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Aéraulique et COVID-19

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Google Scholar, Lens et WoS

Kumar, P., Kalaiarasan, G., Bhagat, R. K., Mumby, S., Adcock, I. M., Porter, A. E.*, et al.*
Active Air Monitoring for Understanding the Ventilation and Infection Risks of SARS-CoV-2 Transmission in Public Indoor Spaces.
In: Atmosphere. 2022.

Indoor, airborne, transmission of SARS-CoV-2 is a key infection route. We monitored fourteen different indoor spaces in order to assess the risk of SARS-CoV-2 transmission. PM2.5 and CO2 concentrations were simultaneously monitored in order to understand aerosol exposure and ventilation conditions. Average PM2.5 concentrations were highest in the underground station (261 ± 62.8 µgm−3), followed by outpatient and emergency rooms in hospitals located near major arterial roads (38.6 ± 20.4 µgm−3), the respiratory wards, medical day units and intensive care units recorded concentrations in the range of 5.9 to 1.1 µgm−3. Mean CO2 levels across all sites did not exceed 1000 ppm, the respiratory ward (788 ± 61 ppm) and the pub (bar) (744 ± 136 ppm) due to high occupancy. The estimated air change rates implied that there is sufficient ventilation in these spaces to manage increased levels of occupancy. The infection probability in the medical day unit of hospital 3, was 1.6-times and 2.2-times higher than the emergency and outpatient waiting rooms in hospitals 4 and 5, respectively. The temperature and relative humidity recorded at most sites was below 27 °C, and 40% and, in sites with high footfall and limited air exchange, such as the hospital medical day unit, indicate a high risk of airborne SARS-CoV-2 transmission.

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Choi, J., Poudel, K., Nam, K. S., Piri, A., Rivera-Piza, A., Ku, S. K.*, et al.*
Aero-manufacture of nanobulges for an in-place anticoronaviral on air filters.
Journal of hazardous materials, Vol. **445**, (2022)

The interest in removing contagious viruses from indoor air using ventilation and filtration systems is increasing rapidly because people spend most of the day indoors. The development of an effective platform to regenerate the antiviral function of air filters during use and safe abrogation of used filters containing infectious viruses is a challenging task, because an on-demand safe-by-design manufacture system is essential for in-place antiviral coatings, but it has been rarely investigated. With these considerations, an electrically operable dispenser was prepared for decorating continuous ultrafine Fe-Zn, Fe-Ag, or Fe-Cu particles (<5nm) onto SiO2 nanobeads (ca. 130nm) to form nanobulges (i.e., nanoroughness for engaging coronavirus spikes) in the aerosol state for 3min direct deposition on the air filter surfaces. The resulting nanobulges were exposed to human coronaviruses (HCoV; surrogates of SARS-CoV-2) to assess antiviral function. The results were compared with similar-sized individual Zn, Ag, and Cu particles. The nanobulges exhibited comparable antiviral activity to Zn, Ag, and Cu particles while retaining biosafety in both in vitro and in vivo models because of the significantly smaller metallic fractions. This suggests that the bimetallic bulge structures generate reactive oxygen species and Fenton-mediated hydroxyl radicals for inactivating HCoV.

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Cisneros-Rivas, M. D. C., Ramirez-Victoria, S. D. C., Prieto-Sanchez, J. C., Murrieta-Luna, E.
Analysis of ventilation in Central corridor in UPJR building UPJR using CFD.
ECORFAN®. International Multidisciplinary Congress of Engineering. Poster

To date, the parameters associated with the transmission of SARS-CoV-2 virus and its disease COVID- 19 have not been fully studied. It is known that transmission occurs through dispersed droplets that are exhaled, which contain the virus and are suspended in the air, so characterizing them is complex since many parameters that influence hydrodynamics must be considered. In this study, a CFD analysis of the ventilation in a central corridor in the UD1 building at UPJR was performed.

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Glenn, K., He, J., Rochlin, R., Teng, S., Hecker, J., Novosselov, I.

Assessment of Aerosol Persistence in ICUs via Low-cost Sensor Network and Zonal Models.
Research Square preprint, (2022)

The COVID-19 pandemic heightened public awareness about airborne particulate matter (PM) due to the spread of infectious diseases via aerosols. The persistence of potentially infectious aerosols in public spaces, particularly medical settings, deserves immediate investigation; however, a systematic approach to characterize the fate of aerosols in most clinical environments has not been reported. This paper presents a methodology for mapping aerosol propagation using a low-cost PM sensor network in ICU and adjacent environments and the subsequent development of the data-driven zonal model. Mimicking aerosol generation by a patient, we generated trace NaCl aerosols and monitored their propagation in the environment. In positive (closed door) and neutral-pressure (open door) ICUs, up to 6% or 19% respectively of all PM escaped through the door gaps, however, the outside sensors did not register an aerosol spike in negative-pressure ICUs. The K-means clustering analysis of temporospatial aerosol concentration data suggests that ICU can be represented by three distinct zones: (1) near the aerosol source, (2) room periphery, and (3) the outside region. These zones inform two-phase aerosol plume behavior: dispersion of the original aerosol spike throughout the room and an evacuation phase where "well-mixed" aerosol concentration in the ICU decayed uniformly. Decay rates were calculated in positive, neutral, and negative modes, with negative-pressure rooms clearing out nearly twice as fast. The aerosol concentration decay followed the trends in the air exchange rates. This research demonstrates the methodology for aerosol persistence monitoring in medical settings; however, it is limited by a relatively small data set and is specific to small-size ICU rooms. Future studies need to evaluate medical settings with high risks of infectious disease transmission and optimize hospital infrastructure.

