Rapport de veille n° 21

Aéraulique et COVID-19

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WoS et Google Scholar

Sodiq, A., Khan, M. A., Naas, M., Amhamed, A.
Addressing COVID-19 contagion through the HVAC systems by reviewing indoor airborne nature of infectious microbes: Will an innovative air recirculation concept provide a practical solution ?
Environmental Research, Vol. **199**, (2021)

As the world continues to grapple with the reality of coronavirus disease, global research communities are racing to develop practical solutions to adjust to the new challenges. One such challenge is the control of indoor air quality in the COVID-19 era and beyond. Since COVID-19 became a global pandemic, the “super spread” of the virus has continued to amaze policymakers despite measures put in place by public health officials to sensitize the general public on the need for social distancing, personal hygiene, etc. In this work, we have reviewed the literature to demonstrate, by investigating the historical and present circumstances, that indoor spread of infectious diseases may be assisted by the conditions of the HVAC systems. While little consideration has been given to the possibility of indoor airborne transmission of the virus, the available reports have demonstrated that the virus, with average aerodynamic diameter up to 80–120 nm, is viable as aerosol in indoor atmosphere for more than 3 h, and its spread may be assisted by the HVAC systems. Having reviewed the vulnerability of the conventional ventilation systems, we recommend innovative air circulation concept supported by the use of UVGI in combination with nanoporous air filter to combat the spread of SARS-CoV-2 and other harmful microbes in enclosed spaces.

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Feng, Z., Cao, S.-J., Wang, J., Kumar, P., Haghighat, F.
Indoor airborne disinfection with electrostatic disinfector (ESD): Numerical simulations of ESD performance and reduction of computing time.
Building and environment, Vol. **200**, (2021)

Airborne transmissions of infectious disease (e.g. SARS-CoV-2) in indoor environments may induce serious threat to public health. Air purification devices are necessary to remove and/or inactivate airborne biological species from indoor air environment. Corona discharge in an electrostatic precipitator is capable of removing particulate matter and disinfecting biological aerosols to act as electrostatic disinfector (ESD). The ions generated by ESD can effectively inactivate bacteria/viruses. However, the available research rarely investigated disinfection effect of ESD, and it is urgent to develop quantitative ESD design methods for building mechanical ventilation applications. This study developed an integrated numerical model to simulate disinfection performance of ESD. The numerical model considers the ionized electric field, electrohydrodynamic flow, and biological disinfection. The model prediction was validated with the experimental data (E. coli): Good agreement was observed. The validated model then was used to study the influences of essential design parameters (e.g. voltage, inlet velocity) of ESD on disinfection efficiency. The effects of modeling of electrophoretic force and EHD (electrohydrodynamic) flow patterns on disinfection efficiency and computing time were also analyzed. The disinfection efficiency of well-designed ESD (with space charge density of 3.6*10-06C/m3) could be as high as 100%. Compared with HEPA, ESD could save 99% of energy consumed by HEPA without sacrificing disinfection efficiency.

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Mckeen, P., Liao, Z.

The influence of airtightness on contaminant spread in MURBs in cold climates.
Building simulation, (2021), 1-16 pp.

Tall buildings in cold climates have unique challenges in maintaining indoor air quality due to stack effect. During the heating season, interior air buoyancy creates large pressure differentials in vertical shafts that can drive airflow from lower floors into upper floors. This pressure differential can result in the spread of contaminants throughout a building. Most recently, concern over COVID-19 has increased attention to the potential spread of airborne diseases in densely populated buildings. For many multi-unit residential buildings, suite ventilation has traditionally relied upon fresh air supplied through a mechanically pressurized corridor. In cold climates, large pressure differentials created by stack-effect can reduce the effectiveness of this approach. Multizone and CFD simulations are employed to analyze airflow and contaminant spread due to stack effect. Simulations are conducted on an idealized model of a 10-storey building using a range of experimentally derived airtightness parameters. Simulations demonstrate stack effect can reduce corridor ventilation to suites and even reverse the airflow for leakier buildings. Reduced airflow to suites can result in the accumulation of contaminants. Reversal of the airflow can allow contaminants from a suite to spread throughout the building. Contaminant spread is illustrated as a function of mechanical ventilation, building airtightness, and ambient temperatures. Strategies to reduce the influence of stack effect on mechanically pressurized corridors are discussed.

