
# Rapport de veille n° 68

# Aéraulique et COVID-19

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# Google Scholar, Lens et WoS

Phillips, F., Crowley, J., Warburton, S., Staniforth, K., Parra-Blanco, A., Gordon, G. S. D.
**Air filtration mitigates aerosol levels both during and after endoscopy procedures.**
DEN open, Vol. **3** n°(1), (2023)

Objectives: Upper gastrointestinal endoscopies are aerosol-generating procedures, increasing the risk of spreading airborne pathogens. We aim to quantify the mitigation of airborne particles via improved ventilation, specifically laminar flow theatres and portable high-efficiency particulate air (HEPA) filters, during and after upper gastrointestinal endoscopies. Methods: This observational study included patients undergoing routine upper gastrointestinal endoscopy in a standard endoscopy room with 15-17 air changes per hour, a standard endoscopy room with a portable HEPA filtration unit, and a laminar flow theatre with 300 air changes per hour. A particle counter (diameter range 0.3mum-25mum) took measurements 10cm from the mouth. Three analyses were performed: whole procedure particle counts, event-based counts, and air clearance estimation using post-procedure counts. Results: Compared to a standard endoscopy room, for whole procedures we observe a 28.5x reduction in particle counts in laminar flow ($p < 0.001$) but no significant effect of HEPA filtration ($p = 0.50$). For event analysis, we observe for lateral flow theatres reduction in particles >5mum for oral extubation (12.2x, $p < 0.01$), reduction in particles <5mum for coughing/gagging (6.9x, $p < 0.05$), and reduction for all sizes in anesthetic throat spray (8.4x, $p < 0.01$) but no significant effect of HEPA filtration. However, we find that in the fallow period between procedures HEPA filtration reduces particle clearance times by 40%. Conclusions: Laminar flow theatres are highly effective at dispersing aerosols immediately after production and should be considered for high-risk cases where patients are actively infectious or the supply of personal protective equipment is limited. Portable HEPA filers can safely reduce the fallow time between procedures by 40%.

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Shom, D.
**Airborne Infection Risks from Covid-19 in Meat Processing Plants and Different Solutions to Mitigate the Risks.**
Thèse 2023. University of Nebraska-Lincoln. Faculty of The Graduate College. 2023

Meat processing plants are linked to the rapid spread of COVID-19 cases. A related literature review shows a lack of proper ventilation standards for the meat processing plants for workers' health and safety. Ventilation rates in these plants are considered adequate if the meat products are unadulterated. Thus, the air distribution and ventilation rate experiments were conducted in three meat processing plants. These measured ventilation rates were either compared to ASHRAE Std. 62.1 (2019) for a similar space or the design values provided by the plant's administration. The measured values were low in common spaces, such as the cafeteria and locker rooms. In addition, the total airflow rates from the diffusers also characterize the air distribution. A modified Wells-Riley model was used to calculate the COVID-19 airborne infection risk for two selected spaces to compare different engineering solutions, such as installing portable air cleaners, using ultraviolet lights in the upper room and in-duct, better filtration systems, and enhanced ventilation rates. Infection risks in a single space were used to rank these solutions. However, a worker during a whole shift moved from different spaces for different time durations. Therefore, six case studies were simulated to compare the differences between schedules, ventilation rates, and shedder strength. In two baseline studies, based on regular shifts and existing ventilation conditions, the airborne infection risks were about 42 % and 8 % for high and low shedders, correspondingly. Study II and Study II-L comprised a hypothetical staggered schedule with the existing ventilation conditions, and the relative reductions of infection risks were 23% and

28%, respectively, when compared to the corresponding baselines. Study III and Study III-L used the staggered schedule and enhanced ventilation and found the relative reductions of infection probability were about 43% and 49% respectively. Therefore, administrations should recognize the mentioned engineering solutions and use a staggered schedule to mitigate the infection risks in the meat processing plants.

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Xu, S., Zhang, G., Liu, X., Li, X.
**CFD modelling of infection control in indoor environments: A focus on room-level air recirculation systems.**
Energy and Buildings, Vol. **288**, (2023)

The emergence of viral variants has driven a continuous pandemic with a higher possibility of airborne transmission and a larger scale of infective cases, posing greater demands on indoor risk control. However, the role of room-level air recirculation systems (RRSs) in infection control remains unclear due to insufficient detailed research. There are also fewer analyses of the filtering rating of recirculation filters from the perspective of multi-scale particle size. Thus, a simulation procedure to assess the performance of RRSs on infection control that accounts the transient recirculation of real virus-laden particles in multi-scale sizes was proposed, and focusing on recirculation filter strategies to balance the risk limitation and energy cost. A poorly ventilated winter classroom was selected as a typical environment equipped with RRSs to operate this procedure. Different RRS strategies (i.e., wall-mounted air conditioners (WMAC), floor-standing air conditioners (FSAC) and 4-way cassette air conditioners (WCAC)) were compared. The results show the important contribution of recirculated particles to accumulating the overall infection risk of susceptible occupants towards a high basic reproduction number (Ro > 1). Then, there is a strong correlation of the spatial distributions between high-risk zones and large vortexes at the breathing height of susceptible occupants. Considering rating suitability and filtration effectiveness, the optimization of recirculation filters on energy and cost can be suggested with comparable benefits of infection control.

