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Aéraulique et COVID-19

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Google Scholar, Lens et WoS

Mcneill, V. F.
Airborne Transmission of SARS-CoV-2: Evidence and Implications for Engineering Controls.
Annual Review of Chemical and Biomolecular Engineering, Vol. **13**, (2022), pp. 123-140

Since late 2019, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has spread globally, causing a pandemic (coronavirus disease 2019, or COVID-19) with dire consequences, including widespread death, long-term illness, and societal and economic disruption. Although initially uncertain, evidence is now overwhelming that SARS-CoV-2 is transmitted primarily through small respiratory droplets and aerosols emitted by infected individuals. As a result, many effective nonpharmaceutical interventions for slowing virus transmission operate by blocking, filtering, or diluting respiratory aerosol, particularly in indoor environments. In this review, we discuss the evidence for airborne transmission of SARS-CoV-2 and implications for engineering solutions to reduce transmission risk.

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Singh, R., Dewan, A.
Bioaerosol Spread of COVID-19 and TB in Air ConditionedSpaces : How the Court Spear headed the Movement in India.
Journal of Communicable Diseases, (2022), pp. 30-35

The measures taken in buildings to make them resilient against the spread of airborne diseases have seen a rise during the COVID-19 pandemic. Changes in the heating, ventilation and air conditioning systems are of importance as bioaerosols spread through recirculation based air conditioning systems. This can be tackled by sanitisation or by dilution ventilation caused by increased fresh air supply. In response to a written petition by a lawyer on the issue of air conditioning in the court premises and the spread of COVID-19, the Delhi High Court held the Fundamental Rights of the citizens by extending it to a right to a healthy environment and acknowledging the concerns in the petition. A committee was also set up by the court to relook at the ventilation and air conditioning within the court. The Right to Information Act, 2005 was used to obtain the minutes of the committee meetings. This short communication discusses the decisions which provide insights into the lack of reliable information available in the initial phases of the meetings. This has been hinted to show the possible lack of regulation for infection control through airborne route in public buildings. Design decisions are also looked at. This paper aims at providing a commentary with the aim of linking research and practice in the area of bioaerosol spread of diseases like COVID-19 and tuberculosis in public spaces.

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Scungio, M., Crognale, S., Lelli, D., Carota, E., Calabro, G.
Characterization of the bioaerosol in a natural thermal cave and assessment of the risk of transmission of SARS-CoV-2 virus.
Environmental Geochemistry and Health, Vol. **44** n°(7), (2022), pp. 2009-2020

Thermal caves represent an environment characterized by unique chemical/physical properties, often used for treatment and care of musculoskeletal, respiratory, and skin diseases. However, these environments are poorly characterized for their physical and microbiological characteristics; furthermore, the recent pandemic caused by COVID-19 has highlighted the need to investigate the potential transmission scenario of SARS-CoV-2 virus in indoor environments where an in-depth analysis of the aerosol concentrations and dimensional

distributions are essential to monitor the spread of the virus. This research work was carried out inside a natural cave located in Viterbo (Terme dei Papi, Italy) where a waterfall of sulfur-sulfate-bicarbonate-alkaline earth mineral thermal water creates a warm-humid environment with 100% humidity and 48 degrees C temperature. Characterization of the aerosol and bioaerosol was carried out to estimate the personal exposure to aerosol concentrations, as well as particle size distributions, and to give an indication of the native microbial load. The data obtained showed a predominance of particles with a diameter greater than 8 mu m, associated with low ability of penetration in the human respiratory system. A low microbial load was also observed, with a prevalence of noncultivable strains generated by the aerosolization of the thermal waters. Finally, the estimation of SARS-CoV-2 infection risk by means of mathematical modeling revealed a low risk of transmission, with a decisive effect given by the mechanical ventilation system, which together with the adoption of social distancing measures makes the risk of infection extremely low.

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Erdogan, A. A., Yilmazoglu, M. Z.
Comparison of ventilation strategies in intensive care units for airborne infection control.
Energy Sources Part a-Recovery Utilization and Environmental Effects, Vol. **44** n°(3), (2022), pp. 5829-5851

Healthcare facilities are one of the most important buildings in an outbreak. With the tremendous increment of bed occupancy rates in intensive care units, cross-infection risks to healthcare workers also increase. Along with the personal and societal measures, airborne infection prevention via ventilation systems should be evaluated in detail for each design. In this study, the infection prevention performances of three different ventilation layouts inside a selected intensive care unit design, located in Gazi University Hospital, are compared. Three different ventilation strategies as conventional (head supply-feet exhaust, Case 1), switched (head exhaust-feet supply, Case 2), and local exhaust (Case 3) are evaluated with respect to their aerosol distribution characteristics, airflow patterns, and temperature distribution characteristics. As a result, aerosol removal efficiencies of conventional, switched, and local-exhaust approaches are found to be 18.7%, 68.3%, and 97.8%, respectively, whereas the temperature distribution in Case 3 may also meet the thermal comfort requirements.