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Wang, F.
Letter to the editor regarding Hospers et al. (2020): Electric fans: A potential stay-at-home cooling strategy during the COVID-19 pandemic this summer?
Science of the Total Environment, Vol. **769**, (2021)

In Hospers and colleagues' recent article (Hospers et al., 2020), electric fans have been proposed as a potential stay-at-home cooling strategy during the COVID-19 pandemic under heat wave conditions. Besides, the authors defined the threshold temperatures for electric fan-use so that the public could use this as a guideline. In this letter, I would like to challenge the rigorousness of the methodology used in their work to determine threshold temperature and relative humidity (RH) zone for electric fan-use during heatwave temperatures.

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Wang, J., Zhang, Y., Kuang, L., Yang, J., Xu, C., Mu, B.*, et al.*
Low-voltage driven Ag-Co3O4 textile device for multifunctional air cleaning.
Chemical Engineering Journal, (2021)

Human exposure risks to airborne pollutants, bacteria and viruses in confined spaces have attracted tremendous attention. It is a challenge to degrade these harmful materials over a single device by electrical method other than conventional thermal method. We fabricated an air cleaning device based on a conductive Ag-Co3O4 coating with Ag nanoparticles on a glass fibre cloth (GFC). The device possessed good flexibility and high permeability of the GFC. Powered by low-voltages (< 20 V), the device exhibited a 3-fold formaldehyde conversion in its conventional thermal counterpart, and energy savings of > 90% were achieved. The electrically treated device completely killed Escherichia coli and Staphylococcus aureus and SARS-CoV-2 pseudovirus within a few minutes at a low surface temperature of < 50 °C. The excellent efficiency of the devices was attributed to the confinement of electric power to the coating. The device can serve as a flexible filter for air cleaners or conditioners to ensure that human health is maintained amid the pandemic.

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Gettings, J.

Mask use and ventilation improvements to reduce COVID-19 incidence in elementary schools—Georgia, November 16–December 11, 2020.
Centers for Disease Control and Prevention MMWR. Morbidity and Mortality Weekly Report, Vol. **70**, (2021)

What is already known about this topic?
Kindergarten through grade 5 schools educate and address the students' physical, social, and emotional needs. Preventing SARS-CoV-2 transmission in schools is imperative for safe in-person learning.
What is added by this report?
COVID-19 incidence was 37% lower in schools that required teachers and staff members to use masks and 39% lower in schools that improved ventilation. Ventilation strategies associated with lower school incidence included dilution methods alone (35% lower incidence) or in combination with filtration methods (48% lower incidence).
What are the implications for public health practice?
Mask requirements for teachers and staff members and improved ventilation are important strategies in addition to vaccination of teachers and staff members that elementary schools could implement as part of a multicomponent approach to provide safer, in-person learning environments.

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Champredon, D., Fazil, A., Ogden, N. H.
Méthodes simples de modélisation mathématique pour évaluer le risque de transmission du SRAS-CoV-2 pendant les rassemblements.
RMTC, Vol. **47** n°(4), (2021), 201-212 pp.

