show it is vanishingly unlikely that this was a single point source outbreak as has been widely claimed and on which modelling has been based. Conclusion An unexamined assumption has led to erroneous policy conclusions about the risks of singing, and indoor spaces more generally, and the benefits of increased levels of ventilation. Although never publicly identified, one individual bears the moral burden of knowing what health outcomes have been attributed to their actions. We call for these claims to be re-examined and for greater ethical responsibility in the assumption of a point source in outbreak investigations.

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Kuncoro, C. B. D., Adristi, C., Asyikin, M. B. Z.
Smart Wireless Particulate Matter Sensor Node for IoT-Based Strategic Monitoring Tool of Indoor COVID-19 Infection Risk via Airborne Transmission.
Sustainability, Vol. **14** n°(21), (2022)

Indoor and outdoor air pollution are associated with particulate matter concentration of minute size that deeply penetrates the human body and leads to significant problems. These particles led to serious health problems and an increased spread of infection through airborne transmission, especially during the COVID-19 pandemic. Considering the role of particulate matter during the spread of COVID-19, this paper presents a smart wireless sensor node for measuring and monitoring particulate matter concentrations indoors. Data for these concentrations were obtained and used as a risk indicator for airborne COVID-19 transmission. The sensor node was designed to consider air quality monitoring device requirements for indoor applications, such as real-time, continuous, reliable, remote, compact-sized, low-cost, low-power, and accessible. Total energy consumption of the node during measurement and monitoring of particulate matter concentration was minimized using a low-power algorithm and a cloud storage system embedded during software development. Therefore, the sensor node consumed low energy for one cycle of the particulate matter measurement process. This low-power strategy was implemented as a preliminary design for the autonomous sensor node that enables it to integrate with an energy harvester element to harvest energy from ambient (light, heat, airflow) and store energy in the supercapacitor, which extends the sensor node life. Furthermore, the measurement data can be accessed using the Internet of Things and visualized graphically and numerically on a graphical user interface. The test and measurement results showed that the developed sensor node had very small measurement error, which was promising and appropriate for indoor particulate matter

concentration measurement and monitoring, while data results were utilized as strategic tools to minimize the risk of airborne COVID-19 transmission.

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Soni, N., Sharma, D., Nimesh, V., Reddy, V. M.
Solar energy assisted thermal treatment model to decontaminate airborne viruses in hospital.
Thermal Science and Engineering Progress, Vol. **36**, (2022)

The evolution of airborne viruses across the globe has caused many deaths in recent decades. Currently, the world is witnessing the terrible behavior of SARS-CoV-2. The airborne viruses attached to the suspended air particles for a long time and spread rapidly. The dispersal of airborne viruses in the indoor air increases the risk of diseases. The present study endorses a solar-assisted heat treatment model to decontaminate airborne viruses and provide hospitals with disinfected air. A simplified model comprises the heating and cooling sections to abolish airborne viruses and cool the treated air. The heating section includes a solar parabolic trough collector (PTC)/electrical heater, porous domain, and decontamination chamber, while the cooling unit comprises storage tanks and an air cooler. A heat exchanger exchanges energy between hot and cold air streams. A solar PTC offers air heating during day time; however, the porous domain with the electrical heaters acts during the night and intermediate time. The airborne viruses can be abolished by passing through a porous domain and decontaminating chamber at 105 degrees C upholding an exposure period of 5 mins. The cooling section cools the disinfected air to comfortable conditions. A numerical analysis finds the optimal porosity of 0.9, owing to an exit temperature of 105 degrees C and a minimal pressure drop of 5.16 kPa. The high-temperature disinfected air leaving the storage tank (ST-2) further cools in an air cooler. Besides, the system's energy efficiency is noted at 37.4 % and 91.1 % during daytime and nighttime operations, respectively.

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Martinot, M.
Standard precautions should include ‘safe ventilation’to minimise far-afield airborne transmission in health and social care settings.
Infection, Disease & Health, (2022)

Nosocomial COVID-19 is identified as a major threat for inpatients.
Particles < 5 µm produced by humans are responsible of far-afield transmission.
The risk of far-afield transmission cannot be known for each clinical area.
Safe ventilation should be incorporated into standard precautions to minimize this risk.
Clinical areas should include ventilation indicators and instructions for safe ventilation.