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Prajapati, S., Mehta, N., Chharia, A., Upadhyay, Y.
Computational fluid dynamics-based disease transmission modeling of SARS-CoV-2 Intensive Care Unit.
Materials today. Proceedings, Vol. **56**, (2022), pp. 2967-2972

Covid-19 has become one of the most severe diseases causing acute respiratory problems and has killed millions of people worldwide. It was declared as the ongoing pandemic by the World Health Organization. It is an infectious virus which can be transmitted by sneezing, coughing and exhalation of air by any infected person. There are certain places having high chances of becoming contaminated like hospital rooms. In this context, we studied the transmission of Covid-19 particles in an ICU room. We have considered the combined effect of both of air-conditioning (AC) and ceiling fan in the room. The infected person can transmit the disease when under influence of fan and AC. The work highlights the flow of aerosol particles considering the combined effect as well as the individual effects of fan and AC. The results also emphasized that the aerosol particle flow have a promising application in sanitizing the room.

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Tawfik, A., Law, D., Grasis, J., Oldham, J., Salem, M.
COVID-19 public transportation air circulation and virus mitigation study.
Mineta Transportation Institute Report 2022

COVID-19 may have forever changed our world. Given the limited space and air circulation, potential infections on public transportation could be concerningly high. Accordingly, this study has two objectives: (1) to understand air circulation patterns inside the cabins of buses; and (2) to test the impact of different technologies in mitigating viruses from the air and on surfaces inside bus cabins. For the first objective, different devices, metrics and experiments (including colored smoke; videotaping; anemometers; pressure differentials; particle counts; and 3D numerical simulation models) were utilized and implemented to understand and quantify air circulation inside different buses, with different characteristics, and under different operating conditions (e.g. with windows open and shut). For the second objective, three different live prokaryotic viruses were utilized: Phi6, MS2 and T7. Various technologies (including positive pressure environment inside the cabin, HEPA filters with different MERV ratings, concentrated UV exposure with charged carbon filters in the HVAC systems, center point photocatalytic oxidation technology, ionization, and surface antiviral agents) were tested to evaluate the potential of mitigating COVID-19 infections via air and surfaces in public transportation. The effectiveness of these technologies on the three live viruses was tested in both the lab and in buses in the field. The results of the first objective experiments indicated the efficiency of HVAC system designs, where the speed of air spread was consistently much faster than the speed of air clearing. Hence, indicating the need for additional virus mitigation from the cabin. Results of the second objective experiments indicated that photocatalytic oxidation inserts and UVC lights were the most efficient in mitigating viruses from the air. On the other hand, positive pressure mitigated all viruses from surfaces; however, copper foil tape and fabrics with a high percentage of copper mitigated only the Phi6 virus from surfaces. High-temperature heating was also found to be highly effective in mitigating the different viruses from the vehicle cabin. Finally, limited exploratory experiments to test possible toxic by-products of photocatalytic oxidation and UVC lights inside the bus cabin did not detect any increase in levels of formaldehyde, ozone, or volatile organic compounds. Implementation of these findings in transit buses, in addition to the use of personal protective equipment, could be significantly valuable for protection of passengers and drivers on public transportation modes, possibly against all forms of air-borne viruses.

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Cao, S.-J., Feng, Z., Wang, J., Ren, C., Zhu, H.-C., Chen, G.*, et al.*
Ergonomics-oriented operation, maintenance and control of indoor air environment for public buildings.
Chinese Science Bulletin-Chinese, Vol. **67** n°(16), (2022), pp. 1783-1795