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Hu, C.-P., Cheng, J.-H.
Challenges and Actions of IAQ under COVID-19: A Survey of Taiwanese People's Perception of Epidemic Prevention and Indoor Places Certification.
International journal of environmental research and public health, Vol. **19** n°(22), (2022)

COVID-19 is still spreading around the world, and the pandemic has awakened the public's attention to environmental cleanliness. This article used an online survey for people living in Taiwan, and a total of 1206 valid questionnaires were collected in October 2021. According to the survey results of Taiwanese people's awareness of and needs for epidemic prevention and IAQ, 94.4% of the respondents agreed that maintaining IAQ during the COVID-19 pandemic is very important for prevention. In addition, 95.4% of them also pointed out that the "Clean and Safe" mark certification should be promoted in public places. Finally, this article also uses hierarchical regression to analyze public perceptions of seven indoor places, including elevators, restaurants, dwellings, offices, gyms, kindergartens, and long-term care centers. The results found that: (1) from the perspective of epidemic prevention, improving IAQ through ventilation strategies could prevent the spread of the COVID-19 pandemic, and (2) from the perspective of promotion certification, the elevators, restaurants and offices could establish strengthened IAQ, dwellings, gyms and long-term care centers should emphasize the display of IAQ information in entrances and exits, and kindergartens should focus on increasing safety and reducing infection.

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Takamure, K., Sakamoto, Y., Iwatani, Y., Amano, H., Yagi, T., Uchiyama, T.
Characteristics of collection and inactivation of virus in air flowing inside a winding conduit equipped with 280 nm deep UV-LEDs.
Environment International, Vol. **170**, (2022)

A general-purpose virus inactivation unit that can inactivate viruses was developed using deep ultraviolet (DUV) LEDs that emit DUV rays with a wavelength of 280 nm. The inside of the virus inactivation unit is a rectangular conduit with a sharp turn of 180 degrees (sharp-turned rectangular conduit). Virus inactivation is attempted by directly irradiating the air passing through the conduit with DUV rays. The flow characteristics of air and virus particles inside the virus inactivation unit were investigated using numerical simulations. The air was locally accelerated at the sharp turn parts and flowed along the partition plate in the sharp-turned rectangular conduit. The aerosol particles moving in the sharp-turned rectangular conduit were greatly bent in orbit at the sharp turn parts, and then rapidly approached the partition plate at the lower part of the conduit. Consequently, many particles collided with the partition plates behind the sharp-turn parts. SARS-CoV-2 virus was nebulized in the virus inactivation unit, and the RNA concentration and virus

inactivation rate with and without the emission of DUVLEDs were measured in the experiment. The concentration of SARS-CoV-2 RNA was reduced to 60% through DUV-LED irradiation. In addition, SARS-CoV-2 passing through the virus inactivation unit was inactivated below the detection limit by the emission of DUV-LEDs. The virus inactivation rate and the value of the detection limit corresponded to 99.38% and 35.36 TCID50/mL, respectively.

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Oksanen, L., Auvinen, M., Kuula, J., Malmgren, R., Romantschuk, M., Hyvarinen, A.*, et al.*
Combining Phi6 as a surrogate virus and computational large-eddy simulations to study airborne transmission of SARS-CoV-2 in a restaurant.
Indoor air, Vol. **32** n°(11), (2022)

COVID-19 has highlighted the need for indoor risk-reduction strategies. Our aim is to provide information about the virus dispersion and attempts to reduce the infection risk. Indoor transmission was studied simulating a dining situation in a restaurant. Aerosolized Phi6 viruses were detected with several methods. The aerosol dispersion was modeled by using the Large-Eddy Simulation (LES) technique. Three risk-reduction strategies were studied: (1) augmenting ventilation with air purifiers, (2) spatial partitioning with dividers, and (3) combination of 1 and 2. In all simulations infectious viruses were detected throughout the space proving the existence long-distance aerosol transmission indoors. Experimental cumulative virus numbers and LES dispersion results were qualitatively similar. The LES results were further utilized to derive the evolution of infection probability. Air purifiers augmenting the effective ventilation rate by 65% reduced the spatially averaged infection probability by 30%-32%. This relative reduction manifests with approximately 15min lag as aerosol dispersion only gradually reaches the purifier units. Both viral findings and LES results confirm that spatial partitioning has a negligible effect on the mean infection-probability indoors, but may affect the local levels adversely. Exploitation of high-resolution LES jointly with microbiological measurements enables an informative interpretation of the experimental results and facilitates a more complete risk assessment.

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Woo, J., Bukhari, A., Lane, L., Mei, L., Baglione, M., Yecko, P.*, et al.*
Computational fluid dynamics modeling of the efficacy of hvac adjustments on mitigating airborne transmission of Sars-Cov-2.
In: ASME International Mechanical Engineering Congress and Exposition (IMECE). Electr Network2021.

Assessing and improving the safety of social settings is pivotal for the reopening of facilities and institutions during the pandemic. Recent discoveries now suggest that the predominant medium of SARS-CoV-2 transmission is exposure to infectious respiratory aerosols. Airborne viral spread is particularly effective in indoor environments - which have been strongly implicated in high transmission rates and super-spreading events. This study focuses on computational fluid dynamics models developed to study the specific ventilation features of an indoor space and their effects on indoor particle spread. A case study is conducted on a typical classroom at the Cooper Union. Masked occupants are modeled in the room as aerosol sources to compare the performance of different ventilation settings on the exhaust rates of airborne particles. Simulation results reveal that increasing ventilation rates accelerate particle evacuation. Visualization and segregated data comparisons indicate regions of particle accumulation induced by the design and geometry of the classroom in relation to its occupants. Visualization is also used to observe a uniform distribution of airborne particles after only 10 minutes of simulated time - confirming the need for safety measures beyond the six feet distancing guideline.

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Espínola, E., González, V., Esquivel, L.
Design of a Localized Air Exhaust System for an Undergraduate Dental Practice Room Under Covid-19 Context, a Case Study.
3rd South American International Industrial Engineering and Operations Management Conference, Asuncion, Paraguay, July 19-21, 2022.

The COVID-19 pandemic has caused a significant impact on the global economy and significantly slowed down human activity. Paraguay (PY), a small developing South American country, was not an exception. Since this pandemic reached this country, the local government implemented a series of lockdown and restrictive measures since early 2020. In order to contain the spread of this virus, school activities such as course lectures, especially laboratory practices, were

placed on hold indefinitely. As a result of restrictive access to online learning in Paraguay, the faculty of dentistry requests the faculty of engineering (FIUNA) to design a safe ventilation system to allow resuming laboratory practices in the faculty of dentistry. This led to the urgent need to reopen universities, schools, and other academic institutions to resume teaching activities.
Computational Fluid Mechanics was utilized to validate a localized air exhaust system design. This work helped to support the use of this engineering tool as part of the engineering design procedure. Results showed that a localized airflow of 150 CFM near the patient's head combined with a transparent wall and personal protective equipment helped avoid virus spreading. Different exhaust configurations were taken into consideration. In addition, air flow lines and velocity profiles surrounding the dental chair are shown in this work. It is essential to remark here that this worked to help the school administration to reopen laboratory activities. This helped to confidently decide on resuming practices and, at the same time, keeping students and faculties safe.

