Rapport de veille n° 43

Aéraulique et COVID-19

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Google Scholar, Lens et WoS

Melzow, F., Mertens, S., Todorov, H., Groneberg, D. A., Paris, S., Gerber, A.
Aerosol exposure of staff during dental treatments: a model study.
BMC Oral Health, Vol. **22** n°(1), (2022)

Due to exposure to potentially infectious aerosols during treatments, the dental personnel is considered being at high risk for aerosol transmitted diseases like COVID-19. The aim of this study was to evaluate aerosol exposure during different dental treatments as well as the efficacy of dental suction to reduce aerosol spreading.

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Hardy, N., Dalli, J., Khan, M. F., Nolan, K., Cahill, R. A.
Aerosols, airflow, and airspace contamination during laparoscopy.
The British journal of surgery, Vol. **108** n°(9), (2021), pp. 1022-1025

Laparoscopic surgery has been undermined throughout the COVID-19 pandemic by concerns that it may generate an infectious risk to the operating team through aerosolization of peritoneal particles. There is anyway a need for increased awareness and understanding of the occupational hazard for surgical teams regarding unfiltered escape of pollutants generated by surgical smoke and other microbials. Here, the aerosol-generating nature of this access modality was confirmed through repeatable real-time methodology both qualitatively and quantitively to inform best practice and additional engineering solutions to optimize the operating room environment.

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Burnham, J. P., Betz, F., Lautz, R., Mousavi, E., Martinello, R. A., Mcgain, F.*, et al.*
Air exchanges, climate change, and severe acute respiratory coronavirus virus 2 (SARS-CoV-2): Results from a survey of the Society of Healthcare Epidemiology of America Research Network (SRN).
Antimicrobial Stewardship and Healthcare Epidemiology, Vol. **2** n°(1), (2022)

Abstract In this cross-sectional survey, we assessed knowledge, attitudes and behaviors regarding operating room air-change rates, climate change, and coronavirus disease 2019 (COVID-19) pandemic implications. Climate change and healthcare pollution were considered problematic. Respondents checked air exchange rates for COVID-19 and ∼25% increased them. Respondents had difficulty completing questions concerning hospital heating, ventilation and air conditioning (HVAC) systems.

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Osterman, E., Dovjak, M., Vaupotič, J., Verbajs, T., Mlakar, U., Zavrl, E.*, et al.*
Analysis of Educational Building's Ventilation Suitability to Prevent the Spread of Coronavirus (SARS-CoV-2).
Strojniški vestnik-Journal of Mechanical Engineering, Vol. **68** n°(4), (2022), pp. 233-239

In a larger educational building in Slovenia, we examined the efficiency of ventilation systems by analysing the operation of the heating, ventilation, and air conditioning (HVAC) system in several classrooms. Using the Federation of European Heating, Ventilation and Air Conditioning Associations (REHVA) COVID-19 ventilation calculator, the probability of infection due to the spread of coronavirus through aerosol particles and the reproduction number were calculated based on the classroom occupancy, ventilation rates, and other parameters (i.e., classroom characteristics, preventive measures). Firstly, different levels of ventilation

capacity (50 % and 80 %) were applied. Considering the distance between persons 1.5 m and wearing the masks of all participants, the probability of infection during lectures was always lower than 1 %. Secondly, the maximum number of students that can attend lectures is about 30 %, as calculated according to the legal requirements, recommendations, and given conditions.

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Pelletier, K., Calautit, J.

Analysis of the performance of an integrated multistage helical coil heat transfer device and passive cooling windcatcher for buildings in hot climates.

Journal of Building Engineering, Vol. **48**, (2022)