Contexte : Les rassemblements peuvent contribuer de manière significative à la propagation du coronavirus du syndrome respiratoire aigu sévère 2 (SRAS-CoV-2). C'est pourquoi les interventions de santé publique ont cherché à limiter les rassemblements non répétés ou récurrents pour enrayer la pandémie de maladie à coronavirus 2019 (COVID-19). Malheureusement, l'éventail des différents types de rassemblements ne permet pas de donner des directives précises pour fixer des paramètres limitatifs (e.g. la taille totale du rassemblement, le nombre de cohortes, le degré de distanciation physique).
Méthodes : Nous avons utilisé un cadre de modélisation générique basé sur les principes fondamentaux de probabilité pour dériver des formules simples permettant d'évaluer les risques d'introduction et de transmission liés aux rassemblements ainsi que l'efficacité potentielle de certaines stratégies de dépistage pour atténuer ces risques. Résultats : Le risque d'introduction peut être évalué de manière générale en fonction de la prévalence de la population et de la taille du rassemblement, tandis que le risque de transmission au cours d'un rassemblement dépend principalement de la taille du rassemblement. Pour les rassemblements récurrents, la structure de la cohorte n'a pas d'effet significatif sur la transmission entre cohortes. Les stratégies de test peuvent atténuer les risques, mais la fréquence et la performance des tests permettent d'établir un équilibre entre la détection et les faux positifs.
Conclusion : La généralité du cadre de modélisation utilisé ici permet de démêler les différents facteurs des risques de transmission au cours des rassemblements. Ce cadre pourra éclairer la prise de décisions en matière de santé publique.

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Garzona-Navas, A., Sajgalik, P., Ibolya, C., Askew, J. W., Lopez-Jimenez, F., Niven, A. S.*, et al.*
Mitigation of Aerosols Generated during Exercise Testing with a Portable High-Efficiency Particulate Air (HEPA) Filter with Fume Hood.
Chest, (2021)

BACKGROUND: The role of portable High-Efficiency Particulate Air (HEPA) filters for supplemental aerosol mitigation during exercise testing is unknown and might be relevant during COVID-19 pandemic. RESEARCH

QUESTION: What is the effect of portable HEPA filtering on aerosol concentration during exercise testing and its efficiency in reducing room clearance time in a clinical exercise testing laboratory? STUDY DESIGN AND METHODS: Subjects were 6 healthy volunteers aged 20-56 years. In the first experiment, exercise was performed in a small tent with controlled airflow using stationary cycle, portable HEPA filter with fume hood, and particle counter to document aerosol concentration. Subjects performed a 4-stage maximal exercise test lasting 12 minutes plus 5 minutes pre-test quiet breathing and 3 minutes active recovery. First, they exercised without mitigation then with portable HEPA filter running. In a separate experiment, room aerosol clearance time was measured in a clinical exercise testing laboratory by filling it with artificially generated aerosols and measuring time to 99.9% aerosol clearance with heating, ventilation, and air conditioning (HVAC) only or HVAC plus portable HEPA filter running. RESULTS: In the exercise experiment, particle concentrations reached 1722±1484/L vs. 96±124/L (P<.04) for all particles (> 0.3mum), 1339±1281/L vs. 76±104/L (P<.05) for smaller particles (0.3-1.0mum), and 333±209/L vs. 17±19/L (P<.01) for larger particles (1.0-5.0mum) at the end of the protocol comparing mitigation vs. portable HEPA filter. Use of portable HEPA filter in a clinical exercise laboratory clearance experiment reduced aerosol clearance time 47% versus HVAC alone. INTERPRETATION: Portable HEPA filter reduced the concentration of aerosols generated during exercise testing by 96 ± 2% for all particle sizes, and reduced aerosol room clearance time in clinical exercise testing laboratories. Portable HEPA filters might therefore be useful in clinical exercise testing laboratories to reduce the risk of COVID-19 transmission.