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Luo, H., Zhong, L.
Development and experimental validation of an improved mathematical irradiance model for in-duct ultraviolet germicidal irradiation (UVGI) applications.
Building and Environment, Vol. **226**, (2022)

The application of ultraviolet germicidal irradiation (UVGI) technology inside the heating, ventilation, and air-conditioning (HVAC) air ducts to purify circulating air and improve indoor air quality has attracted extensive interest during the COVID-19 pandemic. In this study, a new view-factor-based mathematical model was developed to calculate the irradiation distribution for a typical twin-tube UV lamp placed at the center of a square duct, in which the contributions from direct emissive irradiance, specular reflection irradiance, and diffuse reflection irradiance were quantified. Furthermore, the "projection area" method was introduced to mathematically estimate the shadowing effects between the two lamps by considering multiple-lamp scenarios in real in-duct UVGI system designs. Subsequently, a computational fluid dynamics (CFD) simulation was employed to compute the average received UV dose and disinfection efficiency of the system. The mathematical model combined with the CFD simulation was validated using the experimental data. It is concluded that by increasing the UV lamps, UV lamp power, and using more reflective duct wall materials, the in-duct UVGI disinfection performance can be improved. For the multiple-lamp arrangements, placing lamps perpendicular to the airflow in the same row results in a more uniform irradiance distribution and higher overall irradiation than placing them in different rows along the duct, thus increasing the disinfection efficiency. In addition, the duct wall with highly diffusive reflection provides a more uniform irradiance distribution and overall higher average radiation, thus providing better disinfection performance for an in-duct UVGI reactor.

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Hou, D., Wang, L., Katal, A., Yan, S., Zhou, L., Wang, V.*, et al.*
Development of a Bayesian inference model for assessing ventilation condition based on CO2 meters in primary schools.
Building Simulation, Vol. **16** n°(1), (2023), pp. 133-149

Outdoor fresh air ventilation plays a significant role in reducing airborne transmission of diseases in indoor spaces. School classrooms are considerably challenged during the COVID-19 pandemic because of the increasing need for in-person education, untimely and incompleted vaccinations, high occupancy density, and uncertain ventilation conditions. Many schools started to use CO2 meters to indicate air quality, but how to interpret the data remains unclear. Many uncertainties are also involved, including manual readings, student numbers and schedules, uncertain CO2 generation rates, and variable indoor and ambient conditions. This study proposed a Bayesian inference approach with sensitivity analysis to understand CO2 readings in four primary schools by identifying uncertainties and calibrating key parameters. The outdoor ventilation rate, CO2 generation rate, and occupancy level were identified as the top sensitive parameters for indoor CO2 levels. The occupancy schedule becomes critical when the CO2 data are limited, whereas a 15-min measurement interval could capture dynamic CO2 profiles well even without the occupancy information. Hourly CO2 recording should be avoided because it failed to capture peak values and overestimated the ventilation rates. For the four primary school rooms, the calibrated ventilation rate with a 95% confidence level for fall condition is 1.96 +/- 0.31 ACH for Room #1 (165 m(3) and 20 occupancies) with mechanical ventilation, and for the rest of the naturally ventilated rooms, it is 0.40 +/- 0.08 ACH for Room #2 (236 m(3) and 21 occupancies), 0.30 +/- 0.04 or 0.79 +/- 0.06 ACH depending

on occupancy schedules for Room #3 (236 m(3) and 19 occupancies), 0.40 +/- 0.32,0.48 +/- 0.37,0.72 +/- 0.39 ACH for Room #4 (231 m(3) and 8-9 occupancies) for three consecutive days.

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Masoomi, M. A., Salmanzadeh, M., Ahmadi, G., Asme.
Dispersion of particles coming out of the mouth while speaking in a ventilated indoor environment.
In: ASME-Fluids-Engineering-Division Summer Meeting (FEDSM). Electr Network2021.

Breathing air that contains virus-infected droplets is the leading cause of Covid-19 transmission. Sneezing, coughing, breathing, and talking of an infected person would generate aerosolized droplets that carry the coronavims. Earlier research efforts have focused on sneezing and coughing as the primary transmission sources. New experiments and field studies have shown that breathing and talking are also effective mechanisms in spreading viruses. In this article, the dispersion of particles/droplets during speaking is studied. COVID-19 virus is about 120 nanometers and is suspended in saliva or mucus droplets emitted by an injected person. These droplets evaporate in a fraction of a second as they enter the environment and reduce in size. However, the droplets' viral content remains the same as they move by the room's airflow. The particles from sneezing and coughing are larger than those released by speaking. As the particles/droplets are small, the effect of gravity is small, and they remain suspended in the air for a long time. Also, being small makes them more easily penetrate the respiratory passages. Using the computational fluid dynamics method in conjunction with the ANSYS-Fluent software, the particle transport and dispersion were simulated. The Eulerian approach modeled the airflow (continuous phase), and the Lagrangian approach modeled the particle (discrete phase) movements. This study also investigated the ventilation system's effects on the distribution of particles in the indoor environment. The displacement and mixing air distribution systems were considered. Simulation results showed that droplets remain suspended in the room for a relatively long time after evaporation. Large particles were deposited quickly, and a significant percentage of smaller particles were removed by the ventilation system. The concentration of particles in the upper half of the room was also quite low for the mixing ventilation system. This was due to the fact that the room air mixing system is relatively uniform; this uniformity of airflow caused the particles to get trapped quickly. Also, for the displacement system, the room airflow was not uniform; these particles were then dispersed in the room and spent more time in the indoor environment.