In a world of increasing population, a pending global energy crisis and the worsening impact of global warming and climate change, there needs to be a focus on re-designing building services to protect occupants at a low-energy cost. Traditional Heating, Ventilation and Air-Conditioning (HVAC) systems do not serve the future of the built environment as they rely on fans which typically constitute 25 % of a building's energy consumption. Additionally, even the energy-saving strategies such as using recirculated air in mechanical ventilation systems have posed an occupancy wellbeing issue in the wake of the Covid-19 pandemic by promoting the spread of airborne disease. Therefore, natural ventilation technologies, such as windcatchers, present an advantage over mechanical systems from energy consumption and occupancy wellbeing perspectives. This paper presents the development of a multistage windcatcher with Helical Coil Heat Transfer Device (HCHTD) to enhance its cooling performance for buildings located in hot climates. The evaluation of the ventilation and cooling performance of the windcatcher with HCHTD, through a Computational Fluid Dynamics (CFD) model, includes geometric parametric studies, operating condition analyses and ventilation requirement assessment. The modelling approach was validated using previous works data, resulting in good agreement. This novel concept achieved a noteworthy range of cooling of 8.6 K-14.25 K for a range of wind speeds of 1-4 m/s and a temperature of 39C, based on typical hot conditions in Australia. The focus of the study was to assess the impact of geometry compactness on the cooling and ventilation performance of the windcatcher with HCHTD. The outcome is that the novel helical coil heat transfer device could offer competitive cooling whilst meeting fresh air requirements, even at low wind speeds, compared to a windcatcher with a straight cylindrical heat transfer device.

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Aguilar, A. J., De La Hoz-Torres, M. L., Costa, N., Arezes, P., Martinez-Aires, M. D., Ruiz, D. P.

Assessment of ventilation rates inside educational buildings in Southwestern Europe: Analysis of implemented strategic measures.

Journal of Building Engineering, Vol. **51**, (2022)

The pandemic caused by COVID-19 has highlighted the need to ensure good indoor air quality. Public buildings (educational buildings in particular) have come under the spotlight because students, teachers and staff spend long periods of the day indoors. This study presents a measurement campaign for the assessment of ventilation rate (VR) and ventilation strategies in educational buildings in Southwestern Europe, Portugal and Spain. A representative sample of the teaching spaces of the Azurém Campus (Guimarães, Portugal) and the Fuentenueva Campus (Granada, Spain) have been analyzed. Natural ventilation is the predominant ventilation strategy in these spaces, being the most common strategy in educational buildings in Europe. VR was estimated under different configurations, using the CO2 decay method. Subsequently, the CO2 concentration was estimated according to occupancy and the probability of infection risk was calculated using the Wells-Riley equation. The obtained VR varied between 2.9 and 20.1 air change per hour (ACH) for natural cross ventilation, 2.0 to 5.1 ACH for single-sided ventilation and 1.8 to 3.5 for mechanically ventilated classrooms. Large differences in CO2 concentrations were verified, depending on the analyzed ventilation strategy, ranging from 475 to 3903 ppm for the different scenarios. However, the probability of risk was less than 1% in

almost all of the classrooms analyzed. The results obtained from the measurement campaign showed that the selection of an appropriate ventilation strategy can provide sufficient air renewal and maintain a low risk of infection. Ventilation strategies need to be reconsidered as a consequence of the health emergency arising from the COVID-19 pandemic.

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Chen, Y.-H., Tu, Y.-P., Sung, S.-Y., Weng, W.-C., Huang, H.-L., Tsai, Y. I.
A comprehensive analysis of the intervention of a fresh air ventilation system on indoor air quality in classrooms.
Atmospheric Pollution Research, Vol. **13** n°(4), (2022)

Adequate classroom air quality is vital to student health and learning outcomes. Prolonged periods of air conditioner use in enclosed classrooms may result in poor air quality. However, opening classroom windows may expose students to air pollutants if the outdoor air quality is poor. This study investigated CO2 and PM2.5 concentrations in 86 classrooms installed with air conditioners in elementary and middle schools in southern Taiwan, each additionally installed with a fresh air ventilation system equipped with an Ell-class filter. Enclosed air-conditioned classrooms generally have a CO2 concentration greater than 2500 ppm; occasionally, this figure reaches 3500 ppm. With the installed air ventilation system operating, the mean classroom CO2 concentration decreased to 1084 +/- 203 ppm, and the median CO2 concentration decreased to 1120 ppm. However, the CO2 concentrations of over half the classrooms remained higher than the concentration advised by the World Health Organization (1000 ppm). This high CO2 concentration was a result of the short distance (1.5-2 m) between the indoor air outlet and the recirculated air inlet resulting in a shortened circuit of air travel. Also, the initial filter installed over the indoor air outlet of the system reduced air penetration into the classroom. When the ventilation system was manually activated without activating the air conditioners, the median PM2.5 concentration measured at the indoor air outlet and the median classroom PM2.5 concentration were 2 mu g/m(3) and 20 mu g/m(3), respectively. This implied the presence of other sources of PM2.5 in classrooms, particularly ceiling and wall-mounted fans. The activation of these fans spread dust onto classroom furniture. Overall, fresh air ventilation systems providing filtered air improve classroom ventilation efficiency and indoor air quality by reducing CO2 and PM2.5 concentrations, but the cleanliness of fans and furniture must be maintained.