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Lisson, Y., Marmor, A., Gomez, A., Hall, R., Parry, A. E., Wright, R.*, et al.*
**Cohorting children in a childcare setting: a strategy to reduce SARS-CoV-2 Delta transmission, August-September 2021.**
Commun Dis Intell, Vol. **47**, (2023)

Background
Childcare centres can be high-risk settings for SARS-CoV-2 transmission due to age, vaccination status, and infection control challenges. We describe the epidemiology and clinical characteristics of a childcare SARS-CoV-2 Delta outbreak. When the outbreak occurred, little was known about the transmission dynamics of SARS-CoV-2 ancestral and Delta strains among children. Vaccinations for coronavirus disease 2019 (COVID-19) were not mandatory for childcare staff, and children (< 12 years) were ineligible.
Methods
A retrospective cohort design of childcare attendees was used to investigate age-cohorts exposure and transmission of SARS-CoV-2. We defined a case as a person who tested positive to SARS-CoV-2; we defined a close contact as a person who attended the childcare during 16–20 August 2021. Childcare centre exposures were defined by three cohorts: younger children (0–< 2.5 years) with designated staff; older children (2.5–5 years) with designated staff; and a staff-only group that moved between both age cohorts. We calculated the number and proportion of SARS-CoV-2 Delta infections, symptom profile and severity in children and adults, secondary attack rates, and relative risks (RR) with 95% confidence intervals (CIs) to compare age-cohort exposures and SARS-CoV-2 infection.
Results
There were 38 outbreak cases that tested positive to SARS-CoV-2 Delta infection, comprising one primary case, 11 childcare attendees and 26 household members. Child attendees were in two non-interacting groups,

0–< 2.5 years and 2.5–5 years, with designated staff, separate rooms, and independent ventilation. The greatest risk of infection to childcare attendees was in the < 2.5 years age cohort which had a secondary attack rate of 41% and were five times more likely to be infected with SARS-CoV-2 (RR = 5.73; 95% CI: 1.37–23.86; p ≤ 0.01). No identified transmission (n = 0/21) occurred in the ≥ 2.5 years age cohort.
Conclusion
Young children play an important role in SARS-CoV-2 Delta transmission to their peers and staff in childcare settings and to household members. Cohorting may be effective at limiting the propagation of SARS-CoV-2 in childcare settings. These findings highlight a need for multi-layered mitigation strategies and implementation support to manage respiratory infection control challenges at childcares. If prevention measures are not in place, this may facilitate ongoing transmission in these settings and into the broader community.

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Asif, A., Zeeshan, M.
**Comparative analysis of indoor air quality in offices with different ventilation mechanisms and simulation of ventilation process utilizing system dynamics tool.**
Journal of Building Engineering, Vol. **72**, (2023)

Keeping COVID-19 pandemic in perspective, good indoor air quality (IAQ) and adequate ventilation are imperative to minimize risk of virus spread, besides other poor IAQ related risks. Thus, present study is focused on evaluation and comparison of ventilation rates (VRs) in office buildings with different ventilation mechanisms. Two-season (summer and winter) data of indoor CO2 was collected, and VRs were calculated adopting three methods i.e., transient mass balance, steady-state and decay method, and were then input in system dynamics-based (SD) model for finding best method for the calculation of VRs. In the last part, simulations were used to calculate the optimum VRs to keep indoor CO2 levels below recommended limits. Results showed statistical difference ($p < 0.05$) of indoor CO2 among buildings and between seasons. Although better VRs were observed in mechanically ventilated offices, it is to be noted that windows in naturally ventilated offices were observed to be closed (to maintain thermal comfort) and thus naturally ventilated buildings were not operated as per design provisions. Moreover, transient mass balance method was found to be more accurate approach for VRs estimation. Furthermore, it was found that to limit indoor CO2 levels below 1100, 800 and 700 ppm, minimum VRs should be maintained as 10, 16 and 20 l/s/person respectively.

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Faulkner, C. A., Castellini, J. E., Zuo, W., Sohn, M. D.
**Comprehensive analysis of model parameter uncertainty influence on evaluation of HVAC operation to mitigate indoor virus: A case study for an office building in a cold and dry climate.**
Building and Environment, Vol. **238**, (2023)

Simulation-based studies of HVAC operation to mitigate indoor virus have been conducted to understand tradeoffs between indoor air quality (IAQ) and energy consumption. However, the influence of model parameter uncertainty in these studies has not been systematically quantified, which is critical when providing guidance to building operators. To address this gap, we identify 20 model parameters for a typical medium office building system in a cold and dry climate that can influence IAQ and energy consumption for indoor virus scenarios. Next, the distributions of the parameter values are estimated from literature and a set of simulation samples for three representative days is generated that simultaneously sample all of the parameters from their distributions. Two HVAC virus mitigation strategies are studied: increased filtration using MERV 13 filters and increased ventilation, via supply of 100% outdoor air into buildings. The model parameter uncertainty leads to significant variability in the results, particularly for the IAQ because of the highly uncertain virus generation rate. Use of 100% outdoor air can be beneficial for some uncertain scenarios on the hot day, but shows less IAQ improvement and/or significant energy increases on the other days. The virus removal efficiency and pressure drop of the HVAC filter, fan efficiency, and internal heat gain are the

most important parameters to determining the tradeoffs of the two strategies. The results demonstrate how this model parameter uncertainty analysis methodology can provide practical guidance to building operators.