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Ming, R., Mustakallio, P., Kosonen, R., Kaukola, T., Kilpeläinen, S., Li, B.*, et al.*
Effect of active chilled beam layouts on ventilation performance and thermal comfort under variable heat gain conditions.
Building and Environment, Vol. **228**, (2023)

The active chilled beam system has been popularly used in office and meeting rooms. There are very few studies of their terminal configuration on the thermal comfort and ventilation performance of systems with different heat gains. A comparative experimental study was implemented in mock-up office and meeting rooms to provide a comprehensive evaluation of the airflow patterns, air distribution, ventilation effectiveness, and local thermal comfort of the 4-way system. Four different terminal layouts with two types of the chilled beams (600 unit and 1200 unit sized 0.6 m × 0.6 m and 1.2 m × 0.6 m, respectively) were tested at three heat gain levels: low (46W/m2) and medium (66W/m2) heat gains in the office room, and high (92W/m2) heat gain in the meeting room. The results revealed that the terminal layouts and heat gain levels had significant effects on air distribution and local thermal comfort. The increased heat gains generated lower heat removal effectiveness, worse indoor thermal uniformity, and increased risk of draught. Generally, the 1200-unit system performed better than that with 600 units for heat removal effectiveness and contaminant removal effectiveness. In terms of local thermal comfort, the 600-unit system generally provided higher performance than that with the 1200-unit system. The practical recommendations for the system design and operation stages are provided based on the operating range of the 4-way systems under variable terminal layouts and heat gain conditions.

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Zafar, M. U., Lee, V., Timms, W., Bounds, P., Uddin, M., Asme.
Effects of HVAC settings and windows open or close on the Sars-Cov-2 virus transmission inside a mass transit system bus.
In: ASME International Mechanical Engineering Congress and Exposition (IMECE). Electr Network2021.

With the current outbreak of SARS-CoV-2, public transportation is a key area which must be investigated to ensure both passenger safety and efficiency of passenger transport to best serve the community and reduce environmental footprint. In this paper, the transport of the SARS-CoV-2 virus through human respiratory particles is examined using transient Computational Fluid Dynamics (CFD) simulations to determine the impacts different ventilation configurations on the probability of viral exposure. The motion of the viral particles was simulated first by solving for the flow field inside the bus using a proprietary Navier-Stokes finite-volume solver, RavenCFD by Corvid Technologies, and then using Lagrangian particle tracking (LPT) post processing techniques. The LPT methods used allowed for the injection of respiratory particles, according to distributions found in literature, which included sneezing, coughing, and speaking. To fully investigate the problem space the moving bus was modeled with the windows in various states of closure and with various HVAC configurations. In all scenarios, a volumetric Viral Mean Exposure Time (VMET), which considers the viral load calculations, was used to quantify the various exposure risk of all passengers on the bus. It was found that the most efficient ventilation system on a public transport bus was to keep the windows closed and HVAC of main cabin at maximum to minimize the viral exposure within the bus.

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Yao, Y., Zhang, H., Yang, R., Huang, L., Deng, Q.
The Effects of Intervention Strategies for COVID-19 Transmission Control on Campus Activity.
BDSC 2022. China National Conference on Big Data and Social Computing. 11-13 August 2022. Hangzhou, China

University is one of the most likely environments for the cluster infection due to the long-time close contact in house and frequent communication. It is critical to understand the transmission risk of COVID-19 under various scenario, especially during public health emergency. Taking the Tsinghua university's anniversary as a representative case, a set of prevention and control strategies are established and investigated. In the case study, an alumni group coming from out of campus is investigated whose activities and routes are designed based on the previous anniversary schedule. The social closeness indicator is introduced into the Wells-Riley model to consider the factor of contact frequency. Based on the anniversary scenario, this study predicts the number of the infected people in each exposure indoor location (including classroom, dining hall, meeting room and so on) and evaluates the effects of different intervention measures on reducing infection risk using the modified Wells-Riley model, such as ventilation, social distancing and wearing mask. The results demonstrate that when applying the intervention measure individually, increasing ventilation rate is found to be the most effective, whereas the efficiency of increased ventilation on reducing infection cases decreases with the increase of the ventilation rate. To better prevent COVID-19 transmission, the combined intervention measures are necessary to be taken, which show the similar effectiveness on the reduction of infected cases under different initial infector proportion. The results provide the insights into the infection risk on university campus when dealing with public health emergency and can guide university to formulate effective operational strategies to control the spread of COVID-19.

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Azevedo, A., Liddie, J., Liu, J., Schiff, J. E., Adamkiewicz, G., Hart, J. E.
Effects of portable air cleaners and A/C unit fans on classroom concentrations of particulate matter in a non-urban elementary school.
PloS one, Vol. **17** n°(12), (2022)

Given the increased use of air cleaners as a prevention measure in classrooms during the COVID-19 pandemic, this study aimed to investigate the effects of portable air cleaners with HEPA filters and window A/C fans on real-time (1 minute) concentrations of PM less than 2.5 microns (PM2.5) or less than 1 microns (PM1.0) in two classrooms in a non-urban elementary school in Rhode Island. For half of each school day, settings were randomized to "high" or "low" for the air cleaner and "on" or "off" for the fan. Descriptive statistics and linear mixed models were used to evaluate the impacts of each set of conditions on PM2.5 and PM1.0 concentrations. The mean half-day concentrations ranged from 3.4-4.1 mug/m3 for PM2.5 and 3.4-3.9 mug/m3 for PM1.0. On average, use of the fan when the air cleaner was on the low setting decreased PM2.5 by 0.53 mug/m3 [95% CI: -0.64, -0.42] and use of the filter on high (compared to low) when the fan was off decreased PM2.5 by 0.10 mug/m3 [95% CI: -0.20, 0.005]. For PM1.0, use of the fan when the air cleaner was on low decreased concentrations by 0.18 mug/m3 [95% CI: -0.36, -0.01] and use of the filter on high (compared to low) when the fan was off decreased concentrations by 0.38 mug/m3 [95% CI: -0.55, -0.21]. In general, simultaneous use of the fan and filter on high did not result in additional decreases in PM concentrations compared to the simple

addition of each appliance's individual effect estimates. Our study suggests that concurrent or separate use of an A/C fan and air cleaner in non-urban classrooms with low background PM may reduce classroom PM concentrations.