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Kendoush, A.
The Elimination of the Return line from the HVAC systems due to COVID-19.
Qeios, (2022)

Due to the spread of the deadly COVID-19 virus in the US and around the world, the author proposes the elimination of the return line from the HVAC (Heating, Ventilation, and Air conditioning) systems , simply by closing the return air damper to avoid the spread of the virus.

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Bi, Y., Aganovic, A., Mathisen, H. M., Cao, G.
Experimental study on the exposure level of surgical staff to SARS-CoV-2 in operating rooms with mixing ventilation under negative pressure.
Building and Environment, (2022)

The purpose of this study was to reveal the exposure level of surgical staff to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) from the patient's nose and wound during operations on COVID-19 patients. The tracer gas N2O is used to simulate SARS-CoV-2 from the patient's nose and wound. In this study, concentration levels of tracer gas were measured in the breathing zones of these surgical staff in the

operating room under three pressure difference conditions: −5 pa–15 pa and −25 pa compared to the adjunction room. These influencing factors on exposure level are analyzed in terms of ventilation efficiency and the thermal plume distribution characteristics of the patient. The results show that the assistant surgeon faces 4 to 12 times higher levels of exposure to SARS-CoV-2 than other surgical staff. Increasing the pressure difference between the OR lab and adjunction room can reduce the level of exposure for the main surgeon and assistant surgeon. Turning on the cooling fan of the endoscope imager may result in a higher exposure level for the assistant surgeon. Surgical nurses outside of the surgical microenvironment are exposed to similar contaminant concentration levels in the breathing zone as in the exhaust. However, the ventilation efficiency is not constant near the surgical patient or in the rest of the room and will vary with a change in pressure difference. This may suggest that the air may not be fully mixed in the surgical microenvironment.

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Fierce, L., Robey, A. J., Hamilton, C.
High efficacy of layered controls for reducing exposure to airborne pathogens.
Indoor Air, Vol. **32** n°(2), (2022)

To optimize strategies for curbing the transmission of airborne pathogens, the efficacy of three key controls-face masks, ventilation, and physical distancing-must be well understood. In this study, we used the Quadrature-based model of Respiratory Aerosol and Droplets to quantify the reduction in exposure to airborne pathogens from various combinations of controls. For each combination of controls, we simulated thousands of scenarios that represent the tremendous variability in factors governing airborne transmission and the efficacy of mitigation strategies. While the efficacy of any individual control was highly variable among scenarios, combining universal mask-wearing with distancing of 1 m or more reduced the median exposure by more than 99 % relative to a close, unmasked conversation, with further reductions if ventilation is also enhanced. The large reductions in exposure to airborne pathogens translated to large reductions in the risk of initial infection in a new host. These findings suggest that layering controls is highly effective for reducing transmission of airborne pathogens and will be critical for curbing outbreaks of novel viruses in the future.

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Shu, S., Mitchell, T. E., Wiggins, M. R. R., You, S., Thomas, H., Li, C.
How opening windows and other measures decrease virus concentration in a moving car.
Engineering Computations, (2022)

Purpose Due to the ongoing Covid-19 pandemic, ventilation in a small cabin where social distancing cannot be guaranteed is extremely important. This study aims to find out the best configuration of open and closed windows in a moving car at varying speeds to improve the ventilation efficiency. The effectiveness of other mitigation measures including face masks, taxi screens and air conditioning (AC) systems are also evaluated. Design/methodology/approach Each window is given three opening levels: fully open, half open and fully closed. For a car with four windows, this yields 81 different configurations. The location of virus source is also considered, either emitting from the driver or from the rear seat passenger. Then three different travelling speeds, 5 m/s, 10 m/s and 15 m/s, are examined for the window opening/closing configurations that provide the best ventilation effect. A study into the effectiveness of face masks is realised by adjusting virus injection amounts; and the simulation of taxi screens and AC system simply requires a small modification to the car model. Findings The numerical studies identify the top window opening/closing configurations that provide the most efficient ventilation at different moving speeds, along with a comprehensive ranking list. The results show that fully opening all windows is not always the best choice. Simulations evaluating other mitigation measures confirm good effect of face masks and poor performance of taxi screens and AC systems. Originality/value This work is the first large-scale numerical simulation and parametric study about different window opening/closing configurations of a moving car. The results provide useful guides for travellers in

shared cars to mitigate Covid-19 transmission risks. The findings are helpful to both individuals' health and society's recovery in the Covid-19 era and they also provide useful information to protect people from other respiratory infectious diseases such as influenza.