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Marom, G., Grossbard, S., Bodek, M., Neuman, E., Elad, D.
**Computational analysis of a new biomimetic active ventilation paradigm for indoor spaces.**
International Journal of Numerical Methods for Heat & Fluid Flow, (2023),

Purpose
Ventilation of indoor spaces is required for the delivery of fresh air rich in oxygen and the removal of carbon dioxide, pollutants and other hazardous substances. The COVID-19 pandemic brought the topic of ventilating crowded indoors to the front line of health concerns. This study developed a new biologically inspired concept of biomimetic active ventilation (BAV) for interior environments that mimics the mechanism of human lung ventilation, where internal air is continuously refreshed with the external environment. The purpose of this study is to provide a detailed proof-of-concept of the new BAV paradigm using computational models.
Design/methodology/approach
This study developed computational fluid dynamic models of unoccupied rooms with two window openings on one wall and two BAV modules that periodically translate perpendicular to or rotate about the window openings. This study also developed a time-evolving spatial ventilation efficiency metric for exploring the accumulated refreshment of the interior space. The authors conducted two-dimensional (2D) simulations of various BAV configurations to determine the trends in how the working parameters affect the ventilation and to generate initial estimates for the more comprehensive three-dimensional (3D) model.
Findings
Simulations of 2D and 3D models of BAV for modules of different shapes and working parameters demonstrated air movements in most of the room with good air exchange between the indoor and outdoor air. This new BAV concept seems to be very efficient and should be further developed.
Originality/value
The concept of ventilating interior spaces with periodically moving rigid modules with respect to the window openings is a new BAV paradigm that mimics human respiration. The computational results demonstrated that this new paradigm for interior ventilation is efficient while air velocities are within comfortable limits.

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Nardell, E., Murray, M., Koutras, C., Vo, V., Zhuang, X., Oh, E.
**A Controlled Pilot Study of the Efficacy of Upper Room Germicidal Uv (GUV) Air Disinfection to Prevent SARS-CoV-2 Transmission in Elementary Schools Using as the Primary Outcome Wastewater Monitoring for Viral RNA.**
B106. FROM ACUTE TO LONG COVID-19. American Thoracic Society 2023 International Conference, May 19-24, 2023 - Washington, DC

School closures to prevent transmission of SARS-CoV-2 have had a major impact on learning and social development. Ventilation, filtration, and GUV air disinfection have been recommended as engineering controls to prevent transmission of SARS-CoV-2 in schools. Upper room GUV was shown to prevent measles transmission in schools in the 1930s. Demonstrating the efficacy of any such interventions against Covid-19 is difficult because cases can be asymptomatic, frequent testing is expensive and invasive, and transmission occurs outside of the school environment

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Cai, J., Chen, J., Hu, Y., Li, S., He, Q.
**Digital twin for healthy indoor environment: A vision for the post-pandemic era.**
Frontiers of Engineering Management, (2023)

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

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Choudhary, K., Krishnaprasad, K. A., Pandey, S., Zgheib, N., Salinas, J. S., Ha, M. Y.*, et al.*
**Effectiveness of RANS in predicting indoor airborne viral transmission: A critical evaluation against LES.**
Computers & Fluids, Vol. **256**, (2023)

We investigate the dispersal of droplet nuclei inside a canonical room of size 10 x 10 x 3.2m(3) with a four-way cassette air-conditioning unit placed at the center of the ceiling. We use Reynolds averaged Navier-Stokes (RANS) simulations with three flow rates corresponding to air changes per hour (ACH) values of 2.5, 5, and 10. The room setup as well as the operating conditions are chosen to match those of a recent high-fidelity large eddy simulation (LES) study. We use statistical overloading with a total of one million droplet nuclei being initially distributed randomly with uniform probability within the room. Six nuclei sizes are considered ranging in radius from 0.1 to 10 mu m (166,667 nuclei per size). The simulations are one-way coupled and employ the Langevin equations to model sub-grid motion. The flow and particle statistics are compared against the reference LES simulations, and we find that the RANS k - epsilon realizable model may be used as a computationally cheaper alternative to LES for predicting pathogen concentration in confined spaces albeit, with potentially increased statistical discrepancy.