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Park, S., Choi, Y., Song, D., Kim, E. K.
Natural ventilation strategy and related issues to prevent coronavirus disease 2019 (COVID-19) airborne transmission in a school building.
Science of The Total Environment, (2021)

The World Health Organization (WHO) announced that severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) may spread through aerosols, so-called airborne transmission, especially in a poorly ventilated indoor environment. Ventilation protects the occupants against airborne transmission. Various studies have been performed on the importance of sufficient ventilation for diluting the concentration of virus and lowering any subsequent dose inhaled by the occupants. However, the ventilation situation can be problematic in public buildings and other shared spaces, such as shops, offices, schools, and restaurants. If ventilation is provided by opening windows, the outdoor airflow rate depends strongly on the specific local conditions (opening sizes, relative positions, climatic and weather conditions). This study uses field measurements to analyze the natural ventilation performance in a school building according to the window opening rates, positions, and weather conditions. The ventilation rates were calculated by the tracer gas decay method, and the infection risk was assessed using the Wells-Riley equation. Under cross-ventilation conditions, the average ventilation rates were measured at 6.51 h-1 for 15% window opening, and 11.20 h-1 for 30% window opening. For single-sided ventilation, the ventilation rates were reduced to about 30% of the values from the cross-ventilation cases. The infection probability is less than 1% in all cases when a mask is worn and more than 15% of the windows are open with cross-ventilation. With single-sided ventilation, if the exposure time is less than one hour, the infection probability can be kept less than 1% with a mask. However, the infection probability exceeds 1% in all cases where exposure time is greater than two hours, regardless of whether or not a mask is worn. Also, when the air conditioner was operated with a window opening ratio of 15%, power consumption increased by 10.2%.

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Xie, H., Yu, B., Wang, J., Ji, J.
A novel disinfected Trombe wall for space heating and virus inactivation: Concept and performance investigation.
Applied Energy, Vol. **291**, (2021)

Trombe wall is a simple and mature passive solar building design while its utilization of solar energy is limited to space heating. Aerosol transmission, as a potential transmission pathway of COVID-19, poses a serious threat to the public health especially in a closed indoor environment. The thermal disinfection of virus, which can be easily integrated into solar systems, seems to be a suitable method for controlling bioaerosols. Therefore, a novel disinfected Trombe wall for virus inactivation and space heating is proposed, providing a potential way to fight the current COVID-19 pandemic. After the proposal of the concept, its performance on space heating and virus inactivation was investigated through experimental and simulation methods. The main results were as follows: (1) The average thermal efficiency was 0.457 and the average indoor temperature was 20.7 °C, 1.9 °C higher than the ambient temperature. (2) The maximum single-pass inactivation ratio was 0.893, 0.591 and 0.893 while the total production of clean air was 112.3, 63.8 and 114.7 m3 for SARS-CoV-1, SARS-CoV-2 and MERS-CoV, respectively. (3) The increase of ambient temperature or solar irradiance may enhance the thermal efficiency while the former has little effect on the thermal disinfection process. (4) Extending the height or narrowing the thickness of the duct by 40% may contribute to an increase in total production of clean air by 510 m3 or 681 m3 per unit area during the heating seasons, but the later may cause a larger decrease (about 8%) in the heat gain of indoor air.

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Wagner, J. A., Dexter, F., Greeley, D. G., Schreiber, K.
Operating room air delivery design to protect patient and surgical site results in particles released at surgical table having greater concentration along walls of the room than at the instrument tray.
American Journal of Infection Control, Vol. **49** n°(5), (2021), 593-596 pp.

Background: During the coronavirus disease 2019 (COVID-19) pandemic, recommendations have included that personnel not involved in procedures releasing airborne contaminants reduce their exposure by moving >2 m away. We tested whether air particle concentrations in operating rooms (ORs) are greater in the periphery, downstream from the supply airflow. Methods: We analyzed data from 15 mock surgical procedures performed in 3 ORs. Two ORs were modern, one with a single large diffuser system above the surgical table, and the other using a multiple diffuser array design. An air particle counting unit was located on the instrument table, another adjacent to an air return grille. Results: Concentrations of air particles were greater at return grille than instrument table for the single large diffuser at 26 air exchanges per hour, and the multiple diffuser array at both 26 and 20 air exchanges per hour (all P < .0044), including during electrocautery (all P < .0072). The ratios of concentrations, return grille versus instrument table, were greater during electrocautery for 0.5 to 1.0-micron particles and 1.0 to 5.0-micron particles (both P < .0001). Conclusions: Modern OR airflow systems are so effective at protecting the surgical field and team from airborne particles emitted during surgery that concentrations of particles released at the OR table are greater at the OR walls than near the center of the room.