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Cai, W.
A hygiene ventilation renovation: Systematic partial engineering control for small sharing room with ceiling mixing ventilation for “corona-proof”.
Thèse 2022

The rapid rise in COVID-19 illnesses and deaths globally makes it an urgent situation to figure out a solution to make ventilation systems decrease indoor infectious risks to ensure the initial daily basic behaviors.

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Demirarslan, K. O., Basak, S.
Indoor air quality evaluation in intercity buses in real time traffic.
Advances in Environmental Research-an International Journal, Vol. **11** n°(1), (2022), pp. 17-30

Road transport allows all forms of land conditions to be met at less cost. Because of this function, despite numerous disadvantages, it becomes the most frequently used method of transport, especially in underdeveloped or developing countries. One of the most significant factors used in evaluating the atmosphere's air quality is the amount of CO2, increasing people's density in indoor spaces. The amount of CO2 indoors is, therefore, vital to determine. In this study, CO2 and temperature measurements made on nine different bus journey was made in Turkey. The minimum and maximum values were recorded as 555 ppm and 3000 ppm CO2, respectively, in the measurements. On all journeys, the average concentration is 1088.72 ppm. The minimum and maximum values were measured as 17.4 degrees C and 32.7 degrees C in the temperature measurements, and the average of all trips was calculated to be 25.76 degrees C. In this study conducted before the Covid-19 pandemic, it was determined that the amount of CO2 increased with the density and insufficient ventilation in the buses. The risk of infection increases in places with high human density and low clean air. For situations such as pandemics, CO2 measurement is a rapid indicator of determining human density.

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Szekeres, S., Kostyák, A., Szodrai, F., Csáky, I.
Investigation of Ventilation Systems to Improve Air Quality in the Occupied Zone in Office Buildings.
Buildings, Vol. **12** n°(4), (2022)

As a result of COVID-19, many office buildings around the world have downsized their employees, but the comfort parameters in the building had to be kept. The facilities operation rearranged the workstations to keep physical distance and placed plexiglass sheets on the desks for physical protection. A series of measurements have been carried out with workstation set-ups to examine the fresh air rate in the occupied zone. The effect of plexiglass sheets placed on the desks was also examined to see how it changes the airflow pattern in the occupied zone. As the sheets act as a barrier, the primary air does not reach the occupied zone, therefore, the fresh air rate is less. To modify the properties of the ceiling diffusers a new air-ventilation service element was developed. This attachment allows modifying the properties of the ceiling diffusers. Simulations were made at the relevant zones to validate the measurements. Based on design software, the fresh air ratio for a standard ceiling swirl diffuser is 2.46 v % (volume percentage). A numerical model was used to show the fresh air ratio with the system elements for the two different table arrangements, which were 18.3 v % and 21.4 v %, respectively.

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Aganovic, A., Bi, Y., Cao, G., Kurnitski, J., Wargocki, P.
Modeling the Impact of Indoor Relative Humidity on the Infection Risk of Five Respiratory Airborne Viruses.
In: Research Square Platform LLC ; 2022.

Abstract With a modified version of the Wells-Riley model, we simulated the size distribution and dynamics of five airborne viruses (measles, influenza, SARS-CoV-2, human rhinovirus, and adenovirus) emitted from a speaking person in a typical residential setting over a relative humidity (RH) range of 20 to 80 % and air temperature of 20-25 °C. Besides the size transformation of virus-containing droplets due to evaporation, respiratory absorption and then removal by gravitational settling, the modified model also considered the removal mechanism by ventilation. The trend and magnitude of RH impact depended on the respiratory virus. For rhinovirus and adenovirus humidifying the indoor air from 20/30 % to 50 % will be increasing the relative infection risk, however, this relative infection risk increase will be negligible for rhinovirus and weak for adenovirus. Humidification will have a potential benefit in decreasing the infection risk only for influenza when there is a large infection risk decrease for humidifying from 20 % to 50 %. Regardless of the dry solution composition, humidification will overall increase the infection risk via long-range airborne transmission of SARS-CoV-2.Compared to humidification at a constant ventilation rate, increasing the ventilation rate to moderate levels 0.5 → 2.0 h−1 will have a more beneficial to infection risk decrease for all viruses except for influenza. Increasing the ventilation rate from low values of 0.5 h−1 to higher levels of 6 h−1 will have the dominating effect on reducing the infection risk regardless of virus type.