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Andamon, M. M., Rajagopalan, P., Woo, J.
**Evaluation of ventilation in Australian school classrooms using long-term indoor CO2 concentration measurements.**
Building and Environment, Vol. **237**, (2023)

School classrooms are often reported as having insufficient ventilation with elevated indoor CO2 concentrations. This paper reports on pre-pandemic field measurements of CO2 concentration levels conducted for an academic year in 10 classrooms from four primary and a secondary school in Victoria, Australia. Measured CO2 concentrations across the 10 classrooms which were operated with a mix of intermittent natural ventilation and air-conditioning for cooling or heating, on average ranged between 657 ppm and 2235 ppm during school hours with median over 1000 ppm in 70% of classrooms. All 10 classrooms in the study exceeded the Australian recommended limit of 850 ppm. Using average peak CO2 concentrations from year-long measurements, estimated ventilation rate (VR) of 4.08 Ls-1 per person show

under-performing classrooms where 60% had VRs 35–40% lower than the 10-12 Ls−1 per person Australian recommendation. Estimated VR range of 1.24–2.07 Ls-1 per person using peak maximum CO2 levels were 19–30% lower than ASHRAE recommendation of 6.7 Ls-1 per person. These VRs translate to a range of air change rates on average between 0.52 and 0.88 h−1 ± 0.26–0.59, well below the 6.0 h−1 recommendation for good indoor ventilation by the World Health Organisation in the context of COVID-19 pandemic. Characterisation of ventilation and indoor air quality in current Australian classroom stock is critical for the improvement of classroom design, induction on room operating practices, understanding of the school community on the relevance of building ventilation on school performance and health, and development of appropriate ventilation and indoor air quality guidelines for schools.

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Akamatsu, T., Mori, T., Hayashi, M., Hayama, H.
**Evaluation on indoor environment and alternative ventilation methods in a school classroom in a cold region under Covid-19 pandemic.**
Journal of Environmental Engineering (Japan), Vol. **88** n°(803), (2023), pp. 43-49

COVID-19 caused a global pandemic. The possibility of aerosol transmission has been pointed out as a possible route of infection, and there are reports that conventional infection control measures are insufficient to counteract aerosol transmission. Therefore, this report presents the results of an actual survey at a high school, including measurement of CO2 concentration and a questionnaire survey, and the results of an experiment to evaluate the attenuation of particle concentration by an air cleaner based on this survey.

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Sengupta, J., Hussain, C. M.
**Graphene-Based Electrochemical Nano-Biosensors for Detection of SARS-CoV-2.**
Inorganics, Vol. **11** n°(5), (2023)

COVID-19, a viral respiratory illness, is caused by Severe Acute Respiratory Syndrome Corona Virus 2 (SARS-CoV-2), which was first identified in Wuhan, China, in 2019 and rapidly spread worldwide. Testing and isolation were essential to control the virus’s transmission due to the severity of the disease. In this context, there is a global interest in the feasibility of employing nano-biosensors, especially those using graphene as a key material, for the real-time detection of the virus. The exceptional properties of graphene and the outstanding performance of nano-biosensors in identifying various viruses prompted a feasibility check on this technology. This paper focuses on the recent advances in using graphene-based electrochemical biosensors for sensing the SARS-CoV-2 virus. Specifically, it reviews various types of electrochemical biosensors, including amperometric, potentiometric, and impedimetric biosensors, and discusses the current challenges associated with biosensors for SARS-CoV-2 detection. The conclusion of this review discusses future directions in the field of electrochemical biosensors for SARS-CoV-2 detection, underscoring the importance of continued research and development in this domain.

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Luo, Q., Yang, X., Hang, J., Fan, X., Luo, Z., Gu, Z.*, et al.*
**Influence of natural ventilation design on the dispersion of pathogen-laden droplets in a coach bus.**
Science of The Total Environment, Vol. **885**, (2023)

Natural ventilation is an energy-efficient design approach to reduce infection risk (IR), but its optimized design in a coach bus environment is less studied. Based on a COVID-19 outbreak in a bus in Hunan, China, the indoor-outdoor coupled CFD modeling approach is adopted to comprehensively explore how optimized bus natural ventilation (e.g., opening/closing status of front/middle/rear windows (FW/MW/RW)) and ceiling wind catcher (WCH) affect the dispersion of pathogen-laden droplets (tracer gas, 5 µm, 50 µm) and IR. Other key

influential factors including bus speed, infector's location, and ambient temperature (Tref) are also considered. Buses have unique natural ventilation airflow patterns: from bus rear to front, and air change rate per hour (ACH) increases linearly with bus speed. When driving at 60 km/h, ACH is only 6.14 h−1 and intake fractions of tracer gas (IFg) and 5 μm droplets (IFd) are up to 3372 ppm and 1394 ppm with ventilation through leakages on skylights and no windows open. When FW and RW are both open, ACH increases by 43.5 times to 267.50 h−1, and IFg and IFd drop rapidly by 1–2 orders of magnitude compared to when no windows are open. Utilizing a wind catcher and opening front windows significantly increases ACH (up to 8.8 times) and reduces IF (5–30 times) compared to only opening front windows. When the infector locates at the bus front with FW open, IFg and IFd of all passengers are <10 ppm. More droplets suspend and further spread in a higher Tref environment. It is recommended to open two pairs of windows or open front windows and utilize the wind catcher to reduce IR in coach buses.