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Fujishiro, A., Asai, T., Saito, T., Okuda, Y.
Efficacy of an aerosol suction device Free-100 M in removing aerosols produced by coughing to minimize COVID-19 infection.
Journal of Anesthesia, (2022)

The healthcare workers are at the greatest risk of being exposed to viral infection during airway management of a patient with coronavirus disease 2019 (COVID-19). An air extractor which suctions air around the patient's face would reduce the spread of viral aerosols during coughing, but no study has confirmed this. We assessed whether or not an air extractor reduces the amount of aerosols spreading toward the operator's face, during coughing of simulated patients.

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Ha, W., Stiefel, M., Gries, J., Cadnum, J., Torres-Teran, M., Wilson, B.*, et al.*
Evaluation of Interventions to Improve Ventilation in Households to Reduce Risk for Transmission of Severe Acute Respiratory Syndrome Coronavirus 2.
Pathogens and Immunity, Vol. **7** n°(2), (2022), pp. 120-130

Background: Inadequate ventilation may contribute to the high risk for household transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).
Methods: We evaluated the effectiveness of several interventions recommended to improve ventilation in households. In 7 residential homes, carbon dioxide monitoring was conducted to assess ventilation in occupied open areas such as family rooms and in bedrooms and/or offices. Carbon dioxide levels above 800 parts per million (ppm) were considered an indicator of suboptimal ventilation for the number of people present. In 1 of the 7 homes, various interventions to improve ventilation or to filter air were assessed in a kitchen area by measuring clearance of aerosol particles produced using an aerosol-based spray system and carbon dioxide generated by cooking with a gas stove.
Results: Carbon dioxide levels rose above 800 ppm in bedrooms and offices with 2 occupants when windows and doors were closed and in open areas during gatherings of 5 to 10 people; carbon dioxide levels decreased when windows or doors were opened. Clearance of carbon dioxide and aerosol particles significantly increased with interventions including running fans, operating portable air cleaners, and opening windows, particularly when there was a noticeable breeze or when a window fan was used to blow contaminated air outside.
Conclusion: In households, several measures to improve ventilation or air filtration were effective in reducing carbon dioxide accumulation or enhancing clearance of carbon dioxide and aerosol particles. Studies are needed to determine if interventions to improve ventilation can reduce the risk for airborne transmission of SARS-CoV-2 in households.

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Shinohara, N., Ogata, M., Kim, H., Kagi, N., Tatsu, K., Inui, F.*, et al.*
Evaluation of shields and ventilation as a countermeasure to protect bus drivers from infection.
Environmental Research, Vol. **216**, (2023)

We evaluated the deposition of droplets and droplet nuclei-generated by simulated coughing and talking from three points in a bus-on the driver's face and on surfaces around the driver (e.g., the steering wheel), based on whether countermeasures were taken, and assuming that an infected passenger was talking to the driver. When a shield, such as acrylic boards or polyvinyl chloride (PVC) sheets, was used as the countermeasure, the deposition of artificial droplets (>4 mu m), emitted from beside or behind the driver, on his eyes, mouth, and cheeks reduced by two to three orders of magnitude or more. Deposition on the surfaces around the driver was also reduced following the use of shields. For artificial droplet nuclei (1.3 mu m of polystyrene latex (PSL)) emitted from at-omizers beside the driver, the operation of the ventilation fan (VF) and air conditioner (AC), and defroster (DEF) greatly reduced the driver's exposure, while the use of the shield did not. The infection risk of the driver was estimated through exposure to the virus via transfer to the mucosa via hands or surface-to-finger, direct adhesion on the mucosa, and direct inhalation of droplets and droplet nuclei. This is under the assumption that the droplets and droplet nuclei measured in this study are 40% the diameter of those after immediately leaving the mouth of the infected person and are constant regardless of particle size. When

using the shield, total infection risk via droplet, airborne, and contact transmission was decreased by 75.0-99.8%. When the shield was not installed, the infection risk decreased by 9.74-48.7% with the operation of the VF, AC, and/or DEF.

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Janssens, A., Laverge, J., Wouters, P., Spruyt, M., Stranger, M., Mampaey, M.*, et al.*
Evaluation of ventilation performance and compliance with Belgian covid-19 guidelines in sport infratructure.
42nd AIVC, 10th TightVent, 8th venticool Conference. 5-6 october 2022, Hilton Hotel, Rotterdam, Netherlands.

During the corona-19 pandemic waves in 2020 and 2021, many cultural and recreational activities inside buildings could no longer take place to prevent virus transmission. In order to allow cultural and recreational sectors to reopen in a safe way by the summer of 2021, a ventilation task force of the corona commissioner's office of the Belgian federal government prepared recommendations for the practical implementation and monitoring of indoor air quality in the context of COVID-19. This implementation plan was conceived as an instrument for building owners or facility managers to evaluate whether existing ventilation facilities, possibly in combination with other technical measures such as opening of windows and doors, or air purification devices, would provide sufficient ventilation to allow a certain number of occupants in a room. In preparation of the resumption of indoor sports activities, a research consortium investigated the applicability and consequences of the federal guidelines specifically for sports infrastructures in Flanders, Belgium. To this end, various sports federations organized a number of test events in the first half of June 2021. The test events took place in four different indoor sports facilities, including fitness centres, a climbing gym and a sports hall, for varying group sizes of athletes and public. In preparation of the test events, the mechanical ventilation systems were inspected and installed ventilation flow rates measured. During the test events, CO2 measurements were carried out throughout the sports infrastructures, and the concentrations were permanently logged. This paper discusses the main results of the ventilation inspections, CO2 monitoring and subsequent analysis. By applying the recommendations of the implementation plan to the test events in sport, the paper further discusses the feasibility of implementing the plan in practice, what the consequences are for the maximum permissible occupation in sports halls (both for athletes and spectators), and provides guidelines on how the ventilation in existing infrastructure can be improved based on the findings.