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Alexi, A., Rosenfeld, A., Lazebnik, T.
The Trade-Off between Airborne Pandemic Control and Energy Consumption Using Air Ventilation Solutions.
Sensors (Basel, Switzerland), Vol. **22** n°(22), (2022)

Airborne diseases cause high mortality and adverse socioeconomic consequences. Due to urbanization, more people spend more time indoors. According to recent research, air ventilation reduces long-range airborne transmission in indoor settings. However, air ventilation solutions often incur significant energy costs and ecological footprints. The trade-offs between energy consumption and pandemic control indoors have not yet been thoroughly analyzed. In this work, we use advanced sensors to monitor the energy consumption and pandemic control capabilities of an air-conditioning system, a pedestal fan, and an open window in hospital rooms, classrooms, and conference rooms. A simulation of an indoor airborne pandemic spread of

Coronavirus (COVID-19) is used to analyze the Pareto front. For the three examined room types, the Pareto front consists of all three air ventilation solutions, with some ventilation configurations demonstrating significant inefficiencies. Specifically, air-conditioning is found to be efficient only at a very high energy cost and fans seem to pose a reasonable alternative. To conclude, a more informed ventilation policy can bring about a more desirable compromise between energy consumption and pandemic spread control.

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Kapoor, N. R., Kumar, A., Kumar, A., Kumar, A., Kumar, K.
Transmission Probability of SARS-CoV-2 in Office Environment Using Artificial Neural Network.
IEEE Access, Vol. **10**, (2022), pp. 121204-121229

In this paper, curve-fitting and an artificial neural network (ANN) model were developed to predict R-Event. Expected number of new infections that arise in any event occurring over a total time in any space is termed as R-Event. Real-time data for the office environment was gathered in the spring of 2022 in a naturally ventilated office room in Roorkee, India, under composite climatic conditions. To ascertain the merit of the proposed ANN and curve-fitting models, the performances of the ANN approach were compared against the curve fitting model regarding conventional statistical indicators, i.e., correlation coefficient, root mean square error, mean absolute error, Nash-Sutcliffe efficiency index, mean absolute percentage error, and a20-index. Eleven input parameters namely indoor temperature (T_{In}), indoor relative humidity (RH_{In}), area of opening (A_{O}), number of occupants (O), area per person (A_{P}), volume per person (V_{P}), CO_{2} concentration (CO_{2}), air quality index (AQI), outer wind speed (W_{S}), outdoor temperature (T_{Out}), outdoor humidity (RH_{Out}) were used in this study to predict the R-Event value as an output. The primary goal of this research is to establish the link between CO_{2} concentration and R-Event value; eventually providing a model for prediction purposes. In this case study, the correlation coefficient of the ANN model and curve-fitting model were 0.9992 and 0.9557, respectively. It shows the ANN model's higher accuracy than the curve-fitting model in R-Event prediction. Results indicate the proposed ANN prediction performance (R = 0.9992, RMSE = 0.0018708, MAE = 0.0006675, MAPE = 0.8643816, NS = 0.9984365, and a20-index = 0.9984300) is reliable and highly accurate to predict the R-event for offices.

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Burridge, H. C., Bontitsopoulos, S., Brown, C., Carter, H., Roberts, K., Vouriot, C.*, et al.*
Variations in classroom ventilation during the COVID-19 pandemic: Insights from monitoring 36 naturally ventilated classrooms in the UK during 2021.
Journal of Building Engineering, Vol. **63**, (2023)

Seasonal changes in the measured CO2 levels at four schools are herein presented through a set of indoor air quality metrics that were gathered during the height of the COVID-19 pandemic in the UK. Data from non-intrusive environmental monitoring units were remotely collected throughout 2021 from 36 naturally ventilated classrooms at two primary schools and two secondary schools in England. Measurements were analysed to assess the indoor CO2 concentration and temperature . Relative to UK school air quality guidance, the CO2 levels within classrooms remained relatively low during periods of warmer weather, with elevated CO2 levels being evident during the colder seasons, indicating lower levels of per person ventilation during these colder periods. However, CO2 data from the cold period during the latter part of 2021, imply that the per person classroom ventilation levels were significantly lower than those achieved during a similarly cold weather period during the early part of the year. Given that the classroom architecture and usage remained unchanged, this finding suggests that changes in the ventilation behaviours within the classrooms may have altered, and raises questions as to what may have given rise to such change, in a year when, messaging and public concerns regarding COVID-19 varied within the UK. Significant variations were observed when contrasting data, both between schools, and between classrooms within the same school building; suggesting

that work is required to understand and catalogue the existing ventilation provisions and architecture within UK classrooms, and that more work is required to ascertain the effects of classroom ventilation behaviours.

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