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Hospers, L., Morris, N. B., Jay, O.
Reply to the "Letter to the editor, regarding Hospers et al. (2020): Electric fans: A potential stay-at-home cooling strategy during the COVID-19 pandemic this summer?".
Science of the Total Environment, Vol. **773**, (2021)

Dear Editor,
We would like to thank Dr. Wang (2021) for his interest in our recent article examining the potential efficacy of fan use during heatwaves (Hospers et al., 2020) and our greater body of work in this area (Ravanelli et al., 2015; Morris et al., 2019a, Morris et al., 2019b; Gagnon et al., 2016).

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Das, D., Ramachandran, G.
Risk analysis of different transport vehicles in India during COVID-19 pandemic.
Environmental Research, Vol. **199**, (2021)

Due to the airborne nature of viral particles, adequate ventilation has been identified as one suitable mitigation strategy for reducing their transmission. While 'dilution of air by opening the window' has been prescribed by national and international health agencies, unintended detrimental consequences might result in many developing countries with high ambient air pollution. In the present study, PM2.5 exposure concentration and probability of mortality due to PM2.5 in different scenarios were assessed. A COVID airborne infection risk estimator was used to estimate the probability of infection by aerosol transmission in various commuter micro-environments: (a) air conditioned (AC) taxi (b) non-AC taxi (c) bus and (d) autorickshaw. The following were the estimated exposure concentrations in the four types of vehicles during pre-lockdown, during lockdown, and lost-lockdown: AC taxi cars (17.16 μg/m3, 4.52 μg/m3, and 25.09 μg/m3); non-AC taxis: (28.74 μg/m3, 7.56 μg/m3, 42.01 μg/m3); buses (21.79 μg/m3, 5.73 μg/m3, 31.86 μg/m3) autorickshaws (51.30 μg/m3, 3.50 μg/m3, 75 μg/m3). Post-lockdown, the probability of mortality due to PM2.5 was highest for autorickshaws (5.67 × 10−3), followed by non-AC taxis (2.07 × 10−3), buses (1.39 × 10−3), and AC taxis (1.02 × 10−3). This order of risk is inverted for the probability of infection by SARS-COV-2, with the highest for AC taxis (6.10 × 10−2), followed by non-AC taxis (1.71 × 10−2), buses (1.42 × 10−2), and the lowest risk in autorickshaws (1.99 × 10−4). The findings of the present study suggest that vehicles with higher ventilation or air changes per hour (ACH) should be preferred over other modes of transport during COVID-19 pandemic.

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Shen, J., Kong, M., Dong, B., Birnkrant, M. J., Zhang, J.
A systematic approach to estimating the effectiveness of multi-scale IAQ strategies for reducing the risk of airborne infection of SARS-CoV-2.
Building and environment, Vol. **200**, (2021)