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Şensoy, E. B., Emecen, A. N., Keskin, S., Süner, A. F., Şiyve, N., Turunç, Ö.*, et al.*
**Investigating household transmission of SARS-CoV-2: an analysis of 1453 households.**
Population Medicine, Vol. **5** n°(Supplement), (2023)

Background: Significant individual variables were being over age 65 (odds ratio-OR, 95% confidence interval-CI: 7.85, 5.38-11.45), having a chronic disease (OR, 95%CI: 1.60, 1.31-1.96) and being a nuclear family member (OR, 95%CI: 3.30, 2.71-4.1). For household-level variables, having a housekeeper in the household (OR, 95%CI: 2.44, 1.00-5.96), never wearing a mask (OR, 95%CI: 1.60, 1.15-2.23), eating at the same table (OR, 95%CI: 1.92, 1.42-2.60) and travelling in the same car (OR, 95%CI: 1.58, 1.17-2.13) were significant. Gender, natural ventilation, type of building and being isolated in a separate room were not statistically significant. Conclusions: The results of the study may represent a useful contribution to understanding the household transmission of SARS-CoV-2. In line with the study results, mitigation strategies in the future could be planned for the household transmission of SARS-CoV-2-like respiratory viruses.

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Mk, H., Jb, B.
**An investigation into Dental Practice Ventilation and Air Purification in Waikato and Bay of Plenty, New Zealand.**
N Z Dent J, Vol. **119** n°(1), (2023)

The SARS-Cov-2 virus is more likely to be spread when people are indoors and in close contact. In response to the COVID-19 pandemic, workplace governing authorities and dental workforce regulators in many jurisdictions have updated their air quality guidelines. Good indoor ventilation provides for a healthier environment and may reduce the risk of airborne pathogen transmission. Representatives of 104 dental practices in the Waikato and Bay of Plenty regions in New Zealand were contacted to seek information about their ventilation systems and any plans for improvement. Responses were obtained from 70.2% (N= 73) of these practices, representing the workplaces of 233 oral health practitioners. The majority of the responding practices (68.5%, N=50) were unventilated. For those that had ventilation systems, only a few knew how many air changes per hour their system was providing. Air purification units are uncommon and any opening windows are usually kept closed. Most of the dental practices surveyed did not have adequate ventilation and if a ventilation system was installed there was often limited knowledge about its performance. This study highlights the need for more attention to be given to air quality in New Zealand dental practices.

https://www.nzda.org.nz/about-us/new-zealand-dental-journal-articles/nzdj-2022

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Li, H., Shan, X., Ba, T., Liu, Y. C., Kang, C.-W., Hing, C. a. K.*, et al.*

**Investigation of Ultraviolet-C light-emitting diode for airborne disinfection in air duct.**
Physics of Fluids, Vol. **35** n°(4), (2023)

Given the current coronavirus (COVID-19) situation around the world, we may have to face a long-term battle with coronavirus. It is necessary to prepare and stay resilient with some other techniques to improve air quality in buildings, especially in clinics and hospitals. In this paper, we have developed Ultraviolet-C (UVC) light-emitting diode (LED) modules which can be implemented in air ducts in heating, ventilation, and air conditioning system for airborne disinfection. An LED module is designed with LED panels as the basic unit so that it is easy to scale up to accommodate for air ducts with different sizes. Both experiments and simulations are carried out to study its disinfection performance. The results show that more than 76% and 85% of the pathogen can be inactivated within 60 and 90 min, respectively, in a meeting room with a volume of 107 m(3) by using one LED module. Simulations for two LED modules show that the disinfection efficacy is more than two times compared to that of one LED module. In addition to the pathogen used in the experiments, the disinfection performance of the LED module for inactivation of SARS-CoV-2 virus based on the literature is investigated numerically. It shows that more than 99.70% of pathogens receive UV dose larger than 4.47 J/m(2), leading to an almost 89.10% disinfection rate for SARS-CoV-2 virus within one hour using the two LED modules in the same meeting room.

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Bruegel, M.
**Law, Labour and Lunch in France at the Turn of the Twentieth Century.**
International Review of Social History, (2023)

Ventilation emerged as an efficient technique to reduce the health impact of dust and gas in workspaces around 1900. However, this technical solution to a major sanitary problem collided with the human factor. When, in 1894, French law imposed shop-floor clearance during lunch to facilitate aeration, workers resisted the injunction as a disturbance of their daily eating routine. Authorities relied on labour inspectors to find solutions to contentious situations. The 1901 union-led strike in the high-fashion district in Paris propelled the issue to national attention. Striking women demanded the strict enforcement of the aeration rule. The executive obliged, but the newfound zeal subsequently rekindled antagonism towards the regulation. Reversing their claim, women workers launched a community-based petitioning campaign to return to pre-strike tolerance. Rumours of another walk-out by seamstresses, triggered by the enforcement of the regulation in 1902, precipitated a governmental volte-face. Authorities apprehended the power of the street and the threat of public disorder. Government yielded to the women's influence. A more relaxed version of the decree - it did not automatically require the evacuation of workspaces - appeared on 29 November 1904. It had taken ten years, and a zigzagging trajectory, to overcome the unanticipated consequences of purposive legislative action. The new rules proved to be very solid: they remained in place until Covid-19 pushed the government to temporarily authorize eating at one's workplace to prevent the spread of the virus in canteens and restaurants.