In response to the construction process of Healthy China. it is rather important to create a safe, healthy and energy-efficient indoor environment for public buildings. The public building space is often densely populated, with a large flow of people and many types of air pollution, which presents non-uniform dynamic distribution characteristics. This brings great challenges to the control of indoor air safety, especially during the pandemic period of COVID-19. Excessive ventilation may not only cause large energy waste. but also lead to cross-contamination and even a cluster of infection. In this paper, an operation and maintenance (O&M) control system for indoor air safety is developed based on the core concepts and basic methods of human ergonomics. In this system, one of the important human environmental variables is focused for control, i.e.. indoor air pollution level. Especially after the outbreak of COVID-19. droplets and droplet nuclei from respiration are the most significant air pollution categories required for mitigation. Towards the efficient control of air pollution in large public buildings. it should further take into account the interaction of human, equipment and machines (i.e., ventilation_ air purification and disinfection and intelligent control system) and building environment. Firstly, on the basis of the online monitoring of indoor air pollution concentration and personnel flow, the non-uniform dynamic distribution of indoor pollutants and personnel can be obtained by using the non-uniform and low-dimensional rapid prediction models and computer vision processing. Then, the optimal setting results of ventilation parameters (e.g., ventilation modes, supply air rate. etc.) can be outputted by the environmental control decision system. Finally, based on a combination of monitoring sensors, controllers and actuator hardware equipment (at the location of fans or dampers), the intelligent regulation and control of ventilation system can be realized, aimed at minimizing energy consumption and

reducing pollutant concentration and exposure level. Meanwhile, the air purification and disinfection system (especially for the disinfection of virus particles) are operated under the condition of the ventilated environment, which can serve as a powerful auxiliary to the maintenance of indoor air safety. The workflow and effect of the O&M control system are demonstrated by an engineering application case of the front hall in the International Convention and Exhibition Center. The results indicate that the non-uniform and low-dimensional rapid prediction model for pollutant concentration is effective for the ventilation control with the average prediction difference of 11.9%. The implementation of the intelligent ventilation system can reduce the risk of human infection to less than 4%. and its energy-saving ratio for the ventilation can be as high as about 45%. Through optimizing the layout strategies of disinfection devices based on the intelligent ventilation control, the space accessibility of negative oxygen ions can be well accepted, to further increase the removal efficiency of air pollution. The calculated value of space disinfection rate is more than 99%, which can further reduce the risk of infection by 1-2 orders of magnitude. This study can provide an important reference for the promotion and upgrading of O&M control system for indoor air safety.

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Mares-Rodriguez, A., Maria Flores-Serrano, R., Gonzalez-Sanchez, A.
Estimation of Classroom Capacity Based on Its Size and Ventilation Capacity during the SARS-CoV-2 Coronavirus Pandemic (en espagnol).
Revista De Salud Ambiental, Vol. **22** n°(1), (2022), pp. 91-99

An analysis was conducted based on a model of CO2 mass balance inside a classroom of a certain volume (V-classroom). The model considered the parameters of CO2 production rate per person and indoor air renewal capacity (air changes per hour, or ACH), an equation being obtained that can be used to estimate the number of students that can use (at the same time) a classroom of a defined size (V-classroom) without the maximum allowable CO2 concentration level being reached, which would minimize the risk of airborne transmission of the SARS-CoV-2 virus.

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Sharma, N., Bi, Y., Gioti, E., Myrbekk, E. D., Cao, G.
Field investigation of the airborne infection risk in fitness centres during COVID-19 pandemic.
Federation of European Heating, Ventilation and Air Conditioning REHVA, Vol. **3**, (2022)

The objective of the study is to evaluate the effect of social distance requirements set by Norwegian authorities for group activities in closed rooms on airborne infection risk. The CO_2 concentration was measured in two gyms with different activity levels of fitness classes. The ventilation airflow rate was obtained by steady-state mass balance equations. The Wells Riley model was used to assess the risk of infection among people in the room during the exercise class. Moreover, the relationship between social distancing and the number of infected people was obtained. Results show a close relation between CO_2 concentration and activity level. The ventilation airflow rate in Yoga room was calculated to be 343.2 m^3/h, while in Tabata room was 2063.9 m^3/h. Calculations showed that with 1 m social distance and one infected person in the room, the airborne infection risk is 2.23% for the Yoga and 2.14% for the Tabata room. Different levels of activity caused the body to release different concentrations of the virus leading to similar rates of infection in both rooms despite the huge difference in the air change per hour. The conclusion is that social distancing is not the only parameter affecting the airborne infection risk, the ventilation rate also plays a key role.