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Carrasco, I., Molina, C.
Evaluation of ventilation rates in residential and non-residential spaces during occupancy using carbon dioxide concentrations.
36th PLEA "Passive and Low Energy Architecture" Conference. Pontificia Universidad Católica. 22-25 november 2022. Santiago, Chile

Over the last few decades, concerns regarding air quality within buildings have increased, particularly in Europe and the United States. Although it is possible to know the ventilation rate by design, the actual values (during the occupation) usually remain unknown. We measured CO2 concentrations in 40 occupied rooms of three types of buildings (residences, workplaces, and classrooms) during the 2021 winter in Santiago de Chile. Two methods were applied to estimate the ventilation rates: the Decay rate and the Steady State. Results were analyzed by group and method to show variability and disparity. Results show a moderate agreement between methods. They also show a significant difference between houses and other building typologies—none of the residential buildings complied with the national or international standard for minimum ventilation rates. Conversely, 78% of workplaces meet the minimum recommendation, and 55% meet the minimum recommendation against COVID-19. Finally, 91% of the evaluated classrooms satisfactorily meet the international standard, but only 9% of them meet the minimum recommendation against COVID-19. This study suggests that an increase in ventilation rates might be required to achieve acceptable indoor air quality and reduce the risk of airborne transmission.

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Micolier, A., Berger, C., Rigault, B., Lepelletier, D., Roubaty, J.-L., Mendez, M.
Identification des stratégies de ventilation efficaces pour réduire le risque d'infection Covid-19 à l'intérieur des bâtiments grâce au modèle numérique multizone INDALO®.
Environnement, Risques & Santé, Vol. **21** n°(6), (2022), pp. 419-431

Faced with epidemic risks, ensuring an exchange of air and sufficient direction of airflow is essential to reduce the airborne transmission of infectious agents in buildings. In this study, we strove to identify effective ventilation strategies to reduce the risk of infection by COVID-19 inside buildings. To do so, we developed a multi-route transmission model of SARS-CoV-2 (INDALO®-COVID) which estimates a risk of infection.
This study enabled us to quantify the impact of two preventive measures (installation of a mobile air purifier and increase in the renewal of air by the air purification unit) on the risk of COVID-19 infection in a nursing home. In the configuration used in this study, the use of an air purifier in the rooms of residents with COVID-19 appears to be the most effective measure to reduce the viral load potentially transported to other areas of the building, and thus to reduce the risk of COVID-19 infection among all residents.
The digital model developed is a versatile and ready-to-use solution, which can compare preventive measures and design/renovation choices for different types of buildings and uses.

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Jassim, S. S., Mahdi, A. A.
An investigation of a nonthermally insulated mixing ventilated office room for partitioning in hot and dry climate by simulation approach.
Heat Transfer, (2022)

Due to the recent situation, especially since the beginning of the spread of COVID-19, work in administrative or service offices under conditions of social divergence and the working environment has become conditional on the ventilation system; thus, enhancing ventilation's function to minimize the spread of infections, and impurities to larger areas or limiting its transition from one employee to another who work in the same place for long hours. A nonisothermal office room, designed with a mixing ventilation system has been simulated by using AIRPAK3.0.16 software, and RNG k–epsilon as a turbulence model, where the adoption of partitions in such rooms was studied and its effect on thermal employee's comfort and quality of fresh air, by monitoring the air diffusion performance index, prediction of the mean vote, and percentage of predicted dissatisfied. The main findings were that partitions are seen as a technique of preventing and protecting against the spread of pollutants and illnesses since they prevent contaminants from reaching the breathing zones of the office's inhabitants. It was noted that the change in the height of the partition with an increase of 10% of the room's height as a gap, gives a more acceptance value of the heat removal efficiency and ventilation rate.

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Srikrishna, D.
Long-term experience with rapid air filtration (6 to 15 air changes per hour) in a K-5 elementary school using HEPA and Do-It-Yourself (DIY) air purifiers during the COVID-19 pandemic.
medRxiv. Preprint, (2022)

EPA recommends DIY air cleaners for temporary use during wildfires, and a recent EPA study reported inconsistent usage in homes due to excessive noise. Questions also remain about wear and tear including how long filters retain their filtration properties and need to be replaced. Herein we report real-world experience from daily usage of 47 HEPA and 60 DIY air cleaners in a California elementary school during the academic school year from spring 2021 through fall of 2022 across 16 classrooms, a library, an auditorium, a lunchroom, and in a hallway. Three to six purifiers were needed in classrooms to meet California (CDPH) recommended 6 to 12 air changes per hour (ACH) for prevention of aerosol transmission of COVID-19 in classrooms. Teachers reported noise generated by DIY purifiers on lowest fan speed as acceptable for classroom use. Filtration efficiency at 0.3 µm (most penetrating particle size) for DIY air cleaners with 5” MERV 16 filters used in the classrooms averages 77 % after six months compared to 92% for newly installed filters. Portable air cleaners (HEPA and DIY) averaged and estimated 10 ACH (6-15 ACH) across the 16 classrooms demonstrating feasibility and unit economics of meeting CDPH targets per classroom for $200-$650 with DIY versus $600-$12,000 with the HEPA models used. In one 9000 cubic foot classroom with 7 air purifiers, air exchange rate was measured using ambient aerosols at 18 ACH from air purifiers (within 20% of ACH estimated based on CADR of purifiers) and 7 ACH from HVAC for a combined total of 25 ACH. The procedure using ambient aerosols to verify ACH from portable air cleaners and HVAC can be the basis for ACH certification or verification without generating aerosol contaminants (e.g. salt water, smoke, tracers) which may be unsafe or disallowed in schools.Competing Interest StatementThe authors have declared no competing interest.Funding StatementThis study did not receive any funding Author DeclarationsI confirm all relevant ethical guidelines have been followed, and any necessary IRB and/or ethics

committee approvals have been obtained.YesI confirm that all necessary patient/participant consent has been obtained and the appropriate institutional forms have been archived, and that any patient/participant/sample identifiers included were not known to anyone (e.g., hospital staff, patients or participants themselves) outside the research group so cannot be used to identify individuals.YesI understand that all clinical trials and any other prospective interventional studies must be registered with an ICMJE-approved registry, such as ClinicalTrials.gov. I confirm that any such study reported in the manuscript has been registered and the trial registration ID is provided (note: if posting a prospective study registered retrospectively, please provide a statement in the trial ID field explaining why the study was not registered in advance).YesI have followed all appropriate research reporting guidelines and uploaded the relevant EQUATOR Network research reporting checklist(s) and other pertinent material as supplementary files, if applicable.YesAll data produced in the present study are available upon reasonable request to the authors