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Chang, Y., Wang, Y., Li, W., Wei, Z., Tang, S., Chen, R.
**Mechanisms, Techniques and Devices of Airborne Virus Detection: A Review.**
International journal of environmental research and public health, Vol. **20** n°(8), (2023)

Airborne viruses, such as COVID-19, cause pandemics all over the world. Virus-containing particles produced by infected individuals are suspended in the air for extended periods, actually resulting in viral aerosols and the spread of infectious diseases. Aerosol collection and detection devices are essential for limiting the spread of airborne virus diseases. This review provides an overview of the primary mechanisms and enhancement techniques for collecting and detecting airborne viruses. Indoor virus detection strategies for scenarios with

varying ventilations are also summarized based on the excellent performance of existing advanced comprehensive devices. This review provides guidance for the development of future aerosol detection devices and aids in the control of airborne transmission diseases, such as COVID-19, influenza and other airborne transmission viruses.

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Li, Y., Fan, Y., Zhi, C., Ye, W., Zhang, X.
**Multi-objective optimization of mechanical ventilation with the aid of purifiers in two scenarios: Regular operation and mitigating the spread of respiratory infectious diseases.**
Building simulation, Vol. **16** n°(5), (2023), pp. 795-811

COVID-19 and its impact on society have raised concerns about scaling up mechanical ventilation (MV) systems and the energy consequences. This paper attempted to combine MV and portable air cleaners (PACs) to achieve acceptable indoor air quality (IAQ) and energy reduction in two scenarios: regular operation and mitigating the spread of respiratory infectious diseases (RIDs). We proposed a multi-objective optimization method that combined the NSGA-II and TOPSIS techniques to determine the total equivalent ventilation rate of the MV-PAC system in both scenarios. The concentrations of PM2.5 and CO2 were primary indicators for IAQ. The modified Wells-Riley equation was adopted to predict RID transmissions. An open office with an MV-PAC system was used to demonstrate the method's applicability. Meanwhile, a field study was conducted to validate the method and evaluate occupants' perceptions of the MV-PAC system. Results showed that optimal solutions of the combined system can be obtained based on various IAQ requirements, seasons, outdoor conditions, etc. For regular operation, PACs were generally prioritized to maintain IAQ while reducing energy consumption even when outdoor PM2.5 concentration was high. MV can remain constant or be reduced at low occupancies. In RID scenarios, it is possible to mitigate transmissions when the quanta were < 48 h-1. No significant difference was found in the subjective perception of the MV and PACs. Moreover, the effects of infiltration on the optimal solution can be substantial. Nonetheless, our results suggested that an MV-PAC system can replace the MV system for offices for daily use and RID mitigation. Electronic Supplementary Material ESM: The Appendix is available in the online version of this article at 10.1007/s12273-023-0999-z.

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Lee, L., Landry, S., Jamriska, M., Subedi, D., Joosten, S., Barr, J.*, et al.*
**Quantifying the reduction of airborne infectious virus load using a ventilated patient hood.**
Journal of Hospital Infection, (2023)

Background
Healthcare workers treating SARS-CoV-2 patients are at risk of infection by respiratory exposure to patient-emitted, virus-laden aerosols. Source control devices such as ventilated patient isolation hoods have been shown to limit the dissemination of non-infectious airborne particles in laboratory tests, but data on their performance in mitigating the airborne transmission risk of infectious viruses are lacking.
Aim
We used an infectious airborne virus to quantify the ability of a ventilated hood to reduce infectious virus exposure in indoor environments.
Methods
We nebulized 109 plaque forming units (pfu) of bacteriophage PhiX174 virus into a ~30-m3 room when the hood was active or inactive. The airborne concentration of infectious virus was measured by BioSpot-VIVAS and settle plates using plaque assay quantification on the bacterial host Escherichia coli C. The airborne particle number concentration (PNC) was also monitored continuously using an optical particle sizer.
Findings
The median airborne viral concentration in the room reached 1.41 × 105 pfu/m3 with the hood inactive. When active, the hood reduced infectious virus concentration in air samples by 374-fold. The deposition of

infectious virus on the surface of settle plates was reduced by 87-fold. This was associated with a 109-fold reduction in total airborne particle number escape rate.
Conclusion
A personal ventilation hood significantly reduced airborne particle escape, considerably lowering infectious virus contamination in an indoor environment. Our findings support the further development of source control devices to mitigate nosocomial infection risk among healthcare workers exposed to airborne viruses in clinical settings.