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Tsuchihashi, Y., Yamagishi, T., Suzuki, M., Sekizuka, T., Kuroda, M., Itoi, T.*, et al.*
High attack rate of SARS-CoV-2 infections during a bus tour in Japan.
Journal of Travel Medicine, Vol. **28** n°(8), (2021)

t is critical to prevent and control tour-related coronavirus disease 2019 (COVID-19) outbreaks for the travel industry. Although airplane- or bus-related COVID-19 outbreaks were reported in several countries, the evidence on severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) transmission in vehicles is limited.1–3 Here, we report the findings from an investigation of a COVID-19 outbreak occurring following a 4-day tour on four buses visited 11 tourist sites around Hokkaido, Japan, in October 2020. The total number of people on the bus tour was 158 (146 participants and 12 staff members): 41 for Bus 1, 39 for Bus 2, 40 for Bus 3 and 38 for Bus 4.

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Skanata, A., Spagnolo, F., Metz, M., Smyth, D. S., Dennehy, J. J.
Humidity Reduces Rapid and Distant Airborne Dispersal of Viable Viral Particles in Classroom Settings.
Environmental Science & Technology Letters, (2022)

The transmission of airborne pathogens is considered to be the main route through which a number of known and emerging respiratory diseases infect their hosts. While physical distancing and mask wearing may help mitigate short-range transmission, the extent of long-range transmission in closed spaces where a pathogen remains suspended in the air remains unknown. We have developed a method to detect viable virus particles by using an aerosolized bacteriophage Phi6 in combination with its host Pseudomonas phaseolicola, which when seeded on agar plates acts as a virus detector that can be placed at a range of distances away from an aerosol-generating source. By applying this method, we consistently detected viable phage particles at distances of up to 18 feet away from the source within 15 min of exposure in a classroom equipped with a state of the art HVAC system and determined that increasing the relative humidity beyond 40% significantly reduces dispersal. Our method, which can be further modified for use with other virus/host combinations, quantifies airborne transmission in the built environment and can thus be used to set safety standards for room capacity and to ascertain the efficacy of interventions in dosed spaces of specified sizes and intended uses.

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Fleck, B. A., Thornton, G. M., Zhong, L., Hartling, L. A., Dandnayak, D., Kroeker, E.*, et al.*
The impact of heating, ventilation, and air conditioning design features on the transmission of viruses, including the 2019 novel coronavirus: a systematic review of filtration.
PLOS Global Public Health, Vol. **2** n°(7), (2021)

Aerosol transmission has been a pathway for the spread of many viruses. Similarly, emerging evidence has determined aerosol transmission for Severe Acute Respiratory Syndrome coronavirus 2 (SARS-CoV-2) and the resulting COVID-19 pandemic to be significant. As such, data regarding the effect of Heating, Ventilation, and Air Conditioning (HVAC) features to control and mitigate virus transmission is essential. A systematic review was conducted to identify and comprehensively synthesize research examining the effectiveness of ventilation for mitigating transmission of coronaviruses. A comprehensive search was conducted in Ovid MEDLINE, Compendex, Web of Science Core to January 2021. Study selection, data extraction, and risk of bias assessments were performed by two authors. Evidence tables were developed and results were described narratively. Results from 32 relevant studies showed that: increased ventilation rate was associated with decreased transmission, transmission probability/risk, infection probability/risk, droplet persistence, virus concentration, and increased virus removal and virus particle removal efficiency; increased ventilation rate decreased risk at longer exposure times; some ventilation was better than no ventilation; airflow patterns affected transmission; ventilation feature (e.g., supply/exhaust, fans) placement influenced particle distribution. Few studies provided specific quantitative ventilation parameters suggesting a significant gap in current research. Adapting HVAC ventilation systems to mitigate virus transmission is not a one-solution-fits-all approach. Changing ventilation rate or using mixing ventilation is not always the only way to mitigate and

control viruses. Practitioners need to consider occupancy, ventilation feature (supply/exhaust and fans) placement, and exposure time in conjunction with both ventilation rates and airflow patterns. Some recommendations based on quantitative data were made for specific scenarios (e.g., using air change rate of 9 h-1 for a hospital ward). Other recommendations included using or increasing ventilation, introducing fresh air, using maximum supply rates, avoiding poorly ventilated spaces, assessing fan placement and potentially increasing ventilation locations, and employing ventilation testing and air balancing checks.