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Jahromi, H. T., Rolland, S., Jones, J., Coccarelli, A., Sazonov, I., Kershaw, C.*, et al.*
Modelling ozone disinfection process for creating COVID-19 secure spaces.
International Journal of Numerical Methods for Heat & Fluid Flow, Vol. **32** n°(1), (2022), pp. 353-363

Purpose A novel modelling approach is proposed to study ozone distribution and destruction in indoor spaces. The level of ozone gas concentration in the air, confined within an indoor space during an ozone-based disinfection process, is analysed. The purpose of this work is to investigate how ozone is distributed in time within an enclosed space. Design/methodology/approach A computational methodology for predicting the space- and time-dependent ozone concentration within the room across the consecutive steps of the disinfection process (generation, dwelling and destruction modes) is proposed. The emission and removal of ozone from the air volume are possible by means of a generator located in the middle of the room. This model also accounts for ozone reactions and decay kinetics, and gravity effect on the air. Finding This work is validated against experimental measurements at different locations in the room during the disinfection cycle. The numerical results are in good agreement with the experimental data. This comparison proves that the presented methodology is able to provide accurate predictions of the time evolution of ozone concentration at different locations of the enclosed space. Originality/value This study introduces a novel computational methodology describing solute transport by turbulent flow for predicting the level of ozone concentration within a closed room during a COVID-19 disinfection process. A parametric study is carried out to evaluate the impact of system settings on the time variation of ozone concentration within the space considered.

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Ahmadzadeh, M., Shams, M.
Multi-objective performance assessment of HVAC systems and physical barriers on COVID-19 infection transmission in a high-speed train.
Journal of Building Engineering, (2022)

A computational fluid dynamics (CFD) simulation was performed to model and study the transmission risk associated with cough-related SARS-CoV-2 droplets in a real-world high-speed train (HST). In this study, the

evaporating of the droplets was considered. Simulation data were post-processed to assess the fraction of the particles deposited on each passenger's face and body, suspended in air, and escaped from exhausts. Firstly, the effects of temperature, relative humidity, ventilation rate, injection source, exhausts' location and capacity, and adding the physical barriers on evaporation and transport of respiratory droplets are investigated in long distance HST. The results demonstrate that overall, 6–43 % of the particles were suspended in the cabin after 2.7 min, depending on conditions, and 3–58 % of the particles were removed from the cabin in the same duration. Use of physical barriers and high ventilation rate is therefore recommended for both personal and social protection. We found more exhaust capacity and medium relative humidity to be effective in reducing the particles' transmission potential across all studied scenarios. The results indicate that reducing ventilation rate and exhaust capacity, increased aerosols shelf time and dispersion throughout the cabin.

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Van Egeren, D., Stoddard, M., Malakar, A., Ghosh, D., Acharya, A., Mainuddin, S.*, et al.*
No magic bullet: limiting in-school transmission in the face of variable SARS-CoV-2 viral loads.
medRxiv, (2022)

In the face of a long-running pandemic, understanding the drivers of ongoing SARS-CoV-2 transmission is crucial for the rational management of COVID-19 disease burden. Keeping schools open has emerged as a vital societal imperative during the pandemic, but in-school transmission of SARS-CoV-2 can contribute to further prolonging the pandemic. In this context, the role of schools in driving SARS-CoV-2 transmission acquires critical importance. Here we model in-school transmission from first principles to investigate the effectiveness of layered mitigation strategies on limiting in-school spread. We examine the effect of masks and air quality (ventilation, filtration and ionizers) on steady-state viral load in classrooms, as well as on the number of particles inhaled by an uninfected person. The effectiveness of these measures in limiting viral transmission is assessed for variants with different levels of mean viral load (Wuhan, Delta, Omicron). Our results suggest that a layered mitigation strategy can be used effectively to limit in-school transmission, with certain limitations. First, poorly designed strategies (insufficient ventilation, no masks, staying open under high levels of community transmission) will permit in-school spread even if some level of mitigation is ostensibly present. Second, for viral variants that are sufficiently contagious, it may be difficult to construct any set of interventions capable of blocking transmission once an infected individual is present, underscoring the importance of other measures. Our findings provide several practical recommendations: the use of a layered mitigation strategy that is designed to limit transmission, with other measures such as frequent surveillance testing and smaller class sizes (such as by offering remote schooling options to those who prefer it) as needed. All additional data are available from the authors upon reasonable request.
https://github.com/dvanegeren/covid-indoor-transmission