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Kusuluri, R., Mirikar, D., Palanivel, S., Arumuru, V.
**Risk assessment of airborne virus transmission in an intensive care unit due to single and sequential coughing.**
Risk Anal, (2023)

The virus causing COVID-19 has constantly been mutating into new variants. Some of them are more transmissive and resistant to antibiotics. The current research article aims to examine the airborne transmission of the virus expelled by coughing action in a typical intensive care unit. Both single and sequential coughing actions have been considered to get closer to practical scenarios. The objective is to assess the effectiveness of air change per hour (ACH) on the risk of infection to a healthcare person and how the air change rate influences the dispersion of droplets. Such a study is seldom reported and has significant relevance. A total of four cases were analyzed, of which two were of sequential cough. When the ACH is changed from 6 to 12, the average particle residence time is reduced by similar to 7 s. It is found that the risk of infection in the case of sequential cough will be relatively low compared to a single cough if the outlet of the indoor environment is placed above the patient's head. This arrangement also eliminates the requirement of higher ACH, which has significance from an energy conservation perspective.

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Madubuike, O. C., Anumba, C. J., Agapaki, E.
**Scenarios for digital twin deployment in healthcare facilities management.**
Journal of Facilities Management, (2023)

Purpose This paper aims to focus on identifying key health-care issues amenable to digital twin (DT) approach. It starts with a description of the concept and enabling technologies of a DT and then discusses potential applications of DT solutions in healthcare facilities management (FM) using four different scenarios. The scenario planning focused on monitoring and controlling the heating, ventilation, and air-conditioning system in real-time; monitoring indoor air quality (IAQ) to monitor the performance of medical equipment; monitoring and tracking pulsed light for SARS-Cov-2; and monitoring the performance of medical equipment affected by radio frequency interference (RFI).Design/methodology/approach The importance of a healthcare facility, its systems and equipment necessitates an effective FM practice. However, the FM practices adopted have several areas for improvement, including the lack of effective real-time updates on performance status, asset tracking, bi-directional coordination of changes in the physical facilities and the computational resources that support and monitor them. Consequently, there is a need for more intelligent and holistic FM systems. We propose a DT which possesses the key features, such as real-time updates and bi-directional coordination, which can address the shortcomings in healthcare FM. DT represents a virtual model of a physical component and replicates the physical data and behavior in all instances. The replication is attained using sensors to obtain data from the physical component and replicating the physical component's behavior through data analysis and simulation. This paper focused on identifying key healthcare issues amenable to DT approach. It starts with a description of the concept and enabling technologies of a DT and then discusses potential applications of DT solutions in healthcare FM using four different scenarios.Findings The scenarios were validated by industry experts and concluded that the scenarios offer significant potential benefits for the

deployment of DT in healthcare FM such as monitoring facilities' performance in real-time and improving visualization by integrating the 3D model.Research limitations/implications In addition to inadequate literature addressing healthcare FM, the study was also limited to one of the healthcare facilities of a large public university, and the scope of the study was limited to IAQ including pressure, relative humidity, carbon dioxide and temperature. Additionally, the study showed the potential benefits of DT application in healthcare FM using various scenarios that DT experts validated.Practical implications The study shows the practical implication using the various validated scenarios and identified enabling technologies. The combination and implementation of those mentioned above would create a system that can effectively help manage facilities and improve facilities' performances.Social implications The only identifiable social solution is that the proposed system in this study can manually be overridden to prevent absolute autonomous control of the smart system in cases when needed.Originality/value To the best of the authors' knowledge, this is the only study that has addressed healthcare FM using the DT approach. This research is an excerpt from an ongoing dissertation.

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Pang, Z., Lu, X., Hu, P., O'neill, Z., Wang, Q.
**SIREN – smart ventilation for infection risk mitigation and HVAC energy efficiency: a case study amid the COVID-19 pandemic.**
Journal of Building Performance Simulation, (2023), pp. 1-29

The COVID-19 pandemic has underscored the need for effective ventilation control in public buildings. This study develops and evaluates a smart ventilation control algorithm (SIREN) that dynamically adjusts zone and system-level HVAC operation to maintain an acceptable COVID-19 infection risk and HVAC energy efficiency. SIREN uses real-time building operation data and Trim & Respond control logic to determine zone primary and system outdoor airflow rates. An EnergyPlus and CONTAM co-simulation framework was developed to assess its performance across various control scenarios and US climate zones. Results show that SIREN can flexibly control infection risk within a customized threshold (e.g. 3%) for every zone, while traditional controls cannot. At the building level, SIREN?s HVAC energy consumption is comparable to a fixed 70% outdoor airflow fraction scenario, while its infection risk is lower than the 100% outdoor airflow scenario, illustrating its potential for safe and energy-efficient HVAC operation during pandemics.

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Liu, S., Deng, Z.
**Transmission and infection risk of COVID-19 when people coughing in an elevator.**
Building and Environment, Vol. **238**, (2023)

People in cities use elevators daily. With the COVID-19 pandemic, there are more worries about elevator safety, since elevators are often small and crowded. This study used a proven CFD model to see how the virus could spread in elevators. We simulated five people taking in an elevator for 2 min and analyzed the effect of different factors on the amount of virus that could be inhaled, such as the infected person's location, the standing positions of the persons, and the air flow rate. We found that the position of the infected person and the direction they stood greatly impacted virus transmission in the elevator. The use of mechanical ventilation with a flow rate of 30 ACH (air changes per hour) was effective in reducing the risk of infection. In situations where the air flow rate was 3 ACH, we found that the highest number of inhaled virus copies could range from 237 to 1186. However, with a flow rate of 30 ACH, the highest number was reduced to 153 to 509. The study also showed that wearing surgical masks decreased the highest number of inhaled virus copies to 74 to 155.