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Lee, J.-H., Bang, J.-I., Sung, M., Jeong, J.-W.
Inactivation of airborne microbial contaminants by a heat-pump-driven liquid-desiccant air-conditioning system.
Journal of Building Engineering, Vol. **50**, (2022)

The COVID-19 pandemic has led to increasing interest in controlling airborne virus transmission during the operation of air-conditioning systems. Therefore, beyond an examination of the ability of liquid-desiccant material itself to inactivate microbes, a heat-pump-driven liquid-desiccant airconditioning system was proposed and constructed to experimentally investigate the effect of liquid-desiccant solution on the inactivation of airborne bacteria and fungi in various air-conditioning processes. The proposed system comprises a liquid-desiccant unit to dehumidify or humidify process air using a desiccant-solution and heat-pump unit to cool or heat it and accommodate solution thermal loads. The decrease in the concentration of airborne bacteria and fungi before and after passing through the system (i.e., inactivation efficiency) were compared for the base, summer, and winter operating modes. The results indicated that airborne fungi were less inactivated than bacteria because they possess more stress-resistant cellular structures that resist inactivation. During the air-conditioning processes in both the summer and winter operating modes, the bacterial and fungal inactivation efficiencies improved compared to the base mode owing to the contact with desiccant solution. The higher solution flow rate and solution temperature improved the bacterial inactivation efficiency by 27% for the winter compared to the summer mode. Conversely, because of possible growth of fungi in the heated and humidified supply air in the winter, the fungal inactivation efficiency improved by only 1.5% for the winter compared to the summer mode. In conclusion, the proposed system can contribute to control the airborne transmission of microbial contaminants while operating air-conditioning systems.

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Ricolfi, L., Stabile, L., Morawska, L., Buonanno, G.
Increasing ventilation reduces SARS-CoV-2 airborne transmission in schools: a retrospective cohort study in Italy's Marche region.
arXiv preprint arXiv:2207.02678, (2022)

Background: While increasing the ventilation rate is an important measure to remove inhalable virus-laden respiratory particles and lower the risk of infection, direct validation in schools with population-based studies is far from definitive.
Methods: We investigated the strength of association between ventilation and SARS-CoV-2 transmission reported among the students of Italy's Marche region in more than 10,000 classrooms, of which 316 were equipped with mechanical ventilation. We used ordinary and logistic regression models to explore the relative risk associated with the exposure of students in classrooms.
Findings: For classrooms equipped with mechanical ventilation systems, the relative risk of infection decreased with the increase in ventilation: ventilation ranging from 10 to 14 L s-1 student-1 reduced the likelihood of infection for students by 80% compared with a classroom with only natural ventilation. From the regression analysis, as confirmed by the predictive theoretical approach, we obtained a relative risk reduction in the range 12%-15% for each additional unit of ventilation rate per person.

Interpretation: We need high ventilation rates (> 10 L s−1 student−1) to protect students in classrooms from airborne transmission; this is higher than the rate needed to ensure indoor air quality. The excellent agreement between the results from the retrospective cohort study and the outcomes of the predictive theoretical approach makes it possible to assess the risk of airborne transmission for any indoor environment.

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Andres, M., Garcia, M. C., Fajardo, A., Grau, L., Pagespetit, L., Plasencia, V.*, et al.*
Nosocomial outbreak of COVID-19 in an internal medicine ward: Probable airborne transmission.
Revista clinica espanola, (2022)

BACKGROUND AND OBJECTIVES: Despite the increasing evidence supporting the importance of airborne transmission in SARS-CoV-2 infection, it has not been considered relevant in the vast majority of reported nosocomial outbreaks of COVID-19. The aim of this study is to describe a nosocomial outbreak of SARS-CoV-2 infection whose features suggest that aerosol transmission had an important role. METHODS: This is a descriptive analysis of a nosocomial outbreak of SARS-CoV-2 infection in an internal medicine ward that occurred in December 2020. All cases were confirmed by a positive PCR test for SARS-CoV-2. RESULTS: From December 5 to December 17, 21 patients and 44 healthcare workers (HCWs) developed a nosocomial SARS-CoV-2 infection. Fifty-one of the 65 cases (78.5%) were diagnosed between December 6 and 9. The attack rate in patients was 80.8%. Among HCWs, the attack rate was higher in those who had worked at least one full working day in the ward (56.3%) than in those who had occasionally been in the ward (25.8%; p = 0.005). Three days before the first positive case was detected, two extractor fans were found to be defective, affecting the ventilation of three rooms. Sixteen cases were asymptomatic, 48 cases had non-severe symptoms, and 2 cases required admission to the intensive care unit. All patients eventually recovered. CONCLUSION: The high attack rate, the explosive nature of the outbreak, and the coincidence in time with the breakdown in air extractors in some rooms of the ward suggest that airborne transmission played a key role in the development of the outbreak.