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Zhao, Y., Feng, Y., Ma, L.
Numerical evaluation on indoor environment quality during high numbers of occupied passengers in the departure hall of an airport terminal.
Journal of Building Engineering, Vol. **51**, (2022), p.

The rapid development of airports and the rapid spread of coronavirus disease 2019 (COVID-19) have brought increased attention to indoor environment quality, airflow organization, key pollutant dispersion, and ventilation modes in airport terminals. However, the characteristics of these parameters, especially carbon dioxide (CO2) and aerosol diffusion, are not fully understood. Therefore, in this study, the airflow patterns; CO2 and aerosol dispersion; and several thermal environment indices, including temperature, wind velocity, and predicted mean vote (PMV), of an airport terminal departure hall with high numbers of occupied passenger were numerically evaluated using the realizable k-epsilon and passive scalar models. The efficacies

of three common ventilation modes, namely, up-supply and up-return, up-supply and down-return with different sides, and up-supply and down-return with the same side, were evaluated based on the CO2 removal efficiency and spreading range of aerosols. The results indicated that under high numbers of occupied passenger conditions, these ventilation modes vary slightly, with respect to create a comfortable and healthy environment. In particular, the up-supply and down-return with different sides mode was the best among the modes considered, when comparing the indices of temperature, wind speed PMV, and CO2 emission efficiency. Conversely, with respect to decreasing the risk of aerosol exposure, the up-supply and down-return with the same side mode was the best. Overall, the results from this study provide fundamental information for predicting CO2 and aerosol exposure levels and will act as a reference for the design and operation of ventilation systems in airport terminal buildings.

https://doi.org/10.1016/j.jobe.2022.104276

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Trevisan, M.

Numerical simulations of the air flow generated by forced ventilation in a rectangular room.

Thèse 2022

In these two years, due to the spreading of SARS-COV2 pandemics, it has become important to understand the dynamics of ventilation inside closed environments to determine the infection risk. It is known that Covid-19 is a viral infection and the probability to get infected by the virus increases inside closed spaces because saliva droplets, which contain the virus copies that cause the infection, could remain suspended in the air for long times. In this context, it is important to study the quality of the air inside indoor spaces and quantify the efficiency of ventilation systems in cleaning the air inside the environment. The study of the recirculation of the air becomes crucial to evaluate how long it takes to change a certain volume of air. During ventilation, some vortex could form inside a room, caused by the geometry, the ventilation type and temperature. This can affect the air change rate due to the formation of some recirculations. The problem of air ventilation inside a closed environment is numerically addressed in this thesis by solving the 3D Reynolds Average Navier-Stokes (RANS) equations on a rectangular domain. The air conditioning system is represented by setting two rectangular inflows that inject clean air inside the environment. The air exits from an additional couple of rectangular outflows at the opposite side of the room. Two cases are considered: heating and cooling. It is found that a perfect mixing model can adequately represent the air changing rate inside the room, especially in the case of cooling.

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Guo, Y., Zhang, N., Hu, T., Wang, Z., Zhang, Y.

Optimization of energy efficiency and COVID-19 pandemic control in different indoor environments.

Energy and buildings, Vol. **261**, (2022)

The COVID-19 pandemic has led to considerable morbidity and mortality, and consumed enormous resources (e.g. energy) to control and prevent the disease. It is crucial to balance infection risk and energy consumption when reducing the spread of infection. In this study, a quantitative human, behavior-based, infection risk-energy consumption model for different indoor environments was developed. An optimal balance point for each indoor environment can be obtained using the anti-problem method. For this study we selected Wangjing Block, one of the most densely populated places in Beijing, as an example. Under the current ventilation standard (30m3/h/person), prevention and control of the COVID-19 pandemic would be insufficient because the basic reproduction number (R0) for students, workers and elders are greater than 1. The optimal required fresh air ventilation rates in most indoor environments are near or below 60m3/h/person, after considering the combined effects of multiple mitigation measures. In residences, sports buildings and restaurants, the demand for fresh air ventilation rate is relatively high. After our global optimization of infection risk control (R0 ≤1), energy consumption can be reduced by 13.7 % and 45.1 % on

weekdays and weekends, respectively, in contrast to a strategy of strict control (R0 =1 for each indoor environment).