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Garg, H., Ringe, R. P., Das, S., Parkash, S., Thakur, B., Delipan, R.*, et al.*
**UVC-Based Air Disinfection Systems for Rapid Inactivation of SARS-CoV-2 Present in the Air.**

Pathogens, Vol. **12** n°(3), (2023)

The World Health Organization (WHO) declared in May 2021 that SARS-CoV-2 is transmitted not only by close contact with infectious respiratory fluids from infected people or contaminated materials but also indirectly through air. Airborne transmission has serious implications for the control measures we can deploy, given the emergence of more transmissible variants. This emphasizes the need to deploy a mechanism to reduce the viral load in the air, especially in closed and crowded places such as hospitals, public transport buses, etc. In this study, we explored ultraviolet C (UVC) radiation for its ability to inactivate the SARS-CoV-2 particles present in aerosols and designed an air disinfection system to eliminate infectious viruses. We studied the virus inactivation kinetics to identify the UVC dosage required to achieve maximum virus inactivation. Based on the experimental data, UVC-based devices were designed for the sanitization of air through HVAC systems in closed spaces. Further, a risk assessment model to estimate the risk reduction was applied which showed that the use of UVC radiation could result in the reduction of the risk of infection in occupied spaces by up to 90%.

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Martínez-Espinosa, E., Carvajal-Mariscal, I.

**Virus-laden droplet nuclei in vortical structures associated with recirculation zones in indoor environments: A possible airborne transmission of SARS-CoV-2.**

Environmental Advances, (2023)

Droplet nuclei dispersion patterns in indoor environments are reviewed from a physics view to explore the possibility of airborne transmission of SARS-CoV-2. This review analyzes works on particle dispersion patterns and their concentration in vortical structures in different indoor environments. Numerical simulations and experiments reveal the formation of the buildings' recirculation zones and vortex flow regions by flow separation, airflow interaction around objects, internal dispersion of airflow, or thermal plume. These vortical structures showed high particle concentration because particles are trapped for long periods. Then a hypothesis is proposed to explain why some medical studies detect the presence of SARS-CoV-2 and others do not detect the virus. The hypothesis proposes that airborne transmission is possible if virus-laden droplet nuclei are trapped in vortical structures associated with recirculation zones. This hypothesis is reinforced by a numerical study in a restaurant that presented possible evidence of airborne transmission by a large recirculating air zone. Furthermore, a medical study in a hospital is discussed from a physical view for identifying the formation of recirculation zones and their relation with positive tests for viruses. The observations show air sampling site located in this vortical structure is positive for the SARS-CoV-2 RNA. Therefore, the formation of vortical structures associated with recirculation zones should be avoided to minimize the possibility of airborne transmission. This work tries to understand the complex phenomenon of airborne transmission as a way in the prevention of transmission of infectious diseases.

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Gu, X., Cao, T., Mou, J., Liu, J.

**Water bath is more efficient than hot air oven at thermal inactivation of coronavirus.**

Virology journal, Vol. **20** n°(1), (2023), pp. 84-84

BACKGROUND: Thermal inactivation is a conventional and effective method of eliminating the infectivity of pathogens from specimens in clinical and biological laboratories, and reducing the risk of occupational exposure and environmental contamination. During the COVID-19 pandemic, specimens from patients and potentially infected individuals were heat treated and processed under BSL-2 conditions in a safe, cost-effective, and timely manner. The temperature and duration of heat treatment are optimized and standardized in the protocol according to the susceptibility of the pathogen and the impact on the integrity of the specimens, but the heating device is often undefined. Devices and medium transferring the thermal

energy vary in heating rate, specific heat capacity, and conductivity, resulting in variations in efficiency and inactivation outcome that may compromise biosafety and downstream biological assays. METHODS: We evaluated the water bath and hot air oven in terms of pathogen inactivation efficiency, which are the most commonly used inactivation devices in hospitals and biological laboratories. By evaluating the temperature equilibrium and viral titer elimination under various conditions, we studied the devices and their inactivation outcomes under identical treatment protocol, and to analyzed the factors, such as energy conductivity, specific heat capacity, and heating rate, underlying the inactivation efficiencies. RESULTS: We compared thermal inactivation of coronavirus using different devices, and have found that the water bath was more efficient at reducing infectivity, with higher heat transfer and thermal equilibration than a forced hot air oven. In addition to the efficiency, the water bath showed relative consistency in temperature equilibration of samples of different volumes, reduced the need for prolonged heating, and eliminated the risk of pathogen spread by forced airflow. CONCLUSIONS: Our data support the proposal to define the heating device in the thermal inactivation protocol and in the specimen management policy.

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