The unprecedented coronavirus disease 2019 (COVID-19) pandemic caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has made more than 125 million people infected and more than 2.7 million people dead globally. Airborne transmission has been recognized as one of the major transmission routes for SARS-CoV-2. This paper presents a systematic approach for evaluating the effectiveness of multi-scale IAQ control strategies in mitigating the infection risk in different scenarios. The IAQ control strategies across multiple scales from a whole building to rooms, and to cubical and personal microenvironments and breathing zone, are introduced, including elevated outdoor airflow rates, high-efficiency filters, advanced air distribution strategies, standalone air cleaning technologies, personal ventilation and face masks. The effectiveness of these strategies for reducing the risk of COVID-19 infection are evaluated for specific indoor spaces, including long-term care facility, school and college, meat plant, retail stores, hospital, office, correctional facility, hotel, restaurant, casino and transportation spaces like airplane, cruise ship, subway, bus and taxi, where airborne transmission are more likely to occur due to high occupancy densities. The baseline cases of these spaces are established according to the existing standards, guidelines or practices. Several integrated mitigation strategies are recommended and classified based on their relative cost and effort of implementation for each indoor space. They can be applied to help meet the current challenge of ongoing COVID-19, and provide better preparation for other possible epidemics and pandemics of airborne infectious diseases in the future.

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Crowell, N. A., Hanson, A., Boudreau, L., Robbins, R., Sokas, R. K.
Union Efforts to Reduce COVID-19 Infections Among Grocery Store Workers.

NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy, (2021)

Grocery store workers are essential workers, but often have not been provided with appropriate protection during the current pandemic. This report describes efforts made by one union local to protect workers, including negotiated paid sick leave and specific safety practices. Union representatives from 319 stores completed 1612 in-store surveys to assess compliance between 23 April 2020 and 31 August 2020. Employers provided the union with lists of workers confirmed to have COVID-19 infection through 31 December 2020. Worker infection rates were calculated using store employees represented by the union as the denominator and compared to cumulative county infection rates; outcome was dichotomized as rates higher or lower than background rates. Restrictions on reusable bags and management enforcement of customer mask usage were most strongly associated with COVID-19 rates lower than rates in the surrounding county. Stores that responded positively to worker complaints also had better outcomes. The union is currently engaging to promote improved ventilation and vaccination uptake.

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Huang, Q., Marzouk, T., Cirligeanu, R., Malmstrom, H., Eliav, E., Ren, Y. F.
Ventilation Assessment by Carbon Dioxide Levels in Dental Treatment Rooms.
Journal of dental research, (2021)

It is important for dental care professionals to reliably assess carbon dioxide (CO2) levels and ventilation rates in their offices in the era of frequent infectious disease pandemics. This study was to evaluate CO2 levels in dental operatories and determine the accuracy of using CO2 levels to assess ventilation rate in dental clinics. Mechanical ventilation rate in air change per hour (ACHVENT) was measured with an air velocity sensor and airflow balancing hood. CO2 levels were measured in these rooms to analyze factors that contributed to CO2 accumulation. Ventilation rates were estimated using natural steady-state CO2 levels during dental treatments and experimental CO2 concentration decays by dry ice or mixing baking soda and vinegar. We compared the differences and assessed the correlations between ACHVENT and ventilation rates estimated by the steady-state CO2 model with low (0.3 L/min, ACHSS30) or high (0.46 L/min, ACHSS46) CO2 generation rates, by CO2 decay constants using dry ice (ACHDI) or baking soda (ACHBV), and by time needed to remove 63% of excess CO2 generated by dry ice (ACHDI63%) or baking soda (ACHBV63%). We found that ACHVENT varied from 3.9 to 35.0 in dental operatories. CO2 accumulation occurred in rooms with low ventilation (ACHVENT ≤6) and overcrowding but not in those with higher ventilation. ACHSS30 and ACHSS46 correlated well with ACHVENT ($r = 0.83$, $P = 0.003$), but ACHSS30 was more accurate for rooms with low ACHVENT. Ventilation rates could be reliably estimated using CO2 released from dry ice or baking soda. ACHVENT was highly correlated with ACHDI ($r = 0.99$), ACHBV ($r = 0.98$), ACHDI63% ($r = 0.98$), and ACHBV63% ($r = 0.98$). There were no statistically significant differences between ACHVENT and ACHDI63% or ACHBV63%. We conclude that ventilation rates could be conveniently and accurately assessed by observing the changes in CO2 levels after a simple mixing of household baking soda and vinegar in dental settings.

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