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Fang, Y.
A Numerical Study of the Effect of Limited Space Air Stability on SARS-CoV-2 Spreading in a Ventilated Room.
ASHRAE Topical Conference Proceedings ; Atlanta, 2022.

Worldwide concern has been focused on the airborne disease of the COVID-19 pandemic. This study investigated the effect of the limited space air stability on the mechanism of SARS-CoV-2 spreading in the interpersonal breathing microenvironment using an unsteady computational fluid dynamics (CFD) method. A validated numerical model was employed to simulate the transient SARS-CoV-2 releasing process from normal breathing activity. The computational domain was divided into an interpersonal breathing microenvironment and the rest macroenvironment. A displacement ventilation system was implemented with 1.5 ACH, 3 ACH, 7.4 ACH and 9 ACH. Two standing CSPs (Computational Simulated Person) were placed in the middle of the macroenvironment face-to-face with a relative distance of 1 m. Simulation results indicated that in stable cases, the exhaled SARS-CoV-2 tended to accumulate in the interpersonal breathing microenvironment and resulted in a relatively high infection risk for people; whereas in cases where unstable air presented, SARS-CoV-2 concentration was significantly reduced. The unstable conditions lowered the risk of person-to-person transmission in confined spaces. Also, it was found that unstable cases performed better in energy efficiency in comparison with the stable conditions.

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Crespi Rotger, S., Ordonez Iriarte, J. M.
The relevance of air hygiene: an urgent matter after the COVID-19 pandemic (en espagnol).

Revista De Salud Ambiental, Vol. **22** n°(1), (2022), pp. 81-90

Historically, major public health advances-water sanitation and hygiene, as well as food safety- have gone hand in hand with the healthcare responses to the big epidemic outbreaks that have beset humankind. The current COVID-19 pandemic has highlighted the weaknesses of environmental health when it comes to addressing one of the most important aspects of the prevention of respiratory infectious diseases: airborne, or aerosol, transmission in indoor environments. Although there exist standards that regulate air quality inside public buildings, in practice they are not perceived as health or prevention requirements, so compliance therewith is rarely monitored. Therefore, from a public health perspective, and based on the experience gained from the pandemic, it would seem reasonable to incorporate "air hygiene" monitoring into environmental health-going beyond energy or comfort considerations and emphasizing sanitary and microbiological aspects. This would represent a substantial breakthrough in the containment of the transmission of infectious diseases via aerosols.

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Zhang, Y., Hui, F. K. P., Duffield, C., Saeed, A. M.
A review of facilities management interventions to mitigate respiratory infections in existing buildings.
Building and environment, Vol. **221**, (2022)

The Covid-19 pandemic reveals that the hazard of the respiratory virus was a secondary consideration in the design, development, construction, and management of public and commercial buildings. Retrofitting such buildings poses a significant challenge for building owners and facilities managers. This article reviews current research and practices in building operations interventions for indoor respiratory infection control from the perspective of facilities managers to assess the effectiveness of available solutions. This review systematically selects and synthesises eighty-six articles identified through the PRISMA process plus supplementary articles identified as part of the review process, that deal with facilities' operations and maintenance (O&M) interventions. The paper reviewed the context, interventions, mechanisms, and outcomes discussed in these articles, concluding that interventions for respiratory virus transmission in existing buildings fall into three categories under the Facilities Management (FM) discipline: Hard services (HVAC and drainage system controls) to prevent aerosol transmissions, Soft Services (cleaning and disinfection) to prevent fomite transmissions, and space management (space planning and occupancy controls) to eliminate droplet transmissions. Additionally, the research emphasised the need for FM intervention studies that examine occupant behaviours with integrated intervention results and guide FM intervention decision-making. This review expands the knowledge of FM for infection control and highlights future research opportunities.

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Ebadi, M., Mccague, C., Vallee, O., Taylor, P. K., Lee, A. H. Y., Bahrami, M.
Salt and surfactant coated filters with antiviral properties and low pressure drop for prospective SARS-CoV2 applications.
Scientific Reports, Vol. **12** n°(1), (2022)