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Ren, C., Cao, S.-J., Haghighat, F.
A practical approach for preventing dispersion of infection disease in naturally ventilated room.
Journal of Building Engineering, Vol. **48**, (2022)

During the ongoing COVID-19 pandemic period, the airborne transmission of viruses has raised widespread concern as daily activities are resumed in public buildings. It is essential to develop mitigation strategies of infection disease transmission (e.g., increase of ventilation rate) in different scenarios to reduce the infection risk. For classrooms in schools, natural ventilation is generally used to provide outdoor air into rooms. However, the supply air volume depends strongly on the local conditions, e.g., window opening size and outdoor wind speed. In this study, the optimal design of classroom window openings is investigated, based on which low-cost window-integrated fans are then employed to enhance the efficiency of natural ventilation and infection disease control. Taking infected students as pollutant sources, numerical simulations are carried out to predict the pollutant concentration under various scenarios of pollutant sources and window opening modes (with/without fans), and to calculate the infection risk. It is found that by redesigning window openings, the airflow distribution performance index (ADPI) can be increased by 17 % with corresponding infection likelihood decreased by 27 %. The window integrated fan has a significant effect on improving ventilation performance and prevention of infection disease transmission, leading to an ADPI of 99 % and minimum infection probability of 11 % for students sitting near the windows. This work can help to develop low-cost and effective mitigating measures of infection disease in classrooms by using hybrid ventilation systems.

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Coyle, J. P., Derk, R. C., Lindsley, W. G., Boots, T., Blachere, F. M., Reynolds, J. S.*, et al.*
Reduction of exposure to simulated respiratory aerosols using ventilation, physical distancing, and universal masking.
Indoor Air, Vol. **32** n°(2), (2022)

To limit community spread of SARS-CoV-2, CDC recommends universal masking indoors, maintaining 1.8 m of physical distancing, adequate ventilation, and avoiding crowded indoor spaces. Several studies have examined the independent influence of each control strategy in mitigating transmission in isolation, yet controls are often implemented concomitantly within an indoor environment. To address the influence of physical distancing, universal masking, and ventilation on very fine respiratory droplets and aerosol particle exposure, a simulator that coughed and exhaled aerosols (the source) and a second breathing simulator (the recipient) were placed in an exposure chamber. When controlling for the other two mitigation strategies, universal masking with 3-ply cotton masks reduced exposure to 0.3-3 mu m coughed and exhaled aerosol particles by >77% compared to unmasked tests, whereas physical distancing (0.9 or 1.8 m) significantly changed exposure to cough but not exhaled aerosols. The effectiveness of ventilation depended upon the respiratory activity, that is, coughing or breathing, as well as the duration of exposure time. Our results demonstrate that a layered mitigation strategy approach of administrative and engineering controls can reduce personal inhalation exposure to potentially infectious very fine respiratory droplets and aerosol particles within an indoor environment.

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Lin, Y., Yuan, X., Yang, W., Hao, X., Li, C.
A Review on Research and Development of Healthy Building in China.
Buildings, Vol. **12** n°(3), (2022)

Healthy buildings are a deep-level development of green buildings, which can effectively help relieve stress and improve occupants' physical and mental health. In addition, they are is likely to play an important role in preventing the spread of respiratory infectious diseases. Therefore, healthy buildings have attracted worldwide attention. This article reviews the research and development of healthy buildings in China. First, it briefly introduces the definition of healthy buildings, the key elements of evaluation standards, energy conservation measures and new technology applications for healthy buildings, and lessons learned from the global outbreak of SARS-CoV-2. Secondly, it presents the milestones of healthy building development and healthy building projects in China, and the benefits of healthy buildings were also discussed. Finally, the differences in the evaluation systems of healthy buildings between China and other countries were analyzed, the problems of the current policy system of healthy buildings in China were identified, and suggestions for future development were provided.