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Dixon, B. E., Fadel, W. F., Duszynski, T. J., Caine, V. A., Meyer, J. F., Saysana, M.
Mitigation of COVID-19 at the 2021 National Collegiate Athletic Association Men's Basketball Tournament.
Bmc Public Health, Vol. **22** n°(1), (2022)

Background Data are lacking regarding the risk of viral SARS-CoV-2 transmission during a large indoor sporting event involving fans utilizing a controlled environment. We sought to describe case characteristics, mitigation protocols used, variants detected, and secondary infections detected during the 2021 National Collegiate Athletic Association (NCAA) Men's Basketball Tournament involving collegiate athletes from across the U.S. Methods This retrospective cohort study used data collected from March 16 to April 3, 2021, as part of a closed environment which required daily reverse transcription-polymerase chain reaction (RT-PCR) testing, social distancing, universal masking, and limited contact between tiers of participants. Nearly 3000 players, staff, and vendors participated in indoor, unmasked activities that involved direct exposure between cases and noninfected individuals. The main outcome of interest was transmission of SARS-CoV-2 virus, as measured by the number of new infections and variant(s) detected among positive cases. Secondary infections were identified through contact tracing by public health officials. Results Out of 2660 participants, 15 individuals (0.56%) screened positive for SARS-CoV-2. Four cases involved players or officials, and all cases were detected before any individual played in or officiated a game. Secondary transmissions all occurred outside the controlled environment. Among those disqualified from the tournament (4 cases; 26.7%), all individuals tested positive for the Iota variant (B.1.526). All other cases involved the Alpha variant (B.1.1.7). Nearly all teams (N = 58; 85.3%) reported that some individuals had received at least one dose of a vaccine. Overall, 17.9% of participants either had at least one dose of the vaccine or possessed documented infection within 90 days of the tournament. Conclusion In this retrospective cohort study of the 2021 NCAA Men's Basketball Tournament closed environment, only a few cases were detected, and they were discovered in advance of potential exposure. These findings support the U.S. Centers for Disease Control and Prevention (CDC) guidelines for large indoor sporting events during the COVID-19 pandemic.

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Foat, T. G., Higgins, B., Abbs, C., Maishman, T., Coldrick, S., Kelsey, A.*, et al.*
Modeling the effect of temperature and relative humidity on exposure to SARS-CoV-2 in a mechanically ventilated room.
Indoor air, Vol. **32** n°(11), (2022)

Computational fluid dynamics models have been developed to predict airborne exposure to the SARS-CoV-2 virus from a coughing person in a mechanically ventilated room. The models were run with three typical indoor air temperatures and relative humidities (RH). Quantile regression was used to indicate whether these have a statistically significant effect on the airborne exposure. Results suggest that evaporation is an important effect. Evaporation leads to respiratory particles, particularly those with initial diameters between 20 and 100mum, remaining airborne for longer, traveling extended distances and carrying more viruses than expected from their final diameter. In a mechanically ventilated room, with all of the associated complex air movement and turbulence, increasing the RH may result in reduced airborne exposure. However, this effect may be so small that other factors, such as a small change in proximity to the infected person, could rapidly counter the effect. The effect of temperature on the exposure was more complex, with both positive and negative correlations. Therefore, within the range of conditions studied here, there is no clear guidance on how the temperature should be controlled to reduce exposure. The results highlight the importance of ventilation, face coverings and maintaining social distancing for reducing exposure.

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Indoor air, Vol. **32** n°(11), (2022)

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Quintero, F., Nagarajan, V., Schumacher, S., Todea, A. M., Lindermann, J., Asbach, C.*, et al.*

Reducing Particle Exposure and SARS-CoV-2 Risk in Built Environments through Accurate Virtual Twins and Computational Fluid Dynamics.

Atmosphere, Vol. **13** n°(12), (2022)

The World Health Organization has pointed out that airborne transmission via aerosol particles can be a strong vector for the spread of SARS-CoV-2. Protecting occupants from infectious diseases or harmful particulate matter (PM) in general can be challenging. While experimentally outlining the detailed flow of PM in rooms may require complex setups, computational fluid dynamics (CFD) simulations can provide insights into improving the safety of the built environment and the most effective positioning of air-purifying devices. While previous studies have typically leveraged Reynolds-averaged Navier–Stokes (RANS) approaches for predicting particle propagation, the turbulence length scales accurately captured in these simulations may not be sufficient to provide a realistic spread and the mixing of particles under the effects of forced convection. In this paper, we experimentally validate a Lattice Boltzmann very large eddy simulation (VLES) approach including particle modeling. We also demonstrate how this simulation approach can be used to improve the effectiveness of air filtration devices in realistic office environments.

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Bueno De Mesquita, P. J., Sokas, R.

SARS-CoV-2 Reduction in Shared Indoor Air.

JAMA, Vol. **328** n°(21), (2022)

To the Editor A recent Viewpoint underscored the importance of implementing proven approaches to reducing the risk of COVID-19 in shared indoor spaces through ventilation, filtration, and upper-room germicidal UV-C light. However, we believe the authors may have understated important engineering controls. Although opening windows and doors helps improve ventilation, increasing temperatures, wildfire smoke, and air pollution driven by global climate change reduce the usefulness of these interventions.Air disinfection by UV-C light (known as UV germicidal irradiation or, more recently, germicidal UV [GUV]) effectively inactivates airborne pathogens, including SARS-CoV-2, influenza viruses, and Mycobacterium tuberculosis. Exhaled breath with infectious aerosols flows overhead for disinfection via thermal plumes, assisted by ceiling fans or other means of circulation, before returning to the breathing zone. This technology has decades of demonstrated effectiveness, requires no active participation by room occupants, and offers a nonpharmaceutical intervention to reduce transmission and mitigate super-spreader events. Given the frequency of breakthrough infections and the continued emergence of subvariants, we believe that GUV air disinfection is warranted not only in high-risk settings such as school nurses' offices and homeless shelter sleeping areas, but in every cafeteria, gymnasium, classroom, and other congregate public settings.