The COVID-19 pandemic motivated research on antiviral filtration used in personal protective equipment and HVAC systems. In this research, three coating compositions of NaCl, Tween 20 surfactant, and NaCl-Tween 20 were examined on polypropylene spun-bond filters. The pressure drop, coverage, and crystal size of the coating methods and compositions were measured. Also, in vitro plaque assays of the Phi6 Bacteriophage on Pseudomonas syringae as a simulation of an enveloped respiratory virus was performed to investigate the antiviral properties of the coating. NaCl and NaCl-Tween 20 increased the pressure drop in the range of 40–50 Pa for a loading of 5 mg/cm2. Tween 20 has shown an impact on the pressure drop as low as 10 Pa and made the filter surface more hydrophilic which kept the virus droplets on the surface. The NaCl-Tween 20 coated samples could inactivate 108 plaque forming units (PFU) of virus in two hours of incubation. Tween 20

coated filters with loading as low as 0.2 mg/cm2 reduced the activity of 108 PFU of virus from 109 to 102 PFU/mL after 2 h of incubation. NaCl-coated samples with a salt loading of 15 mg/cm2 could not have antiviral properties higher than reducing the viral activity from 109 to 105 PFU/mL in 4 h of incubation.

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Kumar, S., Nguye, A., Gayler, N. K., Madigan, G., Xing, R.
Ventilation for Energy Efficiency and Improved Indoor Air Quality in University Classrooms.
ASHRAE Topical Conference Proceedings; Atlanta, (2022).

This paper reports preliminary analysis from a large field study of 100 university classrooms in Central Texas. Lecture classrooms and auditoriums were sampled for three consecutive weekdays in the 2019 – 2020 academic year. Carbon dioxide (CO2) concentrations, used as a marker for both ventilation and exposure, and temperature were measured in the general room area and when able, the supply airstream. HVAC control data that relates to ventilation was also saved for comparison. Preliminary results of typical CO2 concentrations during occupied hours suggest that university classrooms rarely exceed ASHRAE 62.1 recommendations for classrooms. Contrastingly to K-12 classrooms that are often under-ventilated, our data shows that university classrooms are well-ventilated if not over-ventilated. The reason for this over-ventilation is due to non-uniform classroom temporal usage in university buildings resulting in empty classrooms and therefore the variable air volume (VAV) systems, typically found in university buildings, cannot properly adjust ventilation rates.

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Ferrari, S., Blazquez, T., Cardelli, R., Puglisi, G., Suarez, R., Mazzarella, L.
Ventilation strategies to reduce airborne transmission of viruses in classrooms: A systematic review of scientific literature.
Building and environment, Vol. **222**, (2022)

The recent pandemic due to SARS-CoV-2 has brought to light the need for strategies to mitigate contagion between human beings. Apart from hygiene measures and social distancing, air ventilation highly prevents airborne transmission within enclosed spaces. Among others, educational environments become critical in strategic planning to control the spread of pathogens and viruses amongst the population, mainly in cold conditions. In the event of a virus outbreak - such as COVID or influenza - many school classrooms still lack the means to guarantee secure and healthy environments. The present review examines school contexts that implement air ventilation strategies to reduce the risk of contagion between students. The analysed articles present past experiences that use either natural or mechanical systems assessed through mathematical models, numerical models, or full-scale experiments. For naturally ventilated classrooms, the studies highlight the importance of the architectural design of educational spaces and propose strategies for aeration control such as CO2-based control and risk-infection control. When it comes to implementing mechanical ventilation in classrooms, different systems with different airflow patterns are assessed based on their ability to remove airborne pathogens considering parameters like the age of air and the generation of airflow streamlines. Moreover, studies report that programmed mechanical ventilation systems can reduce risk-infection during pandemic events. In addition to providing a systematic picture of scientific studies in the field, the findings of this review can be a valuable reference for school administrators and policymakers to implement the best strategies in their classroom settings towards reducing infection risks.

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Böke, E. S., Keleş, A., Keskin, C., Çaycı, Y. T., Turk, T.
Are aerosol control devices effective in preventing the spread of dental aerosol ?
PeerJ, Vol. **10**, (2022)

Background
In dental clinics, aerosols produced from dental instruments have become a matter of concern following breakout of coronavirus disease 19 (COVID-19) evolving into a pandemic. This study compared aerosol reduction systems and in terms of their ability to reduce Enterococcus faecalis (E. faecalis) contaminated aerosol in a simulated dental office set-up.
Methods
Closed clinic model with manikin and mandibular molar typodont was simulated. For 10 min, the air and water dispersed by the rotating bur mounted on an aerator was contaminated by pouring the suspension containing 1–3 × 108 CFU/mL E. faecalis directly on the bur. During and after the procedures, the air within the cabin was also sampled. CFU count was recorded and scored. The mean CFU scores obtained from agar plate count and air sampling device was compared using Kruskal–Wallis H test among groups with 5% significance threshold.
Results
The use of WS Aerosol Defender device led to greater CFU scores on the agars levelled to patient's chest compared to other directions (p = 0.001). Combined use of VacStation and WS Aerosol Defender resulted in significantly decreased CFU score in the air samples compared to experimental and positive control groups (p = 0 < 0.05).
Conclusions
Although the devices prevented the spread of aerosol around the patient to some extent, they could not completely eliminate the contaminated aerosol load in the cabin environment.