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Yao, M.
SARS-CoV-2 aerosol transmission and detection.
Eco-Environment & Health, (2022)

Aerosol transmission has been officially recognized by the world health authority resulting from its overwhelming experimental and epidemiological evidences. Despite substantial progress, few additional actions were taken to prevent aerosol transmission, and many key scientific questions still await urgent investigations. The grand challenge, i.e., effective control of aerosol transmission of COVID-19, remains unsolved. A better understanding of the viral shedding into the air has been developed, but its temporal pattern is largely unknown. Sampling tools, as one of the critical elements for studying SARS-CoV-2 aerosol, are not readily available around the world. Many of them are less capable of preserving the viability of SARS-CoV-2, thus offering no clues about viral infectivity. As evidenced, the viability of SARS-CoV-2 is also directly impacted by temperature, humidity, sunlight, and pollutants. For SARS-CoV-2 aerosol detection, liquid samplers, together with real-time polymerase chain reaction (RT-PCR), are currently used in certain enclosed or semi-enclosed environments. Sensitive and rapid COVID-19 screening technologies are in great need. Among others, the breath-borne-based method emerges with global attention due to its advantages in sample collection and early disease detection. To collectively confront these challenges, scientists from different fields around the world need to fight together for the welfare of mankind. This review summarized the current understanding of the aerosol transmission of SARS-CoV-2 and identified the key knowledge gaps and a to-do list. This review also serves as a call for efforts to develop technologies to better protect the people in a forthcoming reopening world.

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Del Real, A., Exposito, A., Ruiz-Azcona, L., Santibanez, M., Fernandez-Olmo, I.
SARS-CoV-2 surveillance in indoor and outdoor size-segregated aerosol samples.
Environmental science and pollution research international, (2022)

We aimed to determine the presence of SARS-CoV-2 RNA in indoor and outdoor size-segregated aerosol samples (PM10-2.5, PM2.5). Five outdoor daily samples were collected between November and December 2020 in an urban/industrial area with relatively high PM10 levels (Maliano, Santander, Spain) by using a PM impactor (air flowrate of 30 L/min). In a non-hospital indoor sampling surveillance context, 8 samples in classrooms and 6 samples in the central library-Paraninfo of the University of Cantabria (UC) were collected between April and June 2021 by using personal PM samplers (air flowrate of 3 L/min). Lastly, 8 samples in the pediatric nasopharyngeal testing room at Liencres Hospital, 6 samples from different single occupancy rooms of positive patients, and 2 samples in clinical areas of the COVID plant of the University Hospital Marques de Valdecilla (HUMV) were collected between January and May 2021. N1, N2 genes were used to test the

presence of SARS-CoV-2 RNA by RT-qPCR. SARS-CoV-2 positive detection was only obtained from one fine fraction (PM2.5) sample, corresponding to one occupancy room, where a patient with positive PCR and cough was present. Negative results found in other sampling areas such as the pediatric nasopharyngeal testing rooms should be interpreted in terms of air sampling volume limitation and good ventilation.

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Pastor-Fernández, A., Cerezo-Narváez, A., Montero-Gutiérrez, P., Ballesteros-Pérez, P., Otero-Mateo, M.
Use of Low-Cost Devices for the Control and Monitoring of CO2 Concentration in Existing Buildings after the COVID Era.
Applied Sciences, Vol. **12** n°(8), (2022)

In the COVID-19 era, a direct relationship has been consolidated between the concentration of the pollutant carbon dioxide (CO2) and indoor disease transmission. For reducing its spread, recommendations have been established among which air renewal is a key element to improve indoor air quality (IAQ). In this study, a low-cost CO2 measurement device was designed, developed, assembled, prototyped, and openly programmed so that the IAQ can be monitored remotely. In addition, this clonic device was calibrated for correct data acquisition. In parallel, computational fluid dynamics (CFD) modeling analysis was used to study the indoor air flows to eliminate non-representative singular measurement points, providing possible locations. The results in four scenarios (cross ventilation, outdoor ventilation, indoor ventilation, and no ventilation) showed that the measurements provided by the clonic device are comparable to those obtained by laboratory instruments, with an average error of less than 3%. These data collected wirelessly for interpretation were evaluated on an Internet of Things (IoT) platform in real time or deferred. As a result, remaining lifespan of buildings can be exploited interconnecting IAQ devices with other systems (as HVAC systems) in an IoT environment. This can transform them into smart buildings, adding value to their refurbishment and modernization.

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