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Park, S.-H., Lee, H.-S., Ahn, N.-H.
A Study on the Development of Window-Attached Ventilation Panel Using Air-Flow Inducing (en coréen).
Journal of Korean Institute of Architectural Sustainable Environment and Building Systems, Vol. **16** n°(4), (2022), pp. 285-295

It is very important to prepare ventilation measures in buildings. In particular, the importance of indoor ventilation has been further emphasized due to the COVID-19. In this study, the window-attached ventilation panel that combines mechanical ventilation and natural ventilation was developed for ventilation of school classrooms, which is a typical densely populated facility, and its performance was verified through experiments. As a result of the experiment, when the airflow outlet of the ventilation panel faces the center at an angle of about 45°, and the smaller the panel area, the higher the airflow velocity and airflow by airflow induction. When the airflow rate of the impeller is high, the air flow speed of the diffuser increases, which increases the induced air flow, so the ventilation air volume is also high. When the window- attached ventilation panel was applied to a classroom having a general volume, about 12 ventilation cycles could be satisfied.

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Goupil De Bouille, J., Luong Nguyen, L. B., Crepey, P., Garlantezec, R., Dore, V., Dumas, A.*, et al.*
Transmission of SARS-CoV-2 during indoor clubbing events: A clustered randomized, controlled, multicentre trial protocol.
Frontiers in public health, Vol. **10**, (2022)

Introduction: The SARS-CoV-2 pandemic led to the implementation of several non-pharmaceutical interventions (NPIs), from closings of bars and restaurants to curfews and lockdowns. Vaccination campaigns started hoping it could efficiently alleviate NPI. The primary objective of the "Indoor Transmission of COVID-19" (ITOC) study is to determine among a fully vaccinated population the relative risk of SARS-CoV-2 transmission during one indoor clubbing event. Secondary objectives are to assess the transmission of other respiratory viruses, risk exposure, and attitudes toward COVID-19 vaccination, health pass, and psychological impact of indoor club closing. Methods and analysis: Four thousand four hundred healthy volunteers aged 18-49 years and fully vaccinated will be included in Paris region. The intervention is an 8-hour indoor clubbing event with no masks, no social distance, maximum room capacity, and ventilation. A reservation group of up to 10 people will recruit participants, who will be randomized 1:1 to either the experimental group (2,200 volunteers in two venues with capacities of 1,000 people each) or the control group (2,200 volunteers asked not to go to the club). All participants will provide a salivary sample on the day of the experiment and 7 days later. They also will answer several questionnaires. Virological analyses include polymerase chain reaction (PCR) of salivary samples and air of the venue, investigating SARS-CoV-2 and 18 respiratory viruses. Ethics and dissemination: Ethical clearance was first obtained in France from the institutional review board (Comite de Protection des Personnes Ile de France VII - CPP), and the trial received clearance from the French National Agency for Medicines and Health Products (Agence National de Securite du Medicament - ANSM). The trial is supported and approved by The Agence Nationale Recherche sur le SIDA, les hepatites et maladies emergences (ANRS-MIE). Positive, negative, and inconclusive results will be published in peer-reviewed scientific journals.

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Kehler, P., Chaves, C., Garcia, A., Centurion, H., Escobar, A., Lopes, L.*, et al.*
Ventilation CFD analysis at an classroom as a tool for air safety verification under Covid19 context, a case study.
ASME International Mechanical Engineering Congress and Exposition (IMECE). November 1–5, 2021, Virtual, Online

The COVID 19 pandemic has struck the global economy and slowed down human activity. Paraguay, a small South-American country, was not an exception. This work results from the urgent need to reopen universities, schools, and other academic institutions to resume teaching activities in light of restrictive access to online learning in Paraguay. In order to contain the spread of this virus, school activities such as course lectures were placed on hold indefinitely. Inappropriate airflow in an enclosed space is one of the main factors in the spread of this virus. When combined with personal protective equipment, proper air ventilation and air replacement can significantly reduce this airborne virus's spread. Potential sources of contaminant accumulation are stagnant locations of air in a closed volume. It is, therefore, essential to first identify these hot spots. Utilizing computational tools, such as CFD, an airflow analysis can be conducted to see any potential stagnant point. In the case of a classroom, it will then allow proper airflow by avoiding

stagnant points by moving furniture, equipment, and chairs in combination to adding walls and opening windows and doors. This type of CFD study will set the benchmark for future classroom layout standards in this pandemic background. The work discussed here is a case study on a 300 student classroom at the Faculty of Engineering at the National University of Asuncion. The CFD results showed detailed infounation on flow patterns and velocity profiles in the analyzed classroom environment and air cycle and exhaust results. The six air conditioning systems blowing 300 CFM each, combined with eight fans installed at the ceiling, forced air to recirculate and helped to remove old air to the windows and suction some new air from doors. This helped university administrators to reopen some class areas and keep their faculties and students safe for lectures. It is important to remark here that air reposition could be measured, showing 200 CFM air removal in this first simulation run. Further analysis with a different internal layout will be needed to see if any improvements can be made. It is expected to have a much better air removal by adding a localized exhaust fan. This work suggests the location of each location's outlet points and flows capacity to ensure proper ventilation is achieved in this particular case study. Other academic institutions are showing interest in implementing this computational tool to design classroom layout as well as ventilation schemes.

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Wouters, P., Janssens, A., Borsboom, W., Kapsalaki, M.
Ventilation challenges in a changing world.
42nd AIVC, 10th TightVent, 8th venticool Conference. 5-6 october 2022, Hilton Hotel, Rotterdam, Netherlands.

More than ever in the past, climate change and the transition to carbon neutrality are at the center of many countries´ policies and research programmes. The building sector plays a crucial role in achieving these goals, considering the carbon emissions attributed to buildings' construction and operation, and its potential for better energy performance. At the same time the COVID-19 crisis has emphasized the need to improve indoor air quality (IAQ) and ventilation in our buildings to reduce the risks of airborne virus transmission. All these challenges require a transformation of the existing building stock that at the same time achieves better IAQ and lowers environmental impact. In 2022 the Air Infiltration and Ventilation Centre organizes its first international conference since the beginning of the COVID-19 crisis. Therefore the conference organizers want to pay specific attention to the role of ventilation and infiltration in building decarbonization, and improvement of indoor air quality including epidemic preparedness. How can design, construction and renovation practices, innovative and digital technologies help in today's challenges? This is the context defining the core theme of the joint 42nd AIVC, 10th TightVent and 8th venticool Conference: "Ventilation Challenges in a Changing World".

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