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Lu, F., Gecgel, O., Ramanujam, A., Botte, G. G.
SARS-CoV-2 Surveillance in Indoor Air Using Electrochemical Sensor for Continuous Monitoring and Real-Time Alerts.
Biosensors, Vol. **12** n°(7), (2022)

The severe acute respiratory syndrome related coronavirus 2 (SARS-CoV-2) has spread globally and there is still a lack of rapid detection techniques for SARS-CoV-2 surveillance in indoor air. In this work, two test rigs were developed that enable continuous air monitoring for the detection of SARS-CoV-2 by sample collection and testing. The collected samples from simulated SARS-CoV-2 contaminated air were analyzed using an ultra-fast COVID-19 diagnostic sensor (UFC-19). The test rigs utilized two air sampling methods: cyclone-based collection and internal impaction. The former achieved a limit of detection (LoD) of 0.004 cp/L in the air (which translates to 0.5 cp/mL when tested in aqueous solution), lower than the latter with a limit of 0.029 cp/L in the air. The LoD of 0.5 cp/mL using the UFC-19 sensor in aqueous solution is significantly lower than the best-in-class assays (100 cp/mL) and FDA EUA RT-PCR test (6250 cp/mL). In addition, the developed test rig provides an ultra-fast method to detect airborne SARS-CoV-2. The required time to test 250 L air is less than 5 min. While most of the time is consumed by the air collection process, the sensing is completed in less than 2 s using the UFC-19 sensor. This method is much faster than both the rapid antigen (<20 min) and RT-PCR test (<90 min).

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Goodlad, C., Collier, S., Davenport, A.
Spread of Covid-19 in haemodialysis centres; the effects of ventilation and communal transport.
Artificial Organs, (2022)

Aims Haemodialysis (HD) patients are at increased risk of respiratory infections, due to increased use of communal travel, waiting areas, close proximity to others when dialysing, and contact with healthcare personnel. We wished to determine the major factors associated with transmission of COVID-19 within dialysis centres. Methods We compared the differences in the number of COVID-19 infections in patients and

staff in 5 dialysis centres during the 1st COVID-19 pandemic between March and June 2020, and analysed differences between centres. Isolation policies and infection control practices were identical between centres. Results 224 (30.3%) patients tested positive for COVID-19, by reverse transcriptase polymerase chain reaction, ranging from 4.8% (centre 1 size 55 patients) to 41.5% (centre 5-248 patients) p=0.007. Communal transport had a significant effect; with 160 of 452 (35.4%) patients using communal testing positive compared to 22.2% of those not using communal transport (X214.5, p<0.001). Staff sickness varied; 35 of 36 (97.3% centre 5) dialysis staff contracting COVID-19, compared to 60% from centre 4 (189 patients 30 staff) (p<0.001). Whereas centre 5 had no natural ventilation, and fan assisted ventilation did not meet standards for air changes and air circulation, centre 4 met ventilation standards. Conclusions Although there are many potential risk factors accounting for the increased risk of COVID-19 infection in haemodialysis patients, we found that differences in communal transport for patients and ventilation between centres was a major contributor accounting for the differences in patients testing positive for COVID-19 and staff sickness rates. This has important practical applications for designing kidney dialysis centres.

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Guo, Y., Li, X., Luby, S., Jiang, G.
Vertical outbreak of COVID-19 in high-rise buildings: the role of sewer stacks and prevention measures.
Current Opinion in Environmental Science & Health, (2022)

COVID-19 outbreaks in high-rise buildings suggested the transmission route of fecal-aerosol-inhalation due to the involvement of viral aerosols in sewer stacks. The vertical transmission is likely due to the failure of water traps that allow viral aerosols to spread through sewer stacks. This process can be further facilitated by chimney effect in vent stack, extract ventilation in bathrooms, or wind-induced air pressure fluctuations. To eliminate the risk of such vertical disease spread, installation of protective devices is highly encouraged in high-rise buildings. Although the mechanism of vertical pathogen spread through drainage pipeline has been illustrated by tracer gas or microbial experiments and numerical modeling, more research is needed to support the update of regulatory and design standards for sewerage facilities.

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